

Organic Reactions in Aqueous Medium & Development of New Ditribromide Reagent

Submitted by

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February 2007

Dedicated to

My Parents
&
Grand Parents



INDIAN INSTITUTE OF TECHNOLOGY, GUWAHATI

Department of Chemistry

STATEMENT

I do hereby declare that the matter embodied in this thesis is the result of investigations carried out by me in the Department of Chemistry, Indian Institute of Technology Guwahati, India under the guidance of Professor Bhisma K. Patel.

In keeping with the general practice of reporting scientific observations, due acknowledgements have been made wherever the work described is based on the findings of other investigators.

February, 2007.
IIT Guwahati


Veerababurao Kavala



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CERTIFICATE

This is to certify that Veerababurao Kavala has been working under my supervision since July, 2002 as a regular registered Ph. D. student. I am forwarding his thesis entitled “**Organic Reactions in Aqueous Medium & Development of New Ditribromide Reagent**” being submitted for the Ph. D. (Science) Degree of this Institute. I certify that he has fulfilled all the requirements according to the rules of this Institute regarding the investigations embodied in his thesis and this work has not been submitted elsewhere for a degree.

February, 2007.
IIT Guwahati


Prof. Bhisma K. Patel
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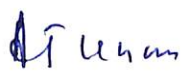
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CERTIFICATE OF COURSE WORK

This is to certify that Veerababurao Kavala has satisfactorily completed all the courses required for the Ph.D degree program. These courses include

CH 603 :	Supramolecules: Concepts and Applications
CH 627 :	New Reagents in Organic Chemistry
CH 630 :	A Molecular Approach to Physical Chemistry
CH 632 :	Group Theory

Veerababurao Kavala has successfully completed her Ph.D qualifying examination in May 2003.


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Semester: July-Nov, 2002

Course	Course Name	Credit	Grade
CH 603	Supra Molecules: Concept and Applications	6	BC
CH 627	New Reagents in Organic Synthesis	6	BB
CH 630	A Molecular Approach to Physical Chemistry	6	AB
CH 632	Group Theory	6	BB

Semester Performance Index: (S. P. I): 8.00

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February, 2007

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Finally, thanks are due to IIT Guwahati for financial assistance in the form of fellowship.

Classification of Compounds

The products or compounds prepared have been listed in the present work section of chapter I and chapter II of the thesis with the following names

Mono THP ethers	a
Di THP ethers	b
Dibenzyl tertiary amines	c
Di-4-Nitro benzyl tertiary amines	d
N-Butylated products	e
N-Hexylated products	f
N-Octylated products	g
Six membered cyclic tertiary amines	h
Seven membered cyclic tertiary amines	i
Diallyl tertiaryamines	j
Mixed benzyl tertiary amines	k
Mixed 4-NO ₂ benzyl tertiary amines	l
Mixed allyl tertiary amines	m
Bromoproducts	n
2-Phenyl benzothiazoles	o
2-Arylamino benzothiazole	p
Xanthene products	q
<i>gem</i> -Diacetates	r
<i>gem</i> -Dipropionoates	s
<i>gem</i> -Diisobutyrate	t
<i>gem</i> -Dipivalates	u
<i>gem</i> -Dibenzoates	v

Abbreviations

Ac	acetyl	DMF	dimethylformamide
acac	acetylacetone	DMSO	dimethyl sulfoxide
anhy	anhydrous	DMT	dimethoxytrityl
Ar	aryl	DDQ	2,3-dichloro-5,6-dicyano- 1,4-benzoquinone
ATPB	acetyltriphenyl phosphonium bromide	ee	enantiomeric excess
Bn	benzyl	Et	ethyl
Boc	<i>tert</i> -butoxycarbonyl	TEA	triethylamine
br	broad	FAB	fast atom bombardment
BTMATB	benzyl trimethylammonium tribromide	FID	flame ionization detection
Bu	butyl	Fmoc	9-fluorenyl methoxycarbonyl
iBu	isobutyl	FT	Fourier transform
Bz	benzoyl	g	grams (s)
°C	degrees Celsius	GC	gas chromatography
calcd	calculated	h	hour(s)
CAN	cerium (IV) ammoniumnitrate	HMPA	hexamethyl- phosphorictriamide
CBz	benzyloxycarbonyl	Hz	hertz
CSA	camphorsulfonic acid	IR	infrared
CTMATB	cetyl trimethylammonium tribromide	L	liter(s)
d	doublet (spectral)	μL	micro liter(s)
DBU	1,8-diazabicyclo[5/4/0]- undec-7-ene	m	multiplet (spectral)
DBDMH	1,3-dibromo-5,5-dimethyl hydantoin	Me	methyl
		MHz	megahertz

MPHT	<i>N</i> -methylpyrrolidin-2-one	SPC	sodium percarbonate
	hydrotribromide	TBATB	tetrabutylammonium tribromide
mol	moles(s)	TBS	<i>tert</i> -butyldimethylsilyl
NBS	<i>N</i> -bromosuccinimide	TBDPS	<i>tert</i> -butyldiphenylsilyl
NMR	nuclear magnetic resonance	TBHP	<i>tert</i> -butylhydroperoxide
NMPO	<i>N</i> -methylpyrrolidine oxide,	Tf	trifluoromethane sulfonyl
PDC	pyridinium dichromate	TFA	trifluoroacetic acid
Ph	phenyl	TFAA	trifluoroacetic anhydride
Piv	pivaloyl	THF	tetrahydrofuran
PMB	<i>p</i> -methoxybenzyl	THP	tetrahydropyran; tetrahydropyranyl
ppm	parts per million	TLC	thin layer chromatography
PPTS	pyridinium <i>p</i> -toluenesulfonate	TMATB	tetramethyl-ammonium tribromide
Pr	propyl	TMS	trimethylsilyl
iPr	isopropyl	TMSCl	trimethylsilyl chloride
PTSA	<i>p</i> -toluenesulfonic acid	Tr	trityl
PPTB	pentylpyridinium tribromide	Ts	tosyl (<i>p</i> -toluenesulfonyl)
PTATB	phenyltrimethylammonium tribromide	UV	ultraviolet
Py	pyridine		
PHPB	pyridine hydrobromide perbromide		
q	quartet (spectral)		
rt	room temperature		
s	singlet (spectral)		
SPB	sodium perborate		
t	triplet (spectral)		

Abstract

The contents of this thesis have been divided into two chapters summarizing the results based on the experimental works performed during the complete course of the research period. Each chapter constitutes four sections, sections **A-D** describing introduction, present work, experimental work and spectral data respectively. Organic transformations in aqueous medium are the theme of first chapter in which various synthetically useful reactions such as tetrahydropyranylation of alcohols and syntheses of tertiary amines are described. The second chapter describes the synthesis of newer tribromide reagent and its utilization in various organic transformations such as bromination, synthesis of benzothiazole from thiourea and thioamide, diacylation of aldehydes and synthesis of various xanthene derivatives from enalizable ketones and 9-phenyl xanthene-9-ol.

CHAPTER I

Part (I): Organic Reactions in Aqueous Medium

Section IA: Introduction

Water plays an essential role in life processes; however its use as a solvent has been limited in organic synthesis. Despite the fact that it is the cheapest, safest and most non toxic solvent in the world, its presence is generally avoided through dehydration of substrates and solvents. The use of water as a medium for organic reactions is therefore one of the latest challenges for modern organic chemists. For years limited organic transformations has been performed in water as a reaction medium. Breslow has demonstrated that the hydrophobic effect accelerates the rate of Diels-Alder reaction and gives high endo-exo selectivity. Despite the solubility problems of organic substrates in water after the seminal contribution of Breslow, new additions are continuously being made to the catalogue of organic reactions that can be performed effectively with water as the solvent.

Tetrahydropyranyl ethers (THP ethers) were one of the first generally useful protecting groups for alcohols to be adopted. The easy installation as well as facile and selective removal of these ethers renders them attractive in complex organic synthesis. In addition tetrahydropyran derivatives are less expensive, and stable under a variety of reaction conditions such as strongly basic media, metal hydrides, Grignard reagents, acylating agents, oxidative and alkylating agents. The only drawback is the formation of an additional stereocentre that may lead to diastereomeric mixtures if

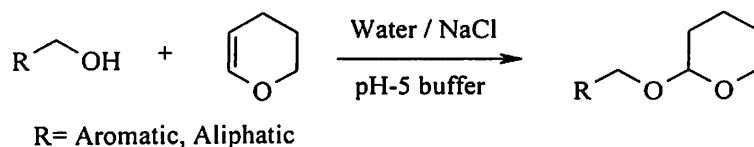
the alcohol already possesses a stereogenic centre. This complicates the NMR spectra and hence makes its interpretation difficult. In spite of this detraction, it is the most extensively and frequently used protecting group for alcohols.

Amines are one of the most common structural features of naturally occurring biologically active compounds and are widely used throughout the chemical industry as a basic intermediate to prepare pharmaceutically and agro chemically useful chemicals. Due to their unique biological properties, amines have played an important role as chemotherapeutic agents for the treatment of various diseases. They are useful agents for potentiation of opiate analgesia, treatment of extrapyramidal movement disorders, besides, of course their use as antifungal, general anesthetic, antipsychotic, antihistamic and calcium channel blocking agents. Indeed no less than a quarter of the registered drugs contain tertiary amine. Thus, the development of new synthetic routes to these pharmaceutically important compounds has stimulated constant interest and has been the focus of many research groups over the years.

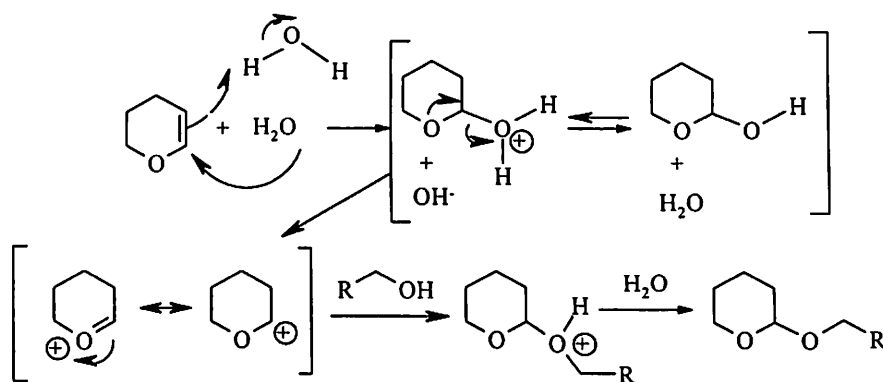
Section 1B: Present Work

1B.1. Water as Catalyst and Solvent: Tetrahydropyranylation of Alcohols in an Aqueous Medium

This part of the thesis describes the utilization of water as catalyst and solvent for tetrahydropyranylation of alcohols. Tetrahydropyranylation is usually performed in anhydrous aprotic organic solvents because of the longer reaction time and poor yields of product obtained in the presence of water. Based on the pKa's of water (15.74), alcohols (~16.5), protonated hydroxyls of 2-hydroxy tetrahydropyran (~ -2) and protonated ethereal functions (~ -6), we speculate that pyranlation of alcohol should occur in an aqueous medium and due to an unfavorable pKa phenol should not undergo tetrahydro pyranlation in water (Scheme 1B. 1 and 2). Water is found to catalyze the tetrahydropyranylation of alcohols at elevated temperature. Interestingly, tetrahydropyranylation of alcohols works under a wide range of pH examined *i.e* 6.5 to 2 and do not work beyond pH 7.5 in aqueous medium. Hydrophobic interactions between the substrate alcohol and dihydropyran ether (DHP) and favorable pKa's of water, alcohols, and protonated hydroxyl and protonated ethereal functions are the driving forces for the reaction.



Scheme 1B.1. Formation of THP ether in water



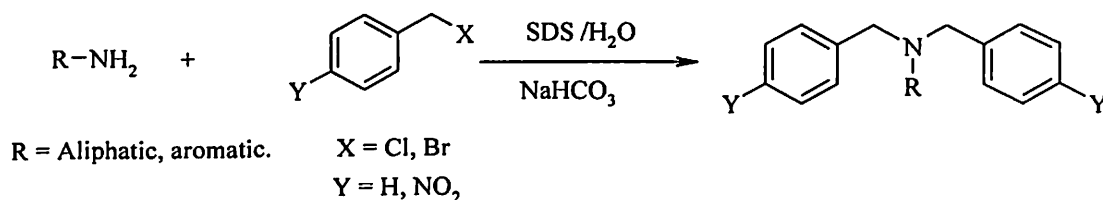
Scheme 1B.2. Mechanism of formation of THP ether in water

This method has advantage of using highly acidic pH to weakly acidic pH and can even be carried out in pure water without using any acidic or basic reagents hence most acceptable from environmental point of view for the development of green strategies. Thus the reaction, which is carried out in anhydrous aprotic solvents, can be carried out in aqueous medium in an environmentally benign way. Besides understanding the reaction mechanism, mild reaction conditions, simplicity of the procedure, general applicability for a wide range of alcohols and selective mono-tetrahydropyranylation of diols offer significant advantages over many existing procedures.

1B.1.2. Aqueous Mediated N-Alkylation of Amines

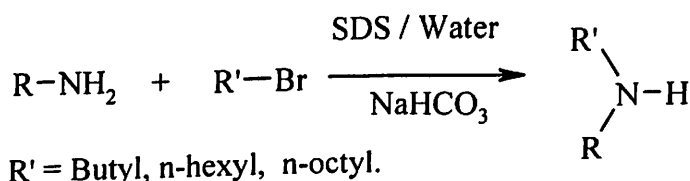
This section of thesis focused on N-alkylation of amine in an aqueous medium. The efficient dissolution of amines in an aqueous medium and its subsequent acylation using various anhydrides by our group prompted us to perform N-alkylation in an aqueous medium. Initially, alkylation was

performed using benzyl bromide. Various conditions were sampled, but a 1 : 2.2 : 2.2 ratio of substrate to benzyl halide to NaHCO_3 at 80°C gave best result. Using this optimized reaction conditions we were able to alkylate structurally diverse primary and secondary amines with different benzyl halides to their corresponding tertiary amines (Scheme 1B.3). Amines of different stereo-electronic factors react with equal ease with different benzyl halides. The synthetic step includes a two steps alkylation of primary amine with benzyl halide through intermediate secondary amine.



Scheme 1B.3. *N*-Alkylation of primary amines to tertiary amines with benzyl halides

Having successfully applied to benzylic systems, we extended this methodology to aliphatic halides. Under the reaction conditions to that of benzylic system, the products obtained were a mixture of tertiary and secondary amines in the ratio 3 : 2. The products ratio remained nearly unaltered even after refluxing the reaction for 12 hours. Thus, we focused our attention to controlling it at the secondary amine rather than at the tertiary amine stage. Thus, a 1 : 1 : 1.3 ratio of substrate to alkyl bromide to NaHCO_3 using above conditions gave exclusively secondary amines in good yields. It may be noted here that reaction of alkyl bromides took relatively longer reaction time as compared to benzyl halides.



Scheme 1B.4. *N*-Alkylation of primary amines to secondary amines with alkyl halides

The general nature of the reaction is shown by the intramolecular double-alkylation of primary amines with dihalides such as 1,5-dibromopentane and 1,6-dibromohexane giving corresponding cyclic amines. Allyl bromide also reacted successfully with various amines giving good yields of diallylated tertiary amines. As suggested earlier and proved by isolating some of the

secondary amines, the synthetic steps include a two steps alkylation of primary amine with alkyl halide through an intermediate secondary amine. To further prove this we reacted some of the secondary amines with benzyl and allyl bromide to obtain good yields of mixed tertiary amines containing three different substituents.

In conclusion, we have demonstrated an efficient and economic process for the synthesis of secondary and tertiary amines by direct N-alkylation of primary amines or secondary amines with various benzyl halides, alkyl halides and dihalides in an aqueous medium in the presence of sodium dodecyl sulfate and NaHCO_3 . Mild reaction conditions, higher product yields, scalability, absence of quarternary ammonium salt and operationally convenient conditions are some of the advantages. Selective formation of secondary amines and mixed tertiary amines will find useful applications in organic synthesis.

CHAPTER II

Development of New Ditribromide Reagent

Section IIA: Introduction

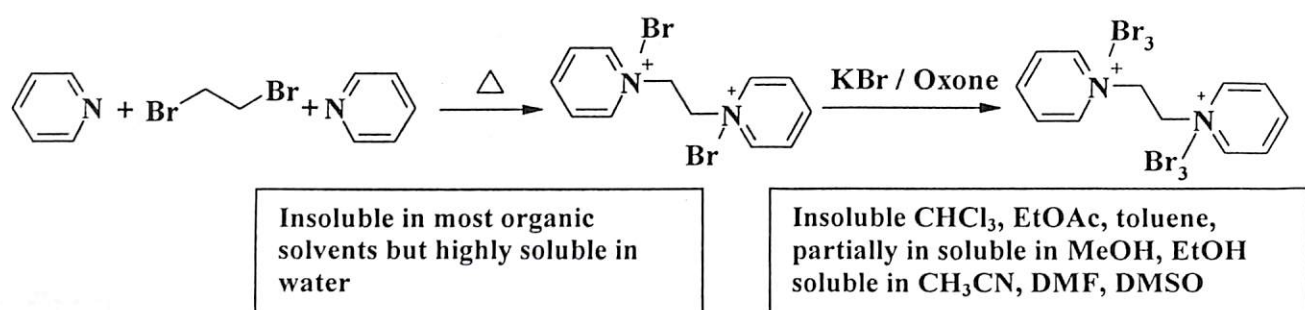
Organic ammonium tribromides are the attractive solid bromine less brominating agents. These crystalline stable solids are convenient source of bromine owing to the ease in maintenance of the desired stoichiometry and the ease in storage, transportation and handling. Apart from bromination, tribromides also can be used for several organic transformations such as oxidation of sulfides and alcohols, brominative cyclizations, intramolecular cyclizations. These reagents are an efficient generator of anhydrous HBr in alcohols and many other organic solvents whose acidity can be tuned to a wide range of pH that can be utilized for various acid catalyzed organic transformations.

Problems associated with the existing organic ammonium tribromides are the use of expensive organic ammonium cations and the use of one third of its total bromide for an aromatic electrophilic substitution type reaction and two third of its bromide towards addition to C–C multiple bonds. Some of the organic ammonium tribromides have phase transfer property hence a substantial amount gets extracted along with the organic products in an organic solvent during workup, thereby making the purification process tedious and the method expensive for large scale reaction. Recovery

and recycling of expensive organic ammonium cation is also poor after the reaction. Pyridinium tribromide is not so stable compared to other organic ammonium tribromide and reported to have three different melting points and different bromine composition. To overcome the phase transfer property, poor stability, regio and stereoselectivity, recovery, and recycling of the spent reagent we have synthesized a novel di-tribromide reagent.

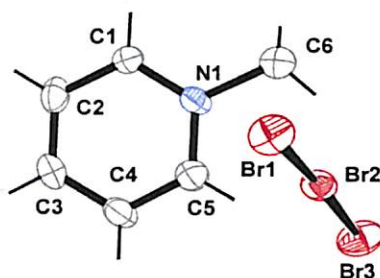
Section IIB: Present Work

IIB.1. A New Recyclable Dtribromide Reagent for Efficient Bromination Under Solvent Free Condition



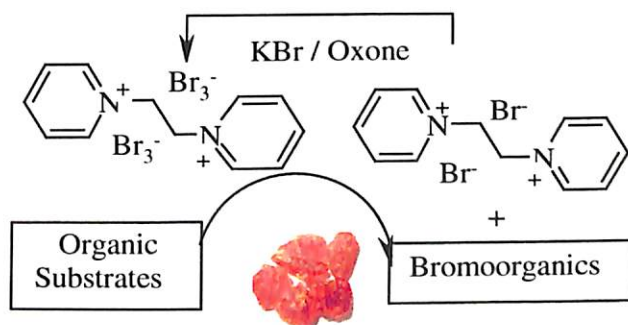
Scheme 11B.1. Synthesis of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT)

This section focuses on the synthesis of the reagent 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) and its utilization for the bromination of various organic compounds. The reagent can be prepared by refluxing pyridine (2 equiv.) with 1,2-dibromoethane (1 equiv.). The resultant solid 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) and KBr (4.5 equiv) was dissolved in water and treated with Oxone® (2 equiv) which oxidizes bromide to bromine. The *in situ* liberated bromine gets trapped forming precipitate of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) (Scheme 11B.1). The orange precipitate was filtered and was recrystallized from acetonitrile. The compound has been characterized by spectral and analytical data. Single crystal X-RD revealed the presence of two linear tribromide per molecule. Scheme 11B.2.



Scheme 11B.2. ORTEP diagram of asymmetric unit of EDPBT with atom numbering

The crystalline ditribromide reagent is stable for months and acts as a safe source of bromine requiring just 0.5 equiv for bromination per equivalent of substrate. It has high active bromine content per molecule and shows a remarkable reactivity compared to other tribromide reagents towards various substrates (phenols, anilines, alkenes, alkynes, ketones) by just grinding the reagent and substrates in a porcelain mortar at room temperature. No organic solvent has been used during any stage of the reaction for substrates giving product as solid. Product can easily be isolated by just washing the highly water soluble 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) from the brominated product. The spent reagent can be recovered, regenerated and reused without any significant loss (Scheme 11B.3).



Scheme 11B.3. Bromination of organic substrates using EDPBT

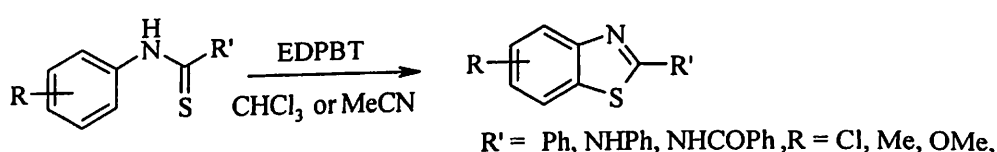
In summary, we have for the first time reported a ditribromide reagent with high active bromine content per molecule, which acts as an excellent bromine carrier capable of brominating an equivalent of the substrate with just half an equivalent of the reagent. The reaction is carried out under a solvent free condition. Selectivities and reactivities were shown to be far superior to any of the reported reagents and methodologies. It has unique features of providing enhanced yields, reduction in synthesis temperatures, shorter process times and environmentally friendly process. The

spent reagent EDPBT can be easily recycled, hence the process is economically viable for large-scale reaction.

IIB.2. Synthesis of 2-Substituted Benzothiazoles Using the Recyclable Reagent EDPBT

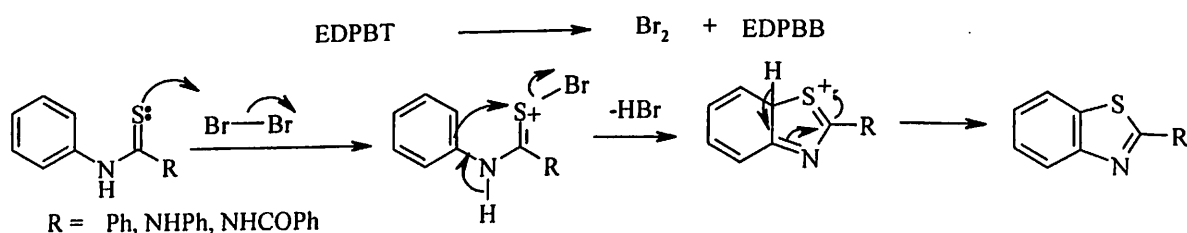
In this part EDPBT has been utilized for the conversion of thioamides and thioureas to benzothiazole derivatives. Benzothiazoles are found in various natural products and are important in the drug discovery research. They are precursors to natural products, pharmaceutical agents and other compounds that exhibit a wide spectrum of biological activity.

Due to its numerous applications, several procedures have been developed for their synthesis. The important ones are: (i) by the condensation of 2-amino thiophenol with aromatic carbonyl moiety; (ii) oxidative cyclization of thioureas and thioamides and (iii) intramolecular aryl thiolation. Although many synthetic strategies are available for synthesis of benzothiazoles, the oxidative cyclization of thiomides and thioureas are preferred. The first reported synthesis of benzothiazole is by Hegerschoff method using molecular bromine and arylthiourea. We have used bromine less oxidative cyclization strategy. Various 2-substituted benzothiazoles were obtained in good yields by reacting thioamides and thioureas with 0.5 equivalent of EDPBT either in CHCl_3 or in acetonitrile at elevated temperature (Scheme II B.4).



Scheme IIB.4. Formation benzothiazole

The proposed mechanism is shown in Scheme II B.5.

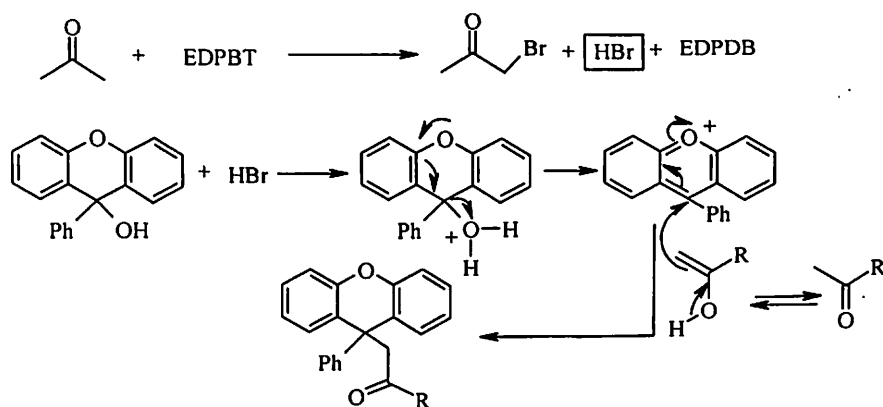


Scheme IIB.5. Mechanism of formation of benzothiazoles

Products are obtained in good yields and spent reagent can be recovered and regenerated for further reaction. Problem of handling toxic bromine, metal catalysts both toxic and expensive can be avoided by this method.

IIB.3. Syntheses and Regiochemistry of Enol Addition to Xanthene

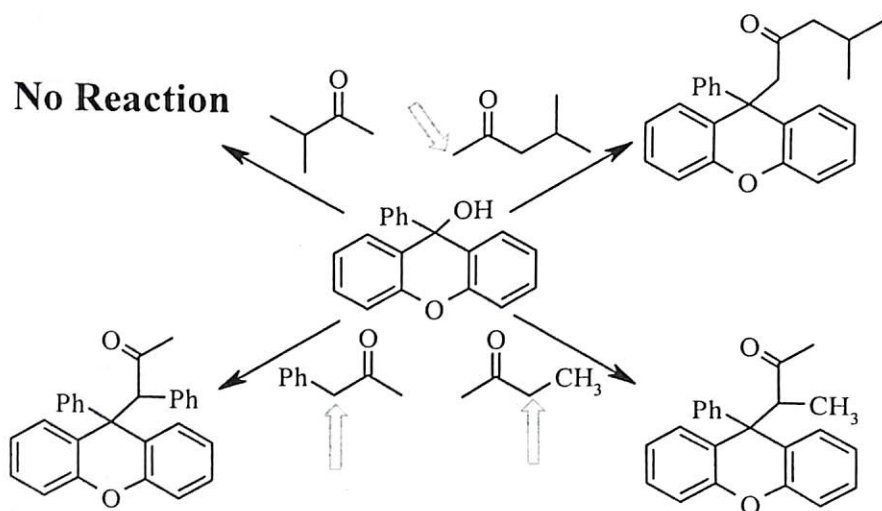
In this part of the dissertation we have focused our attention on the syntheses and regiochemistry of various enol addition to 9-phenyl-9H-xanthen-9-ol and analyzed the self assembled super structures of the addition products in solid state. Xanthene derivatives are useful pharmaceuticals such as, muscarinic receptor antagonist, cancer chemotherapy, trypanothione reductase inhibitor, and chemosensitizers against chloroquine-resistant *Plasmodium falciparum*, nonpeptidic inhibitors, as mGluR1 enhancer and CCR1 antagonist. They are also useful as dyes, photosensitizers, as ligand for asymmetric catalysis and have the propensity to form inclusion compounds with various aromatic compounds.



Scheme IIB.6. Plausible mechanism of enol addition to 9-phenyl-9H-xanthen-9-ol

In an attempt to acetylate 9-phenyl-9H-xanthen-9-ol employing acetic anhydride in acetone and 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) as catalyst gave no trace of acetylated product, rather an unusual three carbon homologation was observed. The proposed mechanism of product formation is shown in (Scheme IIB.6).

Being buoyant by this result we focused our attention to synthesize various xanthene analogues. Various multi carbon homologation of 9-phenyl-9H-xanthen-9-ol were obtained through a C-C bond formation by reacting it with various enolizable ketones (acetone, 2-butanone, isobutylmethyl ketone, acetophenone, cyclopentanone, cyclohexanone, phenyl acetone and dibenzyl ketone) in presence of 1,1'-(ethane-1,2-diyl)dipyridinium bistrisbromide (EDPBT). Except for isobutylmethyl ketone in all other cases examined the attack to xanthenyl carbocation is from the thermodynamically stable enolizable side of unsymmetrical ketones. Due to complete shift in equilibrium in favor of more stable enolizable ketone which has large steric factor, no reaction was observed during the addition of isopropylmethyl ketone with 9-phenyl-9H-xanthen-9-ol (Scheme IIB.7).



Scheme IIB.7. Summary of the regiochemistry of enol addition to xanthen

All the addition products obtained were highly crystalline compounds. During the course of structural analysis of 9-phenyl-9H-xanthen-9-ol and its derivatives they were found to be synthons for supramolecular design. In order to delineate our objectives of supramolecular synthons, we have carried single crystal X-ray diffraction studies of all the products along with its starting compound. Critical investigation of the solid state structure can help us to reveal the effect of variation of alkyl and aryl appendage on the supramolecular assembly / crystal engineering. The supramolecular assemblies of the addition products held by weak non covalent interactions are shown below (Figure IIB.1).

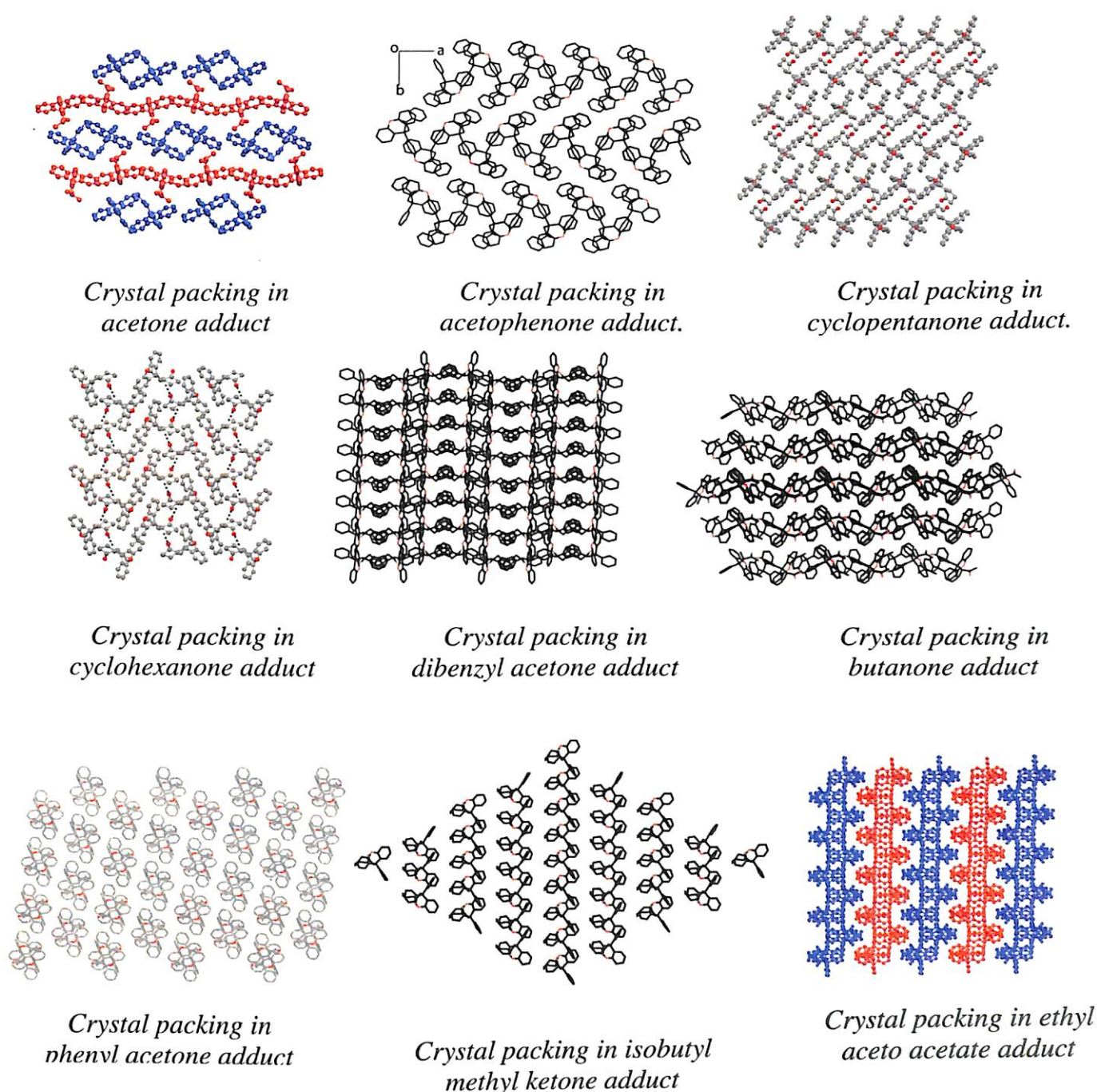


Figure IIB.1. Crystal packing in different xanthene derivatives

In conclusion, we have achieved multicarbon homologation of 9-phenyl-9H-xanthen-9-ol through a C–C bond formation by various enolizable ketones in an acidic medium. Regiochemistry of the product can be explained with the help of kinetic and thermodynamic stability of the enol. X-ray crystallography of all the products revealed the disposition of the pendant group in the opposite

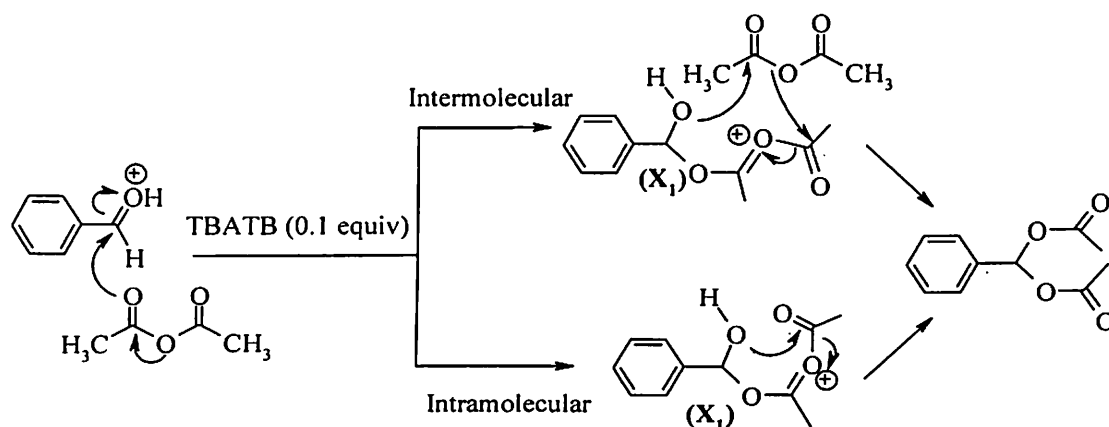
direction with respect to the xanthene unit to relieve the steric crowding in the solid state. The precursor xanthene and its derivatives serve as an interesting supramolecular synthons and contain remarkable systems of interconnectivity by conventional and non-conventional hydrogen bonds. A programmed variation in the side arm of the xanthene derivatives results not only in interesting regiochemistry of addition products but also lead to self-assembled superstructure by different types of weak interactions.

IIB.4. Reinvestigation of the Mechanism of *gem*-Diacylation: Chemoselective Conversion of Aldehydes to Various *gem*-Diacylates and Their Cleavage under Acidic and Basic Conditions

The mechanism of the formation of *gem*-diacylate, the addition product of acid anhydride with aldehyde is not yet well understood. *Gem*-diacylate functionalities have served as an interesting protecting group for aldehydes in addition to acetals, oxathioacetals and thioacetals. Unlike acetal protecting group which is removed only under acidic conditions, *gem*-diacylates can be removed both under acidic and basic conditions. The *gem*-diacylate of aldehydes are useful precursors for nucleophilic substitution reactions, used in the synthesis of acetoxydienes, vinyl acetates and dienes for Diels-Alder reaction and also used as several industrial intermediates. Due to the remarkable stability of *gem*-diacetates towards a variety of reaction conditions and their easy preparation, they are gaining importance in organic synthesis as an alternative to cyclic and acyclic acetals for protection of aldehydes. It is superior over acetals because during acetalization, the water formed in the reaction medium is required to be removed either by physical or by chemical means using water scavengers such as orthoformates, that is not required during *gem*-diacylation of aldehydes.

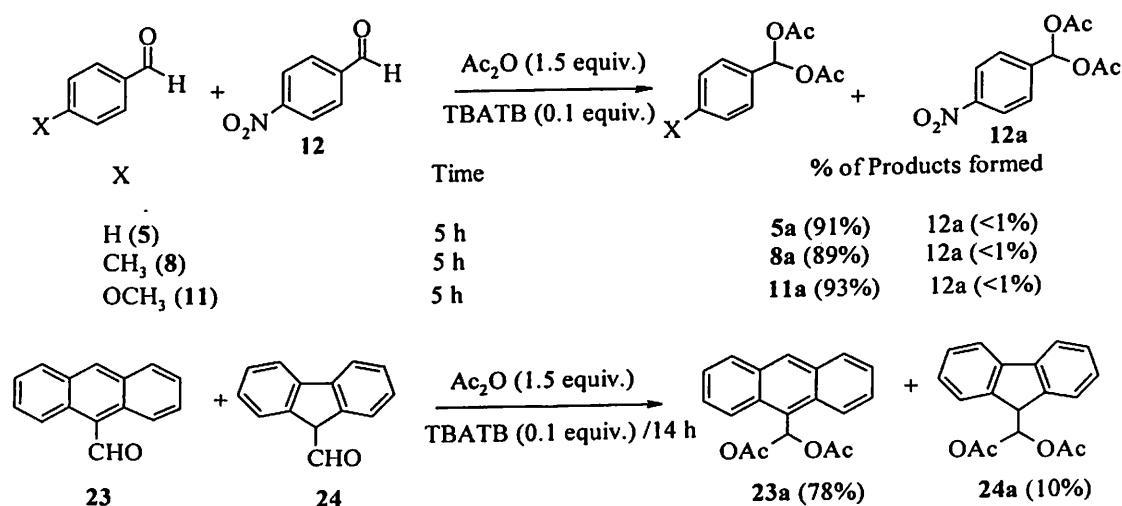
In the past the mechanism of *gem*-diacylation has been a subject of some controversy. In this part, we have reinvestigated the mechanism of *gem*-diacylate formation using tetrabutylammonium tribromide (TBATB), which liberates acid in the reaction medium to catalyze the reaction. Two plausible mechanisms could be thought of for *gem*-diacylation, one involving an intramolecular and other an intermolecular transfer of a second acylate group after the initial nucleophilic attack by an anhydride on an aldehydic group as proposed in Scheme IIB.8. After a series of experiments an intermolecular mechanism has been postulated. The reaction proceeds by a nucleophilic attack of an anhydride on an aldehydic carbonyl group, nucleophilic attack of the hemiacylate intermediate on a

second molecule of an anhydride, followed by an intermolecular attack of a second acetate group to regenerate the anhydride.



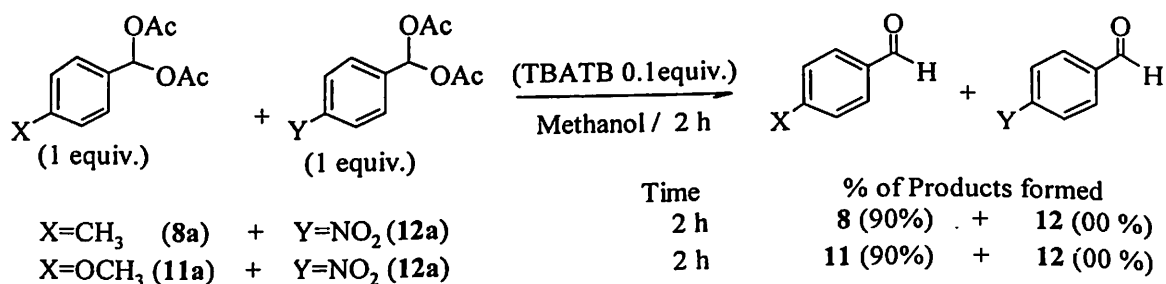
Scheme IIB.8. Mechanism of formation for the Diacylation

Gem-diacylates of various aliphatic and aromatic aldehydes were obtained directly by reacting with a variety of aliphatic and aromatic acid anhydrides in the presence of a catalytic quantity of tetrabutylammonium tribromide (TBATB) under solvent free conditions. Significant electronic effect was observed during its formation as well as deprotection to the corresponding aldehyde. Chemoselective *gem*-diacylation of the aromatic aldehyde containing an electron-donating group has been achieved in the presence of an aldehyde containing an electron-withdrawing group which could be seen in Scheme IIB.9.



Scheme IIB.9. Chemoselective *gem*-diacylation of aldehydes

Deprotection of *gem*-diacylate to the parent carbonyl compound can be accomplished in methanol in the presence of the same catalyst. Here again, chemoselective deprotection of *gem*-diacylate of the substrate containing an electron-donating group has been achieved in presence of the substrate containing an electron-withdrawing group as shown in Scheme IIB.10.



Scheme IIB.10. Chemoselective deprotection of *gem*-diacylates

Both the acid and base stability order of various *gem*-diacylates examined follows the similar order. The stability order determined from the present study is: *gem*-dibenzoate > *gem*-dipivalate > *gem*-diisobutyrate > *gem*-diacetate > *gem*-dipropionate. All the *gem*-diacylals are more stable under basic condition than acidic condition. No correlation was found between the stability order and the pKa's of the corresponding acids; rather, the stability order is directly related to their steric crowding around carbonyl carbon.

In conclusion we have demonstrated the mechanism of *gem* diacylation of aldehydes and the *gem*-diacylates of various aliphatic and aromatic aldehydes can be prepared from a variety of aliphatic and aromatic anhydrides under solvent free conditions in the presence of a catalytic quantity of tetrabutylammonium tribromide (TBATB). Deprotection of *gem*-diacylates to the corresponding parent carbonyl compounds has been accomplished by performing the reaction in methanol with the same catalyst. We also demonstrated the stability of diacylates derived from the cinnamaldehyde. Diacylates are more stable under basic conditions than acidic conditions. Interestingly, both acid and base stability of various *gem*-diacylates follow the same order, The stability order obtained from a series of competitive experiments is: *gem*-dibenzoate > *gem*-dipivalate > *gem*-diisobutyrate > *gem*-diacetate > *gem*-dipropionate, and is directly related to the steric crowding around the carbonyl carbon rather than to the pKa of corresponding acid.

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IA. Introduction

The quest to discover new synthetic transformations which enable the syntheses of complex organic molecules in a highly selective fashion remains an exciting challenge. An integral part of modern day synthetic organic chemistry is the designing of novel reactions that proceed with high atom economy in an environmentally viable strategy. Solvent usage is often an integral part of manufacturing process in industrial sector. Thus, this unavoidable choice of a specific solvent for a desired manufacturing process can have profound economical, environmental, and societal implications. The pressing need to develop alternative solvents for manufacturing processes originates, in part, from these implications and constitutes an essential strategy under an emerging field of “Green chemistry”. To ensure compatibility with conservation of global environment, chemical processes are required to be changed to Green processes, which includes atom economy, use of safer solvents, use of safer reagents and processes. Most of the organic solvents are flammable or toxic. Hence the process, which avoids the use of volatile organic solvents, will gain importance in modern days.

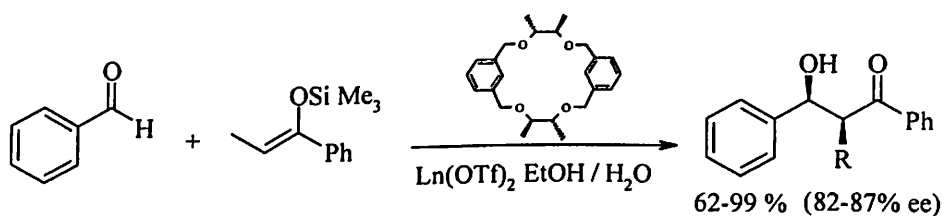
IA.1. Aqueous Mediated Organic Synthesis

Water plays an essential role in life processes; however its use as a solvent has been limited in organic synthesis. Despite the fact that it is the cheapest, safest and non-toxic solvent, its presence is generally avoided by drying of substrates and solvents. The use of water as a medium for organic reactions is therefore one of the latest challenges for modern organic chemists. This section of the thesis describes different organic reactions in an aqueous medium from the literature of the past few years. Excellent reviews about stereo-selective organic reactions in water have been recently published.¹ Considerable interest has been developed in the use of water in organic synthesis either at normal temperature (3-150 °C, 1-5 atm), at elevated temperature (250 -500 °C, 40-170 atm) or under super critical conditions (400 °C, 250-500 atm).² At elevated temperature and pressure the spatial structures of water changes significantly and consequently the physiochemical properties such as dielectric constant, density, solubility parameter and dissociation constant.³ Under supercritical conditions water can act either as a reagent or as an acid or a base. Many non-polar organic substrates

and gases are soluble in aqueous phase facilitating or making organic reactions that were previously thought to occur only in the presence of strong acids, bases or organic solvents.

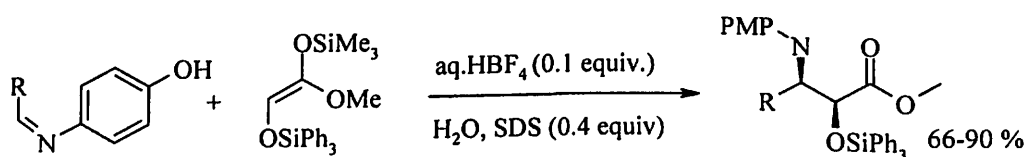
For years, numerous organic transformations have been performed in water as reaction medium or catalyst. On the other hand, after Breslow's discovery of a positive effect on the reaction rates and selectivities of the Diels-Alder reaction, a special attention has been focused on the origin of the aqueous acceleration. Breslow has demonstrated that the hydrophobic effect accelerates the rate of Diels-Alder reaction and gives high endo-exo selectivity.⁴ Despite the solubility problems of organic substrates in water, after this seminal contribution of Breslow new additions are continuously being made to the catalog of organic reactions that can be performed effectively with water as the solvent. Although in many cases water is an "anti solvent" *i.e* bringing the reactants together by hydrophobic effect but in other cases owing to the special affects of water reactions can now be performed in water.

Extensive studies revealed that a wide range of rare earth metal triflates⁵ and some other metal salts can be useful as Lewis acid promoters in aqueous media for various organic transformations.⁶ A typical example of a synthesis of chiral β -hydroxy ketone is shown in Scheme IA.1.1.



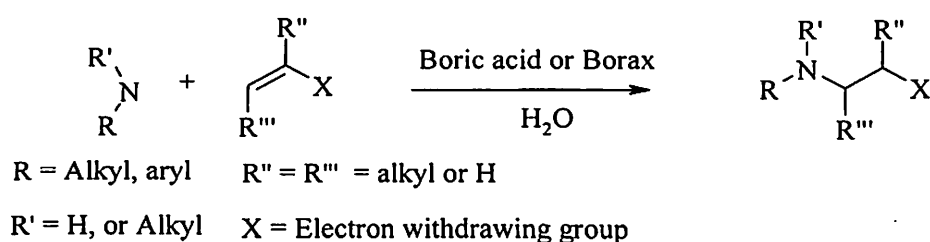
Scheme IA.1.1

The development of Mannich type reactions in aqueous media has made the incentive of finding a milder and more convenient approach towards the construction of β -amino ketone or esters. Towards this end, several research groups have recently reported one-pot Mannich type reactions in water to give β -amino carbonyl compounds using various Lewis acids (Scheme IA.1.2)⁷ or Brønsted catalysis.⁸



Scheme IA.1.2

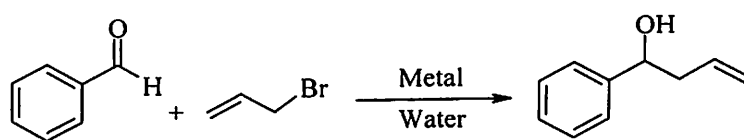
Many variations of Michael-type addition reaction for the formations of new carbon–carbon and carbon–hetero atom bonds have been reported to work well in water. Both basic catalysis and Lewis acid catalyst have been applied, and nucleophiles ranging from neutral amines, alcohols and thiols to some anionic species including carbanions.⁹ Boric acid and borax efficiently catalyzes the conjugate addition of aliphatic amines to α,β -unsaturated compounds to produce β -amino compounds, with great alacrity and good yields, in water under mild conditions (Scheme IA.1.3).¹⁰



Scheme IA.1.3

The addition of amines to conjugated alkenes has been carried out in water at room temperature very efficiently without any catalyst. Significant rate acceleration of this reaction is observed in water compared to organic solvents.¹¹

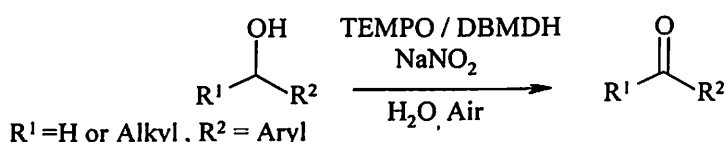
Metal mediated allylation (Scheme IA.1.4) of carbonyl compounds in aqueous medium has been focus of attention in the recent years. Numbers of metals such as Zn, Sn, Mg etc. have been reported to be useful for this purpose and indium metal is reported to be the most promising one due to its unique properties.¹²



Scheme IA.1.4

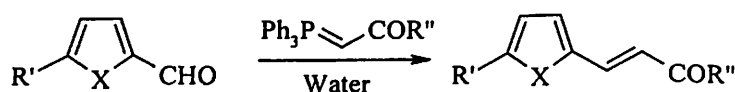
Cobalt complex, $\text{Co}(\text{acac})_2 \cdot 2\text{H}_2\text{O}$ efficiently catalyzes SnCl_2 -mediated Barbier coupling in water between carbonyls, including aromatic, aliphatic and α,β -unsaturated aldehydes, ketones, sugars and allyl bromide to afford the corresponding homoallylic alcohols in high yields. The catalyst was reused for several cycles with consistent activity.¹³

Hu and co-workers have developed a highly efficient (88-98 % yield) aerobic oxidation of benzylic alcohols, to their corresponding aldehydes or ketones in an aqueous media in the presence of TEMPO (2,2,6,6-tetramethylpiperidine 1-oxyl) using DBDMH (1,3-dibromo-5,5-dimethylhydantoin) and NaNO_2 as a co-catalysts (Scheme IA.1.5).¹⁴



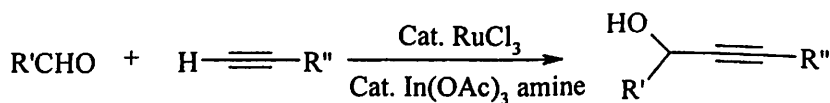
Scheme IA.1.5

Jesse *et al.* has recently reported for the first time the Wittig reactions of stabilized (and poorly water-soluble) ylides with aldehydes (Scheme IA.1.6). The rate of this reaction was found to be much faster compared to the reaction in other medium.¹⁵



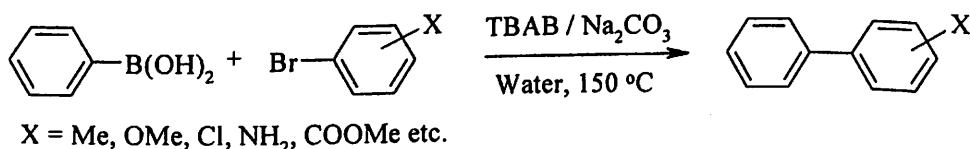
Scheme IA.1.6

Li and coworkers have developed a direct addition of terminal alkyne to aldehydes in water using a ruthenium-indium bimetallic system (Scheme IA.1.7).¹⁶



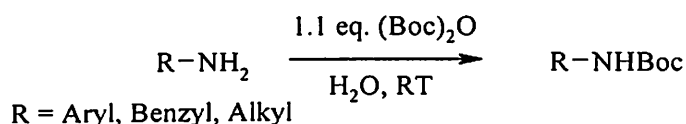
Scheme IA.1.7

Recently, Leadbeater and Marco have found that the Suzuki reaction could be carried out in water at higher temperature without using any transition metal catalyst (Scheme IA.1.8).¹⁷



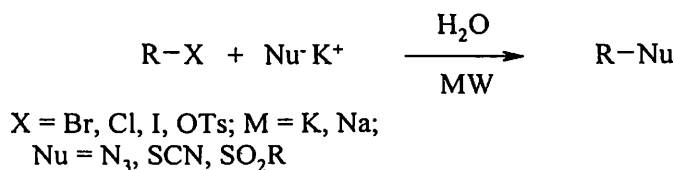
Scheme IA.1.8

A catalyst-free *N*-*tert*-butoxycarbonylation of amines in water gives *N*-*t*-Boc derivatives chemoselectively without any side products such as isocyanate, urea, *N,N*-di-*t*-Boc. Chiral amines and esters of α -amino acids afforded optically pure *N*-*t*-Boc derivatives. Amino alcohols and 2-aminophenol afforded *N*-*t*-Boc protected derivatives without oxazolidinone formation.¹⁸



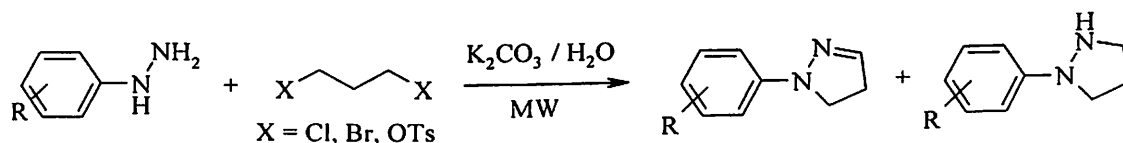
Scheme IA.1.9

Varma *et al.* has developed several useful synthetic methodologies using water as the reaction medium. A practical, rapid, and efficient microwave (MW) promoted synthesis of various azides, thiocyanates, and sulfones is described in an aqueous medium (Scheme IA.1.10). This general and expeditious MW-enhanced nucleophilic substitution approach uses commercially available starting materials such as halides or tosylates in reaction with alkali metal azides, thiocyanates, or sulfinates in the absence of any phase-transfer catalyst.¹⁹



Scheme IA.1.10

Direct syntheses of 4,5-dihydro-pyrazole, pyrazolidine, and 1,2-dihydro-phthalazine derivatives via double-alkylation of hydrazines by alkyl dihalides or ditosylates were accomplished in aqueous media under microwave irradiation (Scheme IA.1.11). This environmentally benign chemical transformation occurred in a single step and eliminated the use of expensive metal catalysts.²⁰



Scheme IA.1.11

Some examples of using water as an alternative solvent for chemical reactions with wide-ranging possibilities that include direct use of water soluble renewable materials, C-C bond forming

reactions using organometallic reagents, and exploiting the use of alternate energy sources such as solar, microwave and ultrasound in accelerating chemical syntheses has been highlighted in some of the recent reviews, text books and monographs.²¹

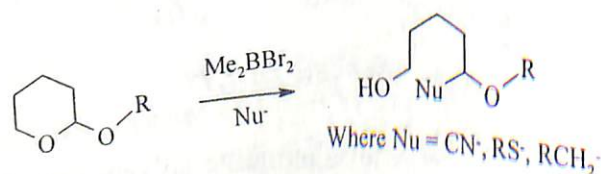
IA.2. Tetrahydropyranyl Ether

Tetrahydropyranyl ethers (THP ethers) were one of the first generally useful protecting groups for alcohols to be adopted during multi-step organic synthesis. The easy formation as well as facile and selective removal of these ethers renders them attractive in complex organic synthesis. In addition, tetrahydropyran derivatives are less expensive, and stable under a variety of reaction conditions such as strongly basic, Grignard reagents, metal hydrides, acylating agents, oxidative and alkylating agents. The only drawback is the formation of an additional stereocentre that may lead to diastereomeric mixtures if the alcohol already possesses a stereogenic center. This complicates the NMR spectra and hence makes its interpretation difficult. In spite of this drawback it is one of the most frequently used protecting group for alcohols.²²

IA.2.1. Applications of Tetrahydropyranyl Ether

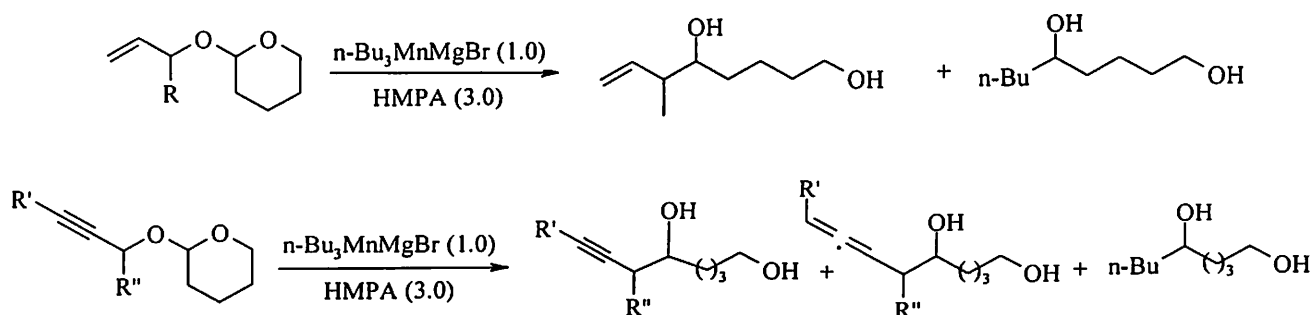
In addition to serving as a protecting group, THP ethers are also useful intermediates in organic synthesis. Some of the useful applications of THP ether in organic synthesis during last few years are described below.

Guindon group has exploited the cleavage of carbon-oxygen bond of the pyran ring of THP ether in the presence of Me_2BBr_2 to generate α -bromo ether intermediates. Various functionalized alcohols have been generated by trapping the ring opened α -bromo ether intermediates with several nucleophiles (Scheme IA.2.1.1). A wide variety of nucleophiles are used, including thiols, sterically hindered alcohols, cyanide, hydride reagents and number of organometallic species.²³



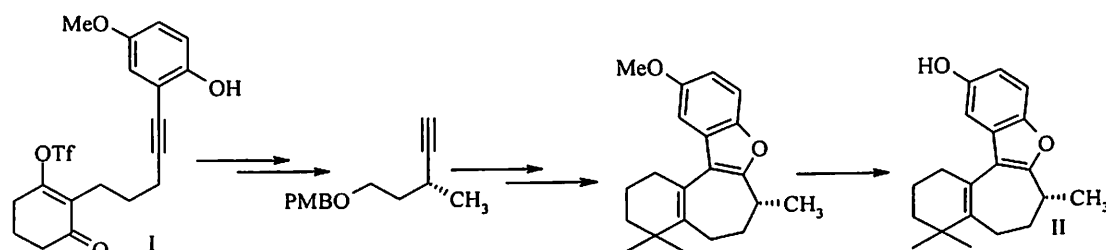
Scheme IA.2.1.1

Treatment of tetrahydropyranyl (or tetrahydrofuranyl) ether of allylic alcohol with tributylmanganate provided 7-octene-1,5-diol, where as propargylic tetrahydropyranyl ether gave a mixture of homopropargylic alcohol and an allenylated product in addition to butylated product as shown in Scheme IA.2.1.2.²⁴

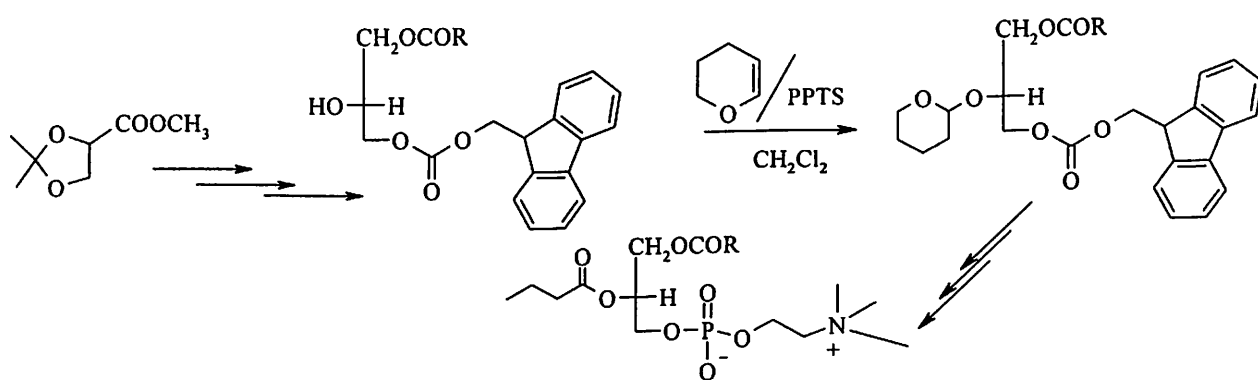


Scheme IA.2.1.2

THP ether as a protecting group has a strong tendency to direct regioselective ortho-lithiation. This has been demonstrate during the total synthesis of the marine terpenoid natural product (-)-frondosin B (II), which has potential HIV-inhibitory properties (Scheme IA.2.1.3).²⁵



Scheme IA.2.1.3

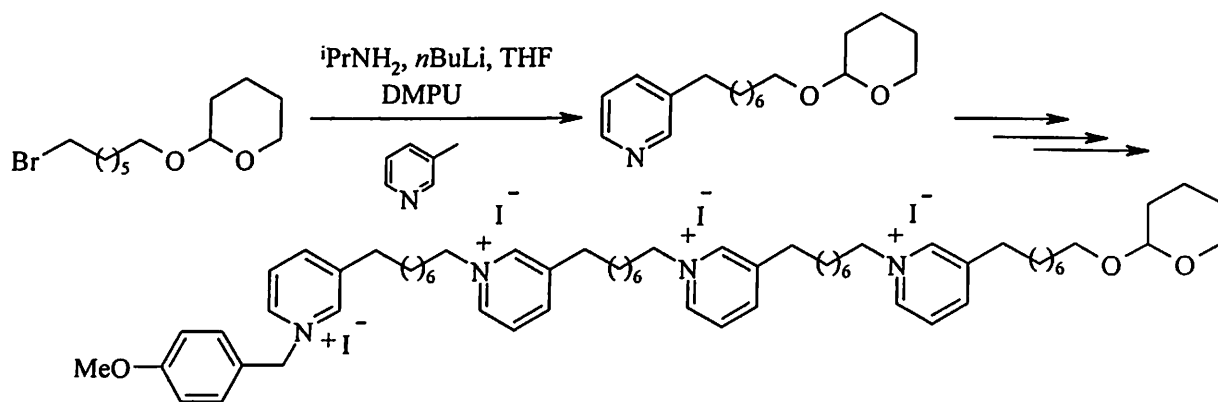


Scheme IA.2.1.4

A new stereospecific synthesis of lysophosphatidylcholines is reported which relies on orthogonal protection of hydroxyl groups derived from glyceric acid, using fluorenylmethylcarbonate

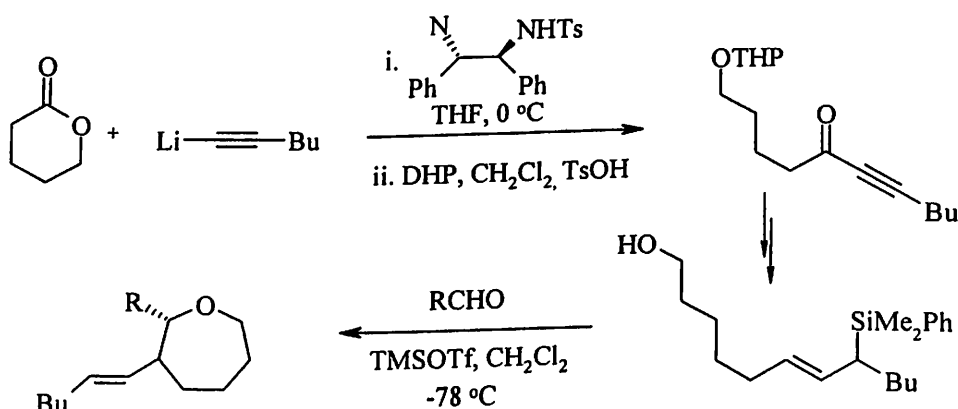
versus tetrahydropyranyl ether functions that allow regiospecific introduction of substituents to obtain the target phospholipid compound (Scheme IA.2.1.4).²⁶

The synthesis of linear oligomers related to polymeric alkylpyridinium metabolites uses THP as the protecting group (Scheme IA.2.1.5).²⁷



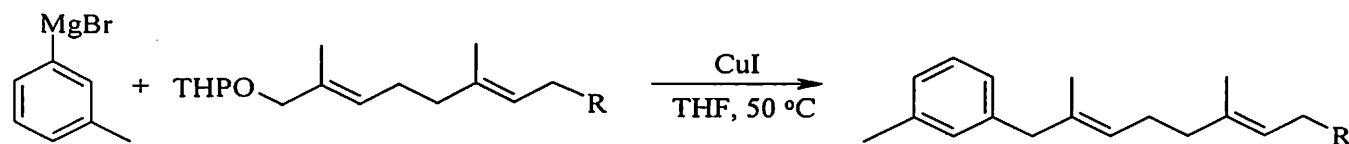
Scheme IA.2.1.5

Suginome *et al.* has described the synthesis of 2,3-disubstituted oxezapanes by reaction of *d*-valerolactone with 1-lithiohex-1-yne followed by THP protection of the resulting hydroxy group provided the desired ynone. Ruthenium catalyzed enantioselective reduction of the carbonyl group afforded the propargyl alcohol with high optical purity, which was then converted to enantioenriched allylsilanes. The palladium-catalyzed intramolecular bis-silylation of the disilanyl ether and subsequent treatment with BuLi followed by THP deprotection with PPTS afforded the (*R*)-enantioenriched allylsilane with a hydroxyl butylchain. New enantioenriched allylsilane, (*R*)-(*E*)-7-(dimethylphenylsilyl)undec-5-en-1-ol, in the presence of a variety of aldehydes provided enantioenriched *trans*-2,3-disubstituted oxepanes stereoselectively (Scheme IA.2.1.6).²⁸



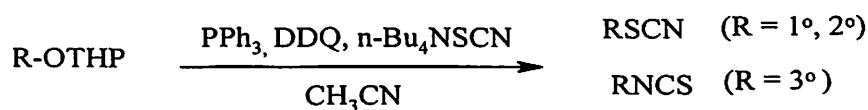
Scheme IA.2.1.6

Wiemer group has reported the synthesis of farnesol analogues through a Cu (I)-mediated displacement of allylic THP ethers employing Grignard reagent (Scheme IA.2.1.7).²⁹ Thus, an allylic THP group can fulfill its traditional role as a protecting group or serve as a leaving group depending on the reaction conditions.



Scheme IA.2.1.7

Iranpoor and his coworkers have prepared the thiocyanates and isothiocyanates from tetrahydropyranyl ethers using triphenylphosphine, 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ) and *n*-Bu₄NSCN,^{30a} diphenylphosphinite ionic liquid (IL-OPPh₂) and SCN⁻,^{30b} and Ph₃P(SCN)₂^{30c} (Scheme IA.2.1.8). Tetrahydropyranyl ethers derived from primary alcohols and secondary alcohols gave thiocyanate where as tertiary amine gave isothiocyanate.

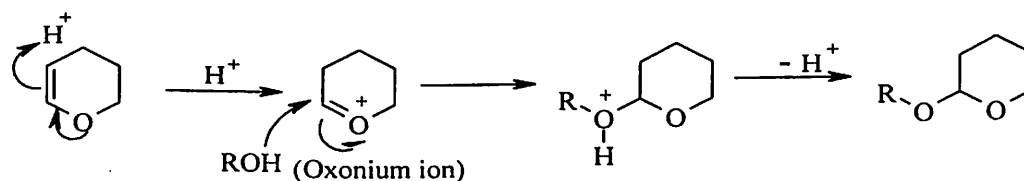


Scheme IA.2.1.8

IA.2.2. Literature Methods of Tetrahydropyranylation

Numerous methods are reported for the preparation of THP ethers. Most of the reported methods use acidic reagents in an aprotic solvent such as CH₂Cl₂, THF, acetone, toluene etc. A wide variety of catalysts, homogeneous as well as heterogeneous has been described for the tetrahydropyranylation of alcohols. Various protic acids, Lewis acids, transition metal catalysts, heterogeneous catalysts and other miscellaneous catalysts have been reported towards this end.

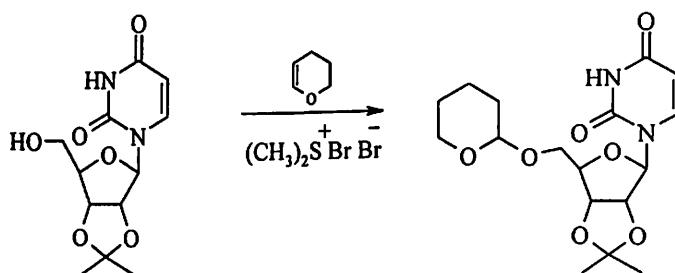
The reaction proceeds by protonation of the enol ether carbon of dihydropyran to generate a highly electrophilic oxonium ion which is then attacked by the alcohol to give the corresponding tetrahydropyranylated derivative, (Scheme IA.2.2.1).



Scheme IA.2.2.1

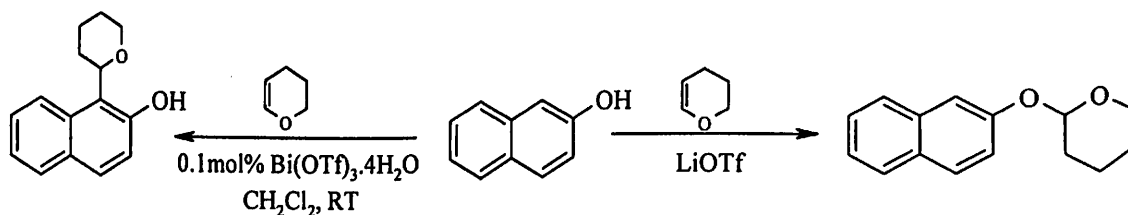
Various protic acids used for pyranylation in the earlier literature include HCl,³¹ *para*-toluene sulphonic acid (PTSA),³² pyridinium *para*-toluene sulphonic acid (PPTs).³³ *para*-Toluene sulphonic acid (PTSA) is a very strong acid giving eliminated product along with the desired product with tertiary alcohols, whereas PPTs being milder than PTSA gave no elimination product for tertiary alcohols. Yadav *et al.* has achieved tetrahydropyranylation of alcohols using equimolar amounts of alcohol, dihydropyran and NH₄Cl in THF under refluxed. The pH of the medium is reported to be 5.93.³⁴

Acetyltriphenylphosphonium bromide (ATPB) and PPTs are comparable catalysts for protection of acid labile substrates but ATPB is preferred as it is less hygroscopic than PPTs. There are two functionalities responsible for the catalytic activities of ATPB, the acidic proton present α to the carbonyl group and the phosphonium center.³⁵



Scheme IA.2.2.2

Khan *et al.* has carried out a solvent free tetrahydropyranylation of various alcohols using bromodimethylsulfonium bromide, (CH₃)₂S⁺ Br Br, which is reported to generate HBr on reaction with alcohol, (Scheme IA.2.2.2). The acid sensitive isopropylidene group remained intact and no bromination of the double or triple bonds were observed.³⁶



Scheme IA.2.2.3

I₂ is speculated to generate HI *in situ* by interaction with alcohol. Yadav and coworkers^{37a} as well as Deka *et al.*^{37b} have exploited the *in situ* acidity of I₂ for tetrahydropyranylation of alcohols. Metal triflates such as Sc(OTf)₃,^{38a} In(OTf)₃,^{38b} LiOTf,^{38c} Bi(OTf)₃,^{38d} have also been used

successfully for carrying out tetrahydropyranylation. The potential of LiOTf as a neutral catalyst for tetrahydropyranylation has been exploited (Scheme IA.2.2.3).

Solvent free tetrahydropyranylation with high substrate to catalyst ratio makes $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ as an efficient and practical alternative. The reaction also proceeds well for tertiary and bulky alcohols.³⁹ Afonso and Branco have shown the tetrahydropyranylation of alcohols in an ionic liquids $[\text{bmim}][\text{BF}_4]$, $[\text{bmim}][\text{PF}_6]$ with PPTs and TPP.HBr.⁴⁰ Various transition metal catalysts such as $[\text{Ru}(\text{CH}_3)_3\text{-(triphos)}](\text{OTf})_2$,⁴¹ heteropolyacids $(\text{H}_3[\text{PW}_{12}\text{O}_{40}]$ and $\text{H}_4[\text{SiMo}_{12}\text{O}_{40}]$,⁴² $\text{K}_5\text{CoW}_{12}\text{O}_{40} \cdot 3\text{H}_2\text{O}$,⁴³ CAN⁴⁴ have also been used for the tetrahydropyranylation of alcohols and phenols. Heteropolyacids exhibit weak super acidic properties and are used where reaction requires electrophilic catalysis. Other reagents such as trimethyliodosilane (TMSI)⁴⁵ and bis [trimethylsilyl] sulphate $[(\text{H}_3\text{C})_3\text{SiO}]_2\text{SO}_2$ ⁴⁶ have also been reported to achieve this transformation.

Heterogeneous catalysis has gained importance with respect to its extensive applications achieving selective reactions, lowering waste production and rendering the synthetic processes more attractive from both economical and environmental standpoint. Acid-base heterogeneous catalysis is based on the physicochemical properties of zeolites, clays and metal oxides.⁴⁷ Various heterogeneous catalysts used for tetrahydropyranylation include amberlyst H-15,⁴⁸ ion-exchange resins,⁴⁹ Nafion,⁵⁰ montmorillonite K10 clay,⁵¹ acid zeolites,⁵² envirocat EPZG[®],⁵³ hydrated zirconia (ZrO_2),⁵⁴ polystyrene supported acetonyltriphenyl phosphonium bromide,³⁵ $\text{SO}_3\text{H-SiO}_2$,⁵⁵ solid acid $\text{H}_6\text{P}_2\text{W}_{18}\text{O}_{62} \cdot 24\text{H}_2\text{O}$,⁵⁶ $\text{Al}_2\text{O}_3/\text{ZnCl}_2$,⁵⁷ dialkylimidazolium tetrachloroaluminates, $[\text{CnMIM}][\text{AlCl}_4]$,⁵⁸ trichloroisocyanuric acid (TCCA)⁵⁹ and dialkylimidazolium tetrachloroaluminates.⁶⁰

Very recently benzyltriphenylphosphonium tribromide,⁶¹ $\text{La}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$,⁶² $\text{CeCl}_3 \cdot 7\text{H}_2\text{O}$ NaI,⁶³ $\text{PdCl}_2(\text{CH}_3\text{CN})_2$,⁶⁴ magnesium halide,⁶⁵ imidazolium-based tetrachloroindate(III),⁶⁶ cupric sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)⁶⁷ and ferric perchlorate⁶⁸ have been used for this purpose by various groups.

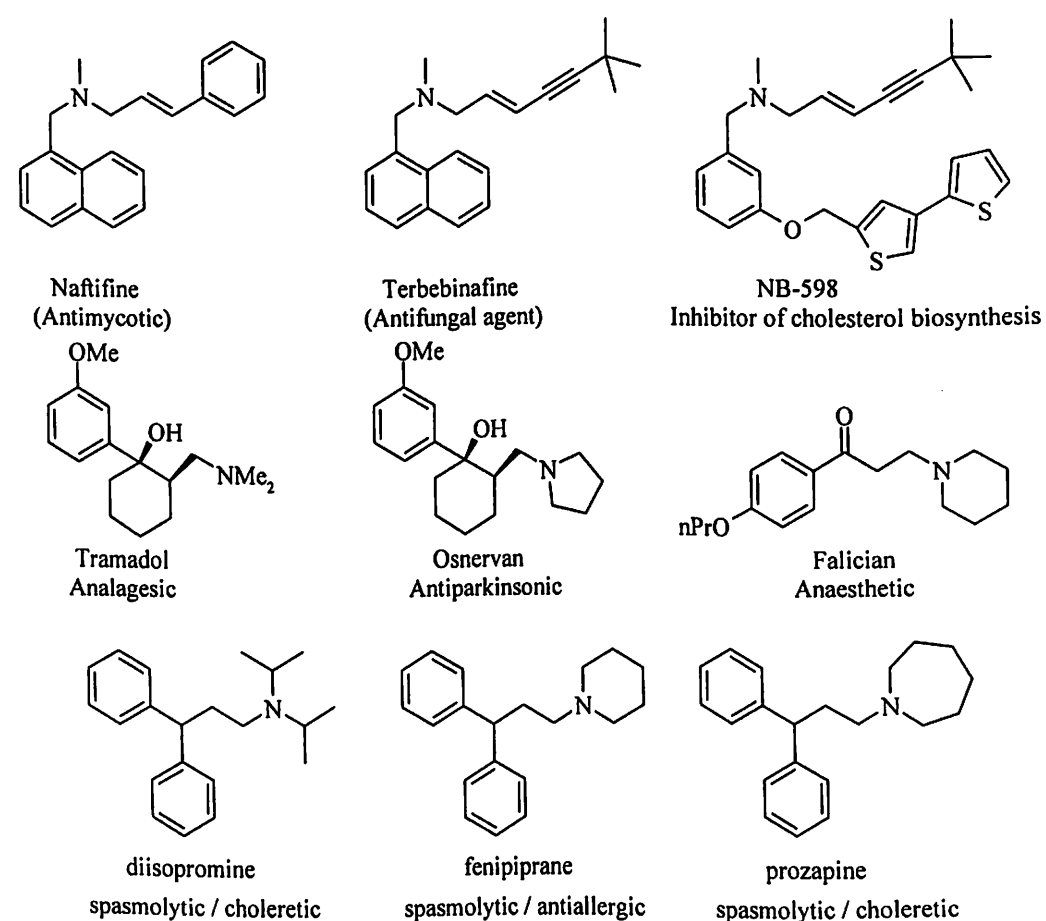
IA.3. Tertiary Amines

Amines are one of the most common structural features of naturally occurring biologically active compounds and are widely used throughout the chemical industry as a basic intermediates to prepare pharmaceutically or agro chemically useful chemicals. Amines in general and tertiary amines in particular are one of the most common structural features of naturally occurring biologically active

compounds and are an extremely important class of compounds from the drug perspective. Due to their unique biological properties, amines have played an important role as chemotherapeutic agents for the treatment of a various diseases. As a result, the developments of new synthetic routes to these pharmaceutically important compounds have stimulated constant interest and have been the focus of many research groups over the years.⁶⁹

IA.3.1. Significance of Tertiary Amines

Tertiaryamines are useful agents for potentiation of opiate analgesia, treatment of extrapyramidal movement disorders, besides, of course their use as antifungal, general anesthetic, antipsychotic, antihistamic and calcium channel blocking agents. Indeed no less than a quarter of the registered drugs contain tertiary amine. Some of the tertiary amines are used widely throughout the chemical industry as basic intermediates such as dyes,⁷⁰ fluorescence probes,⁷¹ pharmaceuticals,⁷² agrochemicals³ and catalysts for polymerization.⁷⁴

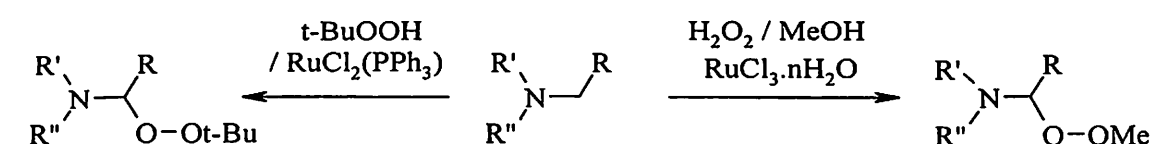


Scheme IA.3.1.1

Several of the pharmaceutically important tertiary amines along with the are shown in Scheme IA.3.1.1.⁷⁵

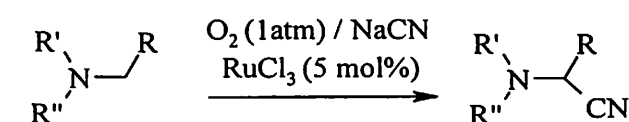
In the discovery of Menaquinone A inhibitors, Kurosu group has observed that a tertiary amine in the molecule is the crucial functional group to exhibit high affinity against MenA enzyme.⁷⁶

Murahashi and his coworkers have reported a ruthenium catalyzed oxidation of tertiary amines using *tert*-butyl hydroperoxide to form α -amino peroxy-ethers.⁷⁷ However, replacement of *tert*-butyl hydroperoxide with aqueous hydrogen peroxide and methanol, gave α -aminoalkyl methyl ethers (Scheme IA.3.1.2).⁷⁸



Scheme IA.3.1.2

Tertiary amine can be used as precursor for the synthesis of α -amino nitriles that are very important intermediates, which can be obtained from tertiary amines with chlorine dioxide in the presence of sodium cyanide.^{79,80} Recently this has been achieved using ruthenium catalyst in presence of molecular oxygen (Scheme IA.3.1.3).⁸¹



Scheme IA.3.1.3

Tertiary amine are easily oxidized to form corresponding N-oxides under a variety of reaction conditions.⁸² Tertiary amine N-oxides undergo preparatively useful reactions namely, rearrangement to trisubstituted hydroxylamines (Scheme IA.3.1.4)^{83,84} thermal cleavage to alkenes and hydroxyl amines (Scheme IA.3.1.5),⁸⁵ addition and rearrangement reaction via iminium cation and azomethane ylide. Further, compounds such as N-methylpyrrolidine oxide (NMPO) is a selective oxidants.⁸⁶

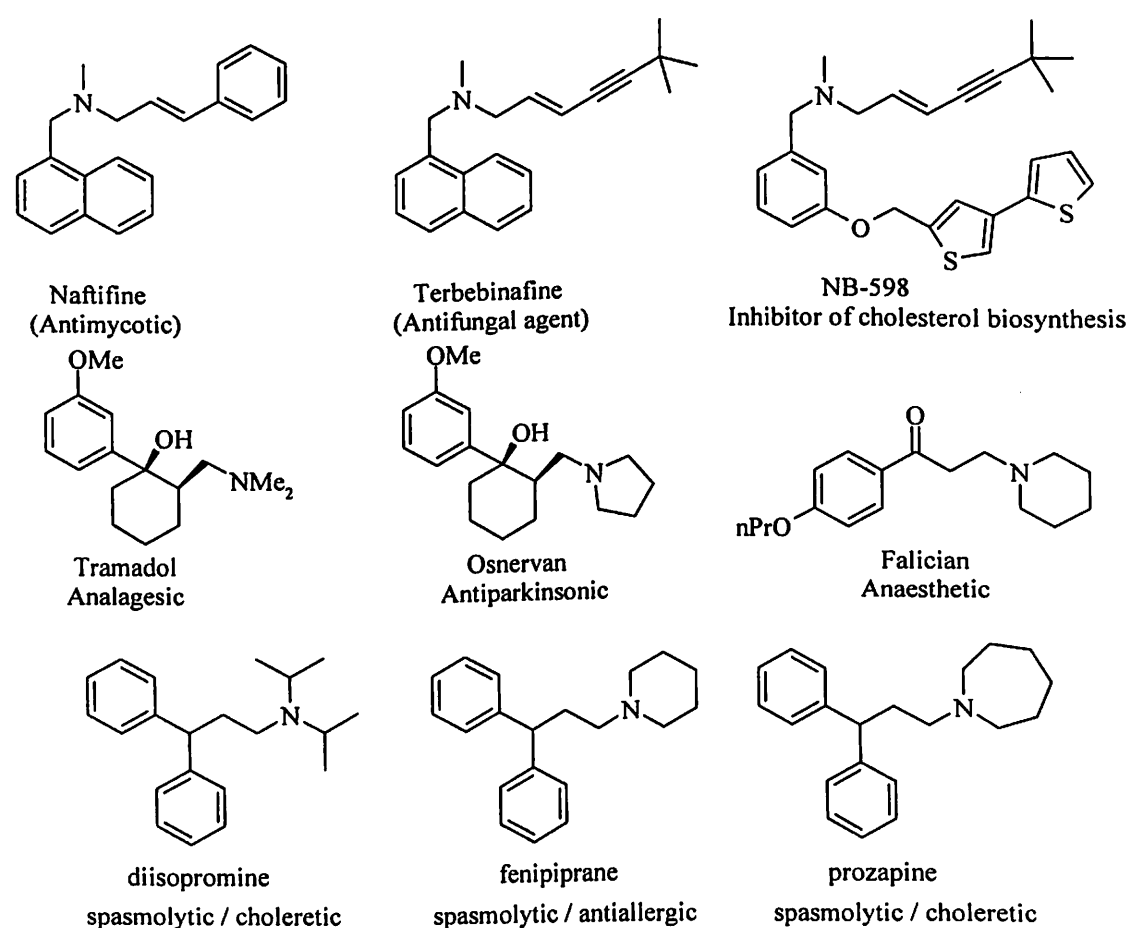


Scheme IA.3.1.4

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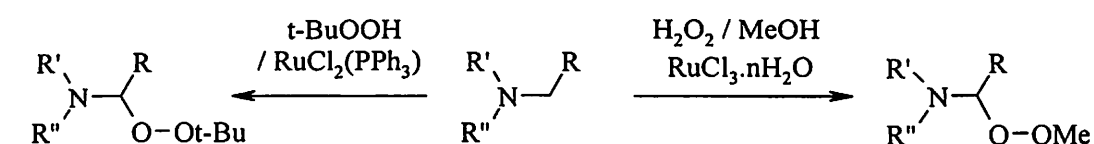


Scheme IA.3.1.1

Several of the pharmaceutically important tertiary amines along with their derivatives are shown in Scheme IA.3.1.1.⁷⁵

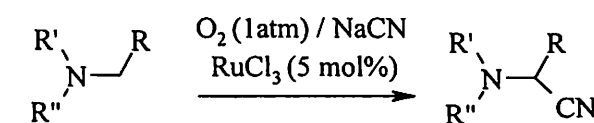
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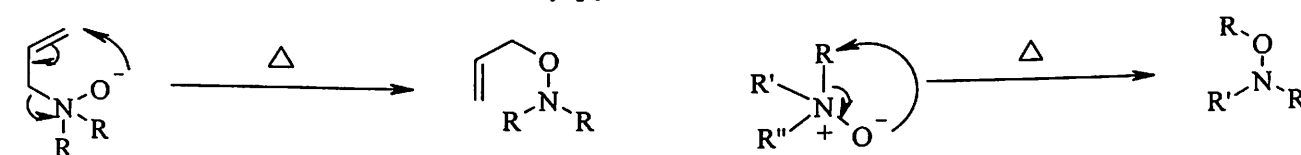
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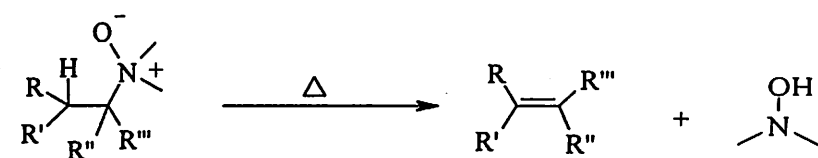


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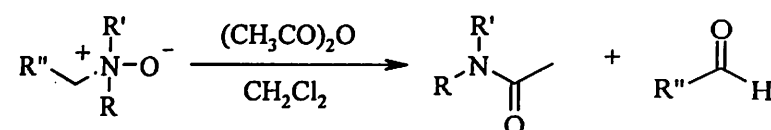


Scheme IA.3.1.4



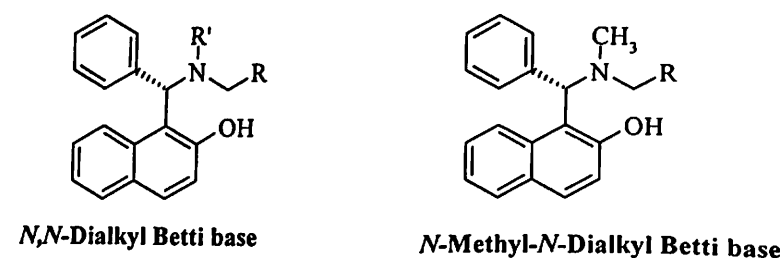
Scheme IA.3.1.5

Treatment of tertiary N-oxide with an activating agent such as acetic anhydride, results in the rearrangement, generating N,N-disubstituted acetamide and aldehyde (Scheme IA.3.1.6).⁸⁷



Scheme IA.3.1.6

Many unnatural homochiral amino-phenol compounds have been reported as excellent ligands in metal ion catalyzed asymmetric reactions in current asymmetric synthesis, particularly those having a structure based on the N-methyl-N-alkyl-Betti base (Scheme IA.3.1.7).⁸⁸



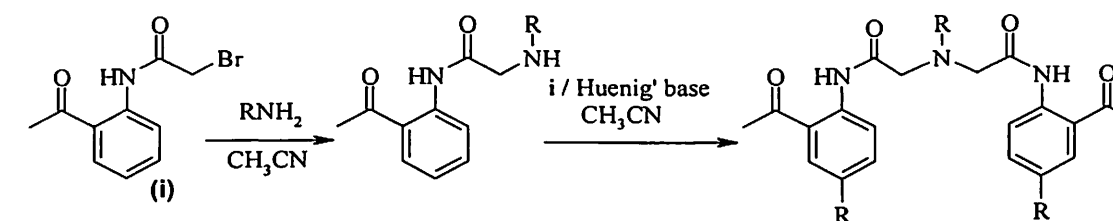
Scheme IA.3.1.7

IA.3.2. Literature Methods for Synthesis of Tertiary Amines

IA.3.2.1. N-Alkylation Using Base and Alkyl or Aryl Halides

The reaction of alkyl or aryl halides with amines (primary, secondary) have been commonly used in the carbon–nitrogen bond formation, however, alkylated amines tend to undergo further alkylation due to their enhanced nucleophilicity compared with that of the parent amines. Thus, primary amines on reaction with alkyl halide usually result in the formation of complex mixtures of amines (secondary, tertiary, quaternary) due to polyalkylation. One of the most frequently used procedures for the preparation of tertiary amines is by the N-alkylation of secondary amines with

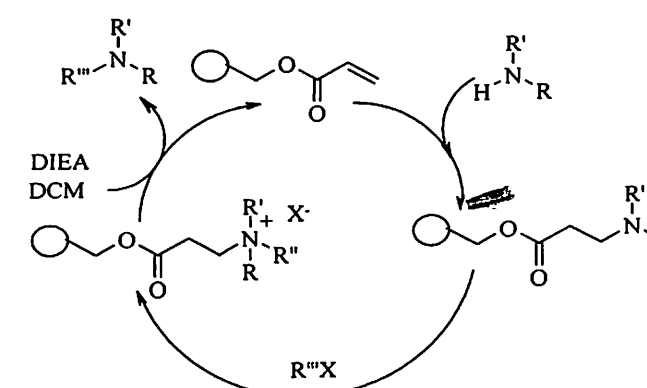
alkylating agent (alkyl halides, sulfonates, oxiranes etc.). In this process gener secondary amine is used.⁸⁹ For this reaction organic or inorganic base are naphthalenide,⁹⁰ Et₃N and KH,⁹¹ KOH in acetone and in DMSO,⁹² potassium,⁹³ sodium amide,⁹⁴ NaOH in hexamethylphosphoric triamide,⁹⁵ thallium(I)ethoxide,⁹⁶ KOH or t-BuOK in the presence of crown ethers,⁹⁷ aqueous or powered KOH in the presence of polyethylene glycol (PEG)⁹⁸ and CsF-Celite.⁹⁹



Scheme IA.3.2.1.1

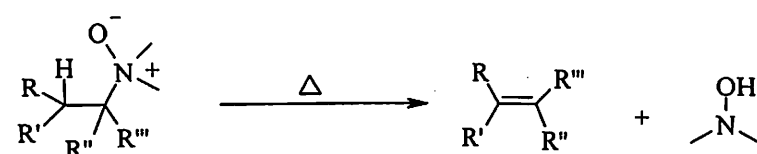
Recently Moore *et al.* has reported a convenient procedure for the synthesis of tertiary amines using Huenig's base (Scheme IA.3.2.1.1).¹⁰⁰ This procedure is highly functional group tolerant and the absence of transition metal catalyst and solid supports makes it further practical alternative.

IA.3.2.2. Solid Supported Synthesis



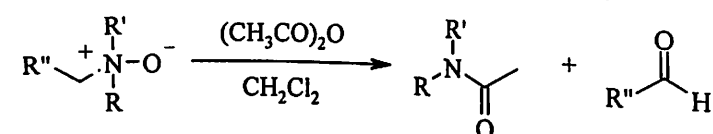
Scheme IA.3.2.2.1

Morphy group has used regenerative Michael acceptors on REM resin for the synthesis of tertiary amines (Scheme IA.3.2.2.1).¹⁰¹ Secondary amine generated by the removal of Boc group attached to REM resin undergoes Michael addition to give polymer bound tertiary amine which on further manipulation releases the tertiary amine and regeneration of REM. The main advantages of



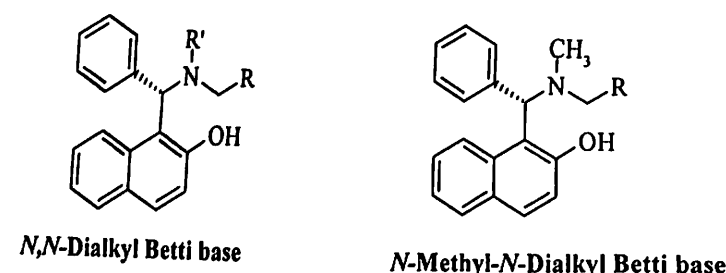
Scheme IA.3.1.5

Treatment of tertiary N-oxide with an activating agent such as acetic anhydride, results in the rearrangement, generating N,N-disubstituted acetamide and aldehyde (Scheme IA.3.1.6).⁸⁷



Scheme IA.3.1.6

Many unnatural homochiral amino-phenol compounds have been reported as excellent ligands in metal ion catalyzed asymmetric reactions in current asymmetric synthesis, particularly those having a structure based on the N-methyl-N-alkyl-Betti base (Scheme IA.3.1.7).⁸⁸



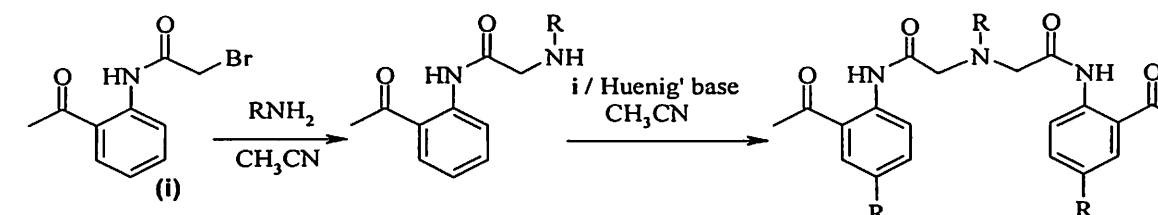
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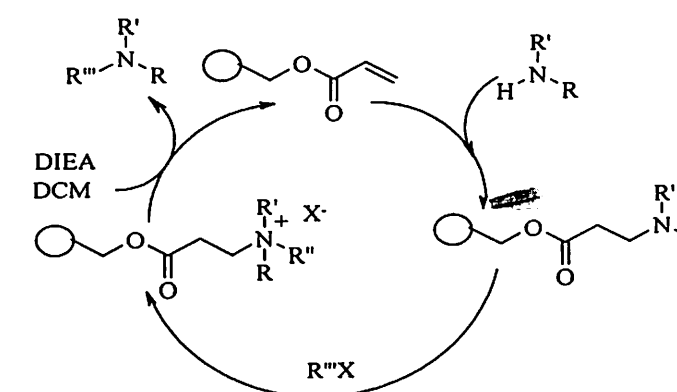
alkylating agent (alkyl halides, sulfonates, oxiranes etc.). In this process general secondary amine is used.⁸⁹ For this reaction organic or inorganic base are used such as potassium naphthalenide,⁹⁰ Et₃N and KH,⁹¹ KOH in acetone and in DMSO,⁹² potassium,⁹³ sodium amide,⁹⁴ NaOH in hexamethylphosphoric triamide,⁹⁵ thallium(I)ethoxide,⁹⁶ KOH or t-BuOK in the presence of crown ethers,⁹⁷ aqueous or powdered KOH in the presence of polyethylene glycol (PEG)⁹⁸ and CsF-Celite.⁹⁹



Scheme IA.3.2.1.1

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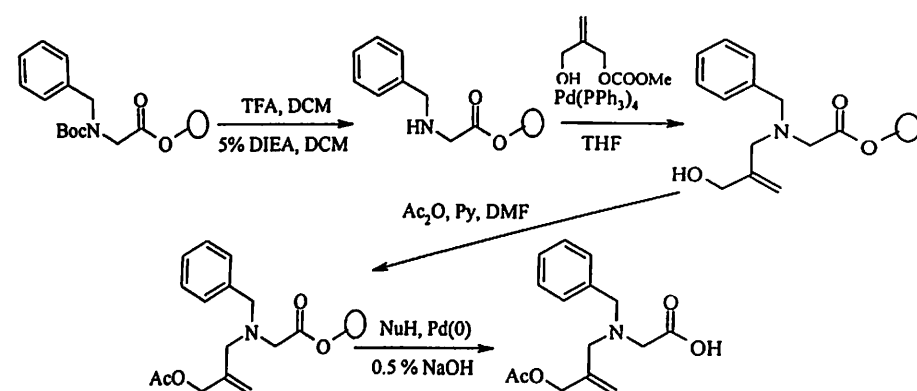
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this strategy is that products obtained are high purity and starting from secondary amine, two sites of diversity and from primary amine three site of diversity can be introduced.¹⁰¹

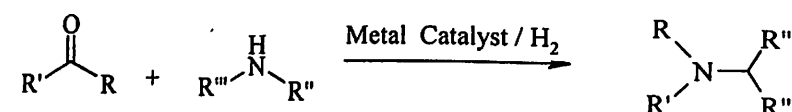


Scheme IA.3.2.2.3

Flegelová and Löber group have reported a general method for the solid phase synthesis of tertiary amines based on the Pd(0)-catalyzed nucleophilic substitution employing bis-allylic templates (Scheme IA.3.2.2.3).¹⁰²

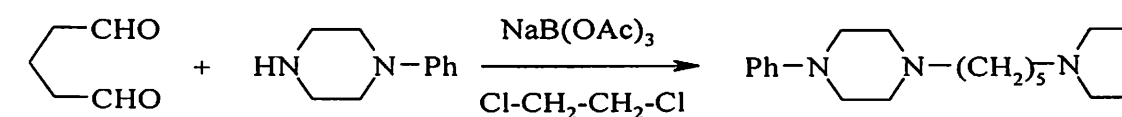
IA.3.2.3. Reductive Amination

The reductive amination reaction is a direct reaction between the carbonyl compound and the amine in the presence of appropriate reducing agents to yield the secondary or the tertiary amine in one pot. Two most commonly used direct reductive amination methods depending on the nature of the reducing agents are reported. The first method is the catalytic hydrogenation with Pt, Pd, Ni or Rh catalyst and the second method is based on metal hydride reducing agents (Scheme IA.3.2.3.1).¹⁰³



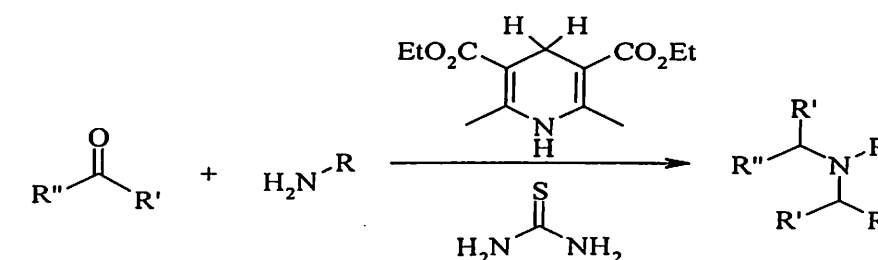
Scheme IA.3.2.3.1

Abdel-magid group have presented sodium triacetoxyborohydride as general reducing agent for the reductive amination of aldehydes and ketones (Scheme IA.3.2.3.2). In comparison with other reductive amination procedures such as NaBH₃CN / MeOH, borane-pyridine and catalytic hydrogenation, sodium triacetoxyborohydride gave higher yields and fewer side products.¹⁰⁴



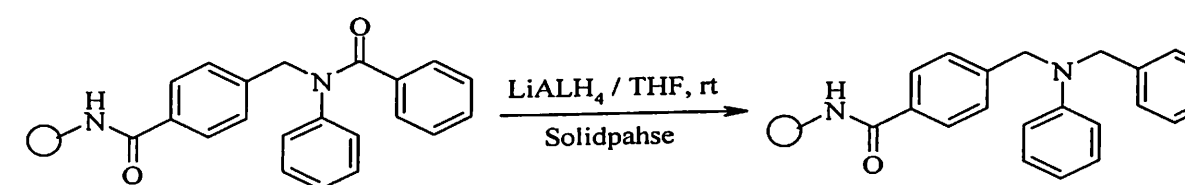
Scheme IA.3.2.3.2

Very recently an efficient metal-free procedure for the synthesis of tertiary amines by the reductive amination of carbonyl compounds is reported. This method allows a convenient synthesis to sterically hindered amines. In this reaction the Hantzsch ester acts as a source of hydrogen for reduction of the *in situ* generated imine and catalytic amounts of thiourea for imine activation (Scheme IA.3.2.3.3).¹⁰⁵



Scheme IA.3.2.3.3

In another reductive amination approach tertiary amides bound to gel type polystyrene support were reduced with LiAlH₄ to give high purity tertiary amine, where as the reduction of similar tertiary amides in solution gave secondary amines as the main product (Scheme IA.3.2.3.4).¹⁰⁶

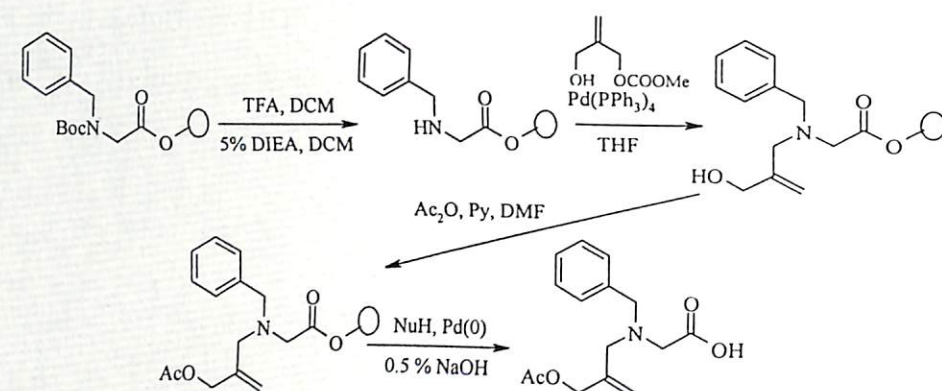


Scheme IA.3.2.3.4

IA.3.2.4. Mannich Approach and Other Methods

Mannich reaction is one of the classical methods for the synthesis of N-alkylated amine. The nucleophiles commonly used for Mannich reaction are enols and enolates, allylic, propargylic organometallics, activated aromatics and alkynes (Scheme IA.3.2.4.1).^{107, 108}

this strategy is that products obtained are high purity and starting from secondary amine, two sites of diversity and from primary amine three site of diversity can be introduced.¹⁰¹

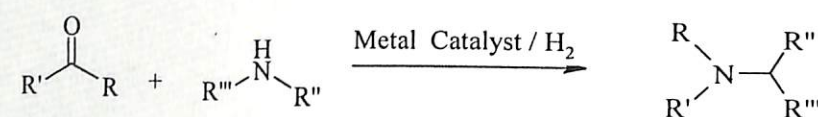


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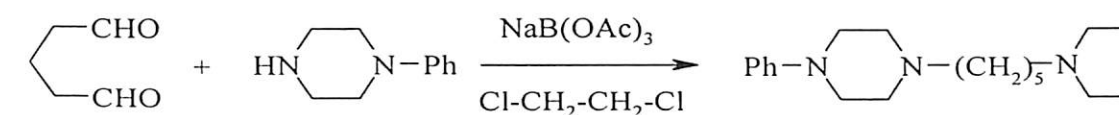
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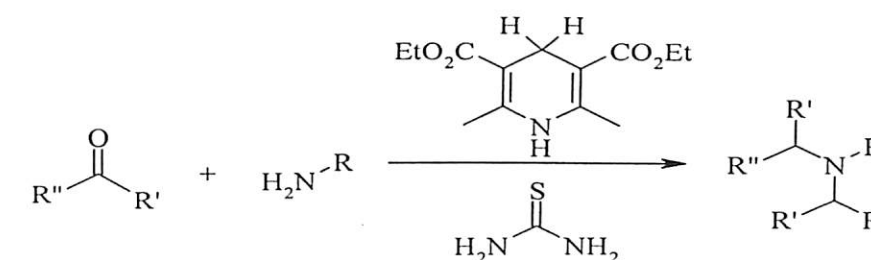
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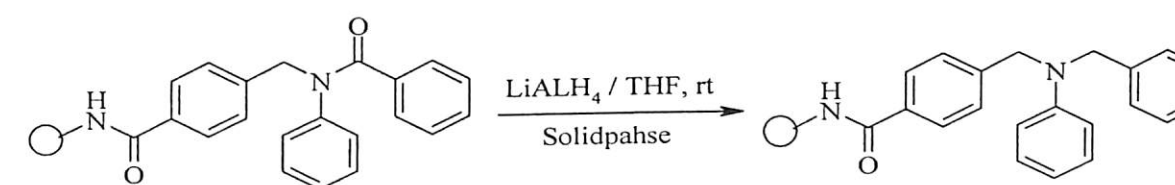
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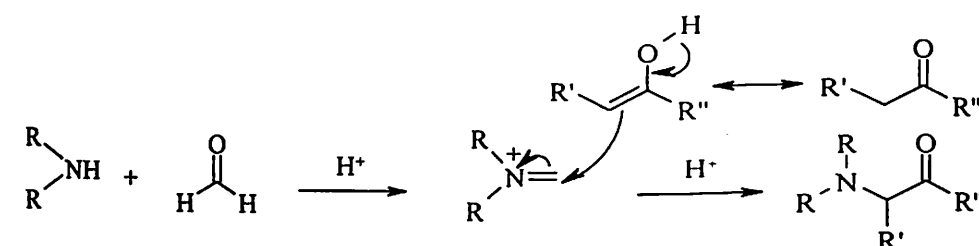
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Scheme IA.3.2.3.4

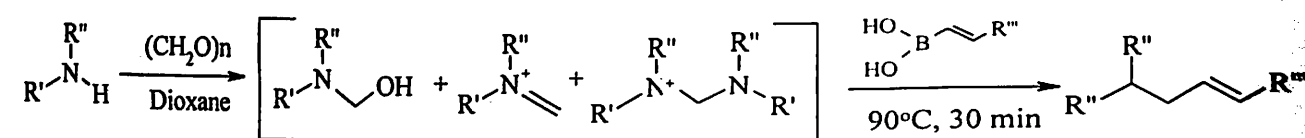
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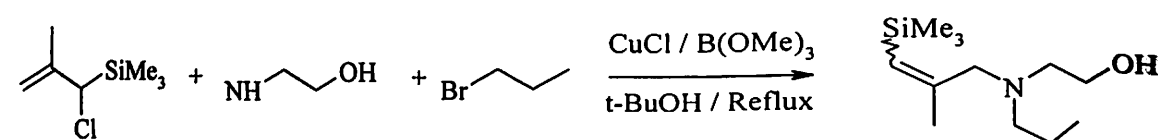
Scheme IA.3.2.4.1

Recently, Petasis group has explored the Mannich type reaction with vinyl boronic acids as nucleophiles for synthesis of various tertiary amines (Scheme IA.3.2.4.2).¹⁰⁹



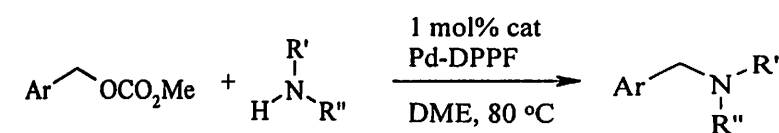
Scheme IA.3.2.4.2

Unsymmetrical tertiary amines were obtained in a single step by the $\text{CuCl} / \text{B(OMe)}_3$ catalyzed reactions of primary amines, alkylhalides and α -chlorine substituted allylsilanes (Scheme IA.3.2.4.3).¹¹⁰



Scheme IA.3.2.4.3

A new method for the synthesis of tertiary amine by nucleophilic substitution of benzylic esters with secondary amines using palladium catalyst has been reported (Scheme IA.3.2.4.4).¹¹¹

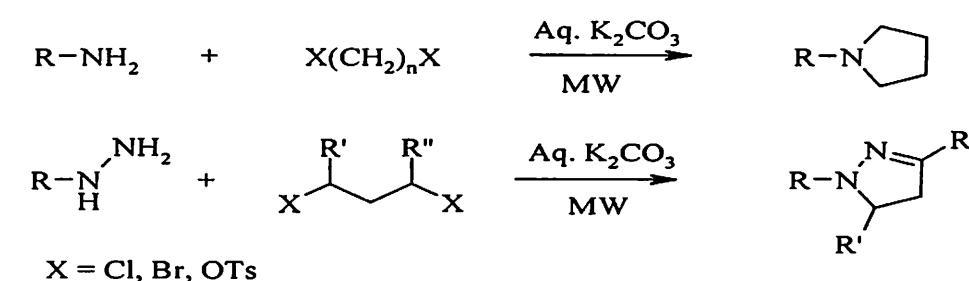


Scheme IA.3.2.4.4

IA.3.2.5. Aqueous Mediated N-Alkylation

Although there are numerous methods known for the N-alkylation of amines in organic medium there are very few methods reported using water as the reaction medium. Varma *et al.* have

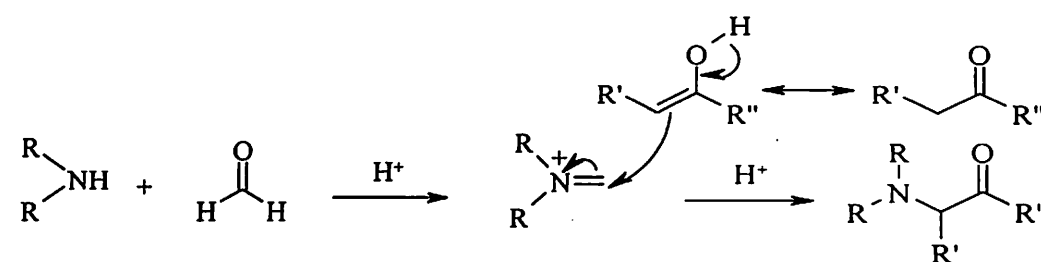
developed some synthetically useful methods in aqueous medium using microwave N-alkylation of primary and secondary amines with alkyl halides in aqueous NaOH under microwave irradiation gave satisfactory yield of tertiary amines.¹¹² The synthesis of nitrogen-containing heterocycles from alkyl dihalides (ditosylates) and primary amines and hydrazines via a simple and efficient cyclocondensation in an alkaline aqueous medium occurs under microwave irradiation. This procedure provides a simple and straightforward one-pot approach to the synthesis of a variety of heterocycles, such as substituted azetidines, pyrrolidines, piperidines, azepanes, N-substituted 2,3-dihydro-1H-isoindoles, 4,5-dihydropyrazoles, pyrazolidines, and 1,2-dihydrophthalazines (Scheme IA.3.2.5.1).¹¹³



Scheme IA.3.2.5.1

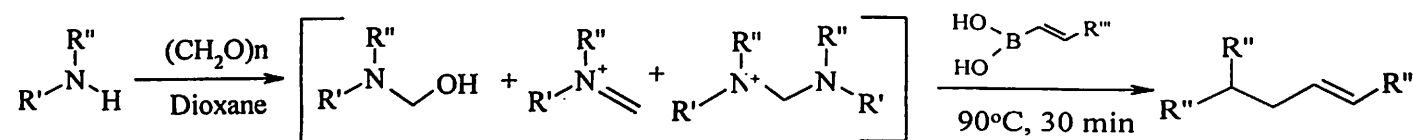
IA.3. References

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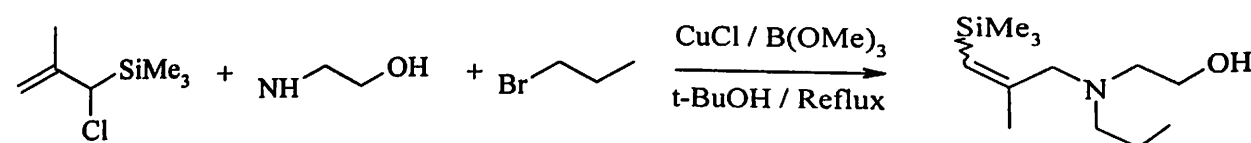
Scheme IA.3.2.4.1

Recently, Petasis group has explored the Mannich type reaction with vinyl boronic acids as nucleophiles for synthesis of various tertiary amines (Scheme IA.3.2.4.2).¹⁰⁹



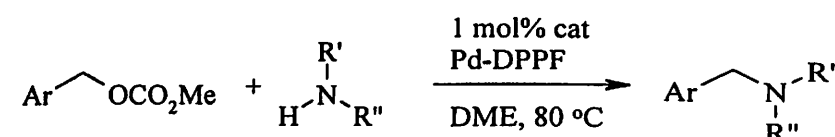
Scheme IA.3.2.4.2

Unsymmetrical tertiary amines were obtained in a single step by the $\text{CuCl} / \text{B(OMe)}_3$ catalyzed reactions of primary amines, alkylhalides and α -chlorine substituted allylsilanes (Scheme IA.3.2.4.3).¹¹⁰



Scheme IA.3.2.4.3

A new method for the synthesis of tertiary amine by nucleophilic substitution of benzylic esters with secondary amines using palladium catalyst has been reported (Scheme IA.3.2.4.4).¹¹¹

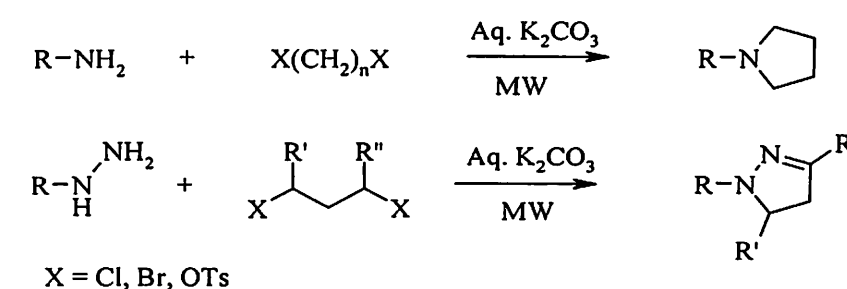


Scheme IA.3.2.4.4

IA.3.2.5. Aqueous Mediated N-Alkylation

Although there are numerous methods known for the N-alkylation of amines in organic medium there are very few methods reported using water as the reaction medium. Varma *et al.* have

developed some synthetically useful methods in aqueous medium using microwave irradiation. N-alkylation of primary and secondary amines with alkyl halides in aqueous NaOH under microwave irradiation gave satisfactory yield of tertiary amines.¹¹² The synthesis of nitrogen-containing heterocycles from alkyl dihalides (ditosylates) and primary amines and hydrazines via a simple and efficient cyclocondensation in an alkaline aqueous medium occurs under microwave irradiation. This procedure provides a simple and straightforward one-pot approach to the synthesis of a variety of heterocycles, such as substituted azetidines, pyrrolidines, piperidines, azepanes, N-substituted 2,3-dihydro-1H-isindoles, 4,5-dihydropyrazoles, pyrazolidines, and 1,2-dihydropthalazines (Scheme IA.3.2.5.1).¹¹³



Scheme IA.3.2.5.1

IA.3. References

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1B. Present Work

1B.1. Water as Catalyst and Solvent: Tetrahydropyranylation of Alcohols in an Aqueous Medium

Aqueous mediated reactions have received considerable attention in organic synthesis due to environmental and safety reasons. Water is the cheapest, most abundant and non-toxic chemical in Nature. It has unique physical and chemical properties such as a high dielectric constant and cohesive energy density compared to organic solvents. It has also special effects on reactions arising from inter and intramolecular non-covalent interactions leading to novel solvation and assembly processes. Large numbers of organic reactions have been performed successfully utilizing water as the reaction medium, and several books and reviews have been devoted to such a use.¹ Thus, development of an efficient and convenient synthetic methodology in water is an important subject in these environmentally conscious days. Recently, we have reported acylation of amines in an aqueous medium.²

The tetrahydropyranyl ether is one of the most frequently used protecting groups for alcohols employed during multi-step organic synthesis.³ Most of the reported methods use acidic reagents in an aprotic solvent such as CH₂Cl₂, THF, acetone and toluene.⁴ At times their formation has been carried out in ionic liquids.⁵ Although these methods are suitable for many synthetic conditions, some of these methods suffer from use of excess amounts and/or toxic catalysts, volatile organic solvents and large amounts of solid supports which ultimately result in the generation of considerable amounts of toxic wastes. Tetrahydropyranylation is usually performed in anhydrous aprotic organic solvents because of the longer reaction time and poor yields of products obtained in the presence of water. Based on the pK_a's of water (15.74), alcohols (~16.5), protonated hydroxyl of 2-hydroxytetrahydropyran (~-2) and protonated ethereal functions (~-6), we speculate that pyranlation of alcohols should occur in an aqueous medium and, due to an unfavorable pK_a, phenol should not undergo pyranlation in water. 2-Hydroxytetrahydropyran is formed in all reactions involving dihydropyran (DHP) and water. The hydroxyl group of 2-hydroxytetrahydropyran is more likely to be protonated compared to the ethereal oxygen. An oxycarbenium species could be generated due to protonation of the hydroxyl group followed by water elimination, which should react with alcohol giving rise to the corresponding THP ether. The attack of water occurs but it is unproductive and

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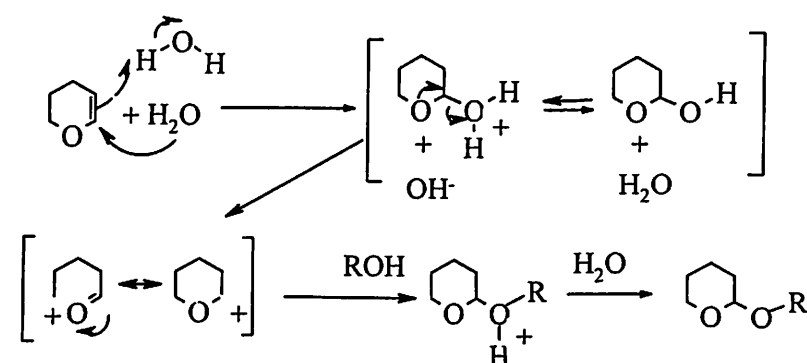
IB.1. Water as Catalyst and Solvent: Tetrahydropyranylation of Alcohols in an Aqueous Medium

Aqueous mediated reactions have received considerable attention in organic synthesis due to environmental and safety reasons. Water is the cheapest, most abundant and non-toxic chemical in Nature. It has unique physical and chemical properties such as a high dielectric constant and cohesive energy density compared to organic solvents. It has also special effects on reactions arising from inter and intramolecular non-covalent interactions leading to novel solvation and assembly processes. Large numbers of organic reactions have been performed successfully utilizing water as the reaction medium, and several books and reviews have been devoted to such a use.¹ Thus, development of an efficient and convenient synthetic methodology in water is an important subject in these environmentally conscious days. Recently, we have reported acylation of amines in an aqueous medium.²

The tetrahydropyranyl ether is one of the most frequently used protecting groups for alcohols employed during multi-step organic synthesis.³ Most of the reported methods use acidic reagents in an aprotic solvent such as CH₂Cl₂, THF, acetone and toluene.⁴ At times their formation has been carried out in ionic liquids.⁵ Although these methods are suitable for many synthetic conditions, some of these methods suffer from use of excess amounts and/or toxic catalysts, volatile organic solvents and large amounts of solid supports which ultimately result in the generation of considerable amounts of toxic wastes. Tetrahydropyranylation is usually performed in anhydrous aprotic organic solvents because of the longer reaction time and poor yields of products obtained in the presence of water. Based on the pK_a's of water (15.74), alcohols (~16.5), protonated hydroxyl of 2-hydroxytetrahydropyran (~2) and protonated etheral functions (~6), we speculate that pyranlation of alcohols should occur in an aqueous medium and, due to an unfavorable pK_a, phenol should not undergo pyranlation in water. 2-Hydroxytetrahydropyran is formed in all reactions involving dihydropyran (DHP) and water. The hydroxyl group of 2-hydroxytetrahydropyran is more likely to be protonated compared to the etheral oxygen. An oxycarbenium species could be generated due to protonation of the hydroxyl group followed by water elimination, which should react with alcohol giving rise to the corresponding THP ether. The attack of water occurs but it is unproductive and



regenerates the oxycarbenium species via a hemiacetal while the attack of the alcohol produces the acetal. The latter should be favored because the hydroxyl group having a lower pKa will leave preferentially over the alkoxide, driving the reaction in favor of product formation as shown in Scheme IB.1.1.



Scheme IB.1.1. Mechanism of formation of THP ether in water

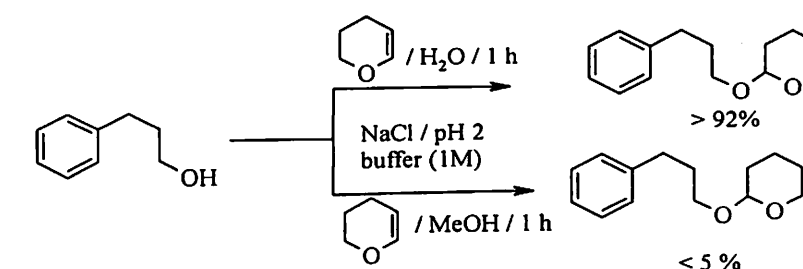
Table IB.1.1. Tetrahydropyranylation of 3-Phenyl-1-propanol **2** in Different Buffers

pH of the Solution	Time (h)	Yield (%) ^a	Types of Buffer Used
8	15	Nil	Na ₂ HPO ₄ + NaH ₂ PO ₄
7.5	15	10%	Na ₂ HPO ₄ + NaH ₂ PO ₄
7	15	20%	Na ₂ HPO ₄ + NaH ₂ PO ₄
6.5	15	72%	Na ₂ HPO ₄ + NaH ₂ PO ₄
6	15	80%	Na ₂ HPO ₄ + NaH ₂ PO ₄
5.5	10	> 95%	Na ₂ HPO ₄ + NaH ₂ PO ₄
5	8	> 95%	Na ₂ HPO ₄ + NaH ₂ PO ₄
4.5	7	> 95%	Na ₂ HPO ₄ + NaH ₂ PO ₄
4	5	> 95%	Sodiumcitrate + Citric acid
3.5	4.5	> 95%	Sodiumcitrate + Citric acid
3	3	> 95%	Sodiumcitrate + Citric acid
2	1	> 95%	Sodiumcitrate + Citric acid

^aGC yields

With this assumption, when 3-phenyl-1-propanol **2** (5 mmol) was treated with DHP (7.5 mmol) in water (5 ml), 60 % of the product was formed after 24 h at room temperature. However, ca.

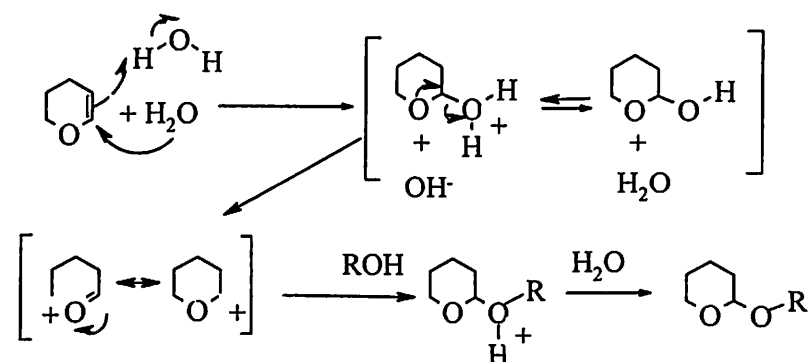
60 % conversion was achieved in 7 h by performing the reaction at reflux temperature. DHP formed a heterogeneous reaction mixture in water. In order to make the reaction homogeneous with the hope of accelerating the reaction, phase transfer reagents such as tetrabutylammonium bromide ca. 50 mg were added to the medium. Unfortunately, the percentage conversion was a mere 50 % after 10 h even at reflux temperature. When the reaction was repeated in a saturated solution of sodium chloride under reflux conditions the yield improved to ca. 80 % within 7 h. Thus, hydrophobic interactions between the alcohol and the DHP unit are essential for the reaction leading to product formation. The pH of the medium progressively decreased from ca. 6.8 at the beginning of the reaction to ca. 4.3 after the completion of the reaction when 3-phenyl-1-propanol **2** was used as the substrate. This prompted us to investigate the optimum pH conditions of the reaction medium required for the pyranilation of alcohol. Pyranilation was performed under reflux at different pH (1 M buffer), saturated with NaCl. The results are summarized in Table IB.1.1.



Scheme IB.1.2. Pyranilation in different solvents.

It is surprising and interesting to note that the reaction worked from pH 7.5 down to pH 2. The process is more facile at lower pH and worked even in 10 % aqueous HCl giving 90 % yield of the product after 2.5 h. It seems that under acidic conditions the oxycarbenium species is more susceptible to attack by alcohol than water (Scheme IB.1.1). There are several reports of deprotection of THP ethers³ in acidic medium and in almost all of these cases methanol or ethanol is used as the co-solvent, possibly because a large excess of the alcohol shifts the equilibrium with concurrent formation of 2-methoxytetrahydropyran via a transacetalization process. When the THP ether of 3-phenyl-1-propanol **2a** (1 mmol) was treated with 10 % aq. HCl (2 mL) and refluxed for 2h, less than 5 % of the product **2a** was deprotected. However, more than 90% deprotection could be achieved after 2 h under identical conditions when methanol (2 mL) was added to the medium. When pyranilation of 3-phenyl-1-propanol **2** (1 mmol) was performed under identical conditions at pH 2 (1M buffer) in

regenerates the oxycarbenium species via a hemiacetal while the attack of the alcohol produces the acetal. The latter should be favored because the hydroxyl group having a lower pK_a will leave preferentially over the alkoxide, driving the reaction in favor of product formation as shown in Scheme IB.1.1.



Scheme IB.1.1. Mechanism of formation of THP ether in water

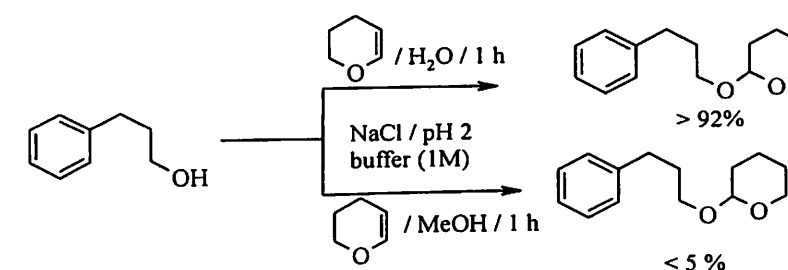
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7	15	20%	Na ₂ HPO ₄ + NaH ₂ PO ₄
6.5	15	72%	Na ₂ HPO ₄ + NaH ₂ PO ₄
6	15	80%	Na ₂ HPO ₄ + NaH ₂ PO ₄
5.5	10	> 95%	Na ₂ HPO ₄ + NaH ₂ PO ₄
5	8	> 95%	Na ₂ HPO ₄ + NaH ₂ PO ₄
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^a GC yields

With this assumption, when 3-phenyl-1-propanol 2 (5 mmol) was treated with DHP (7.5 mmol) in water (5 ml), 60 % of the product was formed after 24 h at room temperature. However, ca.

60 % conversion was achieved in 7 h by performing the reaction at reflux temp. DHP formed a heterogeneous reaction mixture in water. In order to make the reaction homogeneous with the hope of accelerating the reaction, phase transfer reagents such as tetrabutylammonium bromide ca. 50 mg were added to the medium. Unfortunately, the percentage conversion was a mere 50 % after 10 h even at reflux temperature. When the reaction was repeated in a saturated solution of sodium chloride under reflux conditions the yield improved to ca. 80 % within 7 h. Thus, hydrophobic interactions between the alcohol and the DHP unit are essential for the reaction leading to product formation. The pH of the medium progressively decreased from ca. 6.8 at the beginning of the reaction to ca. 4.3 after the completion of the reaction when 3-phenyl-1-propanol 2 was used as the substrate. This prompted us to investigate the optimum pH conditions of the reaction medium required for the pyranlation of alcohol. Pyranlation was performed under reflux at different pH (1 M buffer), saturated with NaCl. The results are summarized in Table IB.1.1.

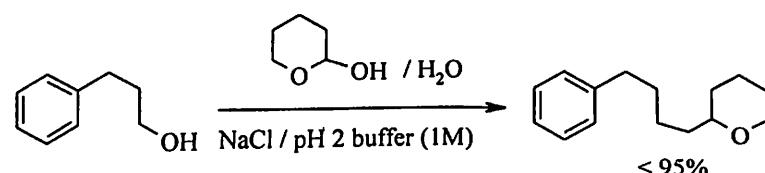


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the presence of methanol (2 mL), only a trace of pyranlated product (< 5 %) could be seen, further supporting the facile formation of 2-methoxytetrahydropyran and the role of methanol during the depyranylation process (Scheme IB.1.2).

Mechanistically, it is possible to suggest other reasonable pathways, as for instance the addition of the alcohol to the aldehyde group of the open-chain tautomer of 2-hydroxy tetrahydropyran followed by protonation of the hemiacetal OH, loss of water, intramolecular acetalization followed by deprotonation. This possibility can be ruled out because IR and ^1H NMR analysis of 2-hydroxytetrahydropyran showed less than 1 % of the open chain tautomer. Similar to reducing sugars it may contain < 0.01 % of the aldehydic form, however unlike glucose, 2-hydroxytetrahydropyran failed to respond to both Tollen's and Fehling's tests. In another experiment, when 2-hydroxytetrahydropyran (5 mmol) and 3-phenyl-1-propanol **2a** (2 mmol) were reacted in a pH 2 buffer (1 M, 2 mL) saturated with NaCl and refluxed for 2 h, more than 95 % of the pyranlated product could be obtained, further supporting the intermediacy of 2-hydroxytetrahydropyran (Scheme IB.1.3).



Scheme IB.1.3. Pyranylation of 3-phenyl-1-propanol **2** with 2-hydroxytetrahydropyrane

The reaction works even in pure water under non buffered conditions, giving a moderate yield of the product, but the pH of the medium changes depending on the nature of the substrate. Therefore, we decided to perform the reaction under buffered conditions. In spite of the shorter reaction time at lower pH we decided to perform the reaction at pH 5 since many acid sensitive groups are expected to survive at this pH. Thus, in a typical reaction, alcohol (5 mmol), DHP (7.5 mmol), in 1M phosphate buffer (5 mL) saturated with NaCl was refluxed for a specific period of time as shown in Table IB.1.2.

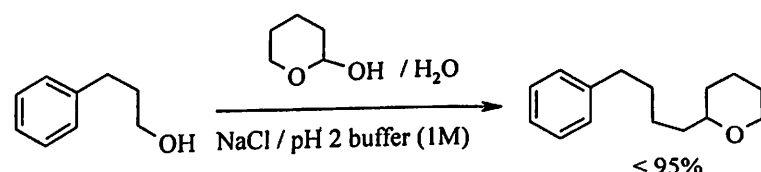
Table IB.1.2. Tetrahydropyranylation^a of Alcohol in Phosphate Buffer pH 5

Substrate	Product ^b	Time (h)	Yield (%)
(1)	(1a)	6	82
(2)	(2a)	5	92
(3)	(3a)	7	85
(4)	(4a)	7	87
(5)	(5a)	10	72
(6)	(6a)	6	82
(7)	(7a)	8	72
(8)	(8a)	10	76
(9)	(9a)	7.5	79
(10)	(10a)	6	88
(11)	(11a)	7	84
(12)	(12a)	9	55
(13)	(13a)	9	81
(14)	(14a)	8.5	78
(15)	(15a)	7.5	72
(16)	(16a)	7	75
(17)	(17a)	7	78

^a Reactions were monitored by TLC. ^b Confirmed by comparison with IR, ^1H NMR of the authentic sample. ^c Isolated yields.

the presence of methanol (2 mL), only a trace of pyranlated product (< 5 %) could be seen, further supporting the facile formation of 2-methoxytetrahydropyran and the role of methanol during the depyranylation process (Scheme IB.1.2).

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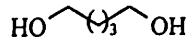
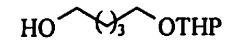
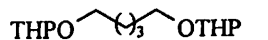
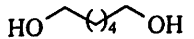
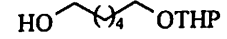
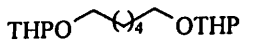
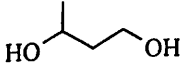
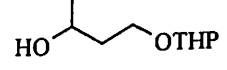
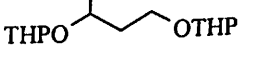
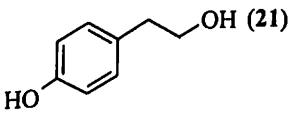
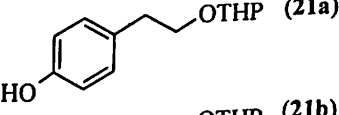
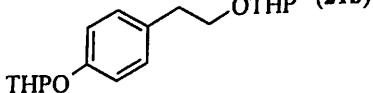
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Substrate	Product ^b	Time (h)	Yield (%) ^c
(1)	(1a)	6	82
(2)	(2a)	5	92
(3)	(3a)	7	85
(4)	(4a)	7	87
(5)	(5a)	10	72
(6)	(6a)	6	82
(7)	(7a)	8	72
(8)	(8a)	10	76
(9)	(9a)	7.5	79
(10)	(10a)	6	88
(11)	(11a)	7	84
(12)	(12a)	9	55
(13)	(13a)	9	81
(14)	(14a)	8.5	78
(15)	(15a)	7.5	72
(16)	(16a)	7	75
(17)	(17a)	7	78

^a Reactions were monitored by TLC. ^b Confirmed by comparison with IR, ^1H NMR of the authentic sample. ^c Isolated yields.

Pyranylation of several alcohols such as primary, benzylic and secondary was achieved in good to excellent yields via this procedure as shown in Table IB.1.2. In all the cases examined the reactions were nearly complete, however isolated yields were 10-15 % less. As evident from Table IB.1.2, acid sensitive protecting groups such as THP, TBS, TBDPS and isopropylidene survived these conditions. Thus, the present method is mild enough to tolerate a wide range of functional groups. As shown in Table IB.1.1, depending on the sensitivity of the other protecting group present in the substrate this reaction can be performed from pH 6.5-2.

Table IB.1.3. Tetrahydropyranylation^a of Alcohol in Phosphate Buffer pH 5

Substrate	Product ^b	Time (h)	Yield (%) ^c
 (18)	 (18a)	8	78
	 (18b)		09
 (19)	 (16)	8	76
	 (16a)		08
 (20)	 (20a)	8	72
	 (20b)		10
 (21)	 (21a)	10	80
	 (21b)		00

^a Reactions were monitored by TLC. ^b Confirmed by comparison with IR, ¹H NMR of the authentic sample. ^c Isolated yields.

Phenol which has a lower pKa than water, is a better leaving group; hence the method was not successful for pyranlation of phenols in the entire range of pH tested. One important feature of this method is the chemoselective mono tetrahydropyranylation of symmetrical 1,n-diols **18** and **19** and unsymmetrical diol **20** Table IB.1.3, a transformation that is difficult to accomplish via conventional

methods. Only a few methods have been reported in the literature.^{4m-s,5a-b} W selectivity of the mono tetrahydropyranylation arises because after the mono pyranlation the hydroxyl group points away from the hydrophobic pockets formed by the DHP and alcohol. A primary alcohol has been selectively pyranlated in the presence of a secondary alcohol **20** and a phenolic hydroxyl group **21**.

In conclusion, this section describes a method for pyranlation in water that takes advantage of the pKa's of different functional groups and the reaction medium. Thus the reaction, which is typically carried out in an anhydrous aprotic solvent, can be carried out in water in an environmentally benign way. The procedure works over a broad pH range and even without an acid catalyst. Mild reaction conditions, simplicity of the procedure, general applicability for a wide range of alcohols and selective mono-tetrahydropyranylation of diols are other significant advantages over many existing procedures.

IB.1.1. Reference

- (a) Breslow, R. *Acc. Chem. Res.* **1991**, *24*, 159. (b) Li, C. -J. *Chem. Rev.* **1993**, *93*, 2023. (c) Herrmann, W. A.; Kohlpaintner, C. W. *Angew. Chem., Int. Ed. Engl.* **1993**, *32*, 1524. (d) Lubineau, A.; Auge, J.; Queneau, Y. *Synthesis* **1994**, 741. (e) Li, C. -J. *Tetrahedron* **1996**, *52*, 5643. (f) Kobayashi, S. *Synlett* **1994**, 689. (g) Lindström, U. M. *Chem. Rev.* **2002**, *102*, 2751. (h) Shu, K.; Kei, M. *Acc. Chem. Res.* **2002**, *35*, 209. (i) Okuhara, T. *Chem. Rev.* **2002**, *102*, 3641. (j) Pae, A. N. Cho, Y. S. *Current Organic Chemistry* **2002**, *6*, 715.
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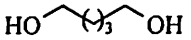
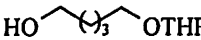
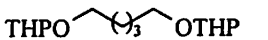
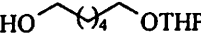
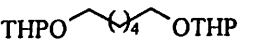
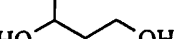
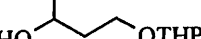
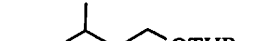
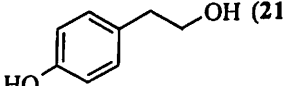
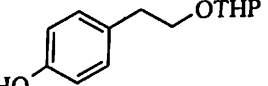
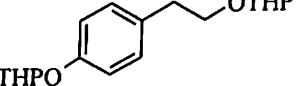
In conclusion, this section describes a method for pyranylation in water that takes advantage of the pKa's of different functional groups and the reaction medium. Thus the reaction, which is typically carried out in an anhydrous aprotic solvent, can be carried out in water in an environmentally benign way. The procedure works over a broad pH range and even without an acid catalyst. Mild reaction conditions, simplicity of the procedure, general applicability for a wide range of alcohols and selective mono-tetrahydropyranylation of diols are other significant advantages over many existing procedures.

IB.1.1. Reference

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Pyranylation of several alcohols such as primary, benzylic and secondary was achieved in good to excellent yields via this procedure as shown in Table IB.1.2. In all the cases examined the reactions were nearly complete, however isolated yields were 10-15 % less. As evident from Table IB.1.2, acid sensitive protecting groups such as THP, TBS, TBDPS and isopropylidene survived these conditions. Thus, the present method is mild enough to tolerate a wide range of functional groups. As shown in Table IB.1.1, depending on the sensitivity of the other protecting group present in the substrate this reaction can be performed from pH 6.5-2.

Table IB.1.3. Tetrahydropyranylation^a of Alcohol in Phosphate Buffer pH 5

Substrate	Product ^b	Time (h)	Yield (%) ^c
 (18)	 (18a)	8	78
	 (18b)		09
 (19)	 (16)	8	76
	 (16a)		08
 (20)	 (20a)	8	72
	 (20b)		10
 (21)	 (21a)	10	80
	 (21b)		00

^a Reactions were monitored by TLC. ^b Confirmed by comparison with IR, ¹H NMR of the authentic sample. ^c Isolated yields.

Phenol which has a lower pKa than water, is a better leaving group; hence the method was not successful for pyranylation of phenols in the entire range of pH tested. One important feature of this method is the chemoselective mono tetrahydropyranylation of symmetrical 1,n-diols **18** and **19** and unsymmetrical diol **20** Table IB.1.3, a transformation that is difficult to accomplish via conventional

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IB.2. Aqueous Mediated N-Alkylation of Amines

A lot of focus is currently devoted towards the replacement of volatile organic solvents by environmentally less hazardous one or by water. Nature's own solvent, water, is ideally suited for this purpose owing to its non-toxic character. Its abundance on this planet makes water a cheapest and readily accessible alternative. The increased focus on water as reaction medium in synthetic organic chemistry during the past two decades has resulted in a large number of reactions that can now be performed successfully in an aqueous medium.¹ In addition to acting as a solvent, it has special effects such as hydrophobic association, high internal solvent pressure, cohesive energy density, high solvent polarity and hydrogen bonding ability. An important part of our efforts towards an environmentally friendly green chemistry is aimed at a reduction of the use of organic solvents.²

Amines in general and tertiary amines in particular are one of the most common structural features of naturally occurring biologically active compounds and are widely used throughout the chemical industry as basic intermediates or additives for the preparation of fine chemicals, dyes, fluorescence probes, pharmaceuticals, agrochemicals and catalysts for polymerization.³ Introduction of secondary and tertiary amino functionalities is a crucial step in the construction of polyamines on solid phase and in the solid-phase organic synthesis of small molecule.⁴ Many unnatural homo chiral amino-phenol compounds have been reported as excellent ligands in metal ion catalyzed asymmetric reactions in current asymmetric synthesis, particularly ligands having the structure of N-methyl-N-alkyl Betti base.⁵

One of the most frequently used procedures for the preparation of tertiary amines are N-alkylation of primary and secondary amines with alkyl halides in the presence of a base such as KOH or ^tBuOK,⁶ potassium,⁷ sodium amide,⁸ CsOH,⁹ thallium(I) ethoxide,¹⁰ CsF-Celite¹¹ and Huenig's base.¹² Other methods for N-alkylation include displacement of methanesulfonates, *p*-toluenesulfonates and *p*-nitrobenzenesulfonates by amines on solid support.¹³ Several other methods for the synthesis of tertiary amines on solid support has also been developed employing varieties of protocols.¹⁴ Some of the other methods such as Mannich type reaction,¹⁵ reductive and catalytic amination,¹⁶ metal-initiated amination of alkene alkynes and aryl halides,¹⁷ deamination of quaternary hydrazinium halides,¹⁸ reduction of N-tosylamidines¹⁹ have been devised for this purpose. Unsymmetrical tertiary amines have been obtained in a single step by the CuCl / B(OMe)₃

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catalyzed reaction of primary amines, alkyl halides and α -chlorine substituted allylsilanes.²⁰ Synthesis of tertiary amines using a palladium catalyzed nucleophilic substitution of benzylic esters and secondary amines have been reported.²¹ Recently, N-alkylation of amines using alkyl halides in aqueous basic (NaOH) medium under microwave irradiation was also found to be quite satisfactory.²²

The direct N-alkylation of primary and secondary amines often results in the formation of the quaternary ammonium salts due to enhanced nucleophilicity of tertiary amines. The formation of a mixture of the desired tertiary amine and quaternary ammonium salt along with the presence of starting amines make the purification procedure tedious and the method more expensive. Solid supported methods although useful are not practical for large scale reactions because of multi-step process and use of expensive polymer like REM. Many of the reductive methods use strong reducing or dangerous hydrogen gas and are not always desirable. The use of excess reagent is particularly undesirable from an environmentally point of view and from an economic standpoint in the case of costly or commercially unavailable reagents as is the case with many methods. The use of expensive and strong nucleophilic bases during the process results in significant hydrolysis of halides. Although the recently reported microwave mediated method is quite useful but it requires the use of specialized microwave equipment and hence not suitable for large scale reactions.²² Thus, there is a need for a simple, efficient and environmentally benign methodology for the preparation of secondary and tertiary amines.

The efficient dissolution of amines in an aqueous medium^{2a} and its subsequent acylation prompted us to perform alkylation reaction in an aqueous medium. Initially aniline was used as a model substrate to test the alkylation. Various conditions were sampled but a 1 : 2.2 : 2.2 ratio of substrate to benzylic halide to NaHCO₃ gave best result. In a typical reaction aniline (5 mmol) was suspended in water (20 mL). To this was added SDS (20 mg) followed by NaHCO₃ (11 mmol) and benzyl bromide (11 mmol). Complete conversion was observed after heating the reaction mixture at 80 °C for 1 h. The reaction mixture, cooled and product was filtered and recrystallized from a mixture of ethyl acetate and hexane to yield the pure product in nearly quantitative yield. Interestingly, side product such as benzyl alcohol was not observed during the reaction. This reaction can be performed at room temperature but the reaction rate was slow and took comparatively longer reaction time (8-10 hrs). Some of the existing aqueous alkylation procedures

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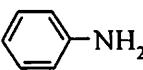
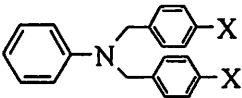
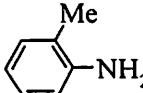
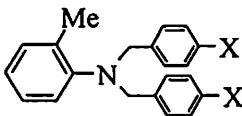
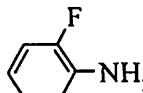
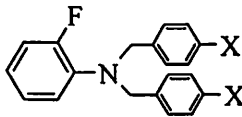
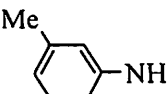
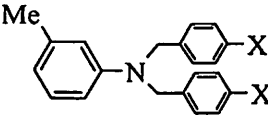
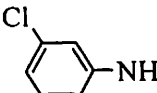
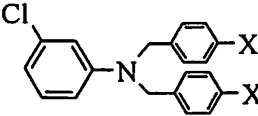
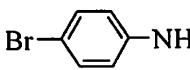
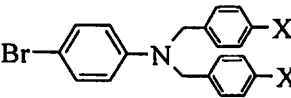
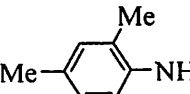
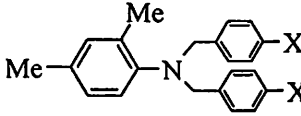
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 (22)		(22c)	94	(22d)	96
 (23)		(23c)	95	(23d)	93
 (24)		(24c)	91	(24d)	93
 (25)		(25c)	96	(25d)	97
 (26)		(26c)	93	(26d)	97
 (27)		(27c)	96	(27d)	94
 (28)		(28c)	91	(28d)	96

Table Contd....

catalyzed reaction of primary amines, alkyl halides and α -chlorine substituted allylsilanes.²⁰ Synthesis of tertiary amines using a palladium catalyzed nucleophilic substitution of benzylic esters and secondary amines have been reported.²¹ Recently, N-alkylation of amines using alkyl halides in aqueous basic (NaOH) medium under microwave irradiation was also found to be quite satisfactory.²²

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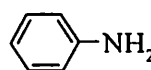
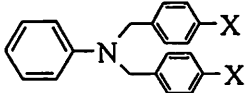
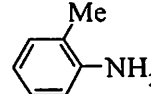
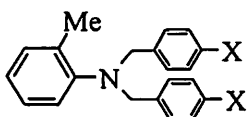
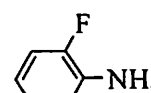
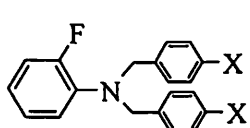
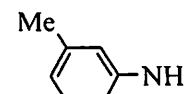
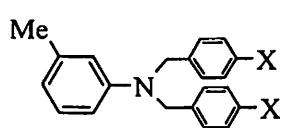
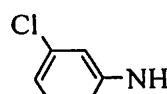
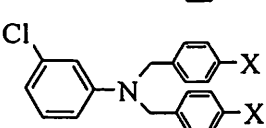
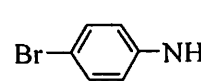
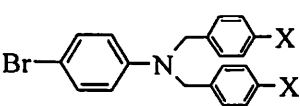
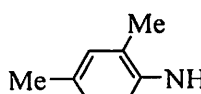
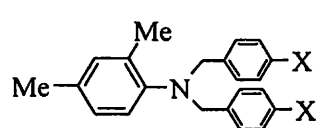
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 (27)		(27c)	96	(27d)	94
 (28)		(28c)	91	(28d)	96

Table Contd. ...

Substrate	Product	X = H	Yield %	X = NO ₂	Yield %
		(29c)	89	(29d)	94
		(30c)	92 ^d	(30d)	92 ^d
		(31c)	95	(31d)	91
		(32c)	93	(32d)	90
		(33c)	89 ^e	(33d)	93 ^e

^aAll reactions were carried out at 5 mmol scale at 80 °C for 1 h. ^bConfirmed by IR, ¹H and ¹³C NMR. ^cIsolated yield.

^dBenzyl halide (22 mmol) and NaHCO₃ (22 mmol) was used. ^eBenzyl halide (22 mmol) and NaHCO₃ (32 mmol) were used.

Compound **30c** was crystallized from a mixture of ethyl acetate: hexane (1:1) and single crystal X-RD was recorded. The asymmetric unit contains one half of the molecules and the ORTEP diagram is shown in Figure IB.2.1. It is propeller shaped molecule (Figure IB2.1b) with oppositely oriented phenyl groups parallel to each other.

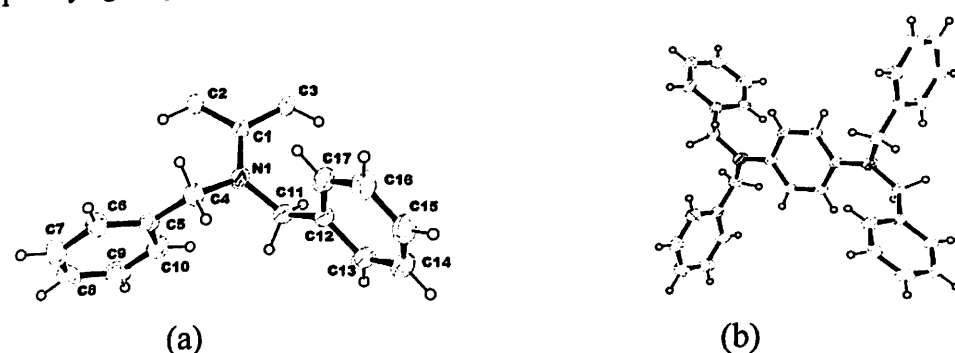


Figure IB.2.1. (a) ORTEP plot with atom numbering of asymmetric unit **30c** (b) ORTEP plot of **30c**

The synthetic methodology was also successfully applied to benzylic **31** and aliphatic amines **32** and **33**. All gave corresponding alkylated product in excellent yields. To our delight, aliphatic diaminehydrochloride **33** was also tetraalkylated in excellent yield with double amount of alkylhalide

(4.4 eq) and 6.4 equivalent of NaHCO₃. The additional amount of NaHCO₃ was the free diamine from the dihydrochloride salt **33**.

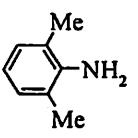
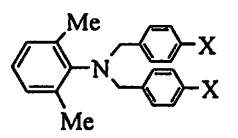
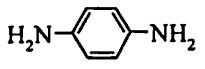
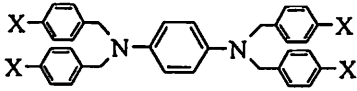
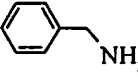
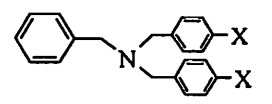
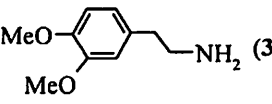
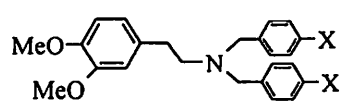
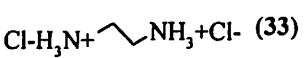
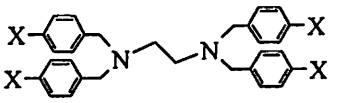
When benzyl bromide and *p*-nitrobenzyl bromide was replaced with benzyl chloride and *p*-nitrobenzyl chloride the reaction worked with almost equal efficiency. The generality of the method has been proved using a variety of amines as shown in Table IB.2.2.

Table IB.2.2. Aqueous N-Alkylation of Amines Using NaHCO₃ and Benzyl Chloride / *p*-Nitrobenzyl Chloride.^a

Substrate	Product ^b	X = H / Yield (%) ^c	X = NO ₂ / Yield (%) ^c
		(22c) 94	(22d) 96
		(23c) 95	(23d) 93
		(24c) 91	(24d) 93
		(28c) 91	(28d) 96
		(31c) 95	(31d) 91
		(32c) 93	(32d) 90

^aAll reactions were carried out at 5 mmol scale at 80 °C for 1.5 h. ^bConfirmed by IR, ¹H and ¹³C NMR. ^cIsolated yield.

Having successfully applied to benzylic systems, we extended this methodology to aliphatic halides. Thus, when aniline (5 mmol) in water (20 mL) containing SDS (20 mg) was treated with NaHCO₃ (11 mmol), butylbromide (11 mmol) and heated at 80 °C. The products obtained were a mixture of tertiary and secondary amines in the ratio 3 : 2. The products ratio remained nearly unaltered even after refluxing the reaction for 12 hours. Thus, we focused our attention controlling it at the secondary amine rather than at the tertiary amine stage. Thus, when aniline (5 mmol) was treated with butylbromide (6 mmol) and NaHCO₃ (6 mmol) under the above reaction conditions the

Substrate	Product	X = H	Yield %	X = NO ₂	Yield %
 (29)	 (29c)		89	(29d)	94
 (30)	 (30c)		92 ^d	(30d)	92 ^d
 (31)	 (31c)		95	(31d)	91
 (32)	 (32c)		93	(32d)	90
 (33)	 (33c)		89 ^e	(33d)	93 ^e

^aAll reactions were carried out at 5 mmol scale at 80 °C for 1 h. ^bConfirmed by IR, ¹H and ¹³C NMR. ^cIsolated yield.

^dBenzylic halide (22 mmol) and NaHCO₃ (22 mmol) was used. ^eBenzylic halide (22 mmol) and NaHCO₃ (32 mmol) were used.

Compound 30c was crystallized from a mixture of ethyl acetate: hexane (1:1) and single crystal X-RD was recorded. The asymmetric unit contains one half of the molecules and the ORTEP diagram is shown in Figure IB.2.1. It is propeller shaped molecule (Figure IB2.1b) with oppositely oriented phenyl groups parallel to each other.

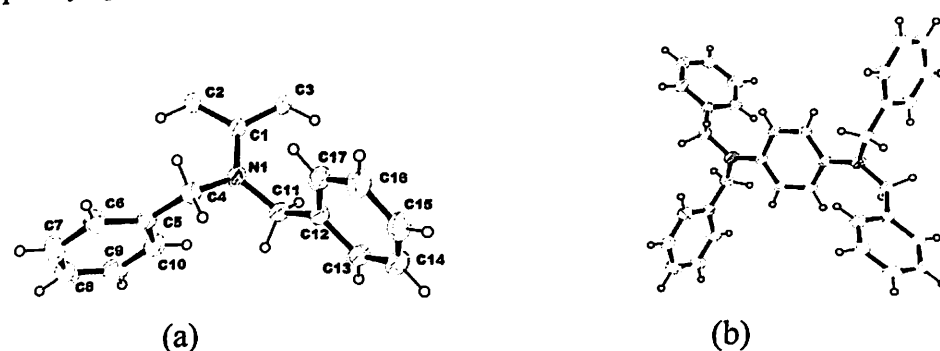


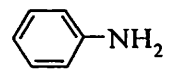
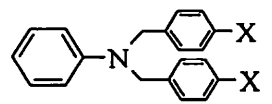
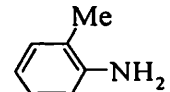
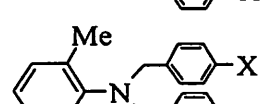
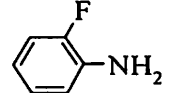
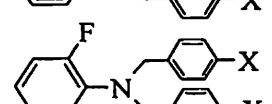
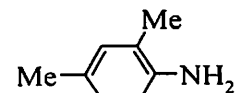
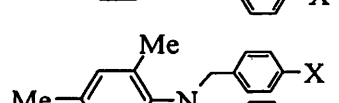
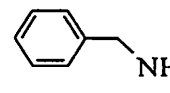
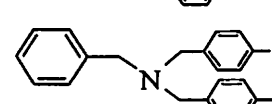
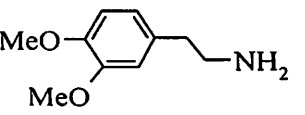
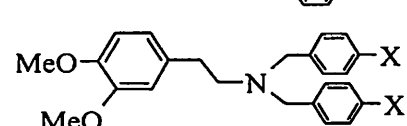
Figure IB.2.1. (a) ORTEP plot with atom numbering of asymmetric unit 30c (b) ORTEP plot of 30c

The synthetic methodology was also successfully applied to benzylic 31 and aliphatic amines 32 and 33. All gave corresponding alkylated product in excellent yields. To our delight, aliphatic diaminehydrochloride 33 was also tetraalkylated in excellent yield with double amount of alkylhalide

(4.4 eq) and 6.4 equivalent of NaHCO₃. The additional amount of NaHCO₃ was the free diamine from the dihydrochloride salt 33.

When benzyl bromide and *p*-nitrobenzyl bromide was replaced with benzyl chloride and *p*-nitrobenzyl chloride the reaction worked with almost equal efficiency. The generality of the method has been proved using a variety of amines as shown in Table IB.2.2.

Table IB.2.2. Aqueous N-Alkylation of Amines Using NaHCO₃ and Benzyl Chloride / *p*-Nitrobenzyl Chloride.^a

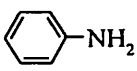
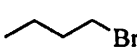
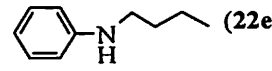
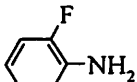
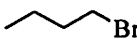
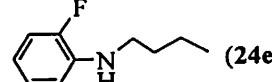
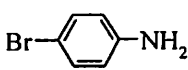
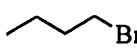
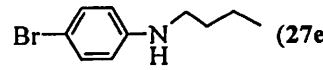
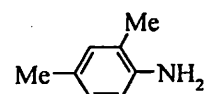
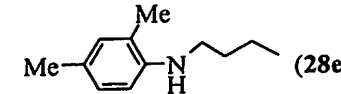
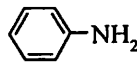
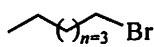
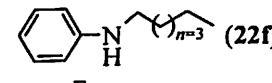
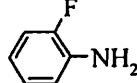
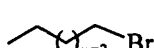
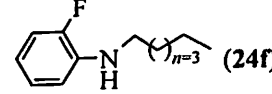
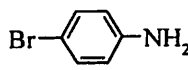
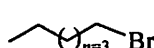
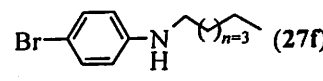
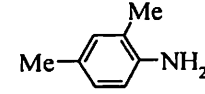
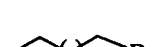
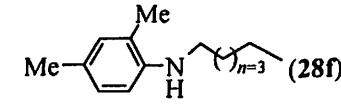
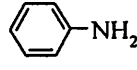
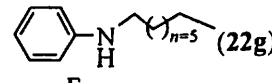
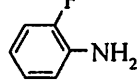
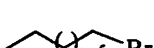
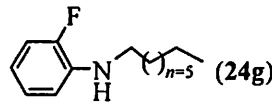
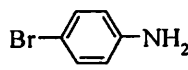
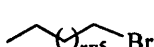
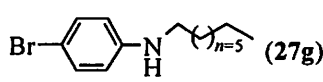
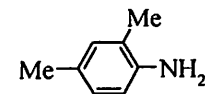
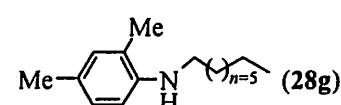
Substrate	Product ^b	X = H / Yield (%) ^c	X = NO ₂ / Yield (%) ^c
 (22)	 (22c)	94	(22d) 96
 (23)	 (23c)	95	(23d) 93
 (24)	 (24c)	91	(24d) 93
 (28)	 (28c)	91	(28d) 96
 (31)	 (31c)	95	(31d) 91
 (32)	 (32c)	93	(32d) 90

^aAll reactions were carried out at 5 mmol scale at 80 °C for 1.5 h. ^bConfirmed by IR, ¹H and ¹³C NMR. ^cIsolated yield.

Having successfully applied to benzylic systems, we extended this methodology to aliphatic halides. Thus, when aniline (5 mmol) in water (20 mL) containing SDS (20 mg) was treated with NaHCO₃ (11 mmol), butylbromide (11 mmol) and heated at 80 °C. The products obtained were a mixture of tertiary and secondary amines in the ratio 3 : 2. The products ratio remained nearly unaltered even after refluxing the reaction for 12 hours. Thus, we focused our attention controlling it at the secondary amine rather than at the tertiary amine stage. Thus, when aniline (5 mmol) was treated with butylbromide (6 mmol) and NaHCO₃ (6 mmol) under the above reaction conditions the

reaction stops at the secondary amine stage giving good yields of secondary amines as shown in Table IB.2.3 (22e, 24e, 27e, 28e) and yielding less than 10 % of the tertiary amines.

Table IB.2.3. Aqueous N-Alkylation of Amines Using NaHCO₃ and Aliphatic Bromides.^a

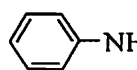
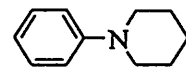
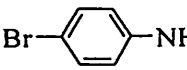
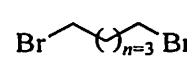
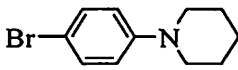
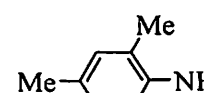
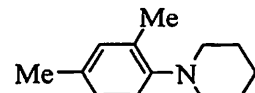
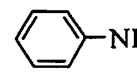
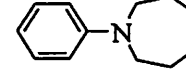
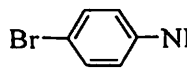
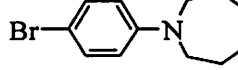
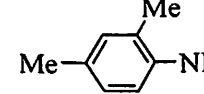
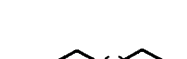
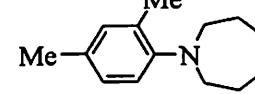
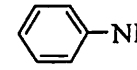
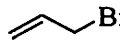
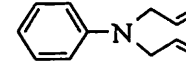
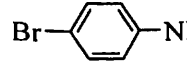
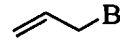
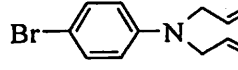
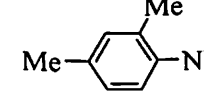
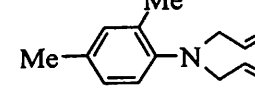
Substrate	Alkyl / Allyl halides	Product ^b	Time / h	Yield
 (22)	 Br	 (22e)	6	65
 (24)	 Br	 (24e)	9	78
 (27)	 Br	 (27e)	7	70
 (28)	 Br	 (28e)	5	67
 (22)	 Br	 (22f)	7	74
 (24)	 Br	 (24f)	10	75
 (27)	 Br	 (27f)	8	82
 (28)	 Br	 (28f)	6	80
 (22)	 Br	 (22g)	9	78
 (24)	 Br	 (24g)	12	80
 (27)	 Br	 (27g)	9	84
 (28)	 Br	 (28g)	7	85

^aAll reactions were carried out at 2 mmol scale at 80 °C. ^bConfirmed by IR, ¹H and ¹³C NMR. ^cIsolated yield.

When similar reaction was performed using hexyl and octyl bromide, the corresponding secondary amines (22f, 24f, 27f, 28f) and (22g, 24g, 27g, 28g) were obtained in good yields as shown in Table IB.2.3. In these cases less than 5% of the tertiary amines were formed. It may be noted here

that reaction of alkyl bromides took relatively longer reaction time (Table IB.2.1 and IB.2.2).

Table IB.2.4. Aqueous N-Alkylation of Amines Using NaHCO₃ and 1,5-Dibromopentane, 1,6-Dibromohexane and Allylbromide^a

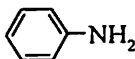
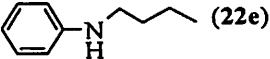
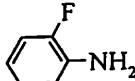
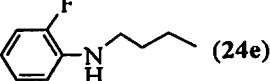
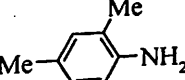
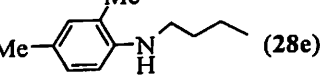
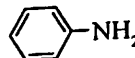
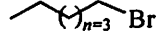
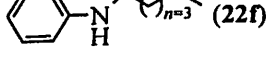
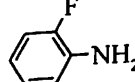
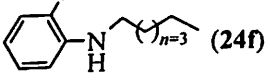
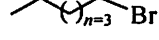
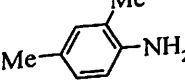
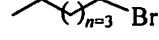
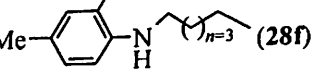
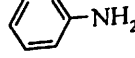
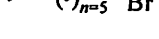
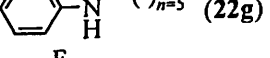
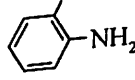
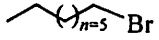
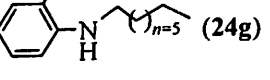
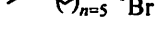
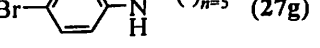
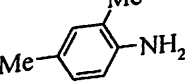
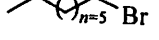
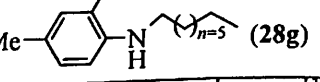
Substrate	Alkyl / Allyl halides	Product ^b	Time / h	Yield ^c (%)
 (22)	 Br	 (22h)	4	59 ^d
 (27)	 Br	 (27h)	6	66 ^d
 (28)	 Br	 (28h)	4	71 ^d
 (22)	 Br	 (22i)	4	64 ^d
 (27)	 Br	 (27i)	6	62 ^d
 (28)	 Br	 (28i)	5	67 ^d
 (22)	 Br	 (22j)	5	84 ^e
 (27)	 Br	 (27j)	7	82 ^e
 (28)	 Br	 (28j)	5	89 ^e

^aAll reactions were carried out at 2 mmol scale at 80 °C. ^bConfirmed by IR, ¹H and ¹³C NMR and GC-MS. ^cIsolated yield. ^dDibromohalides (2.4 mmol) and NaHCO₃ (4.8 mmol) were used. ^eAllylic bromide (6 mmol) and NaHCO₃ (6 mmol) were used.

The general nature of the reaction is shown by the intramolecular double-alkylation of primary amines with dihalides such as 1,5-dibromopentane and 1,6-dibromohexane giving corresponding cyclic amines (22h, 27h, 28h) and (22i, 27i, 28i) respectively providing a potentially useful approach to assemble cyclic amines in a single step (Table I.B.2.4). Allyl bromide also reacted successfully with

reaction stops at the secondary amine stage giving good yields of secondary amines as shown in Table IB.2.3 (22e, 24e, 27e, 28e) and yielding less than 10 % of the tertiary amines.

Table IB.2.3. Aqueous N-Alkylation of Amines Using NaHCO₃ and Aliphatic Bromides.^a

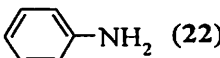
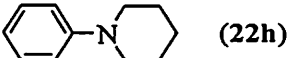
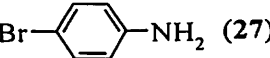
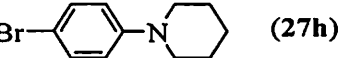
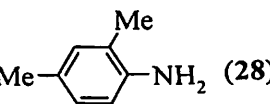
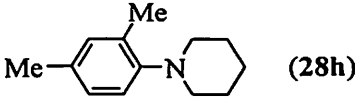
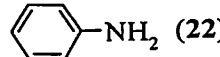
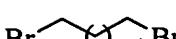
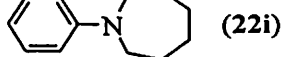
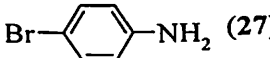
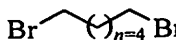
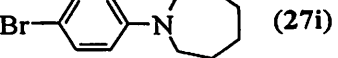
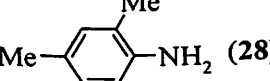
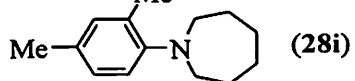
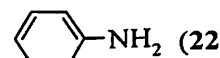
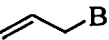
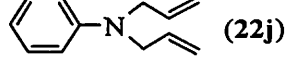
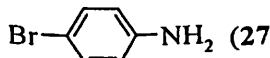
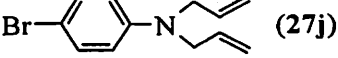
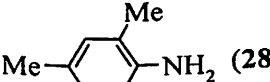
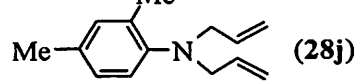
Substrate	Alkyl / Allyl halides	Product ^b	Time / h	Yield
 (22)		 (22e)	6	65
 (24)		 (24e)	9	78
 (27)		 (27e)	7	70
 (28)		 (28e)	5	67
 (22)		 (22f)	7	74
 (24)		 (24f)	10	75
 (27)		 (27f)	8	82
 (28)		 (28f)	6	80
 (22)		 (22g)	9	78
 (24)		 (24g)	12	80
 (27)		 (27g)	9	84
 (28)		 (28g)	7	85

^aAll reactions were carried out at 2 mmol scale at 80 °C. ^bConfirmed by IR, ¹H and ¹³C NMR. ^cIsolated yield.

When similar reaction was performed using hexyl and octyl bromide, the corresponding secondary amines (22f, 24f, 27f, 28f) and (22g, 24g, 27g, 28g) were obtained in good yields as shown in Table IB.2.3. In these cases less than 5% of the tertiary amines were formed. It may be noted here

that reaction of alkyl bromides took relatively longer reaction time (Table IB.2.1 and IB.2.2).

Table IB.2.4. Aqueous N-Alkylation of Amines Using NaHCO₃ and 1,5-Dibromopentane, 1,6-Dibromohexane and Allylbromide^a

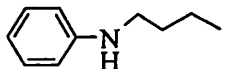
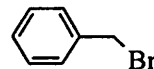
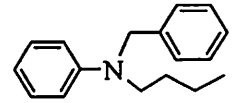
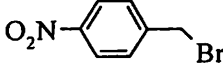
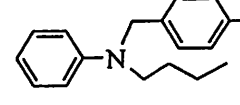
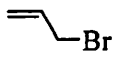
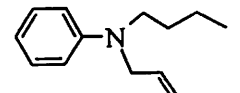
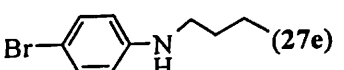
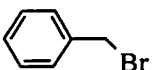
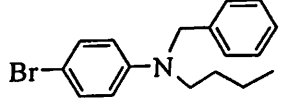
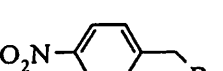
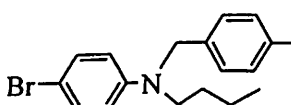
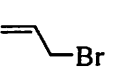
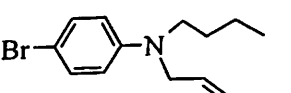
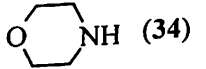
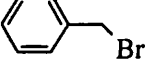
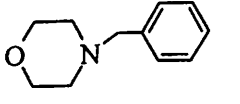
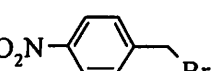
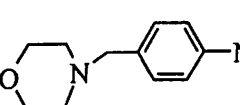
Substrate	Alkyl / Allyl halides	Product ^b	Time / h	Yield ^c (%)
 (22)		 (22h)	4	59 ^d
 (27)		 (27h)	6	66 ^d
 (28)		 (28h)	4	71 ^d
 (22)		 (22i)	4	64 ^d
 (27)		 (27i)	6	62 ^d
 (28)		 (28i)	5	67 ^d
 (22)		 (22j)	5	84 ^e
 (27)		 (27j)	7	82 ^e
 (28)		 (28j)	5	89 ^e

^aAll reactions were carried out at 2 mmol scale at 80 °C. ^bConfirmed by IR, ¹H and ¹³C NMR and GC-MS. ^cIsolated yield. ^dDibromohalides (2.4 mmol) and NaHCO₃ (4.8 mmol) were used. ^eAllylic bromide (6 mmol) and NaHCO₃ (6 mmol) were used.

The general nature of the reaction is shown by the intramolecular double-alkylation of primary amines with dihalides such as 1,5-dibromopentane and 1,6-dibromohexane giving corresponding cyclic amines (22h, 27h, 28h) and (22i, 27i, 28i) respectively providing a potentially useful approach to assemble cyclic amines in a single step (Table I.B.2.4). Allyl bromide also reacted successfully with

various amines giving good yields of diallylated tertiary amines (22j, 27j, 28j) as shown in Table IB.2.4.

Table IB.2.5. Aqueous N-Alkylation of Secondary Amines Using NaHCO₃ and Benzyl Bromide or Allylic Bromide^a

Substrate	Alkyl / Allyl halides	Product ^b	Time / h	Yield ^c (%)
 (22e)		 (22k)	1	93
		 (22l)	1	95
		 (22m)	4	90
 (27e)		 (27k)	1	92
		 (27l)	1	95
		 (27m)	5	87
 (34)		 (34k)	1	93
		 (34l)	1	92

^aAll reactions were carried out at 2 mmol scale at 80 °C for 1h. ^bConfirmed by IR, ¹H and ¹³C NMR and GC-MS. ^cIsolated yield. ^dAllylic bromide (4 mmol) and NaHCO₃ (4 mmol) were used.

As suggested earlier and proved by isolating some of the secondary amines, the synthetic steps include a two steps alkylation of primary amine with alkyl halide through intermediate secondary amine. To further prove this we reacted some of the secondary amines with benzyl and allyl bromide to obtain a good yields of mixed tertiary amines (Table IB.2.5).

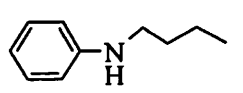
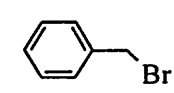
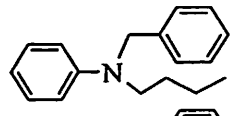
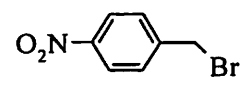
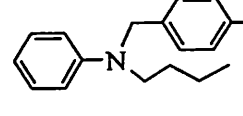
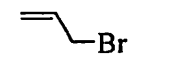
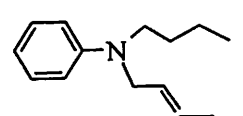
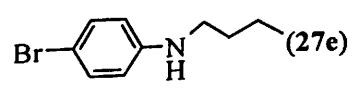
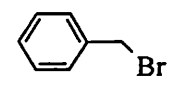
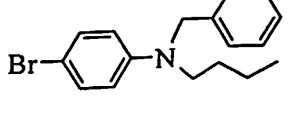
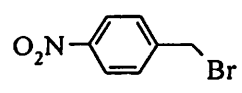
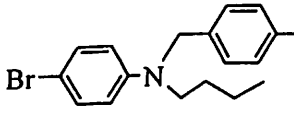
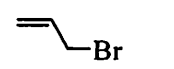
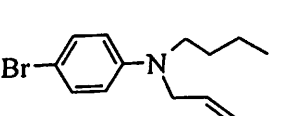
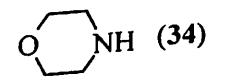
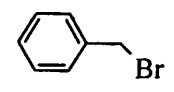
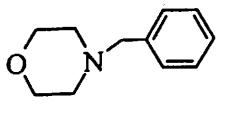
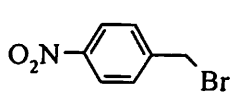
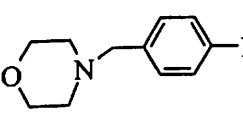
In conclusion, we have demonstrated an efficient and economic process secondary and tertiary amines by direct N-alkylation of primary amines or secondary amines with various benzylic halides in an aqueous medium in the presence of sodium dodecyl sulfate and NaHCO₃. The reaction carried out in mild conditions, higher product yields, scalability, absence of quarternary ammonium salt formation and operationally convenient conditions are some of the advantages. Selective formation of secondary amines and mixed tertiary amines will find useful applications in organic synthesis. Although procedures exist for alkylation of amines, the simplicity and low cost of our procedure allow it to compete as a better practical alternative to the existing methods.

IB.2.1. Reference

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various amines giving good yields of diallylated tertiary amines (22j, 27j, 28j) as shown in Table IB.2.4.

Table IB.2.5. Aqueous N-Alkylation of Secondary Amines Using NaHCO₃ and Benzyl Bromide or Allylic Bromide^a

Substrate	Alkyl / Allyl halides	Product ^b	Time / h	Yield ^c (%)
 (22e)		 (22k)	1	93
		 (22l)	1	95
		 (22m)	4	90
 (27e)		 (27k)	1	92
		 (27l)	1	95
		 (27m)	5	87
 (34)		 (34k)	1	93
		 (34l)	1	92

^aAll reactions were carried out at 2 mmol scale at 80 °C for 1h. ^bConfirmed by IR, ¹H and ¹³C NMR and GC-MS. ^cIsolated yield. ^dAllylic bromide (4 mmol) and NaHCO₃ (4 mmol) were used.

As suggested earlier and proved by isolating some of the secondary amines, the synthetic steps include a two steps alkylation of primary amine with alkyl halide through intermediate secondary amine. To further prove this we reacted some of the secondary amines with benzyl and allyl bromide to obtain a good yields of mixed tertiary amines (Table IB.2.5).

In conclusion, we have demonstrated an efficient and economic process secondary and tertiary amines by direct N-alkylation of primary amines or secondary amines with various benzylic halides in an aqueous medium in the presence of sodium dodecyl sulfate and NaHCO₃. The reaction carried out in mild conditions, higher product yields, scalability, absence of quarternary ammonium salt formation and operationally convenient conditions are some of the advantages. Selective formation of secondary amines and mixed tertiary amines will find useful applications in organic synthesis. Although procedures exist for alkylation of amines, the simplicity and low cost of our procedure allow it to compete as a better practical alternative to the existing methods.

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IC. Experimental Section

IC.1. General Remarks

All the reagents were of reagent grade (AR grade) and were used as purchased without further purification. The solvents were of commercial grade and purified according to established procedures. Organic extracts were dried with anhydrous sodium sulfate. Solvents were removed in a rotary evaporator under reduced pressure. Silica gel (60-120 mesh size) was used for column chromatography. Reactions were monitored by TLC on silica gel GF₂₅₄ (0.25 mm). Gas liquid chromatography was performed using HP 6890 series II instrument and using, a cross linked methyl silicon gum capillary column (30m x 0.32mm x 0.25 μ m) fitted with FID, and quantification was done using HP integrator.

IC.2. Characterization of Organic Substrates

Melting points were recorded with a Büchi B-540 melting point apparatus. Elemental analysis was performed with a Perkin-Elmer 2400 elemental analyzer. Fourier transform-infra red (FT-IR) spectra were recorded on Nicolet Impact-410 instrument either as neat liquid or KBr pellets. Fast atom bombardments (FAB) mass were recorded using a JEOL SX-120/DA-6000 instrument using argon (6KV, 10mA) as the FAB gas. GC-MS were recorded using a capillary column (30 X 0.25 mm X 0.25 μ m) in EI mode. NMR spectra were recorded in CDCl₃ or [D₆] DMSO with tetramethylsilane as the internal standard for ¹H (200, 300 and 400 MHz) or CDCl₃ or [D₆] DMSO solvent as the internal standard for ¹³C (50, 75 and 100 MHz). Crystal Data were collected with Bruker Smart Apex-II CCD diffractometer using graphite monochromated MoK α radiation (λ = 0.71073 Å) at 298 K. Cell parameters were retrieved using SMART software and refined with SAINT on all observed reflections. Data reduction was performed with the SAINT software and corrected for Lorentz and polarization effects. Absorption corrections were applied with the program SADABS. The structure was solved by direct methods implemented in SHELX-97 program and refined by full-matrix least-squares methods on F^2 . All non-hydrogen atomic positions were located in difference Fourier maps

and refined anisotropically. The hydrogen atoms were placed in their geometric positions.

IC.3. General Experimental Procedures

IC.3.1. General Experimental Procedure for the Tetrahydropyranylation of Alcohols in Water

To a mixture of alcohol (5 mmol) and 3,4-dihydro-2H-pyran (7.5 mmol) was added 1M Na₂HPO₄ + NaH₂PO₄ buffer (5 mL) saturated with NaCl. The reaction was refluxed in an oil bath and the progress of the reaction was monitored by TLC. After the specific time, the reaction mixture was extracted with ethyl acetate (2 x 25 mL). The combined organic extracts were dried with anhydrous Na₂SO₄ and the solvent was removed in a rotary evaporator under reduced pressure. The crude product was purified by passing through a short column of silica gel to yield the pure product which was identified by its NMR and IR spectra and GC pattern, and GC co-injection with authentic samples prepared by known methods.

IC.3.2. General Procedure for the Alkylation of Primary Amines to Tertiary Amines with Benzylhalides

Aniline (5 mmol), sodium bicarbonate (11 mmol), sodium dodecyl sulfate (ca. 20 mg) was taken in water (20 mL) and heated at 80 °C for 5 minutes. The benzylic halide (11 mmol) was added to the reaction mixture and heated for a period of 1 h. The reaction mixture was cooled and the alkylated product was filtered and dried. The crude reaction mixture was recrystallized from a mixture of ethyl acetate and hexane to yield the product. The product was identified by its NMR, IR and GC-MS analysis.

IC.3.3. General Procedure for the Alkylation of Primary Amines to Secondary Amines with Alkylhalides

Aniline (5 mmol), sodium bicarbonate (6 mmol), sodium dodecyl sulfate (ca. 20 mg) was taken in water (20 mL) and heated at 80 °C for 5 minutes. Alkyl halide (6 mmol) was added to the reaction mixture and heated for a further period time as mentioned in Table IB.2.3 against each substrate.



IC. Experimental Section

IC.1. General Remarks

All the reagents were of reagent grade (AR grade) and were used as purchased without further purification. The solvents were of commercial grade and purified according to established procedures. Organic extracts were dried with anhydrous sodium sulfate. Solvents were removed in a rotary evaporator under reduced pressure. Silica gel (60-120 mesh size) was used for column chromatography. Reactions were monitored by TLC on silica gel GF₂₅₄ (0.25 mm). Gas liquid chromatography was performed using HP 6890 series II instrument and using, a cross linked methyl silicon gum capillary column (30m x 0.32mm x 0.25 μ m) fitted with FID, and quantification was done using HP integrator.

IC.2. Characterization of Organic Substrates

Melting points were recorded with a Büchi B-540 melting point apparatus. Elemental analysis was performed with a Perkin-Elmer 2400 elemental analyzer. Fourier transform-infra red (FT-IR) spectra were recorded on Nicolet Impact-410 instrument either as neat liquid or KBr pellets. Fast atom bombardments (FAB) mass were recorded using a JEOL SX-120/DA-6000 instrument using argon (6KV, 10mA) as the FAB gas. GC-MS were recorded using a capillary column (30 X 0.25 mm X 0.25 μ m) in EI mode. NMR spectra were recorded in CDCl₃ or [D₆] DMSO with tetramethylsilane as the internal standard for ¹H (200, 300 and 400 MHz) or CDCl₃ or [D₆] DMSO solvent as the internal standard for ¹³C (50, 75 and 100 MHz). Crystal Data were collected with Bruker Smart Apex-II CCD diffractometer using graphite monochromated MoK α radiation (λ = 0.71073 Å) at 298 K. Cell parameters were retrieved using SMART software and refined with SAINT on all observed reflections. Data reduction was performed with the SAINT software and corrected for Lorentz and polarization effects. Absorption corrections were applied with the program SADABS. The structure was solved by direct methods implemented in SHELX-97 program and refined by full-matrix least-squares methods on F^2 . All non-hydrogen atomic positions were located in difference Fourier maps

and refined anisotropically. The hydrogen atoms were placed in their geometric positions.

IC.3. General Experimental Procedures

IC.3.1. General Experimental Procedure for the Tetrahydropyranylation of Alcohols in Water

To a mixture of alcohol (5 mmol) and 3,4-dihydro-2H-pyran (7.5 mmol) was added 1M Na₂HPO₄ + NaH₂PO₄ buffer (5 mL) saturated with NaCl. The reaction was refluxed in an oil bath and the progress of the reaction was monitored by TLC. After the specific time, the reaction mixture was extracted with ethyl acetate (2 x 25 mL). The combined organic extracts were dried with anhydrous Na₂SO₄ and the solvent was removed in a rotary evaporator under reduced pressure. The crude product was purified by passing through a short column of silica gel to yield the pure product which was identified by its NMR and IR spectra and GC pattern, and GC co-injection with authentic samples prepared by known methods.

IC.3.2. General Procedure for the Alkylation of Primary Amines to Tertiary Amines with Benzylhalides

Aniline (5 mmol), sodium bicarbonate (11 mmol), sodium dodecyl sulfate (ca. 20 mg) was taken in water (20 mL) and heated at 80 °C for 5 minutes. The benzylic halide (11 mmol) was added to the reaction mixture and heated for a period of 1 h. The reaction mixture was cooled and the alkylated product was filtered and dried. The crude reaction mixture was recrystallized from a mixture of ethyl acetate and hexane to yield the product. The product was identified by its NMR, IR and GC-MS analysis.

IC.3.3. General Procedure for the Alkylation of Primary Amines to Secondary Amines with Alkylhalides

Aniline (5 mmol), sodium bicarbonate (6 mmol), sodium dodecyl sulfate (ca. 20 mg) was taken in water (20 mL) and heated at 80 °C for 5 minutes. Alkyl halide (6 mmol) was added to the reaction mixture and heated for a further period time as mentioned in Table IB.2.3 against each substrate.

Reaction mixture was cooled and the alkylated product was extracted with ethyl acetate. The crude reaction mixture was purified by passing through a short column of silica gel and eluted with a mixture of ethyl acetate and hexane to yield the pure product. The product was identified by its NMR, IR and GC-MS analysis.

IC.3.4. General Procedure for the Alkylation of Amines with Dialkylhalides

Similar to the procedure for alkylation of amines with alkylhalides (1C.3.3), except 2.4 mmol of the dibromo alkanes and 4.8 mmol of NaHCO_3 were used per 2 mmol of the primary amine.

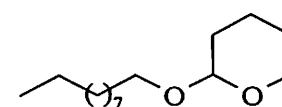
IC.3.5. General Procedure for the Alkylation of Amines with Allylbromide

Similar to the procedure for alkylation of amines with alkylhalide (1C.3.3), except 6 mmol of dibromo alkanes and 6 mmol of NaHCO_3 were used per 2 mmol of the primary amine.

ID. Spectral Data

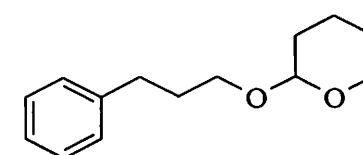
ID.1. Spectral Data of THP Ethers

2-Decyloxy-tetrahydro-pyran (1a)



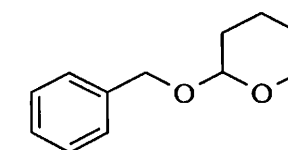
^1H NMR (400 MHz, CDCl_3): δ 0.90 (t, 3H), 1.20-1.40 (brs, 14H), 1.50-1.69 (m, 6H), 1.7 (m, 1H), 1.80 (m, 1H), 3.35 (m, 1H), 3.50 (m, 1H), 3.75 (m, 1H), 3.85 (m, 1H), 4.60 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 20.1, 23.1, 25.9, 26.6, 29.7, 29.9, 29.98, 30.0, 30.2, 31.1, 32.3, 62.6, 68.0, 99.0.

2-(3-Phenyl-propoxy)-tetrahydro-pyran (2a)



^1H NMR (400 MHz, CDCl_3): δ 1.48-1.96 (m, 8H), 2.69 (m, 2H), 3.35-3.49 (m, 2H), 3.72-3.85 (m, 2H), 4.56 (m, 1H), 7.23 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.5, 25.4, 30.6, 31.2, 32.4, 62.1, 66.7, 98.7, 125.6, 128.1, 128.3, 141.9.

2-Benzyloxy-tetrahydro-pyran (3a)



^1H NMR (400 MHz, CDCl_3): δ 1.48-1.90 (m, 6H), 3.52 (m, 1H), 3.89 (m, 1H,), 4.42 (d, 1H, $J = 11.6$ Hz), 4.70 (m, 1H, $-\text{OCH}(\text{CH}_2)_3\text{CH}_2-\text{O}$), 4.80 (d, 1H, $J = 12.0$ Hz), 7.25 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.8, 25.9, 31.0, 62.4, 69.1, 97.9, 127.7, 128.0, 128.5, 138.5.

Reaction mixture was cooled and the alkylated product was extracted with ethyl acetate. The crude reaction mixture was purified by passing through a short column of silica gel and eluted with a mixture of ethyl acetate and hexane to yield the pure product. The product was identified by its NMR, IR and GC-MS analysis.

IC.3.4. General Procedure for the Alkylation of Amines with Dialkylhalides

Similar to the procedure for alkylation of amines with alkylhalides (1C.3.3), except 2.4 mmol of the dibromo alkanes and 4.8 mmol of NaHCO_3 were used per 2 mmol of the primary amine.

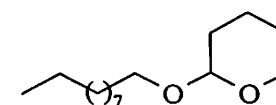
IC.3.5. General Procedure for the Alkylation of Amines with Allylbromide

Similar to the procedure for alkylation of amines with alkylhalide (1C.3.3), except 6 mmol of dibromo alkanes and 6 mmol of NaHCO_3 were used per 2 mmol of the primary amine.

ID. Spectral Data

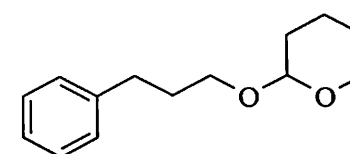
ID.1. Spectral Data of THP Ethers

2-Decyloxy-tetrahydro-pyran (1a)



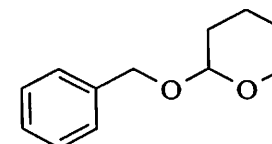
^1H NMR (400 MHz, CDCl_3): δ 0.90 (t, 3H), 1.20-1.40 (brs, 14H), 1.50-1.69 (m, 6H), 1.7 (m, 1H), 1.80 (m, 1H), 3.35 (m, 1H), 3.50 (m, 1H), 3.75 (m, 1H), 3.85 (m, 1H), 4.60 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 20.1, 23.1, 25.9, 26.6, 29.7, 29.9, 29.98, 30.0, 30.2, 31.1, 32.3, 62.6, 68.0, 99.0.

2-(3-Phenyl-propoxy)-tetrahydro-pyran (2a)

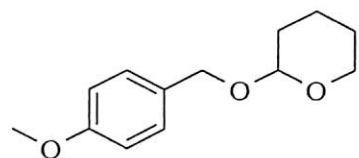


^1H NMR (400 MHz, CDCl_3): δ 1.48-1.96 (m, 8H), 2.69 (m, 2H), 3.35-3.49 (m, 2H), 3.72-3.85 (m, 2H), 4.56 (m, 1H), 7.23 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.5, 25.4, 30.6, 31.2, 32.4, 62.1, 66.7, 98.7, 125.6, 128.1, 128.3, 141.9.

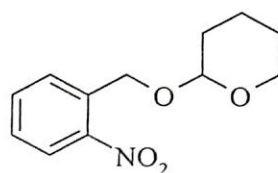
2-Benzyloxy-tetrahydro-pyran (3a)



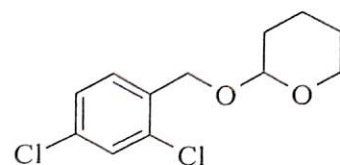
^1H NMR (400 MHz, CDCl_3): δ 1.48-1.90 (m, 6H), 3.52 (m, 1H), 3.89 (m, 1H,), 4.42 (d, 1H, $J = 11.6$ Hz), 4.70 (m, 1H, $-\text{OCH}(\text{CH}_2)_3\text{CH}_2\text{-O}$), 4.80 (d, 1H, $J = 12.0$ Hz), 7.25 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.8, 25.9, 31.0, 62.4, 69.1, 97.9, 127.7, 128.0, 128.5, 138.5.

2-(4-Methoxy-benzyloxy)-tetrahydro-pyran (4a)

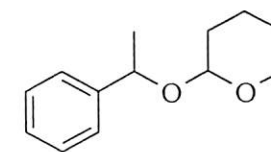
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.91 (m, 6H), 3.50 (m, 1H), 3.76 (s, 3H), 3.90 (m, 1H), 4.42 (d, 1H, $J = 11.6$ Hz), 4.69 (m, 2H), 6.87 (d, 2H, $J = 8.8$ Hz) 7.28 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.8, 25.9, 31.0, 55.6, 62.4, 68.8, 97.7, 113.9, 129.6, 130.5, 159.2.

2-(2-Nitro-benzyloxy)-tetrahydro-pyran (5a)

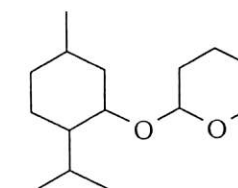
^1H NMR (400 MHz, CDCl_3): δ 1.43-1.99 (m, 6H), 3.52 (m, 1H), 3.89 (m, 1H), 4.75 (m, 1H), 4.89 (d, 1H, $J = 15.6$ Hz), 5.15 (d, 1H, $J = 14.8$ Hz), 7.40 (t, 1H, $J = 7.2$ Hz), 7.63 (t, 1H, $J = 7.2$ Hz), 7.80 (d, 1H, $J = 7.6$ Hz), 8.05 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.7, 20.1, 25.7, 25.8, 30.8, 31.6, 62.6, 63.1, 66.1, 94.7, 98.9, 124.7, 128.0, 128.9, 133.6, 135.2, 147.4.

2-(2,4-Dichloro-benzyloxy)-tetrahydro-pyran (6a)

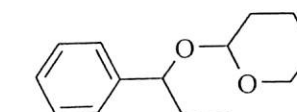
^1H NMR (400 MHz, CDCl_3): δ 1.48-2.0 (m, 5H), 3.55 (m, 1H), 3.88 (m, 1H), 4.50 (d, 1H, $J = 13.2$ Hz), 4.79 (m, 2H), 4.80 (d, 1H, $J = 13.2$ Hz), 7.23 (m, 1H), 7.35 (d, 1H, $J = 1.6$ Hz), 7.44 (d, 1H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.7, 25.8, 30.8, 62.5, 66.0, 98.6, 127.1, 129.1, 129.8, 133.5, 133.6, 135.0.

2-(1-Phenyl-ethoxy)-tetrahydro-pyran (7a)

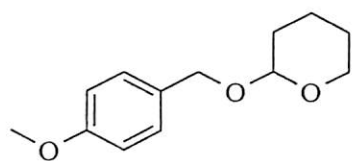
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.98 (m, 9H), 3.50 (m, 1H), 3.98 (m, 1H), 4.40 (m, 1H), 4.90 (m, 1H), 7.30 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.2, 24.8, 25.98, 31.2, 63.0, 73.5, 96.3, 126.6, 127.1, 128.3, 143.8. Peaks appearing due to minor contamination or other diastereomers (19.7, 22.4, 25.95, 31.3, 62.2, 73.3, 96.4, 126.1, 127.5, 128.5, 143.9).

2-(2-Isopropyl-5-methyl-cyclohexyloxy)-tetrahydro-pyran (8a)

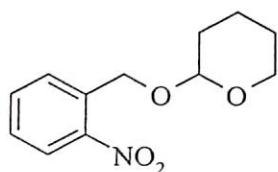
^1H NMR (400 MHz, CDCl_3): Obtained as a mixture of diastereomers. ^{13}C NMR (100 MHz, CDCl_3) (Peaks appearing due to both diastereomers): δ 16.0, 16.7, 20.1, 20.7, 21.6, 21.7, 22.7, 22.8, 23.4, 23.7, 25.6, 25.9, 26.00, 26.04, 31.6, 31.7, 31.8, 32.2, 34.8, 34.9, 40.5, 43.9, 48.5, 49.2, 62.7, 63.3, 74.4, 80.2, 94.6, 101.5.

2-(1-Phenyl-propoxy)-tetrahydro-pyran (9a)

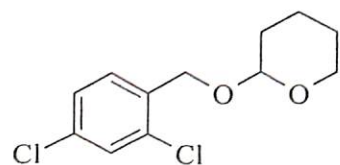
^1H NMR (400 MHz, CDCl_3): Obtained as a mixture of diastereomers. δ 0.93 (t, 3H, $J = 7.6$ Hz), 1.41-1.88 (m, 8H), 3.48 (m, 1H), 3.95 (m, 1H), 4.40 (t, 1H, $J = 4$ Hz), 4.59 (t, 1H, $J = 6$ Hz), 7.2-7.4 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 11.0, 20.0, 26.0, 31.2, 31.6, 62.7, 78.8, 95.5, 126.7, 127.2, 128.2, 142.5. Peaks appearing due to contamination of other diastereomers (10.2, 19.6, 25.9, 30.1, 31.1, 62.2, 80.1, 98.1, 127.0, 127.5, 128.4, 143.5).

2-(4-Methoxy-benzyloxy)-tetrahydro-pyran (4a)

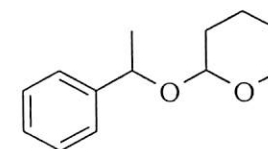
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.91 (m, 6H), 3.50 (m, 1H), 3.76 (s, 3H), 3.90 (m, 1H), 4.42 (d, 1H, $J = 11.6$ Hz), 4.69 (m, 2H), 6.87 (d, 2H, $J = 8.8$ Hz) 7.28 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.8, 25.9, 31.0, 55.6, 62.4, 68.8, 97.7, 113.9, 129.6, 130.5, 159.2.

2-(2-Nitro-benzyloxy)-tetrahydro-pyran (5a)

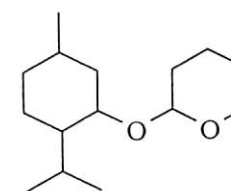
^1H NMR (400 MHz, CDCl_3): δ 1.43-1.99 (m, 6H), 3.52 (m, 1H), 3.89 (m, 1H), 4.75 (m, 1H), 4.89 (d, 1H, $J = 15.6$ Hz), 5.15 (d, 1H, $J = 14.8$ Hz), 7.40 (t, 1H, $J = 7.2$ Hz), 7.63 (t, 1H, $J = 7.2$ Hz), 7.80 (d, 1H, $J = 7.6$ Hz), 8.05 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.7, 20.1, 25.7, 25.8, 30.8, 31.6, 62.6, 63.1, 66.1, 94.7, 98.9, 124.7, 128.0, 128.9, 133.6, 135.2, 147.4.

2-(2,4-Dichloro-benzyloxy)-tetrahydro-pyran (6a)

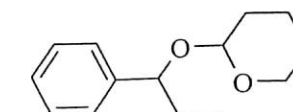
^1H NMR (400 MHz, CDCl_3): δ 1.48-2.0 (m, 5H), 3.55 (m, 1H), 3.88 (m, 1H), 4.50 (d, 1H, $J = 13.2$ Hz), 4.79 (m, 2H), 4.80 (d, 1H, $J = 13.2$ Hz), 7.23 (m, 1H), 7.35 (d, 1H, $J = 1.6$ Hz), 7.44 (d, 1H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.7, 25.8, 30.8, 62.5, 66.0, 98.6, 127.1, 129.1, 129.8, 133.5, 133.6, 135.0.

2-(1-Phenyl-ethoxy)-tetrahydro-pyran (7a)

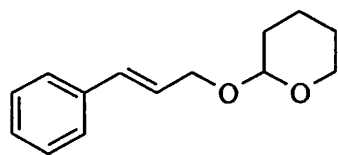
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.98 (m, 9H), 3.50 (m, 1H), 3.98 (m, 1H), 4.40 (m, 1H), 4.90 (m, 1H), 7.30 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.2, 24.8, 25.98, 31.2, 63.0, 73.5, 96.3, 126.6, 127.1, 128.3, 143.8. Peaks appearing due to minor contamination or other diastereomers (19.7, 22.4, 25.95, 31.3, 62.2, 73.3, 96.4, 126.1, 127.5, 128.5, 143.9).

2-(2-Isopropyl-5-methyl-cyclohexyloxy)-tetrahydro-pyran (8a)

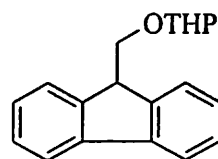
^1H NMR (400 MHz, CDCl_3): Obtained as a mixture of diastereomers. ^{13}C NMR (100 MHz, CDCl_3) (Peaks appearing due to both diastereomers): δ 16.0, 16.7, 20.1, 20.7, 21.6, 21.7, 22.7, 22.8, 23.4, 23.7, 25.6, 25.9, 26.00, 26.04, 31.6, 31.7, 31.8, 32.2, 34.8, 34.9, 40.5, 43.9, 48.5, 49.2, 62.7, 63.3, 74.4, 80.2, 94.6, 101.5.

2-(1-Phenyl-propoxy)-tetrahydro-pyran (9a)

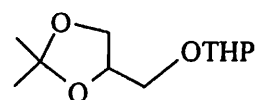
^1H NMR (400 MHz, CDCl_3): Obtained as a mixture of diastereomers. δ 0.93 (t, 3H, $J = 7.6$ Hz), 1.41-1.88 (m, 8H), 3.48 (m, 1H), 3.95 (m, 1H), 4.40 (t, 1H, $J = 4$ Hz), 4.59 (t, 1H, $J = 6$ Hz), 7.2-7.4 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 11.0, 20.0, 26.0, 31.2, 31.6, 62.7, 78.8, 95.5, 126.7, 127.2, 128.2, 142.5. Peaks appearing due to contamination of other diastereomers (10.2, 19.6, 25.9, 30.1, 31.1, 62.2, 80.1, 98.1, 127.0, 127.5, 128.4, 143.5).

2-(3-Phenyl-allyloxy)-tetrahydro-pyran (10a)

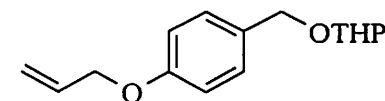
^1H NMR (400 MHz, CDCl_3): δ 1.50-1.86 (m, 6H), 3.50 (m, 1H), 3.90 (m, 1H), 4.15 (m, 1H), 4.38 (m, 1H), 4.69 (m, 1H), 6.30 (m, 1H), 6.60 (d, 1H, $J = 16$ Hz), 7.15-7.40 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.9, 25.9, 31.0, 62.5, 67.9, 98.1, 126.2, 126.7, 127.8, 128.7, 132.5, 136.9.

2-(9H-Fluoren-9-ylmethoxy)-tetrahydro-pyran (11a)

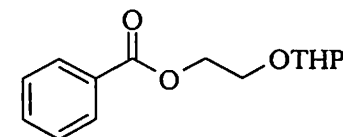
^1H NMR (400 MHz, CDCl_3): δ 1.50-2.0 (brm, 6H), 3.45 (m, 1H), 3.54 (t, 1H, $J = 8.8$ Hz), 3.83 (m, 1H), 4.05 (t, 1H, $J = 8.0$ Hz), 4.18 (t, 1H, $J = 8.0$ Hz), 4.67 (t, 1H, $J = 3.2$ Hz), 7.26 (d, 2H, $J = 7.6$ Hz), 7.34 (t, 2H, $J = 7.2$ Hz), 7.63 (d, 2H, $J = 7.6$ Hz), 7.72 (d, 2H, $J = 7.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 18.0, 24.1, 29.2, 46.4, 60.5, 68.6, 97.4, 118.17, 118.18, 123.6, 123.7, 125.2, 125.2, 125.7, 139.5, 143.0, 143.5.

2-(2,2-Dimethyl-[1,3]dioxalan-4-ylmethoxy)-tetrahydro-pyran (12a)

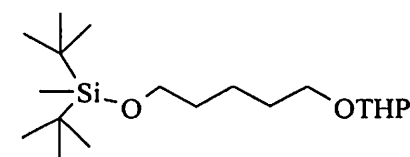
^1H NMR (400 MHz, CDCl_3) Obtained as a mixture of diastereomers. δ 1.30-1.84 (brm, 12H), 3.49 (m, 2H), 3.75 (m, 3H), 4.06 (m, 1H), 4.29 (m, 1H), 4.62 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3) Peaks appearing due to both diastereomers (δ 19.6, 19.8, 25.7, 25.8, 25.9, 27.0, 27.1, 30.7, 62.3, 62.5, 67.0, 67.2, 68.2, 68.8, 74.9, 75.1, 99.1, 99.3, 109.4, 109.6).

2-(4-Allyloxy-benzyloxy)-tetrahydro-pyran (13a)

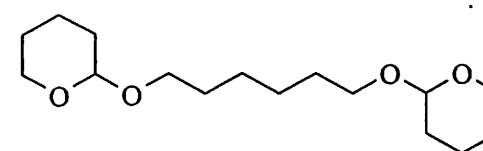
^1H NMR (400 MHz, CDCl_3): δ 1.50-1.86 (m, 6H), 3.54 (m, 1H), 3.90 (m, 1H), 4.42 (d, 1H, $J = 11.2$ Hz), 4.52 (m, 2H), 4.70 (m, 2H), 5.30 (dd, 2H, $J = 10.8$ Hz, $J = 17.2$ Hz), 6.02 (m, 1H), 6.87 (d, 2H, $J = 8.0$ Hz), 7.27 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.8, 25.8, 30.9, 62.4, 68.8, 69.1, 97.7, 114.8, 117.8, 129.6, 130.6, 133.4, 158.2.

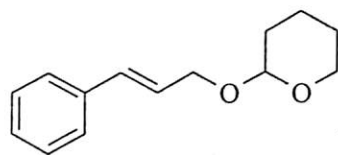
1-Phenyl-3-(tetrahydro-pyran-2-yloxy)-propan-1-one (14a)

^1H NMR (400 MHz, CDCl_3): δ 1.45-1.90 (brm, 6H), 3.51 (m, 1H), 3.80 (m, 1H), 3.88 (m, 1H), 4.05 (m, 1H), 4.51 (m, 2H), 4.71 (m, 1H), 7.44 (m, 2H), 7.55 (m, 1H), 8.06 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.6, 25.8, 30.8, 62.3, 64.5, 65.5, 99.0, 128.5, 129.8, 130.3, 133.0, 166.6.

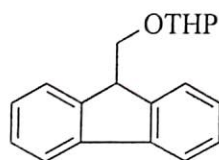
Di-tert-butyl-methyl-[5-tetrahydro-pyran-2-yloxy]-hexyloxy]-silane (15a)

^1H NMR (400 MHz, CDCl_3): δ 0.03 (s, 6H), 0.88 (s, 12H), 1.28-1.90 (m, 14H), 3.37 (m, 1H), 3.48 (m, 1H), 3.59 (t, 2H, $J = 6.8$ Hz), 3.70 (m, 1H), 3.84 (m, 1H), 4.56 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ -4.7, 18.7, 20.0, 25.9, 26.1, 26.3, 26.4, 30.1, 31.1, 33.2, 62.5, 63.5, 67.8, 99.0.

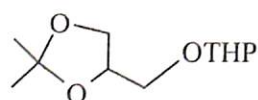
1,6-Di(Tetrahydro-pyran-2-yloxy)-hexane (16a)

2-(3-Phenyl-allyloxy)-tetrahydro-pyran (10a)

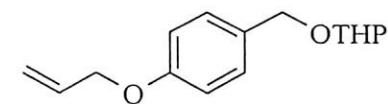
^1H NMR (400 MHz, CDCl_3): δ 1.50-1.86 (m, 6H), 3.50 (m, 1H), 3.90 (m, 1H), 4.15 (m, 1H), 4.38 (m, 1H), 4.69 (m, 1H), 6.30 (m, 1H), 6.60 (d, 1H, $J = 16$ Hz), 7.15-7.40 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.9, 25.9, 31.0, 62.5, 67.9, 98.1, 126.2, 126.7, 127.8, 128.7, 132.5, 136.9.

2-(9H-Fluoren-9-ylmethoxy)-tetrahydro-pyran (11a)

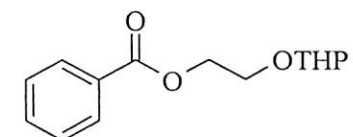
^1H NMR (400 MHz, CDCl_3): δ 1.50-2.0 (brm, 6H), 3.45 (m, 1H), 3.54 (t, 1H, $J = 8.8$ Hz), 3.83 (m, 1H), 4.05 (t, 1H, $J = 8.0$ Hz), 4.18 (t, 1H, $J = 8.0$ Hz), 4.67 (t, 1H, $J = 3.2$ Hz), 7.26 (d, 2H, $J = 7.6$ Hz), 7.34 (t, 2H, $J = 7.2$ Hz), 7.63 (d, 2H, $J = 7.6$ Hz), 7.72 (d, 2H, $J = 7.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 18.0, 24.1, 29.2, 46.4, 60.5, 68.6, 97.4, 118.17, 118.18, 123.6, 123.7, 125.2, 125.2, 125.7, 139.5, 143.0, 143.5.

2-(2,2-Dimethyl-[1,3]dioxalan-4-ylmethoxy)-tetrahydro-pyran (12a)

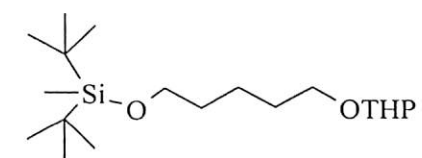
^1H NMR (400 MHz, CDCl_3) Obtained as a mixture of diastereomers. δ 1.30-1.84 (brm, 12H), 3.49 (m, 2H), 3.75 (m, 3H), 4.06 (m, 1H), 4.29 (m, 1H), 4.62 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3) Peaks appearing due to both diastereomers (δ 19.6, 19.8, 25.7, 25.8, 25.9, 27.0, 27.1, 30.7, 62.3, 62.5, 67.0, 67.2, 68.2, 68.8, 74.9, 75.1, 99.1, 99.3, 109.4, 109.6).

2-(4-Allyloxy-benzyloxy)-tetrahydro-pyran (13a)

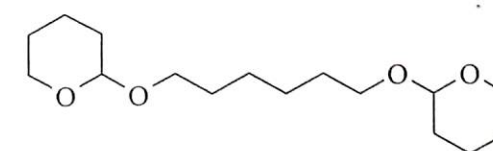
^1H NMR (400 MHz, CDCl_3): δ 1.50-1.86 (m, 6H), 3.54 (m, 1H), 3.90 (m, 1H), 4.42 (d, 1H, $J = 11.2$ Hz), 4.52 (m, 2H), 4.70 (m, 2H), 5.30 (dd, 2H, $J = 10.8$ Hz, $J = 17.2$ Hz), 6.02 (m, 1H), 6.87 (d, 2H, $J = 8.0$ Hz), 7.27 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.8, 25.8, 30.9, 62.4, 68.8, 69.1, 97.7, 114.8, 117.8, 129.6, 130.6, 133.4, 158.2.

1-Phenyl-3-(tetrahydro-pyran-2-yloxy)-propan-1-one (14a)

^1H NMR (400 MHz, CDCl_3): δ 1.45-1.90 (brm, 6H), 3.51 (m, 1H), 3.80 (m, 1H), 3.88 (m, 1H), 4.05 (m, 1H), 4.51 (m, 2H), 4.71 (m, 1H), 7.44 (m, 2H), 7.55 (m, 1H), 8.06 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.6, 25.8, 30.8, 62.3, 64.5, 65.5, 99.0, 128.5, 129.8, 130.3, 133.0, 166.6.

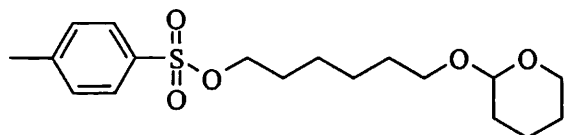
Di-tert-butyl-methyl-[5-tetrahydro-pyran-2-yloxy]-hexyloxy]-silane (15a)

^1H NMR (400 MHz, CDCl_3): δ 0.03 (s, 6H), 0.88 (s, 12H), 1.28-1.90 (m, 14H), 3.37 (m, 1H), 3.48 (m, 1H), 3.59 (t, 2H, $J = 6.8$ Hz), 3.70 (m, 1H), 3.84 (m, 1H), 4.56 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ -4.7, 18.7, 20.0, 25.9, 26.1, 26.3, 26.4, 30.1, 31.1, 33.2, 62.5, 63.5, 67.8, 99.0.

1,6-Di(Tetrahydro-pyran-2-yloxy)-hexane (16a)

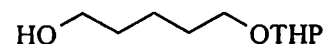
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.88 (m, 20H), 3.38 (m, 2H), 3.48 (m, 2H), 3.73 (m, 2H), 3.85 (m, 2H), 4.57 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.1, 25.9, 26.5, 30.1, 31.1, 62.6, 67.8, 99.0.

Toulene-4-sulphonic acid 5-(tetrahydropyran-2-yloxy)-hexyl ester (17a)



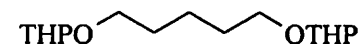
^1H NMR (400 MHz, CDCl_3): δ 1.22-1.83 (m, 14H), 2.45 (s, 3H), 3.34 (m, 1H), 3.49 (m, 1H), 3.68 (m, 1H), 3.83 (m, 1H), 4.02 (t, 2H, $J = 6.4$ Hz), 4.54 (m, 1H), 7.33 (d, 2H, $J = 8.4$ Hz), 7.77 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.1, 22.0, 25.6, 25.8, 26.0, 29.1, 29.8, 31.1, 62.7, 67.6, 70.8, 99.1, 128.0, 129.9, 133.3, 144.7.

5-(Tetrahydro-pyran-2-yloxy)-pentan-1-ol (18a)



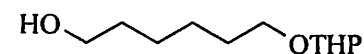
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.84 (brn, 13H), 3.43 (m, 1H), 3.50 (m, 1H), 3.65 (t, 2H, $J = 6.4$ Hz), 3.75 (m, 1H), 3.84 (m, 1H), 4.57 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 22.8, 25.8, 29.8, 31.1, 32.9, 62.7, 63.1, 67.8, 99.1.

1,5-Di(Tetrahydro-pyran-2-yloxy)-pentane (18b)



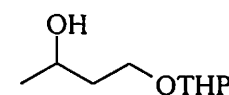
^1H NMR (400 MHz, CDCl_3): δ 1.44-1.86 (m, 18H), 3.39 (m, 2H), 3.49 (m, 2H), 3.72 (m, 2H), 3.86 (m, 2H), 4.57 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.1, 23.3, 25.9, 30.0, 31.1, 62.6, 67.8, 99.0.

5-(Tetrahydro-pyran-2-yloxy)-hexane-1-ol (16)



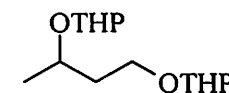
^1H NMR (400 MHz, CDCl_3): δ 1.39 (m, 4H), 1.50-1.80 (m, 11H), 3.38 (m, 1H 2H, $J = 6.4$ Hz), 3.74 (m, 1H), 3.85 (m, 1H), 4.57 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 22.0, 25.9, 26.4, 30.0, 31.1, 33.0, 62.6, 62.9, 67.8, 99.0.

4-(Tetrahydro-pyran-2-yloxy)-butan-2-ol (20a)



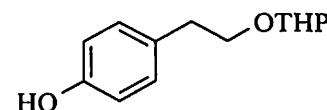
^1H NMR (400 MHz, CDCl_3): δ 1.23 (d, 3H, $J = 6.4$ Hz), 1.40-1.68 (m, 9H), 2.09 (brs, 1H), 3.62 (t, 2H, $J = 6.4$ Hz), 3.73 (m, 2H), 4.07 (m, 1H), 4.53 (t, 1H, $J = 5.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.6, 22.0, 32.6, 33.3, 34.9, 62.4, 66.7, 73.0, 102.0.

1,4-Di-(Tetrahydro-pyran-2-yloxy) butane (20b)



^1H NMR (400 MHz, CDCl_3): Obtained as a mixture of diastereomers. δ 1.23 (d, 3H, $J = 6.4$ Hz), 1.40-1.84 (m, 14H), 3.37 (m, 1H), 3.49 (m, 1H), 3.71 (m, 3H), 3.85 (m, 1H), 4.06 (m, 1H), 4.52 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): Peaks appearing due to both diastereomers. δ 19.8, 20.0, 21.1, 21.2, 21.9, 22.1, 25.7, 25.8, 29.8, 29.9, 30.95, 31.09, 33.2, 33.4, 35.1, 35.3, 62.2, 62.5, 66.6, 66.8, 67.4, 67.6, 72.7, 72.9, 98.7, 98.9, 101.8, 102.0. Anal. calcd for $\text{C}_{14}\text{H}_{26}\text{O}_4$: C, 65.09; H 10.14. Found C, 65.26, H, 9.87.

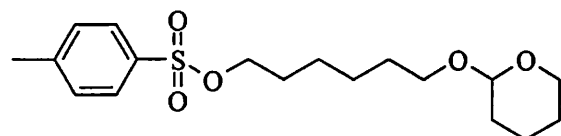
4-[2-(tetrahydro-pyran-2-yloxy)-ethyl]-phenol (21a)



^1H NMR (400 MHz, CDCl_3): δ 1.48-1.84 (m, 6H), 2.82 (t, 2H, $J = 12$ Hz), 3.48-3.62 (m, 2H), 3.79-3.92 (m, 2H), 4.61 (m, 1H), 6.07 (brs, 1H), 6.73 (d, 2H, $J = 8.4$ Hz), 7.05 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.4, 25.4, 26.4, 30.6, 35.4, 62.2, 68.6, 98.7, 115.1, 130.0, 130.7, 154.3.

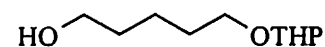
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.88 (m, 20H), 3.38 (m, 2H), 3.48 (m, 2H), 3.73 (m, 2H), 3.85 (m, 2H), 4.57 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.1, 25.9, 26.5, 30.1, 31.1, 62.6, 67.8, 99.0.

Toulene-4-sulphonic acid 5-(tetrahydropyran-2-yloxy)-hexyl ester (17a)



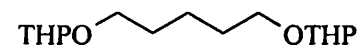
^1H NMR (400 MHz, CDCl_3): δ 1.22-1.83 (m, 14H), 2.45 (s, 3H), 3.34 (m, 1H), 3.49 (m, 1H), 3.68 (m, 1H), 3.83 (m, 1H), 4.02 (t, 2H, $J = 6.4$ Hz), 4.54 (m, 1H), 7.33 (d, 2H, $J = 8.4$ Hz), 7.77 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.1, 22.0, 25.6, 25.8, 26.0, 29.1, 29.8, 31.1, 62.7, 67.6, 70.8, 99.1, 128.0, 129.9, 133.3, 144.7.

5-(Tetrahydro-pyran-2-yloxy)-pentan-1-ol (18a)



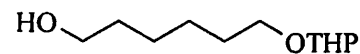
^1H NMR (400 MHz, CDCl_3): δ 1.40-1.84 (brm, 13H), 3.43 (m, 1H), 3.50 (m, 1H), 3.65 (t, 2H, $J = 6.4$ Hz), 3.75 (m, 1H), 3.84 (m, 1H), 4.57 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 22.8, 25.8, 29.8, 31.1, 32.9, 62.7, 63.1, 67.8, 99.1.

1,5-Di(Tetrahydro-pyran-2-yloxy)-pentane (18b)



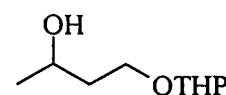
^1H NMR (400 MHz, CDCl_3): δ 1.44-1.86 (m, 18H), 3.39 (m, 2H), 3.49 (m, 2H), 3.72 (m, 2H), 3.86 (m, 2H), 4.57 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.1, 23.3, 25.9, 30.0, 31.1, 62.6, 67.8, 99.0.

5-(Tetrahydro-pyran-2-yloxy)-hexane-1-ol (16)



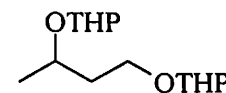
^1H NMR (400 MHz, CDCl_3): δ 1.39 (m, 4H), 1.50-1.80 (m, 11H), 3.38 (m, 1H, 2H, $J = 6.4$ Hz), 3.74 (m, 1H), 3.85 (m, 1H), 4.57 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 22.0, 25.9, 26.4, 30.0, 31.1, 33.0, 62.6, 62.9, 67.8, 99.0.

4-(Tetrahydro-pyran-2-yloxy)-butan-2-ol (20a)



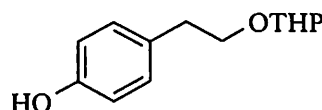
^1H NMR (400 MHz, CDCl_3): δ 1.23 (d, 3H, $J = 6.4$ Hz), 1.40-1.68 (m, 9H), 2.09 (brs, 1H), 3.62 (t, 2H, $J = 6.4$ Hz), 3.73 (m, 2H), 4.07 (m, 1H), 4.53 (t, 1H, $J = 5.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.6, 22.0, 32.6, 33.3, 34.9, 62.4, 66.7, 73.0, 102.0.

1,4-Di-(Tetrahydro-pyran-2-yloxy) butane (20b)



^1H NMR (400 MHz, CDCl_3): Obtained as a mixture of diastereomers. δ 1.23 (d, 3H, $J = 6.4$ Hz), 1.40-1.84 (m, 14H), 3.37 (m, 1H), 3.49 (m, 1H), 3.71 (m, 3H), 3.85 (m, 1H), 4.06 (m, 1H), 4.52 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): Peaks appearing due to both diastereomers. δ 19.8, 20.0, 21.1, 21.2, 21.9, 22.1, 25.7, 25.8, 29.8, 29.9, 30.95, 31.09, 33.2, 33.4, 35.1, 35.3, 62.2, 62.5, 66.6, 66.8, 67.4, 67.6, 72.7, 72.9, 98.7, 98.9, 101.8, 102.0. Anal. calcd for $\text{C}_{14}\text{H}_{26}\text{O}_4$: C, 65.09; H 10.14. Found C, 65.26, H, 9.87.

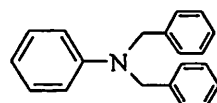
4-[2-(tetrahydro-pyran-2-yloxy)-ethyl]-phenol (21a)



^1H NMR (400 MHz, CDCl_3): δ 1.48-1.84 (m, 6H), 2.82 (t, 2H, $J = 12$ Hz), 3.48-3.62 (m, 2H), 3.79-3.92 (m, 2H), 4.61 (m, 1H), 6.07 (brs, 1H), 6.73 (d, 2H, $J = 8.4$ Hz), 7.05 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 19.4, 25.4, 26.4, 30.6, 35.4, 62.2, 68.6, 98.7, 115.1, 130.0, 130.7, 154.3.

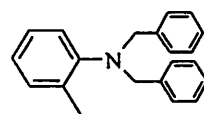
ID.2. Spectral Data of Tertiary Amines

Dibenzyl-phenyl-amine (22c)



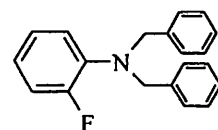
^1H NMR (400 MHz, CDCl_3): δ 4.63 (s, 4H), 6.93 (m, 3H), 7.22 (m, 12H). ^{13}C NMR (100 MHz, CDCl_3): δ 54.2, 112.4, 116.6, 126.5, 126.7, 128.5, 129.1, 138.5, 149.0. IR (KBr): 3027, 2914, 2853, 1598, 1501, 1450, 1399, 1352, 1230, 1163, 953, 738, 692, 646 cm^{-1} .

Dibenzyl-(o-tolyl-phenyl)-amine (23c)



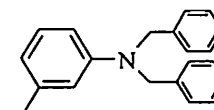
^1H NMR (400 MHz, CDCl_3): δ 2.43 (s, 3H), 4.05 (s, 4H), 6.90-7.24 (m, 14H). ^{13}C NMR (100 MHz, CDCl_3): δ 18.6, 57.0, 122.4, 123.3, 125.9, 126.7, 127.9, 128.5, 130.9, 133.7, 138.4, 149.7. IR (KBr): 3063, 3027, 2925, 2822, 1593, 1496, 1450, 1368, 1214, 1107, 1035, 948, 758, 743, 702 cm^{-1} .

Dibenzyl-(o-fluoro-phenyl)-amine (24c)



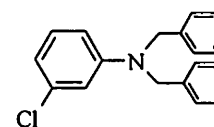
^1H NMR (400 MHz, CDCl_3): δ 4.31 (s, 2H), 4.35 (s, 2H), 6.52-7.37 (m, 14H). ^{13}C NMR (100 MHz, CDCl_3): δ 48.2, 56.0, 112.5, 112.6, 114.5, 114.7, 116.4, 116.6, 117.0, 117.1, 121.6, 124.3, 124.4, 124.8, 124.9, 127.3, 127.5, 127.6, 128.4, 128.5, 128.9, 139.1. IR (KBr): 3124, 3083, 3048, 2935, 2853, 1624, 1521, 1455, 1342, 1250, 1189, 1117, 856, 750 cm^{-1} .

Dibenzyl-(m-tolyl-phenyl)-amine (25c)



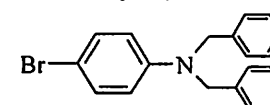
^1H NMR (400 MHz, CDCl_3): δ 2.22 (s, 3H), 4.60 (s, 4H), 6.56 (m, 2H), 7.02 (t, 1H, $J = 7.8$ Hz), 7.26 (m, 11H). ^{13}C NMR (100 MHz, CDCl_3): δ 22.0, 54.0, 109.6, 112.9, 117.6, 126.5, 126.7, 128.4, 128.9, 138.5, 138.7. IR (KBr): 3032, 2904, 2858, 1603, 1501, 1450, 1342, 1265, 1189, 1071, 958, 846, 738, 692 cm^{-1} .

Dibenzyl (m-chloro-phenyl) amine (26c)



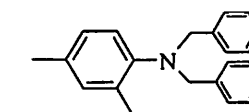
^1H NMR (400 MHz, CDCl_3): δ 4.60 (s, 4H), 6.62 (m, 3H), 7.03 (m, 1H), 7.26 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 54.1, 110.5, 112.1, 116.6, 126.4, 126.9, 128.6, 129.9, 137.6, 150.1. IR (KBr): 3053, 2909, 2863, 1588, 1496, 1450, 1358, 1312, 1230, 1158, 1096, 958, 835, 743, 692 cm^{-1} .

Dibenzyl-(4-bromo-phenyl)-amine (27c)



^1H NMR (400 MHz, CDCl_3): δ 4.60 (s, 4H), 6.56 (d, 2H, $J = 9.2$ Hz), 7.28 (m, 12H). ^{13}C NMR (100 MHz, CDCl_3): δ 54.5, 108.6, 114.1, 126.4, 126.9, 128.6, 131.7, 137.8, 147.8. IR (KBr): 3068, 3022, 2899, 2858, 1588, 1496, 1440, 1347, 1245, 1189, 1076, 963, 799, 723, 680 cm^{-1} .

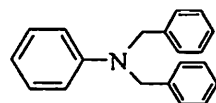
Dibenzyl-(2,4-dimethyl-phenyl)-amine (28c)



^1H NMR (400 MHz, CDCl_3): δ 2.23 (s, 3H), 2.49 (s, 3H), 4.02 (s, 4H), 6.85 (s, 2H), 6.97 (s, 1H), 7.22 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.6, 52.8, 128.1, 128.6, 129.1, 129.5, 129.6, 130.5, 131.7, 133.2. IR (KBr): 3068, 2955, 2919, 1620, 1588, 1496, 1460, 1370, 1230, 1102, 963, 850, 700 cm^{-1} .

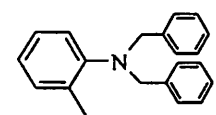
ID.2. Spectral Data of Tertiary Amines

Dibenzyl-phenyl-amine (22c)



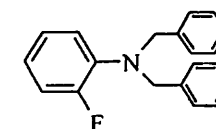
^1H NMR (400 MHz, CDCl_3): δ 4.63 (s, 4H), 6.93 (m, 3H), 7.22 (m, 12H). ^{13}C NMR (100 MHz, CDCl_3): δ 54.2, 112.4, 116.6, 126.5, 126.7, 128.5, 129.1, 138.5, 149.0. IR (KBr): 3027, 2914, 2853, 1598, 1501, 1450, 1399, 1352, 1230, 1163, 953, 738, 692, 646 cm^{-1} .

Dibenzyl-(o-tolyl-phenyl)-amine (23c)



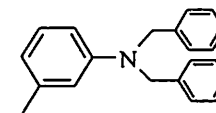
^1H NMR (400 MHz, CDCl_3): δ 2.43 (s, 3H), 4.05 (s, 4H), 6.90-7.24 (m, 14H). ^{13}C NMR (100 MHz, CDCl_3): δ 18.6, 57.0, 122.4, 123.3, 125.9, 126.7, 127.9, 128.5, 130.9, 133.7, 138.4, 149.7. IR (KBr): 3063, 3027, 2925, 2822, 1593, 1496, 1450, 1368, 1214, 1107, 1035, 948, 758, 743, 702 cm^{-1} .

Dibenzyl-(o-fluoro-phenyl)-amine (24c)



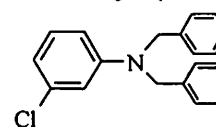
^1H NMR (400 MHz, CDCl_3): δ 4.31 (s, 2H), 4.35 (s, 2H), 6.52-7.37 (m, 14H). ^{13}C NMR (100 MHz, CDCl_3): δ 48.2, 56.0, 112.5, 112.6, 114.5, 114.7, 116.4, 116.6, 117.0, 117.1, 121.6, 124.3, 124.4, 124.8, 124.9, 127.3, 127.5, 127.6, 128.4, 128.5, 128.9, 139.1. IR (KBr): 3124, 3083, 3048, 2935, 2853, 1624, 1521, 1455, 1342, 1250, 1189, 1117, 856, 750 cm^{-1} .

Dibenzyl-(m-tolyl-phenyl)-amine (25c)



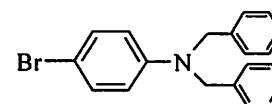
^1H NMR (400 MHz, CDCl_3): δ 2.22 (s, 3H), 4.60 (s, 4H), 6.56 (m, 2H), 7.02 (t, 1H, $J = 7.8$ Hz), 7.26 (m, 11H). ^{13}C NMR (100 MHz, CDCl_3): δ 22.0, 54.0, 109.6, 112.9, 117.6, 126.5, 126.7, 128.4, 128.9, 138.5, 138.7. IR (KBr): 3032, 2904, 2858, 1603, 1501, 1450, 1342, 1265, 1189, 1071, 958, 846, 738, 692 cm^{-1} .

Dibenzyl (m-chloro-phenyl) amine (26c)



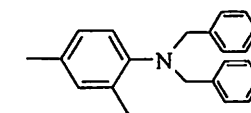
^1H NMR (400 MHz, CDCl_3): δ 4.60 (s, 4H), 6.62 (m, 3H), 7.03 (m, 1H), 7.26 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 54.1, 110.5, 112.1, 116.6, 126.4, 126.9, 128.6, 129.9, 137.6, 150.1. IR (KBr): 3053, 2909, 2863, 1588, 1496, 1450, 1358, 1312, 1230, 1158, 1096, 958, 835, 743, 692 cm^{-1} .

Dibenzyl-(4-bromo-phenyl)-amine (27c)

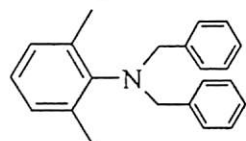


^1H NMR (400 MHz, CDCl_3): δ 4.60 (s, 4H), 6.56 (d, 2H, $J = 9.2$ Hz), 7.28 (m, 12H). ^{13}C NMR (100 MHz, CDCl_3): δ 54.5, 108.6, 114.1, 126.4, 126.9, 128.6, 131.7, 137.8, 147.8. IR (KBr): 3068, 3022, 2899, 2858, 1588, 1496, 1440, 1347, 1245, 1189, 1076, 963, 799, 723, 680 cm^{-1} .

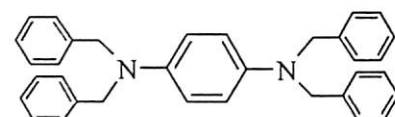
Dibenzyl-(2,4-dimethyl-phenyl)-amine (28c)



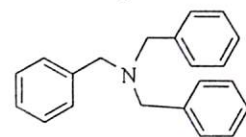
^1H NMR (400 MHz, CDCl_3): δ 2.23 (s, 3H), 2.49 (s, 3H), 4.02 (s, 4H), 6.85 (s, 2H), 6.97 (s, 1H), 7.22 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.6, 52.8, 128.1, 128.6, 129.1, 129.5, 129.6, 130.5, 131.7, 133.2. IR (KBr): 3068, 2955, 2919, 1620, 1588, 1496, 1460, 1370, 1230, 1102, 963, 850, 700 cm^{-1} .

Dibenzyl-(2,6-dimethyl-phenyl)-amine (29c)

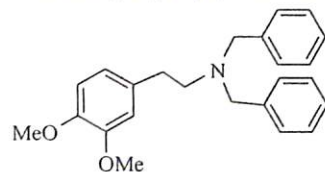
^1H NMR (400 MHz, CDCl_3): δ 2.39 (s, 6H), 4.73 (s, 4H), 6.99 (d, 3H), 7.21 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 53.3, 128.6, 129.3, 129.5, 129.9, 130.0, 131.2, 132.1, 133.6. IR (KBr): 2930, 2858, 1619, 1517, 1342, 1209, 1112, 1015, 866, 702 cm^{-1} .

N, N, N', N'-Tetrabenzyl-benzene-1,4-diamine (30c)

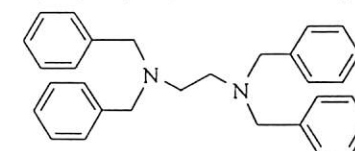
^1H NMR (400 MHz, CDCl_3): δ 4.48 (brs, 8H), 6.27 (brs, 4H), 7.22 (m, 20H). ^{13}C NMR (100 MHz, CDCl_3): δ 55.2, 114.9, 126.5, 126.9, 128.3, 139.3, 141.8. IR (KBr): 3027, 2899, 2843, 1603, 1521, 1440, 1363, 1219, 1168, 1071, 1030, 953, 805, 738, 697, 625 cm^{-1} .

Tribenzylamine (31c)

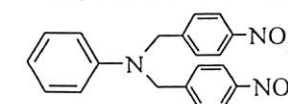
^1H NMR (400 MHz, CDCl_3): δ 3.54 (s, 6H), 7.19 (m, 3H), 7.28 (t, 6H, $J = 6.8$ Hz), 7.38 (d, 6H, $J = 7.6$ Hz), ^{13}C NMR (100 MHz, CDCl_3): δ 57.9, 126.7, 128.1, 128.6, 139.5. IR (KBr): 3068, 3022, 2925, 2802, 1593, 1496, 1445, 1373, 1317, 1250, 1122, 974, 907, 743, 697 cm^{-1} .

Dibenzyl-[2-(3,4-dimethoxy-phenyl)-ethyl]-amine (32c)

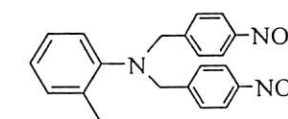
^1H NMR (400 MHz, CDCl_3): δ 2.72 (m, 4H), 3.63 (s, 3H), 3.76 (s, 4H), 3.84 (s, 3H), 6.54 (d, 1H, $J = 1.6$ Hz), 6.59 (dd, 1H, $J_1 = 2$ Hz, $J_2 = 8$ Hz), 7.25 (d, 1H, $J = 8.4$ Hz), 7.27 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 33.2, 55.2, 55.8, 56.0, 58.3, 111.1, 112.1, 120.6, 126.7, 128.0, 128.6. IR (KBr): 3068, 2935, 2827, 2786, 1593, 1516, 1460, 1414, 1265, 1235, 1137, 1030, 805, 748, 702, 641 cm^{-1} .

N, N, N', N'-Tetrabenzyl-ethane-1,2-diamine (33c)

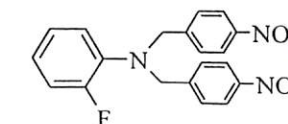
^1H NMR (400 MHz, DMSO-d_6): δ 2.59, (s, 4H), 3.49 (s, 8H), 7.22 (m, 20H). ^{13}C NMR (100 MHz, DMSO-d_6): δ 51.1, 58.6, 126.6, 127.9, 128.5, 139.5. IR (KBr): 3068, 3024, 2948, 2800, 1599, 1492, 1451, 1372, 1320, 1242, 1124, 1089, 1067, 1028, 977, 913, 743, 695 cm^{-1} .

Bis-(4-nitro-benzyl)-phenyl-amine (22d)

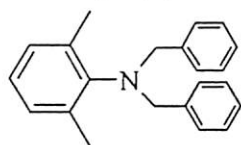
^1H NMR (400 MHz, CDCl_3): δ 4.73 (s, 4H), 6.63 (d, 2H, $J = 8$ Hz), 6.77 (t, 1H, $J = 7.6$ Hz), 7.18 (d, 2H, $J = 7.6$ Hz), 7.39 (d, 4H, $J = 8.4$ Hz), 8.16 (d, 4H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 54.5, 112.7, 118.2, 123.8, 126.9, 127.2, 129.4, 145.8, 147.0. IR (KBr): 3042, 2853, 1609, 1527, 1342, 1214, 1102, 856, 692 cm^{-1} .

Bis-(4-nitro-benzyl)-o-tolyl-phenyl-amine (23d)

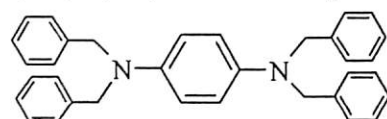
^1H NMR (400 MHz, CDCl_3): δ 2.42 (s, 3H), 4.16 (s, 4H), 6.92 (m, 1H), 7.02 (m, 2H), 7.26 (m, 9H). ^{13}C NMR (100 MHz, CDCl_3): δ 18.6, 57.1, 122.1, 123.5, 124.6, 126.4, 129.0, 131.5, 145.3. IR (KBr): 3048, 2889, 2592, 1614, 1547, 1496, 1143, 1086, 1015, 810, 610 cm^{-1} .

(2-Fluoro-phenyl)-bis-(4-nitro-benzyl)-amine (24d)

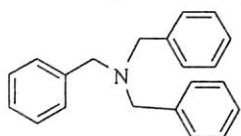
^1H NMR (400 MHz, CDCl_3): δ 4.48 (s, 4H), 6.47 (t, 1H, $J = 8.0$ Hz), 6.62 (m, 1H), 6.95 (m, 2H), 7.50 (d, 4H, $J = 7.6$ Hz), 8.16 (d, 4H, $J = 7.6$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 47.2, 111.7, 112.2,

Dibenzyl-(2,6-dimethyl-phenyl)-amine (29c)

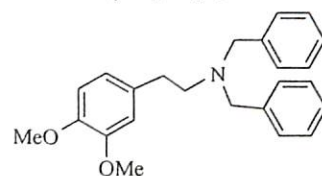
^1H NMR (400 MHz, CDCl_3): δ 2.39 (s, 6H), 4.73 (s, 4H), 6.99 (d, 3H), 7.21 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 53.3, 128.6, 129.3, 129.5, 129.9, 130.0, 131.2, 132.1, 133.6. IR (KBr): 2930, 2858, 1619, 1517, 1342, 1209, 1112, 1015, 866, 702 cm^{-1} .

N, N, N', N'-Tetrabenzyl-benzene-1,4-diamine (30c)

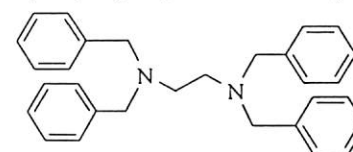
^1H NMR (400 MHz, CDCl_3): δ 4.48 (brs, 8H), 6.27 (brs, 4H), 7.22 (m, 20H). ^{13}C NMR (100 MHz, CDCl_3): δ 55.2, 114.9, 126.5, 126.9, 128.3, 139.3, 141.8. IR (KBr): 3027, 2899, 2843, 1603, 1521, 1440, 1363, 1219, 1168, 1071, 1030, 953, 805, 738, 697, 625 cm^{-1} .

Tribenzylamine (31c)

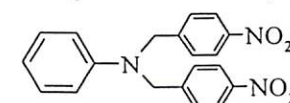
^1H NMR (400 MHz, CDCl_3): δ 3.54 (s, 6H), 7.19 (m, 3H), 7.28 (t, 6H, $J = 6.8$ Hz), 7.38 (d, 6H, $J = 7.6$ Hz), ^{13}C NMR (100 MHz, CDCl_3): δ 57.9, 126.7, 128.1, 128.6, 139.5. IR (KBr): 3068, 3022, 2925, 2802, 1593, 1496, 1445, 1373, 1317, 1250, 1122, 974, 907, 743, 697 cm^{-1} .

Dibenzyl-[2-(3,4-dimethoxy-phenyl)-ethyl]-amine (32c)

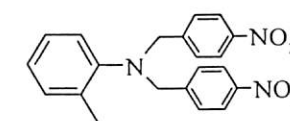
^1H NMR (400 MHz, CDCl_3): δ 2.72 (m, 4H), 3.63 (s, 3H), 3.76 (s, 4H), 3.84 (s, 3H), 6.54 (d, 1H, $J = 1.6$ Hz), 6.59 (dd, 1H, $J_1 = 2$ Hz, $J_2 = 8$ Hz), 7.25 (d, 1H, $J = 8.4$ Hz), 7.27 (m, 10H). ^{13}C NMR (100 MHz, CDCl_3): δ 33.2, 55.2, 55.8, 56.0, 58.3, 111.1, 112.1, 120.6, 126.7, 128.0, 128.6. IR (KBr): 3068, 2935, 2827, 2786, 1593, 1516, 1460, 1414, 1265, 1235, 1137, 1030, 805, 748, 702, 641 cm^{-1} .

N, N, N', N'-Tetrabenzyl-ethane-1,2-diamine (33c)

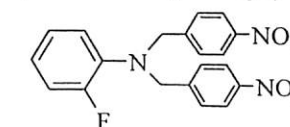
^1H NMR (400 MHz, DMSO-d_6): δ 2.59, (s, 4H), 3.49 (s, 8H), 7.22 (m, 20H). ^{13}C NMR (100 MHz, DMSO-d_6): δ 51.1, 58.6, 126.6, 127.9, 128.5, 139.5. IR (KBr): 3068, 3024, 2948, 2800, 1599, 1492, 1451, 1372, 1320, 1242, 1124, 1089, 1067, 1028, 977, 913, 743, 695 cm^{-1} .

Bis-(4-nitro-benzyl)-phenyl-amine (22d)

^1H NMR (400 MHz, CDCl_3): δ 4.73 (s, 4H), 6.63 (d, 2H, $J = 8$ Hz), 6.77 (t, 1H, $J = 7.6$ Hz), 7.18 (d, 2H, $J = 7.6$ Hz), 7.39 (d, 4H, $J = 8.4$ Hz), 8.16 (d, 4H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 54.5, 112.7, 118.2, 123.8, 126.9, 127.2, 129.4, 145.8, 147.0. IR (KBr): 3042, 2853, 1609, 1527, 1342, 1214, 1102, 856, 692 cm^{-1} .

Bis-(4-nitro-benzyl)-o-tolyl-phenyl-amine (23d)

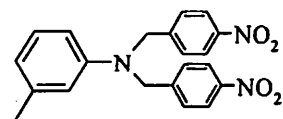
^1H NMR (400 MHz, CDCl_3): δ 2.42 (s, 3H), 4.16 (s, 4H), 6.92 (m, 1H), 7.02 (m, 2H), 7.26 (m, 9H). ^{13}C NMR (100 MHz, CDCl_3): δ 18.6, 57.1, 122.1, 123.5, 124.6, 126.4, 129.0, 131.5, 145.3. IR (KBr): 3048, 2889, 2592, 1614, 1547, 1496, 1143, 1086, 1015, 810, 610 cm^{-1} .

(2-Fluoro-phenyl)-bis-(4-nitro-benzyl)-amine (24d)

^1H NMR (400 MHz, CDCl_3): δ 4.48 (s, 4H), 6.47 (t, 1H, $J = 8.0$ Hz), 6.62 (m, 1H), 6.95 (m, 2H), 7.50 (d, 4H, $J = 7.6$ Hz), 8.16 (d, 4H, $J = 7.6$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 47.2, 111.7, 112.2,

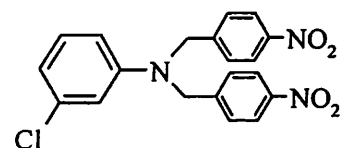
114.4, 114.6, 117.5, 117.5, 123.3, 123.8, 124.5, 127.1, 127.5, 146.7, 150.2, 152.5. IR (KBr): 2899, 2832, 1614, 1516, 1347, 1230, 1117, 958, 856, 758, 687 cm^{-1} .

(3-Methyl-phenyl)-bis-(4-nitro-benzyl)-amine (25d)



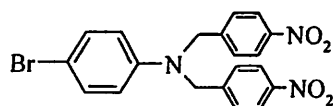
^1H NMR (400 MHz, CDCl_3): δ 2.24 (s, 3H), 4.70 (s, 4H), 6.47 (m, 1H), 6.61 (d, 1H, $J = 7.2$ Hz), 7.07 (t, 2H, $J = 8$ Hz), 7.39 (d, 4H, $J = 8.4$ Hz), 8.16 (d, 4H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 21.9, 54.4, 110.0, 113.4, 119.3, 123.9, 127.3, 129.3, 139.4, 145.9, 147.1, 147.8. IR (KBr): 3048, 2914, 1598, 1516, 1424, 1347, 1255, 1199, 1107, 953, 846, 748, 687 cm^{-1} .

(3-Chloro-phenyl)-bis-(4-nitro-benzyl)-amine (26d)



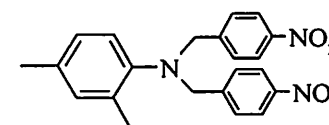
^1H NMR (400 MHz, CDCl_3): δ 4.71 (s, 4H), 6.51 (m, 1H), 6.62 (m, 1H), 6.75 (d, 1H, $J = 8.8$ Hz); 7.08 (t, 1H, $J = 8$ Hz), 7.37 (d, 4H, $J = 8.4$ Hz), 8.18 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 54.3, 110.8, 111.0, 112.6, 118.3, 124.1, 127.2, 130.4, 144.9, 147.3. IR (KBr): 3068, 2919, 2843, 1593, 1511, 1424, 1337, 1225, 1102, 948, 851, 733, 677 cm^{-1} .

(4-Bromo-phenyl)-bis-(4-nitro-benzyl)-amine (27d)



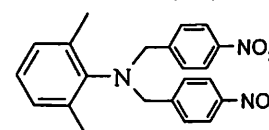
^1H NMR (400 MHz, CDCl_3): δ 4.70 (s, 4H), 6.51 (d, 2H, $J = 8.8$ Hz), 7.25 (d, 2H, $J = 8.8$ Hz), 7.36 (d, 4H, $J = 8.4$ Hz), 8.18 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 54.6, 114.1, 124.1, 127.2, 132.2, 145.0. IR (KBr): 3083, 2914, 2843, 1598, 1506, 1342, 1214, 1112, 943, 825, 738, 687, 595 cm^{-1} .

2, 6-Dimethyl-phenyl)-bis-(4-nitro-benzyl)-amine (28d)



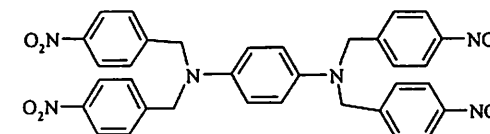
^1H NMR (400 MHz, CDCl_3): δ 2.23 (s, 3H), 2.36 (s, 3H), 4.12 (s, 4H), 6.81 (m, 2H), 6.98 (s, 1H), 7.39 (d, 4H, $J = 8.4$ Hz), 8.11 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 8.4, 20.8, 57.4, 109.7, 121.9, 123.4, 126.9, 129.1, 132.1, 145.5. IR (KBr): 3112, 2930, 2845, 1714, 1600, 1523, 1346, 1200, 1104, 860, 816, 736, 690 cm^{-1} .

2, 6-Dimethyl-phenyl)-bis-(4-nitro-benzyl)-amine (29d)



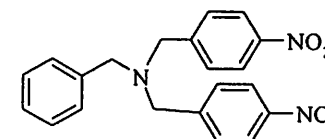
^1H NMR (400 MHz, CDCl_3): δ 2.18 (s, 6H), 4.21 (s, 4H), 6.98 (s, 3H), 7.33 (d, 4H, $J = 8.4$ Hz), 8.12 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 56.6, 123.4, 125.6, 129.5, 136.4, 146.1. IR (KBr): 2930, 2838, 1598, 1516, 1470, 1434, 1342, 1194, 1096, 1025, 927, 861, 784, 697 cm^{-1} .

N,N,N',N'-Tetra(4-nitrobenzyl)-benzene-1,4-diamine (30d)



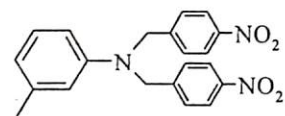
^1H NMR (400 MHz, CDCl_3): δ 4.28 (brs, 4H), 4.63 (brs, 4H), 6.45 (m, 4H), 7.50 (m, 8H), 8.14 (d, 8H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 55.2, 114.9, 126.5, 126.9, 128.3, 139.3, 141.7. IR (KBr): 3119, 3073, 2940, 2853, 1603, 1527, 1352, 1281, 1235, 1107, 856, 820, 748 cm^{-1} .

Benzyl-bis-(4-nitro-benzyl)-amine (31d)



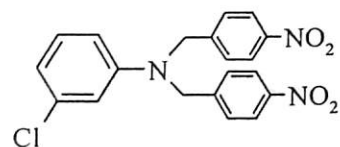
114.4, 114.6, 117.5, 117.5, 123.3, 123.8, 124.5, 127.1, 127.5, 146.7, 150.2, 152.5. IR (KBr): 2899, 2832, 1614, 1516, 1347, 1230, 1117, 958, 856, 758, 687 cm^{-1} .

(3-Methyl-phenyl)-bis-(4-nitro-benzyl)-amine (25d)



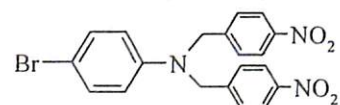
^1H NMR (400 MHz, CDCl_3): δ 2.24 (s, 3H), 4.70 (s, 4H), 6.47 (m, 1H), 6.61 (d, 1H, $J = 7.2$ Hz), 7.07 (t, 2H, $J = 8$ Hz), 7.39 (d, 4H, $J = 8.4$ Hz), 8.16 (d, 4H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 21.9, 54.4, 110.0, 113.4, 119.3, 123.9, 127.3, 129.3, 139.4, 145.9, 147.1, 147.8. IR (KBr): 3048, 2914, 1598, 1516, 1424, 1347, 1255, 1199, 1107, 953, 846, 748, 687 cm^{-1} .

(3-Chloro-phenyl)-bis-(4-nitro-benzyl)-amine (26d)



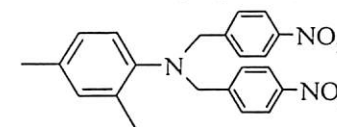
^1H NMR (400 MHz, CDCl_3): δ 4.71 (s, 4H), 6.51 (m, 1H), 6.62 (m, 1H), 6.75 (d, 1H, $J = 8.8$ Hz); 7.08 (t, 1H, $J = 8$ Hz), 7.37 (d, 4H, $J = 8.4$ Hz), 8.18 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 54.3, 110.8, 111.0, 112.6, 118.3, 124.1, 127.2, 130.4, 144.9, 147.3. IR (KBr): 3068, 2919, 2843, 1593, 1511, 1424, 1337, 1225, 1102, 948, 851, 733, 677 cm^{-1} .

(4-Bromo-phenyl)-bis-(4-nitro-benzyl)-amine (27d)



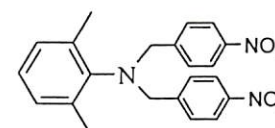
^1H NMR (400 MHz, CDCl_3): δ 4.70 (s, 4H), 6.51 (d, 2H, $J = 8.8$ Hz), 7.25 (d, 2H, $J = 8.8$ Hz), 7.36 (d, 4H, $J = 8.4$ Hz), 8.18 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 54.6, 114.1, 124.1, 127.2, 132.2, 145.0. IR (KBr): 3083, 2914, 2843, 1598, 1506, 1342, 1214, 1112, 943, 825, 738, 687, 595 cm^{-1} .

2, 6-Dimethyl-phenyl)-bis-(4-nitro-benzyl)-amine (28d)



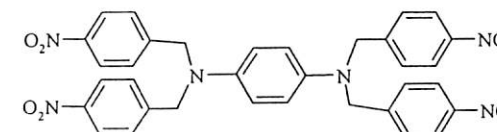
^1H NMR (400 MHz, CDCl_3): δ 2.23 (s, 3H), 2.36 (s, 3H), 4.12 (s, 4H), 6.81 (m, 2H), 6.98 (s, 1H), 7.39 (d, 4H, $J = 8.4$ Hz), 8.11 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 8.4, 20.8, 57.4, 109.7, 121.9, 123.4, 126.9, 129.1, 132.1, 145.5. IR (KBr): 3112, 2930, 2845, 1714, 1600, 1523, 1346, 1200, 1104, 860, 816, 736, 690 cm^{-1} .

2, 6-Dimethyl-phenyl)-bis-(4-nitro-benzyl)-amine (29d)



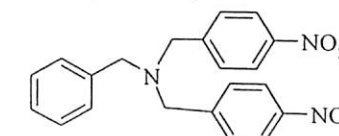
^1H NMR (400 MHz, CDCl_3): δ 2.18 (s, 6H), 4.21 (s, 4H), 6.98 (s, 3H), 7.33 (d, 4H, $J = 8.4$ Hz), 8.12 (d, 4H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.0, 56.6, 123.4, 125.6, 129.5, 136.4, 146.1. IR (KBr): 2930, 2838, 1598, 1516, 1470, 1434, 1342, 1194, 1096, 1025, 927, 861, 784, 697 cm^{-1} .

N,N,N',N',-Tetra(4-nitrobenzyl)-benzene-1,4-diamine (30d)



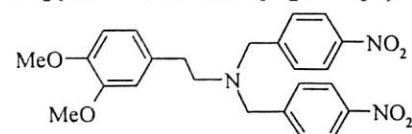
^1H NMR (400 MHz, CDCl_3): δ 4.28 (brs, 4H), 4.63 (brs, 4H), 6.45 (m, 4H), 7.50 (m, 8H), 8.14 (d, 8H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 55.2, 114.9, 126.5, 126.9, 128.3, 139.3, 141.7. IR (KBr): 3119, 3073, 2940, 2853, 1603, 1527, 1352, 1281, 1235, 1107, 856, 820, 748 cm^{-1} .

Benzyl-bis-(4-nitro-benzyl)-amine (31d)



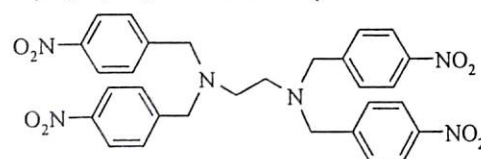
^1H NMR (400 MHz, CDCl_3): δ 3.58 (s, 2H), 3.65 (s, 4H), 7.30 (m, 5H), 7.54 (d, 4H, $J = 8$ Hz), 8.18 (d, 4H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 57.6, 58.4, 123.5, 127.4, 128.4, 128.5, 129.0, 137.8, 146.6, 147.0. IR (KBr): 3076, 2795, 1599, 1515, 1448, 1344, 1255, 1107, 986, 850, 738 cm^{-1} .

2-[(3,4-Dimethoxy-phenyl)-ethyl]-bis-(4-nitro-benzyl)-amine (32d)



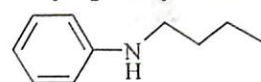
^1H NMR (400 MHz, CDCl_3): δ 2.72 (m, 2H), 3.71 (s, 2H), 3.71 (s, 4H), 3.78 (s, 3H), 3.86 (s, 3H), 6.57 (m, 2H), 6.74 (m, 1H), 7.41 (d, 4H, $J = 6.8$ Hz), 8.10 (d, 4H, $J = 6.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 33.4, 55.6, 55.8, 56.0, 57.8, 111.3, 112.1, 120.5, 123.4, 128.9, 132.2, 146.8, 147.0, 147.5, 148.7. IR (KBr): 2940, 2832, 1603, 1516, 1460, 1337, 1245, 1143, 1102, 1020, 846, 738 cm^{-1} .

N,N,N',N'-Tetrakis-(4-nitro-benzy)-ethane-1,2-diamine (33d)



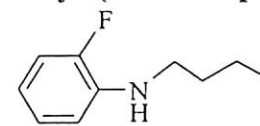
^1H NMR (400 MHz, $\text{DMSO}-d_6$): δ 3.41 (s, 4H), 3.61 (s, 8H), 7.48 (d, 8H, $J = 8.4$ Hz), 8.06 (d, 8H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ 52.1, 58.4, 123.9, 130.1, 148.1. IR (KBr): 3219, 3073, 2940, 2853, 1603, 1527, 1462, 1352, 1281, 1235, 1107, 856, 820, 748 cm^{-1} .

Butyl-phenyl-amine (22e)



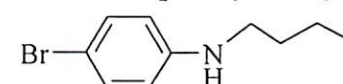
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.29 (m, 2H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.54 (m, 1H), 6.69 (m, 1H), 6.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 43.8, 121.9, 124.8, 130.2, 149.8. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

Butyl-(2-fluoro-phenyl)-amine (24e)



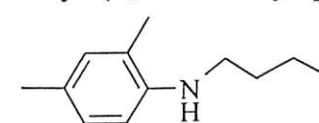
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.25 (m, 2H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 6.8$ Hz), 3.84 (brs, 1H), 6.54 (m, 1H), 6.69 (m, 1H), 6.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 23.4, 29.6, 44.3, 112.2, 112.3, 114.3, 114.6, 116.3, 116.4, 124.8, 137.1, 137.2, 150.5, 150.8. IR (KBr): 3392, 3020, 2945, 2929, 2853, 1615, 1530, 1328, 1176, 1090, 912, 743 cm^{-1} .

4-Bromo-phenyl-butyl-amine (27e)



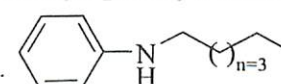
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 6.8$ Hz), 1.31 (m, 2H), 1.56 (m, 2H), 3.04 (t, 2H, $J = 7.2$ Hz), 3.59 (brs, 1H), 6.44 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 29.4, 44.2, 108.6, 114.3, 132.0, 147.6. IR (KBr): 3328, 3020, 2950, 2920, 2840, 1621, 1534, 1347, 1252, 1183, 1102, 1031, 913, 743 cm^{-1} .

Butyl-(2,4-dimethyl-phenyl)-amine (28e)



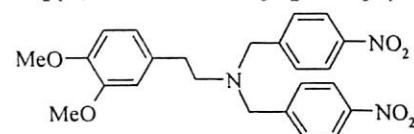
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, 3H, $J = 7.6$ Hz), 1.30 (brs, 2H), 1.62 (m, 2H), 2.13 (s, 3H), 2.21 (s, 3H), 3.14 (t, 2H, $J = 7.2$ Hz), 6.46 (d, 1H, $J = 8.0$ Hz), 6.80 (s, 1H), 6.89 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 17.7, 20.6, 23.0, 27.5, 29.6, 29.7, 29.9, 32.1, 44.5, 109.9, 121.9, 125.7, 127.3, 130.9, 144.1. IR (KBr): 3325, 2920, 2854, 1615, 1524, 1460, 1374, 1300, 1255, 1136, 803, 747 cm^{-1} .

Hexyl-phenyl-amine (22f)



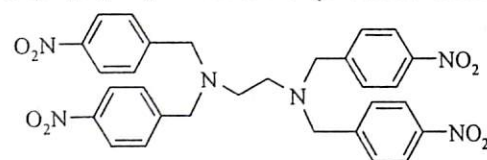
^1H NMR (400 MHz, CDCl_3): δ 3.58 (s, 2H), 3.65 (s, 4H), 7.30 (m, 5H), 7.54 (d, 4H, $J = 8$ Hz), 8.18 (d, 4H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 57.6, 58.4, 123.5, 127.4, 128.4, 128.5, 129.0, 137.8, 146.6, 147.0. IR (KBr): 3076, 2795, 1599, 1515, 1448, 1344, 1255, 1107, 986, 850, 738 cm^{-1} .

2-[(3,4-Dimethoxy-phenyl)-ethyl]-bis-(4-nitro-benzyl)-amine (32d)



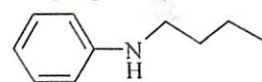
^1H NMR (400 MHz, CDCl_3): δ 2.72 (m, 2H), 3.71 (s, 2H), 3.71 (s, 4H), 3.78 (s, 3H), 3.86 (s, 3H), 6.57 (m, 2H), 6.74 (m, 1H), 7.41 (d, 4H, $J = 6.8$ Hz), 8.10 (d, 4H, $J = 6.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 33.4, 55.6, 55.8, 56.0, 57.8, 111.3, 112.1, 120.5, 123.4, 128.9, 132.2, 146.8, 147.0, 147.5, 148.7. IR (KBr): 2940, 2832, 1603, 1516, 1460, 1337, 1245, 1143, 1102, 1020, 846, 738 cm^{-1} .

N,N,N',N'-Tetrakis-(4-nitro-benzy)-ethane-1,2-diamine (33d)



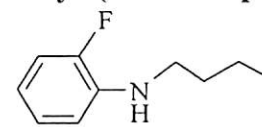
^1H NMR (400 MHz, $\text{DMSO}-d_6$): δ 3.41 (s, 4H), 3.61 (s, 8H), 7.48 (d, 8H, $J = 8.4$ Hz), 8.06 (d, 8H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ 52.1, 58.4, 123.9, 130.1, 148.1. IR (KBr): 3219, 3073, 2940, 2853, 1603, 1527, 1462, 1352, 1281, 1235, 1107, 856, 820, 748 cm^{-1} .

Butyl-phenyl-amine (22e)



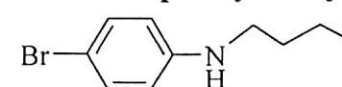
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.29 (m, 2H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.54 (m, 1H), 6.69 (m, 1H), 6.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 43.8, 121.9, 124.8, 130.2, 149.8. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

Butyl-(2-fluoro-phenyl)-amine (24e)



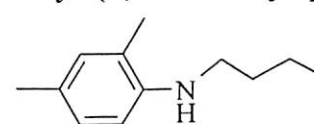
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.25 (m, 2H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 6.8$ Hz), 3.84 (brs, 1H), 6.54 (m, 1H), 6.69 (m, 1H), 6.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 23.4, 29.6, 44.3, 112.2, 112.3, 114.3, 114.6, 116.3, 116.4, 124.8, 137.1, 137.2, 150.5, 150.8. IR (KBr): 3392, 3020, 2945, 2929, 2853, 1615, 1530, 1328, 1176, 1090, 912, 743 cm^{-1} .

4-Bromo-phenyl-butyl-amine (27e)



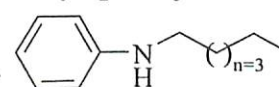
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 6.8$ Hz), 1.31 (m, 2H), 1.56 (m, 2H), 3.04 (t, 2H, $J = 7.2$ Hz), 3.59 (brs, 1H), 6.44 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 29.4, 44.2, 108.6, 114.3, 132.0, 147.6. IR (KBr): 3328, 3020, 2950, 2920, 2840, 1621, 1534, 1347, 1252, 1183, 1102, 1031, 913, 743 cm^{-1} .

Butyl-(2,4-dimethyl-phenyl)-amine (28e)



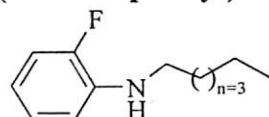
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, 3H, $J = 7.6$ Hz), 1.30 (brs, 2H), 1.62 (m, 2H), 2.13 (s, 3H), 2.21 (s, 3H), 3.14 (t, 2H, $J = 7.2$ Hz), 6.46 (d, 1H, $J = 8.0$ Hz), 6.80 (s, 1H), 6.89 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 17.7, 20.6, 23.0, 27.5, 29.6, 29.7, 29.9, 32.1, 44.5, 109.9, 121.9, 125.7, 127.3, 130.9, 144.1. IR (KBr): 3325, 2920, 2854, 1615, 1524, 1460, 1374, 1300, 1255, 1136, 803, 747 cm^{-1} .

Hexyl-phenyl-amine (22f)



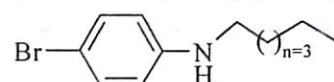
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.29-1.38 (m, 6H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.58 (m, 2H), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 43.8, 122.4, 124.8, 137.1, 137.2, 150.5. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2-Fluoro-phenyl)-hexyl-amine (24f)



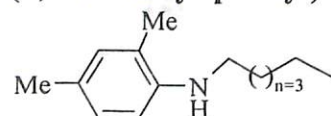
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.25-1.47 (brs, 6H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.54 (m, 1H), 6.69 (m, 1H), 6.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 29.6, 32.0, 43.8, 112.2, 112.3, 114.3, 114.6, 116.3, 116.4, 124.8, 137.1, 137.2, 150.5, 150.8. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(4-bromo-phenyl)-hexyl-amine (27f)



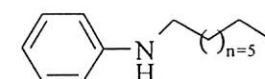
^1H NMR (400 MHz, CDCl_3): δ 0.87 (t, 3H, $J = 6.8$ Hz), 1.24-1.36 (brs, 6H), 1.53 (m, 2H), 3.04 (t, 2H, $J = 7.2$ Hz), 3.59 (brs, 1H), 6.44 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 26.3, 29.4, 29.5, 29.7, 29.9, 31.8, 44.2, 108.6, 114.3, 132.0, 147.6. IR (KBr): 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1} .

(2,4-dimethyl-phenyl)-hexyl-amine(28f)



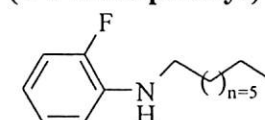
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, 3H, $J = 7.6$ Hz), 1.27-1.40 (brs, 6H), 1.63 (m, 2H), 2.08 (s, 3H), 2.21 (s, 3H), 3.09 (t, 2H, $J = 7.2$ Hz), 6.49 (d, 1H, $J = 8.0$ Hz), 6.84 (s, 1H), 6.88 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 17.7, 20.6, 23.0, 27.5, 29.6, 29.7, 29.9, 32.1, 44.5, 109.9, 121.9, 125.7, 127.3, 130.9, 144.1. IR (KBr): 3423, 2923, 2857, 1615, 1514, 1465, 1374, 1308, 1267, 1146, 803, 743 cm^{-1} .

Phenyl-octyl-amine (22g)



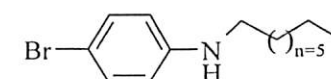
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.29-1.38 (m, 6H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.58 (m, 2H), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 43.8, 122.4, 124.8, 137.1, 137.2, 149.7. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2-Fluorophenyl)-octyl-amine (24g)



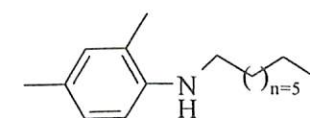
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, 3H, $J = 7.2$ Hz), 1.27-1.49 (brs, 10H), 1.66 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.89 (brs, 1H), 6.58 (m, 1H), 6.67 (m, 1H), 6.97 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.3, 22.8, 27.3, 29.4, 29.6, 29.7, 32.0, 43.8, 112.1, 112.2, 114.4, 114.5, 116.3, 116.4, 124.7, 124.8, 137.1, 137.2, 150.5, 152.8. IR (KBr): 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1} .

(4-bromo-phenyl)-octyl-amine (27g)



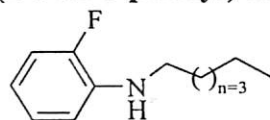
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 6.8$ Hz), 1.26-1.37 (brs, 10H), 1.56 (m, 2H), 3.04 (t, 2H, $J = 7.2$ Hz), 3.59 (brs, 1H), 6.44 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 26.3, 29.4, 29.5, 29.7, 29.9, 31.8, 44.2, 108.6, 114.3, 132.0, 147.6. IR (KBr): 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1} .

(2,4-dimethyl-phenyl)-octyl-amine(28g)



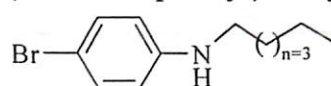
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.29-1.38 (m, 6H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.58 (m, 2H), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 43.8, 122.4, 124.8, 137.1, 137.2, 150.5. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2-Fluoro-phenyl)-hexyl-amine (24f)



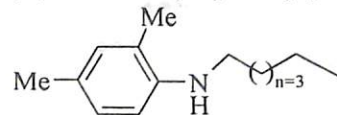
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.25-1.47 (brs, 6H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.54 (m, 1H), 6.69 (m, 1H), 6.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 29.6, 32.0, 43.8, 112.2, 112.3, 114.3, 114.6, 116.3, 116.4, 124.8, 137.1, 137.2, 150.5, 150.8. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(4-bromo-phenyl)-hexyl-amine (27f)



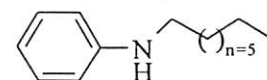
^1H NMR (400 MHz, CDCl_3): δ 0.87 (t, 3H, $J = 6.8$ Hz), 1.24-1.36 (brs, 6H), 1.53 (m, 2H), 3.04 (t, 2H, $J = 7.2$ Hz), 3.59 (brs, 1H), 6.44 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 26.3, 29.4, 29.5, 29.7, 29.9, 31.8, 44.2, 108.6, 114.3, 132.0, 147.6. IR (KBr): 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1} .

(2,4-dimethyl-phenyl)-hexyl-amine(28f)



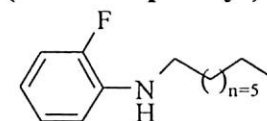
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, 3H, $J = 7.6$ Hz), 1.27-1.40 (brs, 6H), 1.63 (m, 2H), 2.08 (s, 3H), 2.21 (s, 3H), 3.09 (t, 2H, $J = 7.2$ Hz), 6.49 (d, 1H, $J = 8.0$ Hz), 6.84 (s, 1H), 6.88 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 17.7, 20.6, 23.0, 27.5, 29.6, 29.7, 29.9, 32.1, 44.5, 109.9, 121.9, 125.7, 127.3, 130.9, 144.1. IR (KBr): 3423, 2923, 2857, 1615, 1514, 1465, 1374, 1308, 1267, 1146, 803, 743 cm^{-1} .

Phenyl-octyl-amine (22g)



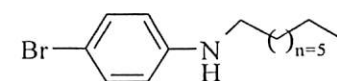
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 7.2$ Hz), 1.29-1.38 (m, 6H), 1.62 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.84 (brs, 1H), 6.58 (m, 2H), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 27.3, 43.8, 122.4, 124.8, 137.1, 137.2, 149.7. IR (KBr): 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2-Fluorophenyl)-octyl-amine (24g)



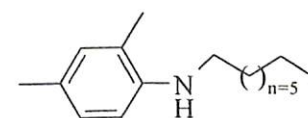
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, 3H, $J = 7.2$ Hz), 1.27-1.49 (brs, 10H), 1.66 (m, 2H), 3.12 (t, 2H, $J = 7.2$ Hz), 3.89 (brs, 1H), 6.58 (m, 1H), 6.67 (m, 1H), 6.97 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.3, 22.8, 27.3, 29.4, 29.6, 29.7, 32.0, 43.8, 112.1, 112.2, 114.4, 114.5, 116.3, 116.4, 124.7, 124.8, 137.1, 137.2, 150.5, 152.8. IR (KBr): 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1} .

(4-bromo-phenyl)-octyl-amine (27g)



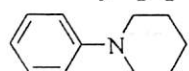
^1H NMR (400 MHz, CDCl_3): δ 0.89 (t, 3H, $J = 6.8$ Hz), 1.26-1.37 (brs, 10H), 1.56 (m, 2H), 3.04 (t, 2H, $J = 7.2$ Hz), 3.59 (brs, 1H), 6.44 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 22.8, 26.3, 29.4, 29.5, 29.7, 29.9, 31.8, 44.2, 108.6, 114.3, 132.0, 147.6. IR (KBr): 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1} .

(2,4-dimethyl-phenyl)-octyl -amine(28g)



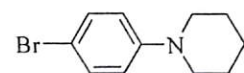
^1H NMR (400 MHz, CDCl_3): δ 0.96 (t, 3H, $J = 7.2$ Hz), 1.37-1.49 (brs, 10H), 1.68 (m, 2H), 2.16 (s, 3H), 2.28 (s, 3H), 3.16 (t, 2H, $J = 7.2$ Hz), 6.58 (d, 1H, $J = 8.0$ Hz), 6.91 (s, 1H), 6.97 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.4, 17.7, 20.6, 22.9, 27.2, 29.9, 31.9, 44.5, 110.0, 121.9, 125.8, 127.4, 130.9, 144.2. IR (KBr): 3423, 2923, 2857, 1615, 1514, 1465, 1308, 1267, 1146, 803, 751 cm^{-1} .

1-Phenyl-piperidine (22h)



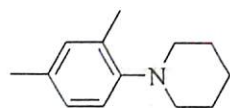
^1H NMR (400 MHz, CDCl_3): δ 1.89 (m, 2H), 1.68 (m, 4H), 3.10 (t, 2H, $J = 5.2$ Hz), 6.58 (m, 2H), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 24.2, 25.8, 50.8, 122.4, 124.8, 137.1, 137.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

1-(4-Bromo-phenyl)-piperidine (27h)



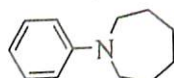
^1H NMR (400 MHz, CDCl_3): δ 1.53 (m, 2H), 1.65 (m, 4H), 3.12 (t, 2H, $J = 5.6$ Hz), 6.76 (d, 2H, $J = 8.4$ Hz), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 24.2, 25.8, 50.8, 118.2, 131.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2,4-dimethyl-phenyl)-piperidine (28h)



^1H NMR (400 MHz, CDCl_3): δ 1.54 (m, 2H), 1.68 (m, 4H), 2.16 (s, 3H), 2.28 (s, 3H), 3.16 (m, 2H), 6.88 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.7, 20.7, 24.5, 26.7, 53.6, 118.7, 126.9, 131.5, 132.5, 151.2. IR (KBr): 3015, 2943, 2757, 1618, 1504, 1455, 1300, 1267, 1146, 803, 747 cm^{-1} .

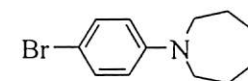
1-Phenyl azepane (22i)



^1H NMR (400 MHz, CDCl_3): δ 1.84 (m, 2H), 1.66 (m, 6H), 3.17 (t, 2H, $J = 5.2$ Hz).

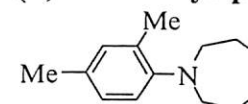
NMR (100 MHz, CDCl_3): δ 24.2, 25.8, 50.8, 122.4, 124.8, 137.1, 137.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(4-bromo-phenyl)-azepane (27i)



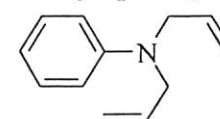
^1H NMR (400 MHz, CDCl_3): δ 1.56 (m, 2H), 1.69 (m, 6H), 3.14 (t, 2H, $J = 5.6$ Hz), 6.76 (d, 2H, $J = 8.4$ Hz), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 24.7, 26.2, 50.8, 109.2, 118.2, 131.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2,4 Dimethyl-phenyl)-azepan (28i)



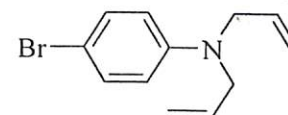
^1H NMR (400 MHz, CDCl_3): δ 1.54 (m, 2H), 1.68 (m, 4H), 2.16 (s, 3H), 2.28 (s, 3H), 3.16 (m, 2H), 6.88 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.7, 20.7, 24.5, 26.7, 53.6, 118.7, 126.9, 131.5, 132.5, 151.2. IR (KBr): 3015, 2943, 2757, 1618, 1504, 1455, 1300, 1267, 1146, 803, 747 cm^{-1} .

Diallyl-phenyl-amine (22j)



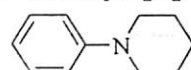
^1H NMR (400 MHz, CDCl_3): δ 3.85 (m, 4H), 5.13 (m, 4H), 5.84 (m, 2H), 6.65 (m, 3H), 7.20 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 52.9, 112.1, 116.4, 116.3, 129.1, 134.0, 148.7. IR (KBr): 3081, 2981, 2929, 2862, 1592, 1498, 1388, 1233, 1180, 992, 920, 806, 750 cm^{-1} .

Diallyl-(4-bromo-phenyl)-amine (27j)



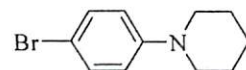
^1H NMR (400 MHz, CDCl_3): δ 0.96 (t, 3H, $J = 7.2$ Hz), 1.37-1.49 (brs, 10H), 1.68 (m, 2H), 2.16 (s, 3H), 2.28 (s, 3H), 3.16 (t, 2H, $J = 7.2$ Hz), 6.58 (d, 1H, $J = 8.0$ Hz), 6.91 (s, 1H), 6.97 (d, 1H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.4, 17.7, 20.6, 22.9, 27.2, 29.9, 31.9, 44.5, 110.0, 121.9, 125.8, 127.4, 130.9, 144.2. IR (KBr): 3423, 2923, 2857, 1615, 1514, 1465, 1308, 1267, 1146, 803, 751 cm^{-1} .

1-Phenyl-piperidine (22h)



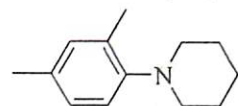
^1H NMR (400 MHz, CDCl_3): δ 1.89 (m, 2H), 1.68 (m, 4H), 3.10 (t, 2H, $J = 5.2$ Hz), 6.58 (m, 2H), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 24.2, 25.8, 50.8, 122.4, 124.8, 137.1, 137.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

1-(4-Bromo-phenyl)-piperidine (27h)



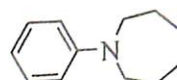
^1H NMR (400 MHz, CDCl_3): δ 1.53 (m, 2H), 1.65 (m, 4H), 3.12 (t, 2H, $J = 5.6$ Hz), 6.76 (d, 2H, $J = 8.4$ Hz), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 24.2, 25.8, 50.8, 118.2, 131.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2,4-dimethyl-phenyl)-piperidine (28h)



^1H NMR (400 MHz, CDCl_3): δ 1.54 (m, 2H), 1.68 (m, 4H), 2.16 (s, 3H), 2.28 (s, 3H), 3.16 (m, 2H), 6.88 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.7, 20.7, 24.5, 26.7, 53.6, 118.7, 126.9, 131.5, 132.5, 151.2. IR (KBr): 3015, 2943, 2757, 1618, 1504, 1455, 1300, 1267, 1146, 803, 747 cm^{-1} .

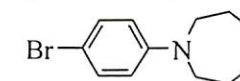
1-Phenyl azepane (22i)



^1H NMR (400 MHz, CDCl_3): δ 1.84 (m, 2H), 1.66 (m, 6H), 3.17 (t, 2H, $J = 5.2$

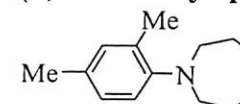
NMR (100 MHz, CDCl_3): δ 24.2, 25.8, 50.8, 122.4, 124.8, 137.1, 137.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(4-bromo-phenyl)-azepane (27i)



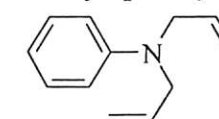
^1H NMR (400 MHz, CDCl_3): δ 1.56 (m, 2H), 1.69 (m, 6H), 3.14 (t, 2H, $J = 5.6$ Hz), 6.76 (d, 2H, $J = 8.4$ Hz), 6.65 (m, 1H), 6.83 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 24.7, 26.2, 50.8, 109.2, 118.2, 131.2, 149.7. IR (KBr): 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1} .

(2,4 Dimethyl-phenyl)-azepan (28i)



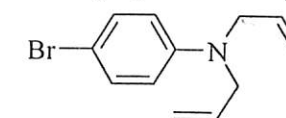
^1H NMR (400 MHz, CDCl_3): δ 1.54 (m, 2H), 1.68 (m, 4H), 2.16 (s, 3H), 2.28 (s, 3H), 3.16 (m, 2H), 6.88 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.7, 20.7, 24.5, 26.7, 53.6, 118.7, 126.9, 131.5, 132.5, 151.2. IR (KBr): 3015, 2943, 2757, 1618, 1504, 1455, 1300, 1267, 1146, 803, 747 cm^{-1} .

Diallyl-phenyl-amine (22j)



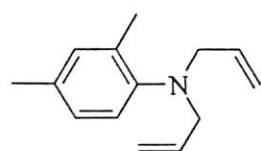
^1H NMR (400 MHz, CDCl_3): δ 3.85 (m, 4H), 5.13 (m, 4H), 5.84 (m, 2H), 6.65 (m, 3H), 7.20 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 52.9, 112.1, 116.4, 116.3, 129.1, 134.0, 148.7. IR (KBr): 3081, 2981, 2929, 2862, 1592, 1498, 1388, 1233, 1180, 992, 920, 806, 750 cm^{-1} .

Diallyl-(4-bromo-phenyl)-amine (27j)



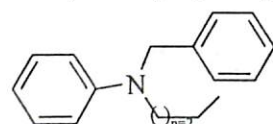
^1H NMR (400 MHz, CDCl_3): δ 3.85 (m, 4H), 5.11 (m, 4H), 5.77 (m, 2H), 6.51 (d, 2H, $J = 7.6$ Hz), 7.20 (d, 2H, $J = 9.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 53.1, 108.2, 114.1, 116.3, 131.8, 133.6, 147.7. IR (KBr): 3081, 2981, 2929, 2862, 1592, 1498, 1388, 1233, 1180, 992, 920, 806, 750 cm^{-1} .

Diallyl-(2,4-dimethyl-phenyl)-amine (28j)



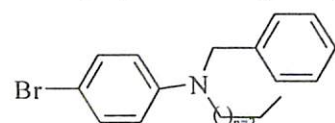
^1H NMR (400 MHz, CDCl_3): δ 2.27 (s, 3H), 2.29 (s, 3H), 3.54 (d, 4H, $J = 6$ Hz), 5.10 (m, 4H), 5.77 (m, 2H), 6.92 (s, 1H), 7.00 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 18.5, 21.1, 56.2, 116.9, 121.9, 126.5, 131.8, 132.5, 133.8, 135.5, 147.3. IR (KBr): 3071, 3000, 2923, 2851, 2813, 1503, 1418, 1264, 1212, 1111, 990, 913, 812, 749 cm^{-1} .

Benzyl-butyl-phenyl-amine (22k)



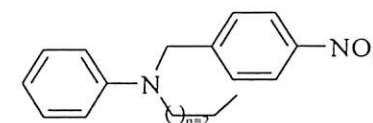
^1H NMR (400 MHz, CDCl_3): δ 1.03 (t, 3H, $J = 7.2$ Hz), 1.43 (m, 2H), 1.73 (m, 2H), 3.46 (t, 2H, $J = 7.6$ Hz), 4.60 (s, 2H), 6.72 (m, 3H), 7.26 (m, 5H), 7.35 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.4, 51.2, 54.6, 112.2, 116.0, 126.6, 126.8, 128.7, 129.3, 139.3, 148.7. IR (KBr): 3063, 3028, 2958, 2932, 2872, 1598, 1505, 1453, 1356, 1252, 1220, 1197, 988, 747, 693 cm^{-1} .

Benzyl-(4-bromo-phenyl)-butyl-amine (27k)



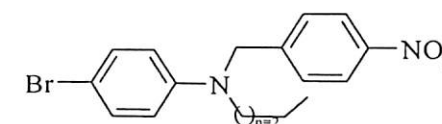
^1H NMR (400 MHz, CDCl_3): δ 1.00 (t, 3H, $J = 7.2$ Hz), 1.42 (m, 2H), 1.68 (m, 2H), 3.41 (t, 2H, $J = 8.0$ Hz), 4.55 (s, 2H), 6.56 (d, 2H, $J = 8.4$ Hz), 7.26 (m, 5H), 7.33 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.4, 51.4, 54.7, 107.9, 113.9, 126.5, 127.0, 128.8, 131.9, 138.6, 147.7. IR (KBr): 3060, 3027, 2961, 2923, 2868, 1593, 1497, 1451, 1363, 1220, 1193, 1075, 801, 724 cm^{-1} .

Butyl-(4-nitro-benzyl)-phenyl-amine (22l)



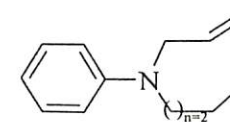
^1H NMR (400 MHz, CDCl_3): δ 0.95 (t, 3H, $J = 7.2$ Hz), 1.36 (m, 2H), 1.62 (m, 2H), 3.40 (t, 2H, $J = 8.0$ Hz), 4.59 (s, 2H), 6.59 (d, 2H, $J = 8$ Hz), 6.67 (t, 1H, $J = 7.2$ Hz), 7.15 (t, 2H, $J = 7.2$ Hz), 7.35 (d, 2H, $J = 8.4$ Hz), 8.12 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.5, 51.7, 54.6, 112.5, 116.9, 124.0, 127.4, 129.5, 147.2, 147.6, 148.1. IR (KBr): 3062, 3046, 2958, 2932, 2872, 1598, 1505, 1343, 1250, 1222, 1195, 1110, 932, 858, 806, 748, 735, 693 cm^{-1} .

(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l)



^1H NMR (400 MHz, CDCl_3): δ 0.94 (t, 3H, $J = 7.2$ Hz), 1.35 (m, 2H), 1.62 (m, 2H), 3.89 (t, 2H, $J = 7.6$ Hz), 4.58 (s, 2H), 6.46 (d, 2H, $J = 8.8$ Hz), 7.21 (d, 2H, $J = 8.8$ Hz), 7.34 (d, 2H, $J = 8.8$ Hz), 8.12 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.1, 20.4, 29.4, 51.8, 54.5, 108.7, 114.0, 124.0, 127.3, 132.1, 146.8, 147.0, 147.2. IR (KBr): 3064, 3032, 2958, 2931, 2872, 1597, 1505, 1342, 1280, 1222, 1195, 1174, 1110, 932, 806, 734 cm^{-1} .

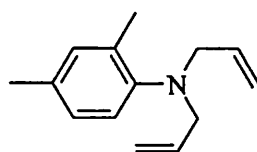
Allyl-phenyl-butyl-amine (22m)



^1H NMR (400 MHz, CDCl_3): δ 0.99 (t, 3H, $J = 7.6$ Hz), 1.34 (m, 2H), 1.55 (m, 2H), 3.24 (m, 2H), 3.88 (m, 2H), 5.13 (m, 2H), 5.82 (m, 1H), 6.63 (m, 3H), 7.18 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.5, 50.7, 50.9, 53.3, 111.8, 112.1, 115.2, 115.8, 134.5, 148.3, 148.5. IR (KBr): 3065, 3026, 2958, 2833, 2873, 1598, 1505, 1364, 1287, 1120, 1187, 988, 917, $745, 691\text{ cm}^{-1}$.

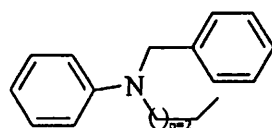
^1H NMR (400 MHz, CDCl_3): δ 3.85 (m, 4H), 5.11 (m, 4H), 5.77 (m, 2H), 6.51 (d, 2H, $J = 7.6$ Hz), 7.20 (d, 2H, $J = 9.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 53.1, 108.2, 114.1, 116.3, 131.8, 133.6, 147.7. IR (KBr): 3081, 2981, 2929, 2862, 1592, 1498, 1388, 1233, 1180, 992, 920, 806, 750 cm^{-1} .

Diallyl-(2,4-dimethyl-phenyl)-amine (28j)



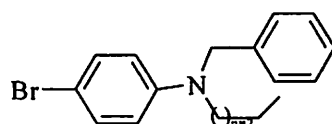
^1H NMR (400 MHz, CDCl_3): δ 2.27 (s, 3H), 2.29 (s, 3H), 3.54 (d, 4H, $J = 6$ Hz), 5.10 (m, 4H), 5.77 (m, 2H), 6.92 (s, 1H), 7.00 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 18.5, 21.1, 56.2, 116.9, 121.9, 126.5, 131.8, 132.5, 133.8, 135.5, 147.3. IR (KBr): 3071, 3000, 2923, 2851, 2813, 1503, 1418, 1264, 1212, 1111, 990, 913, 812, 749 cm^{-1} .

Benzyl-butyl-phenyl-amine (22k)



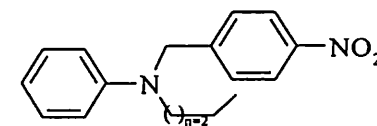
^1H NMR (400 MHz, CDCl_3): δ 1.03 (t, 3H, $J = 7.2$ Hz), 1.43 (m, 2H), 1.73 (m, 2H), 3.46 (t, 2H, $J = 7.6$ Hz), 4.60 (s, 2H), 6.72 (m, 3H), 7.26 (m, 5H), 7.35 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.4, 51.2, 54.6, 112.2, 116.0, 126.6, 126.8, 128.7, 129.3, 139.3, 148.7. IR (KBr): 3063, 3028, 2958, 2932, 2872, 1598, 1505, 1453, 1356, 1252, 1220, 1197, 988, 747, 693 cm^{-1} .

Benzyl-(4-bromo-phenyl)-butyl-amine (27k)



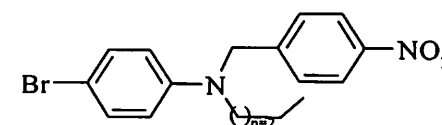
^1H NMR (400 MHz, CDCl_3): δ 1.00 (t, 3H, $J = 7.2$ Hz), 1.42 (m, 2H), 1.68 (m, 2H), 3.41 (t, 2H, $J = 8.0$ Hz), 4.55 (s, 2H), 6.56 (d, 2H, $J = 8.4$ Hz), 7.26 (m, 5H), 7.33 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.4, 51.4, 54.7, 107.9, 113.9, 126.5, 127.0, 128.8, 131.9, 138.6, 147.7. IR (KBr): 3060, 3027, 2961, 2923, 2868, 1593, 1497, 1451, 1363, 1220, 1193, 1075, 801, 724 cm^{-1} .

Butyl-(4-nitro-benzyl)-phenyl-amine (22l)



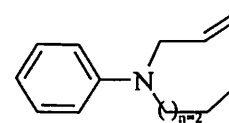
^1H NMR (400 MHz, CDCl_3): δ 0.95 (t, 3H, $J = 7.2$ Hz), 1.36 (m, 2H), 1.62 (m, 2H), 3.40 (t, 2H, $J = 8.0$ Hz), 4.59 (s, 2H), 6.59 (d, 2H, $J = 8$ Hz), 6.67 (t, 1H, $J = 7.2$ Hz), 7.15 (t, 2H, $J = 7.2$ Hz), 7.35 (d, 2H, $J = 8.4$ Hz), 8.12 (d, 2H, $J = 8.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.5, 51.7, 54.6, 112.5, 116.9, 124.0, 127.4, 129.5, 147.2, 147.6, 148.1. IR (KBr): 3062, 3046, 2958, 2932, 2872, 1598, 1505, 1343, 1250, 1222, 1195, 1110, 932, 858, 806, 748, 735, 693 cm^{-1} .

(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l)



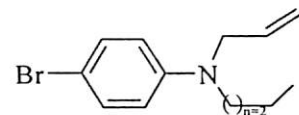
^1H NMR (400 MHz, CDCl_3): δ 0.94 (t, 3H, $J = 7.2$ Hz), 1.35 (m, 2H), 1.62 (m, 2H), 3.89 (t, 2H, $J = 7.6$ Hz), 4.58 (s, 2H), 6.46 (d, 2H, $J = 8.8$ Hz), 7.21 (d, 2H, $J = 8.8$ Hz), 7.34 (d, 2H, $J = 8.8$ Hz), 8.12 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.1, 20.4, 29.4, 51.8, 54.5, 108.7, 114.0, 124.0, 127.3, 132.1, 146.8, 147.0, 147.2. IR (KBr): 3064, 3032, 2958, 2931, 2872, 1597, 1505, 1342, 1280, 1222, 1195, 1174, 1110, 932, 806, 734 cm^{-1} .

Allyl-phenyl-butyl-amine (22m)



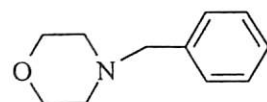
^1H NMR (400 MHz, CDCl_3): δ 0.99 (t, 3H, $J = 7.6$ Hz), 1.34 (m, 2H), 1.55 (m, 2H), 3.24 (m, 2H), 3.88 (m, 2H), 5.13 (m, 2H), 5.82 (m, 1H), 6.63 (m, 3H), 7.18 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.5, 50.7, 50.9, 53.3, 111.8, 112.1, 115.2, 115.8, 134.5, 148.3, 148.5. IR (KBr): 3065, 3026, 2958, 2833, 2873, 1598, 1505, 1364, 1287, 1120, 1187, 988, 917, 745, 691 cm^{-1} .

Allyl-(4-bromo-phenyl)-butyl-amine (27m)



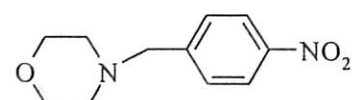
^1H NMR (400 MHz, CDCl_3): δ 0.93 (t, 3H, $J = 7.2$ Hz), 1.32 (m, 2H), 1.55 (m, 2H), 3.24 (t, 2H, $J = 7.6$ Hz), 3.86 (d, 2H, $J = 4.4$ Hz), 5.11 (m, 2H), 5.78 (m, 1H), 6.48 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.5, 50.9, 53.4, 107.6, 113.7, 116.2, 131.9, 133.8, 147.5. IR (KBr): 3065, 3046, 2968, 2833, 2873, 1598, 1505, 1364, 1287, 1120, 988, 806 cm^{-1} .

4-Benzyl-morpholine (34k)



^1H NMR (400 MHz, CDCl_3): δ 2.42 (m, 4H), 3.47 (s, 2H), 3.68 (t, 4H, $J = 4.4$ Hz), 7.51 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 53.5, 63.4, 66.8, 127.1, 128.2, 128.3, 129.2, 137.9. IR (KBr): 3062, 3054, 2967, 2854, 2807, 1599, 1514, 1448, 1338, 1105, 1004, 858 cm^{-1} .

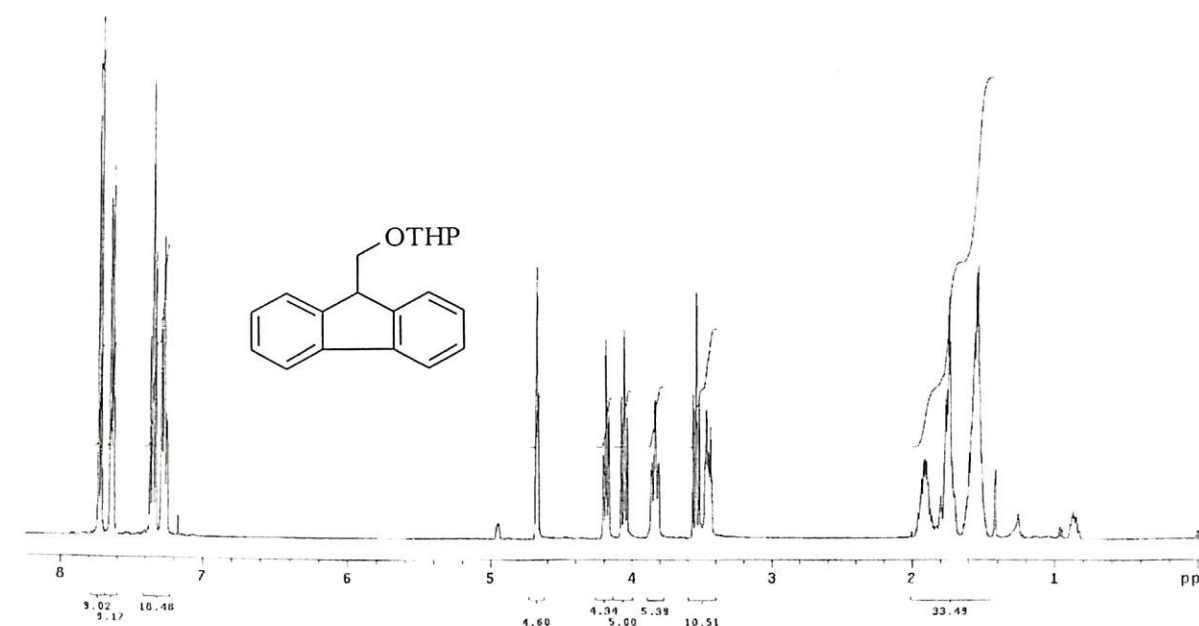
4-(4-Nitro-benzyl)-morpholine (34l)



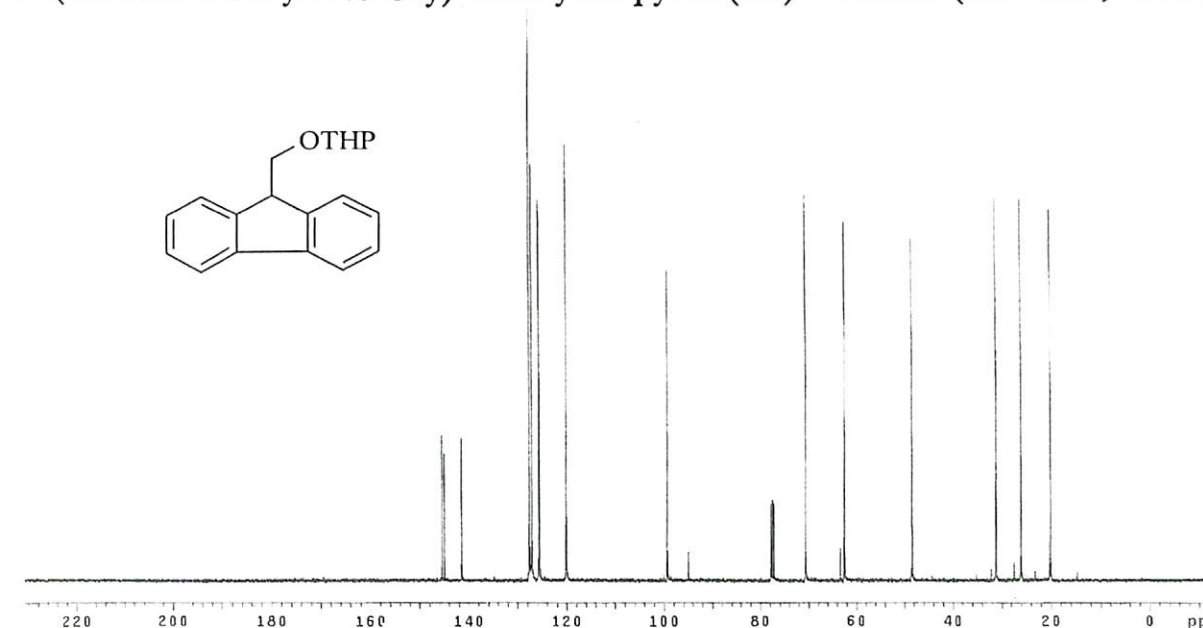
^1H NMR (400 MHz, CDCl_3): δ 2.45 (m, 4H), 3.58 (s, 2H), 3.71 (m, 4H), 7.51 (m, 3H), 7.51 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 53.7, 62.6, 67.0, 123.6, 129.6, 146.1, 147.3. IR (KBr): 3062, 3054, 2967, 2854, 2807, 1599, 1514, 1448, 1338, 1105, 1004, 858 cm^{-1} .

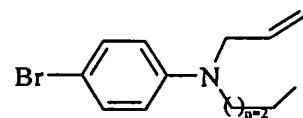
ID.3. Spectra of Selected Compounds

2-(9H-Fluoren-9-ylmethoxy)-tetrahydro-pyran (11a) ^1H NMR (400 MHz, CDCl_3):

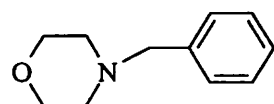


2-(9H-Fluoren-9-ylmethoxy)-tetrahydro-pyran (11a) ^{13}C NMR (100 MHz, CDCl_3):

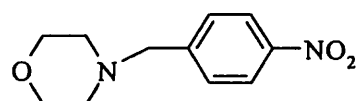


Allyl-(4-bromo-phenyl)-butyl-amine (27m)

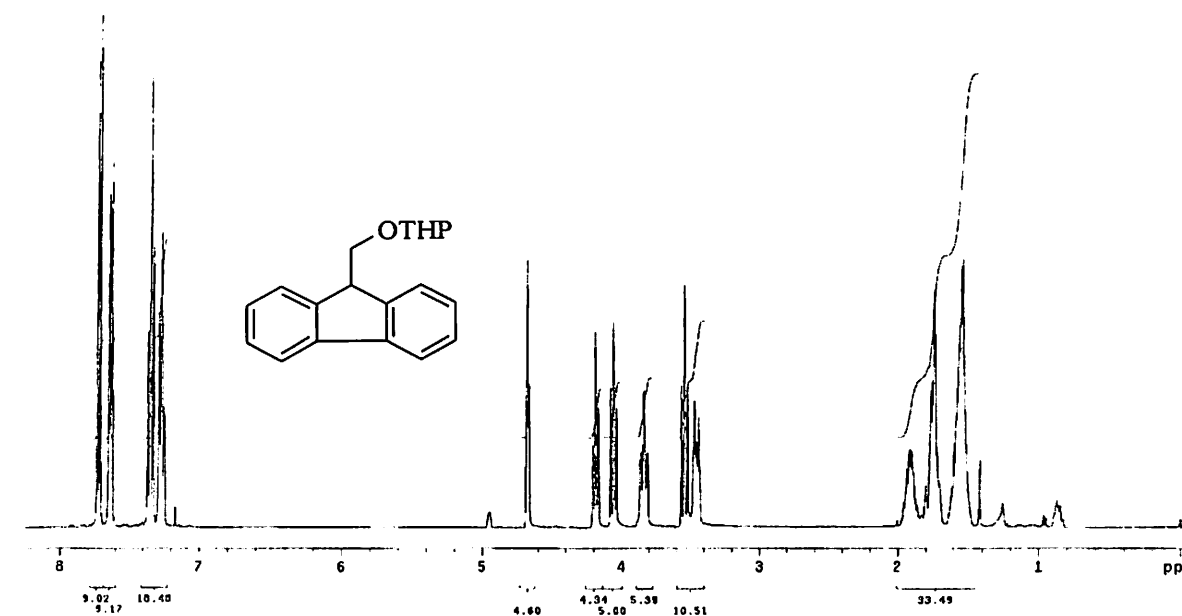
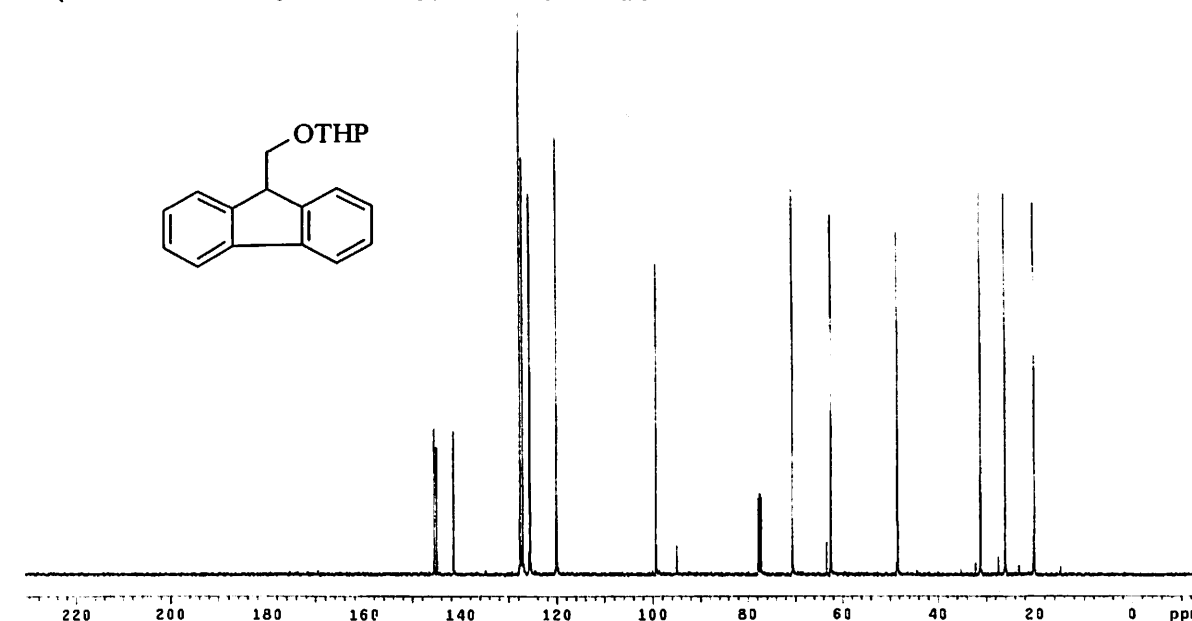
^1H NMR (400 MHz, CDCl_3): δ 0.93 (t, 3H, $J = 7.2$ Hz), 1.32 (m, 2H), 1.55 (m, 2H), 3.24 (t, 2H, $J = 7.6$ Hz), 3.86 (d, 2H, $J = 4.4$ Hz), 5.11 (m, 2H), 5.78 (m, 1H), 6.48 (d, 2H, $J = 8.8$ Hz), 7.22 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.2, 20.5, 29.5, 50.9, 53.4, 107.6, 113.7, 116.2, 131.9, 133.8, 147.5. IR (KBr): 3065, 3046, 2968, 2833, 2873, 1598, 1505, 1364, 1287, 1120, 988, 806 cm^{-1} .

4-Benzyl-morpholine (34k)

^1H NMR (400 MHz, CDCl_3): δ 2.42 (m, 4H), 3.47 (s, 2H), 3.68 (t, 4H, $J = 4.4$ Hz), 7.51 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 53.5, 63.4, 66.8, 127.1, 128.2, 128.3, 129.2, 137.9. IR (KBr): 3062, 3054, 2967, 2854, 2807, 1599, 1514, 1448, 1338, 1105, 1004, 858 cm^{-1} .

4-(4-Nitro-benzyl)-morpholine (34l)

^1H NMR (400 MHz, CDCl_3): δ 2.45 (m, 4H), 3.58 (s, 2H), 3.71 (m, 4H), 7.51 (m, 3H), 7.51 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 53.7, 62.6, 67.0, 123.6, 129.6, 146.1, 147.3. IR (KBr): 3062, 3054, 2967, 2854, 2807, 1599, 1514, 1448, 1338, 1105, 1004, 858 cm^{-1} .

ID.3. Spectra of Selected Compounds**2-(9H-Fluoren-9-ylmethoxy)-tetrahydro-pyran (11a) ^1H NMR (400 MHz, CDCl_3):****2-(9H-Fluoren-9-ylmethoxy)-tetrahydro-pyran (11a) ^{13}C NMR (100 MHz, CDCl_3):**

O=C(OCCc1ccccc1)CCC=O

7.69 7.68 4.26 4.14 4.00 3.78 3.58 3.32 1.17

0.68 10.00 11.88 6.32 41.17

c1ccccc1C(=O)OCC2=CC=CC=C2

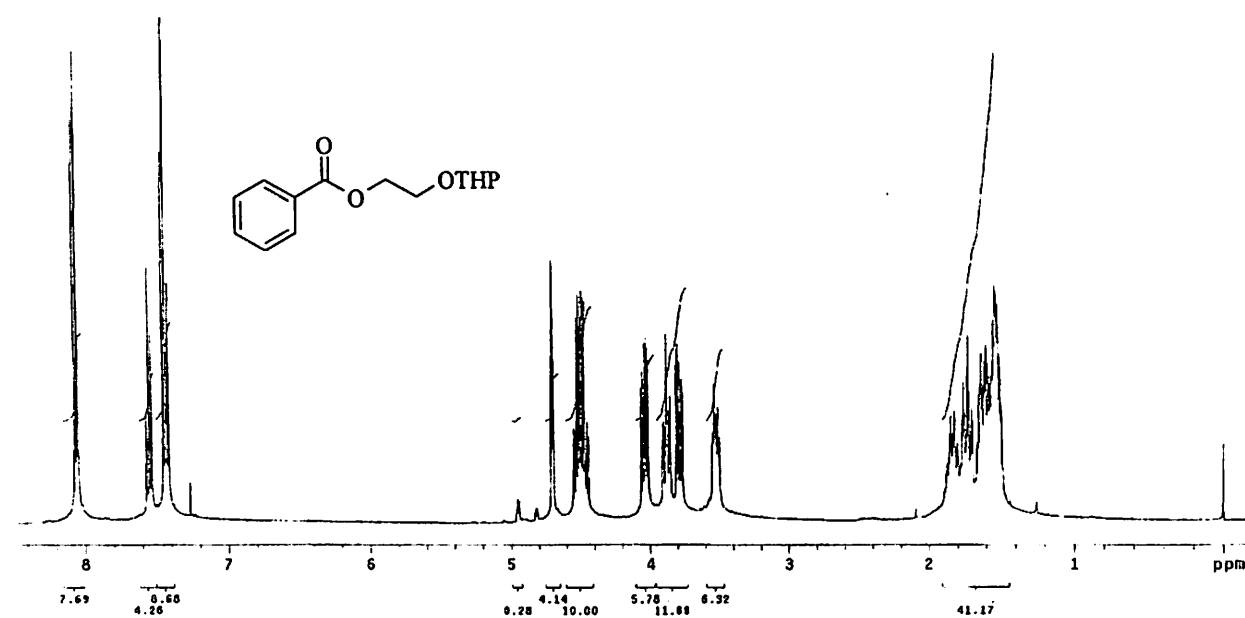
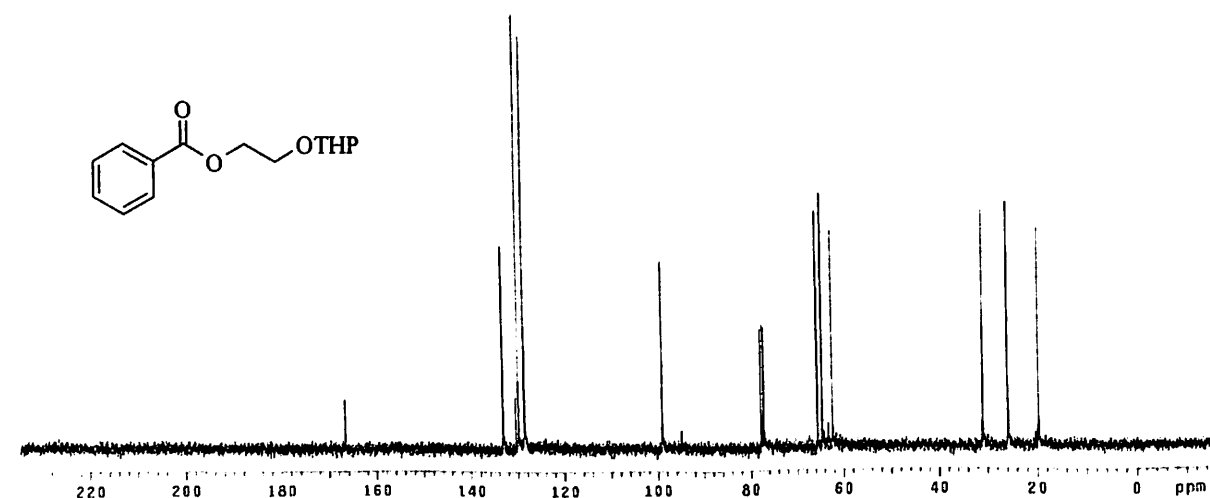
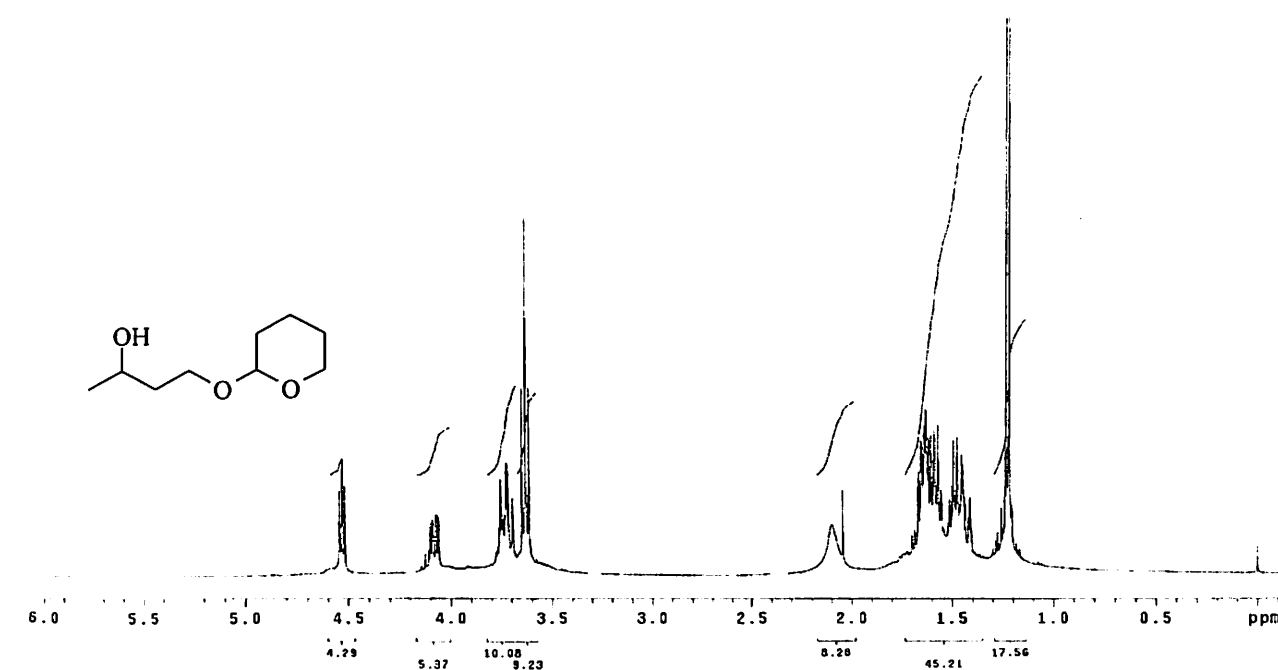
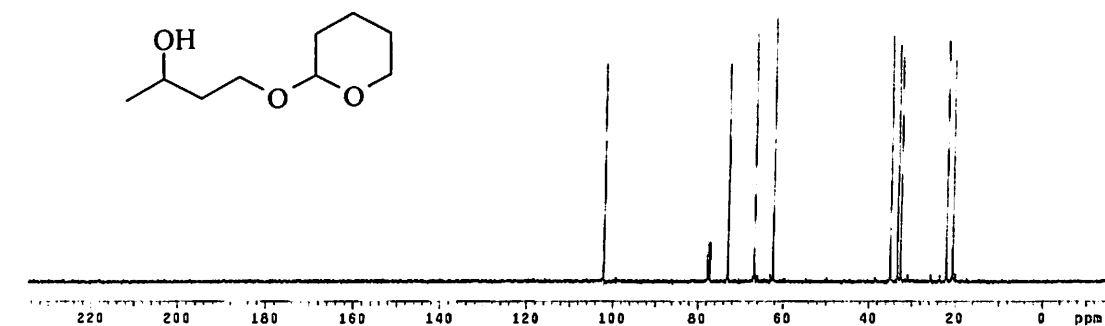
220 200 180 160 140 120 100 80 60 40 20 0 ppm

CC(O)CCOC1OCCCC1

Chemical structure of 1-(4-hydroxybutyl)pyran (top) and its corresponding ¹H NMR spectrum (bottom). The spectrum shows peaks at 4.29, 5.37, 10.08, 9.23, 8.28, 15.21, and 17.56 ppm.

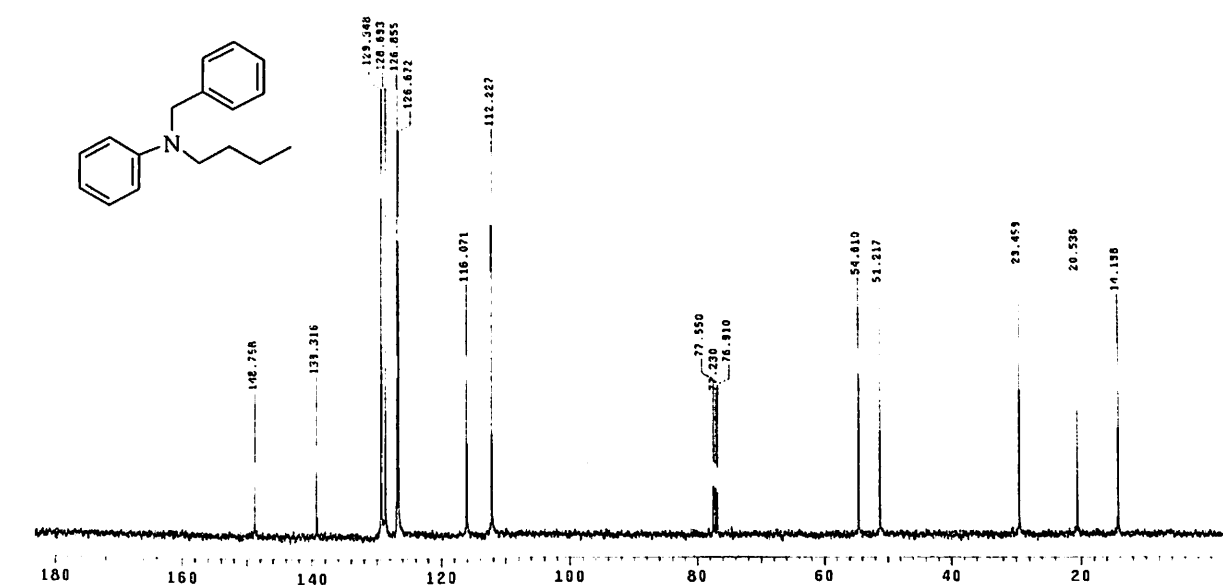
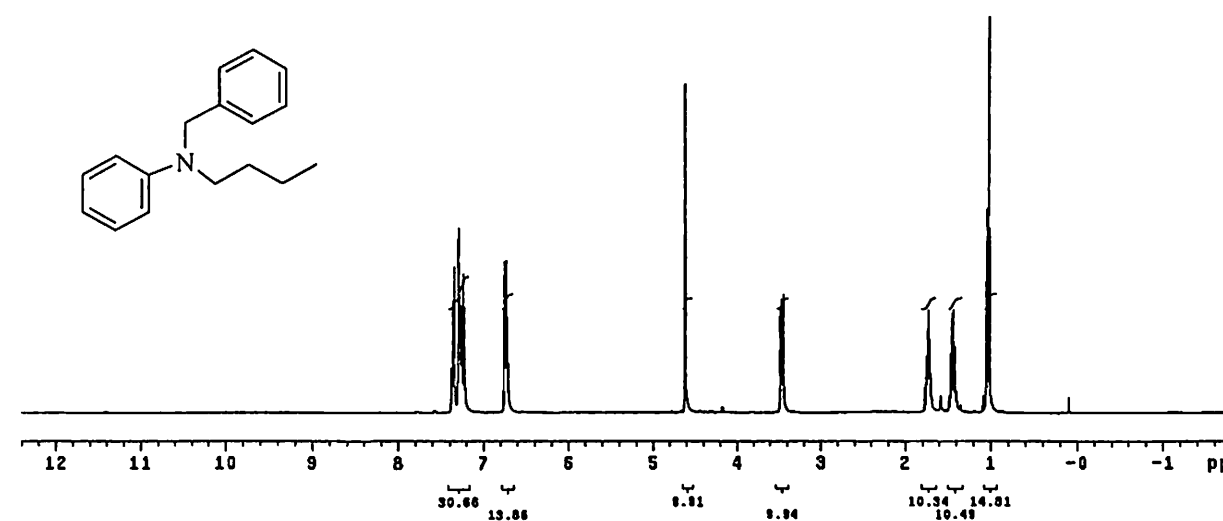
CC(O)CCOC1COCCO1

220 200 180 160 140 120 100 80 60 40 20 0 ppm

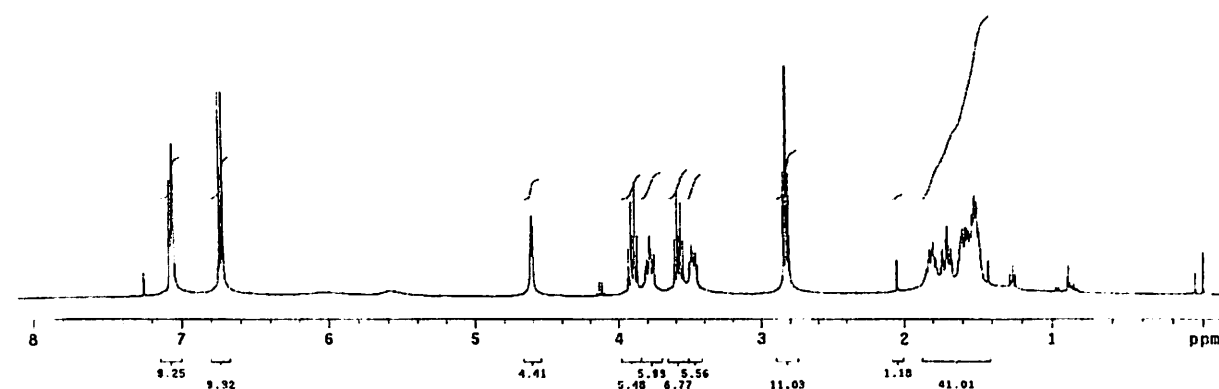
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130.7
130.0
115.1
95.7
77.4
77.3
76.8
68.6
62.2
46.4
46.0
35.3
33.4
19.4

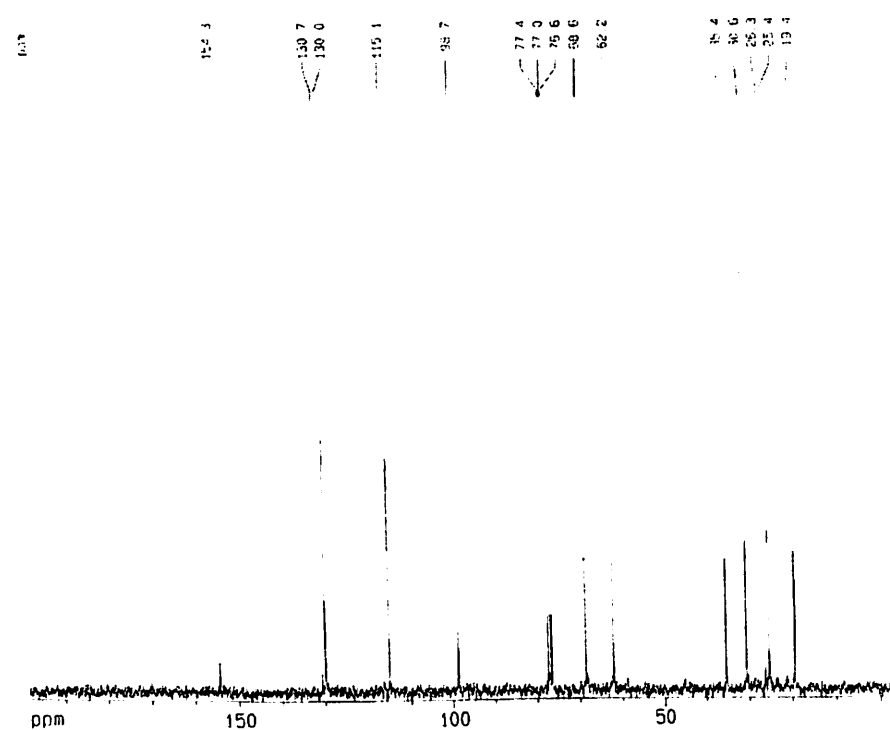
ppm 150 100 50


CCCCN(C1=CC=CC=C1)C2=CC=CC=C2

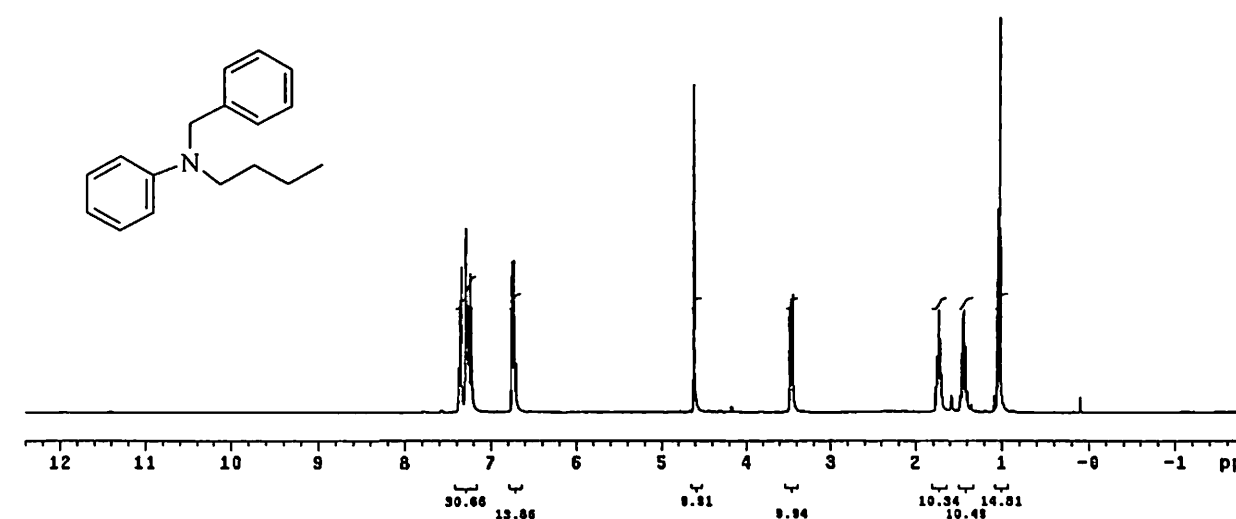
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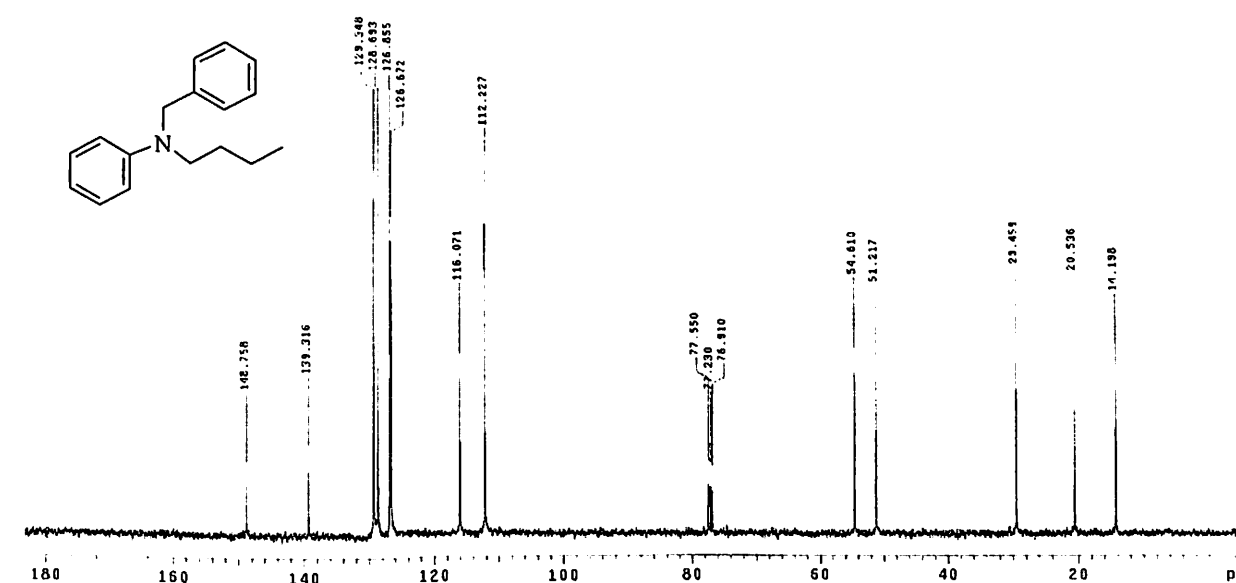
4-[2-(tetrahydro-pyran-2-yloxy)-ethyl]-phenol (21a) ^{13}C NMR (100 MHz, CDCl_3):

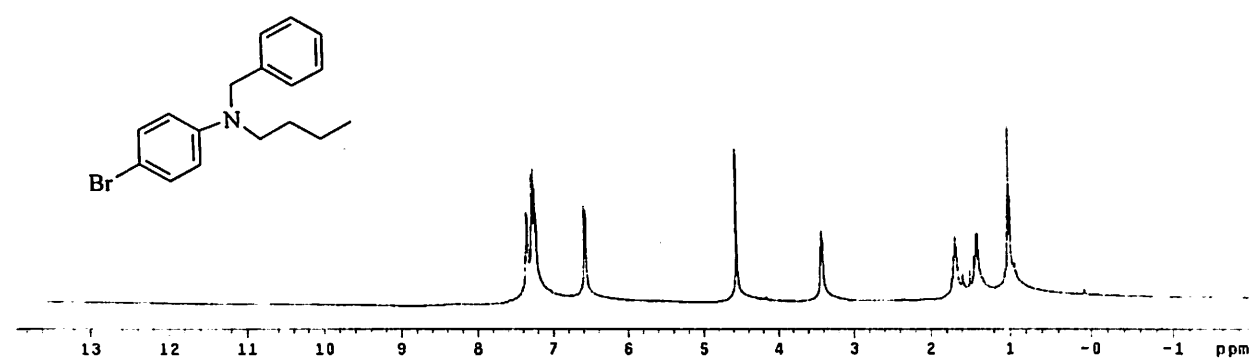
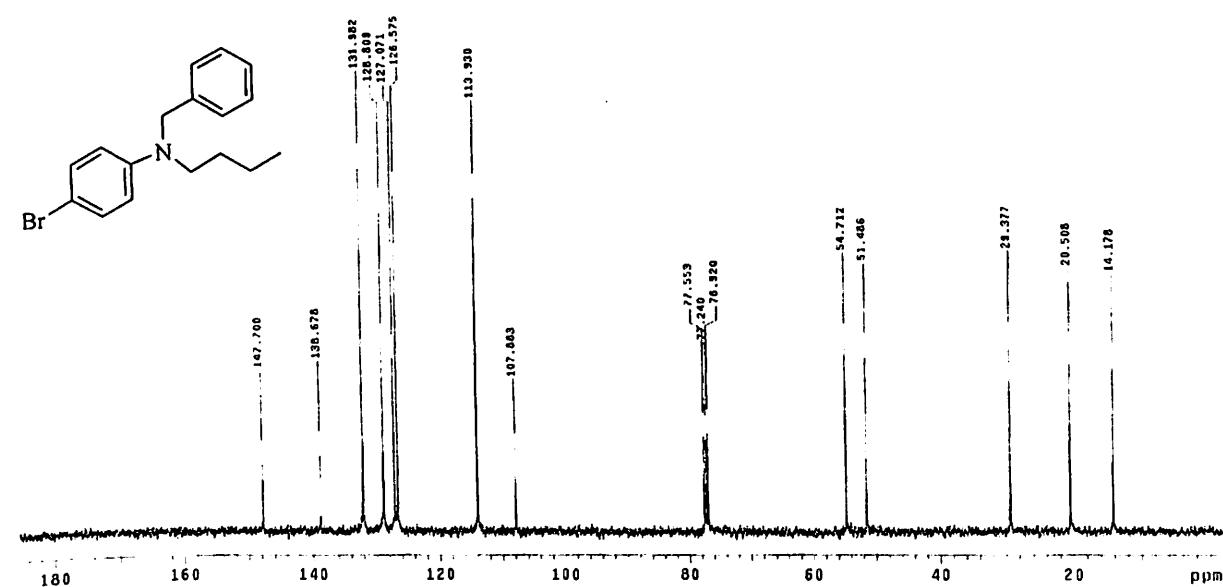
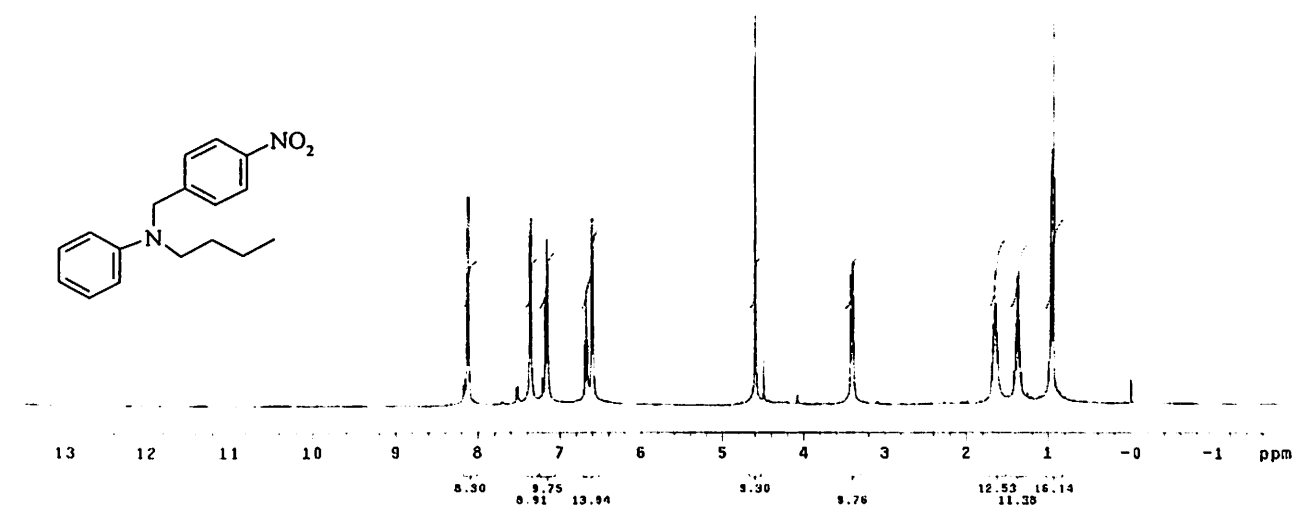
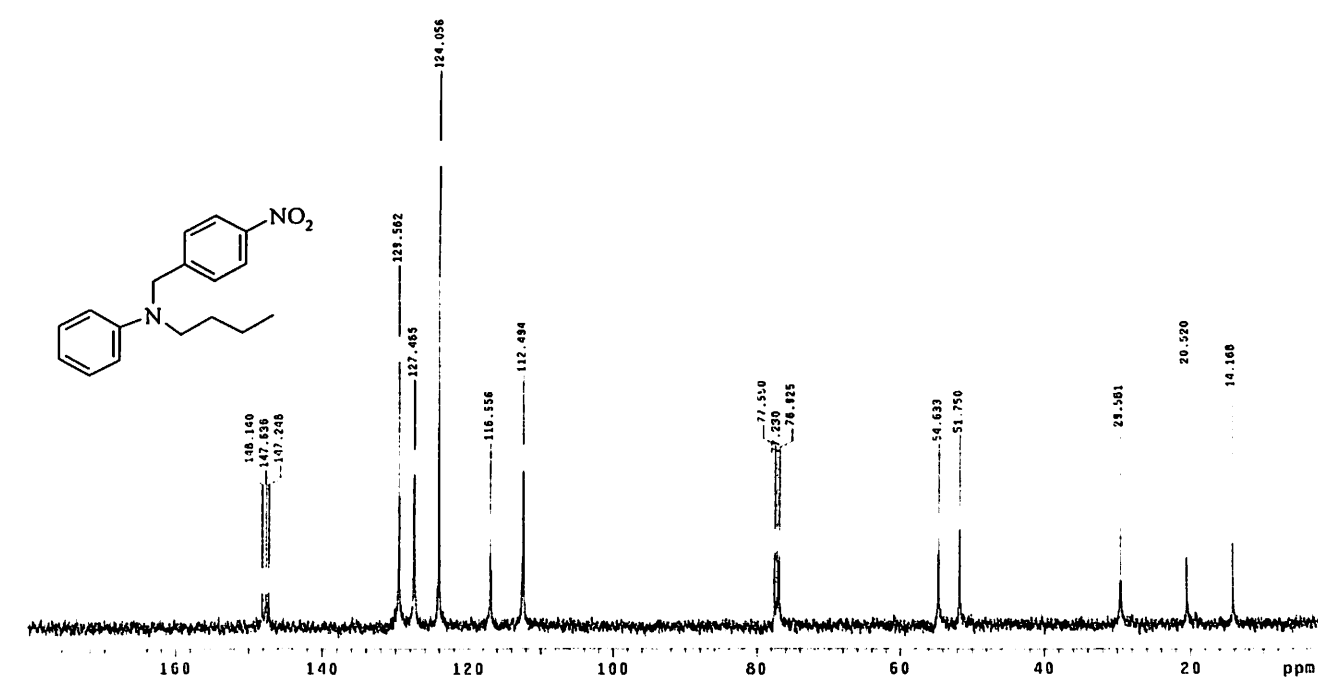


Benzyl-butyl-phenyl-amine (22k) ^1H NMR (400 MHz, CDCl_3):

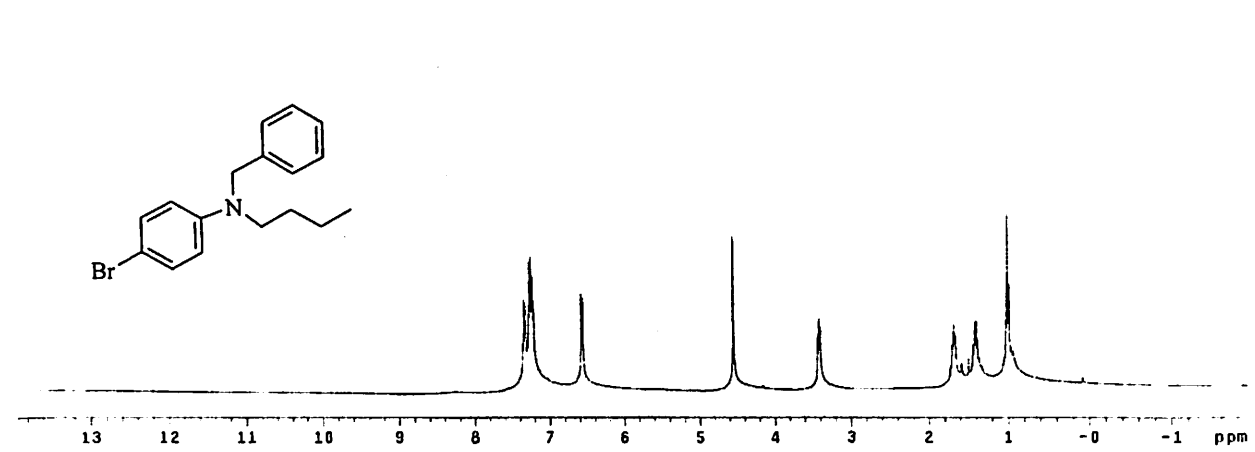


Benzyl-butyl-phenyl-amine (22k) ^{13}C NMR (100MHz, CDCl_3):

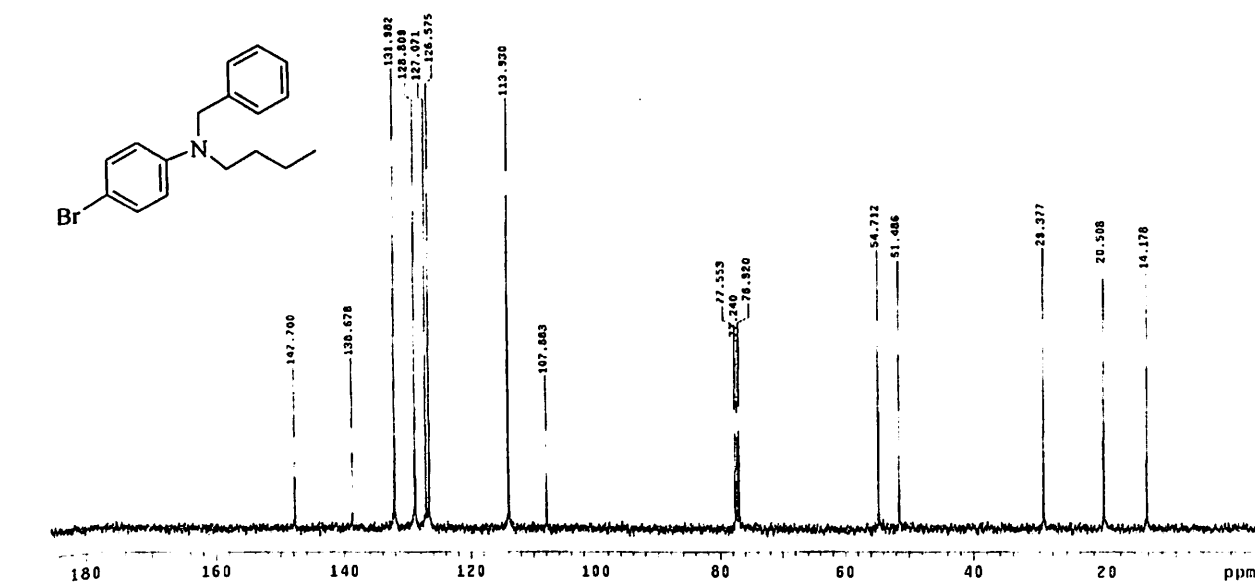


Benzyl-(4-bromo-phenyl)-butyl-amine (27k) ^1H NMR (400 MHz, CDCl_3):Benzyl-(4-bromo-phenyl)-butyl-amine (27k) ^{13}C NMR (100MHz, CDCl_3):Butyl-(4-nitro-benzyl)-phenyl-amine (22l) ^1H NMR (400 MHz, CDCl_3):Butyl-(4-nitro-benzyl)-phenyl-amine (22l) ^{13}C NMR (100MHz, CDCl_3):

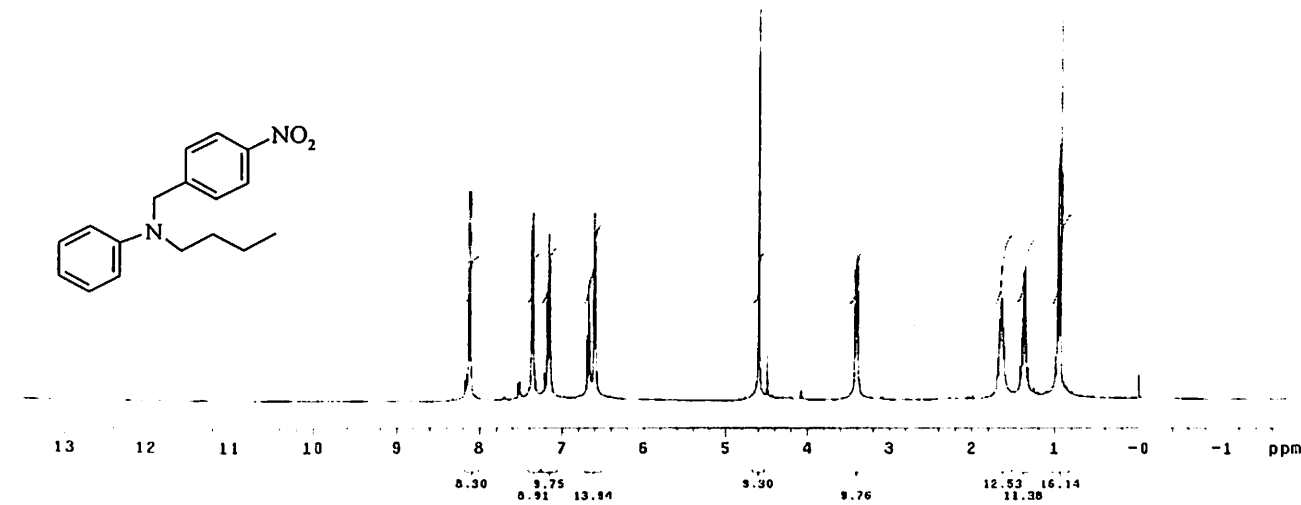
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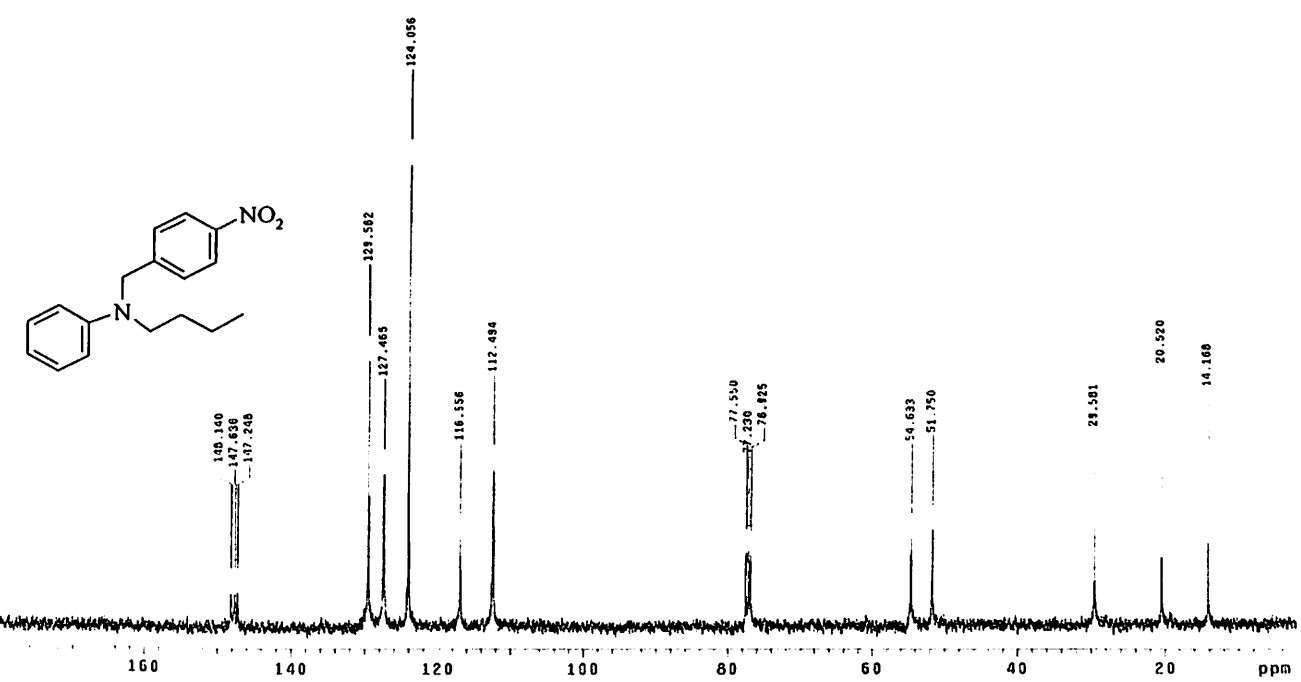
Benzy-(4-bromo-phenyl)-butyl-amine (27k) ¹³C NMR (100MHz, CDCl₃):

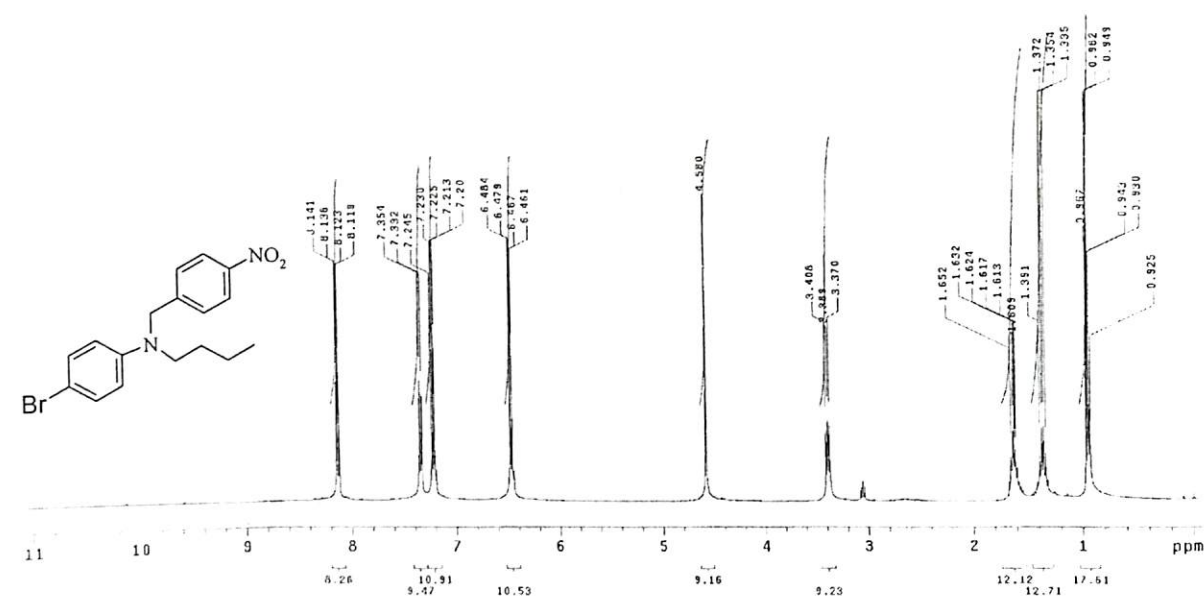
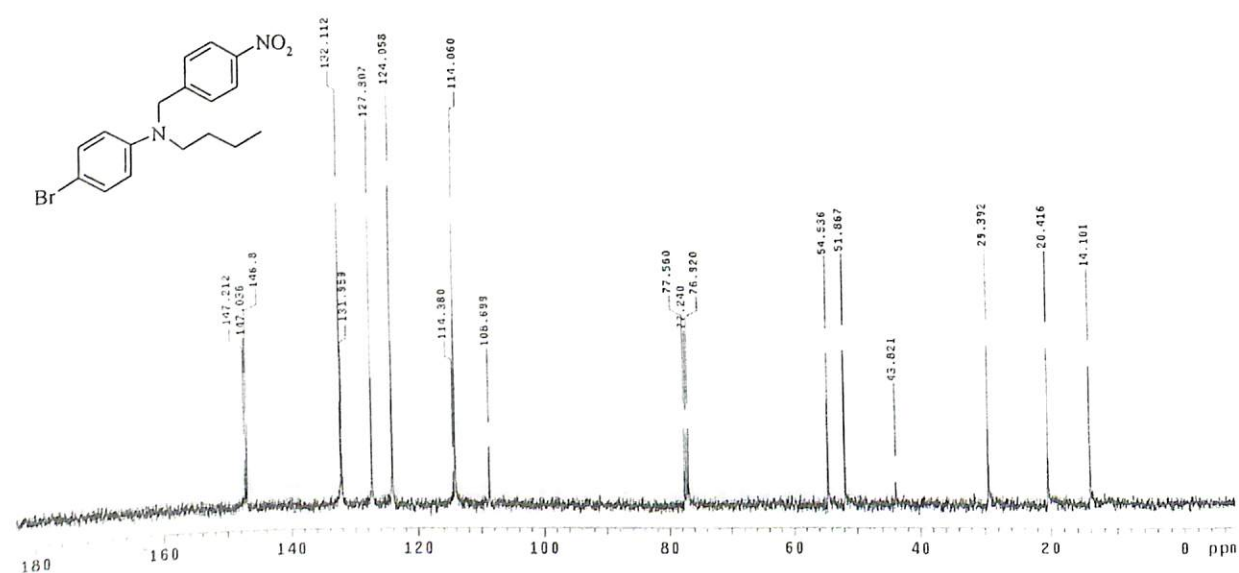
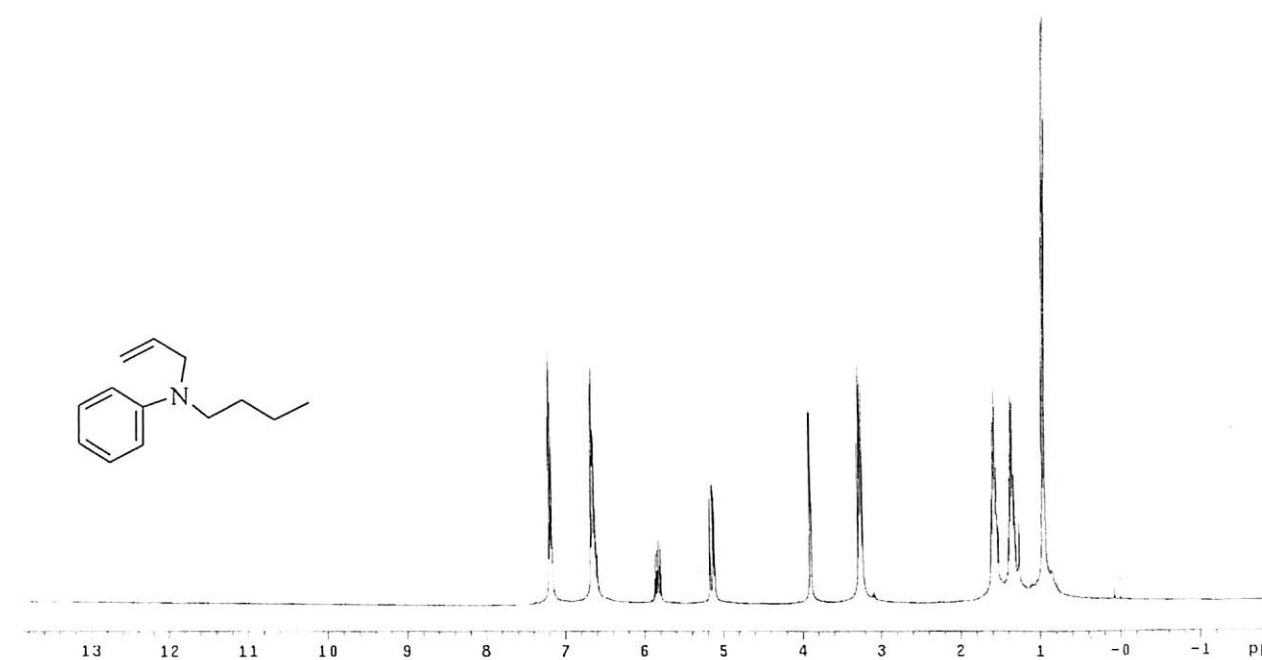
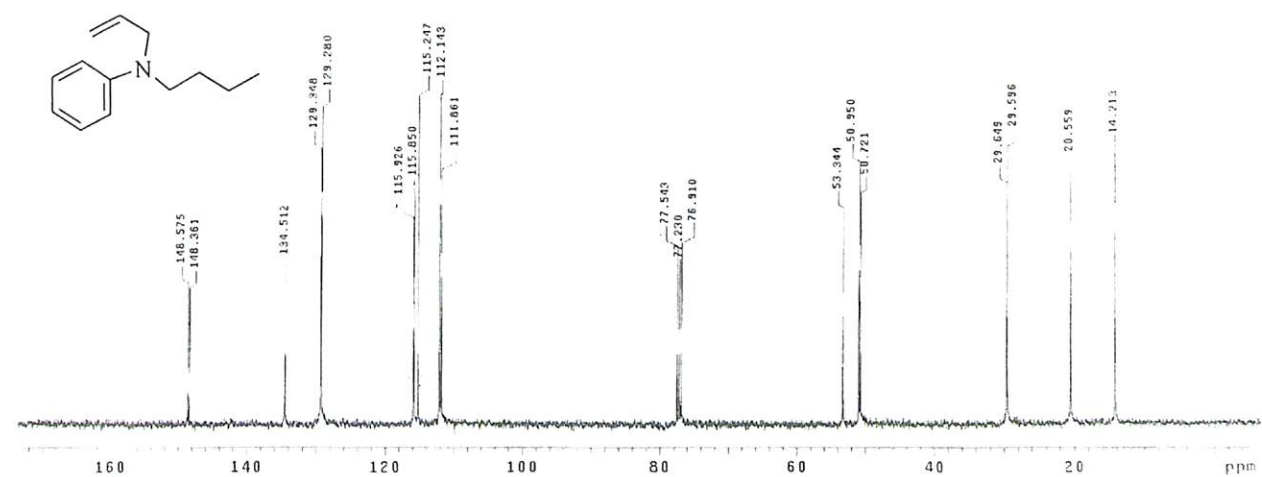


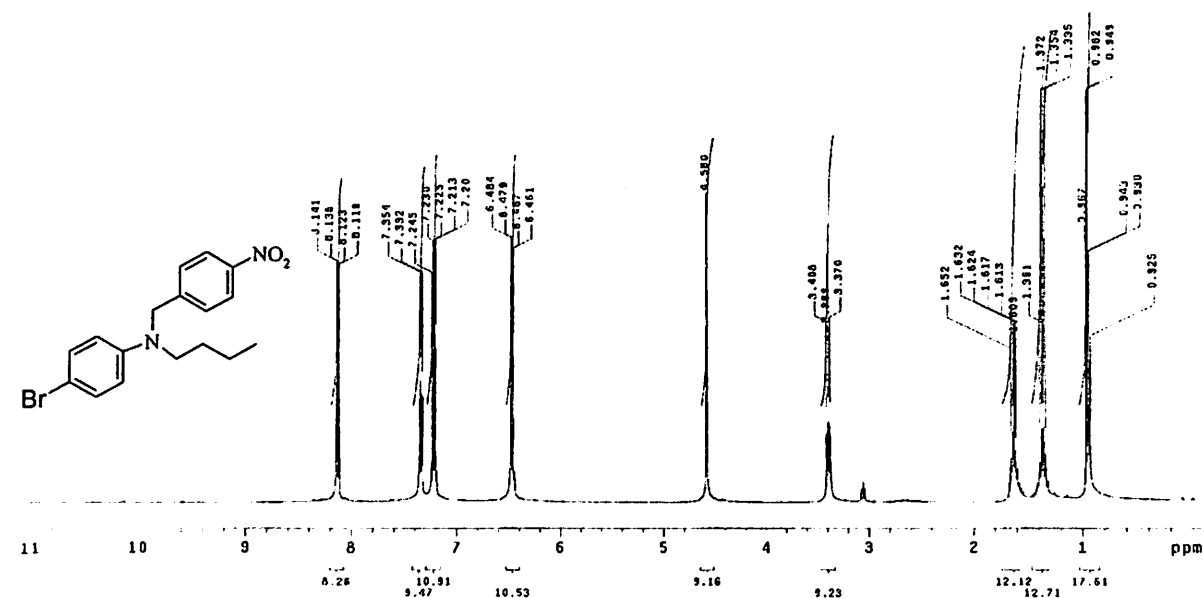
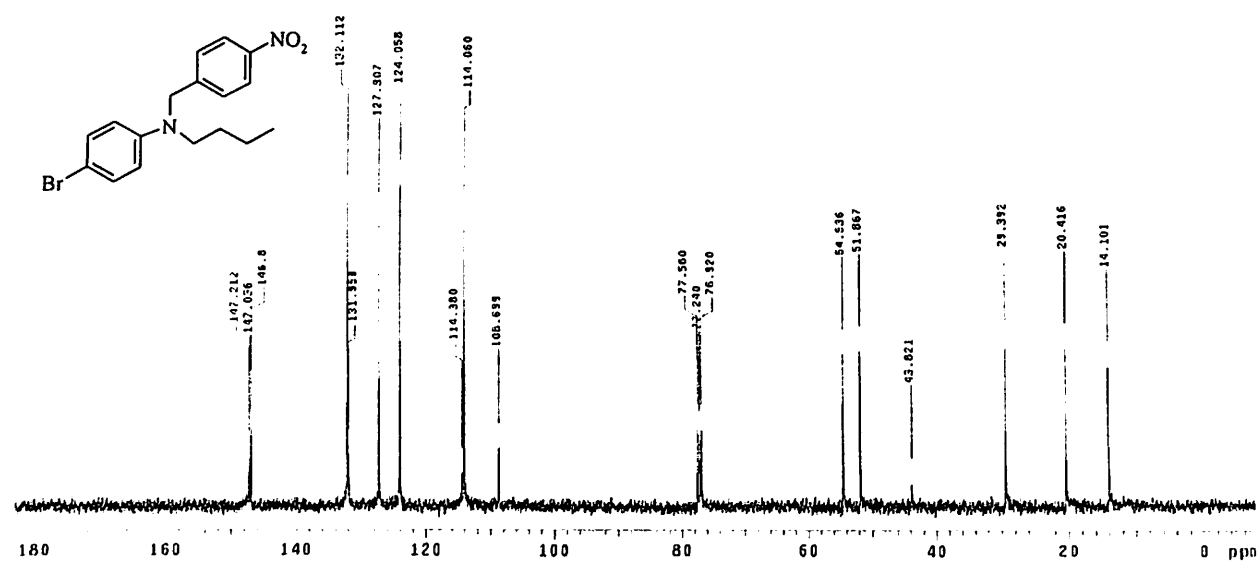
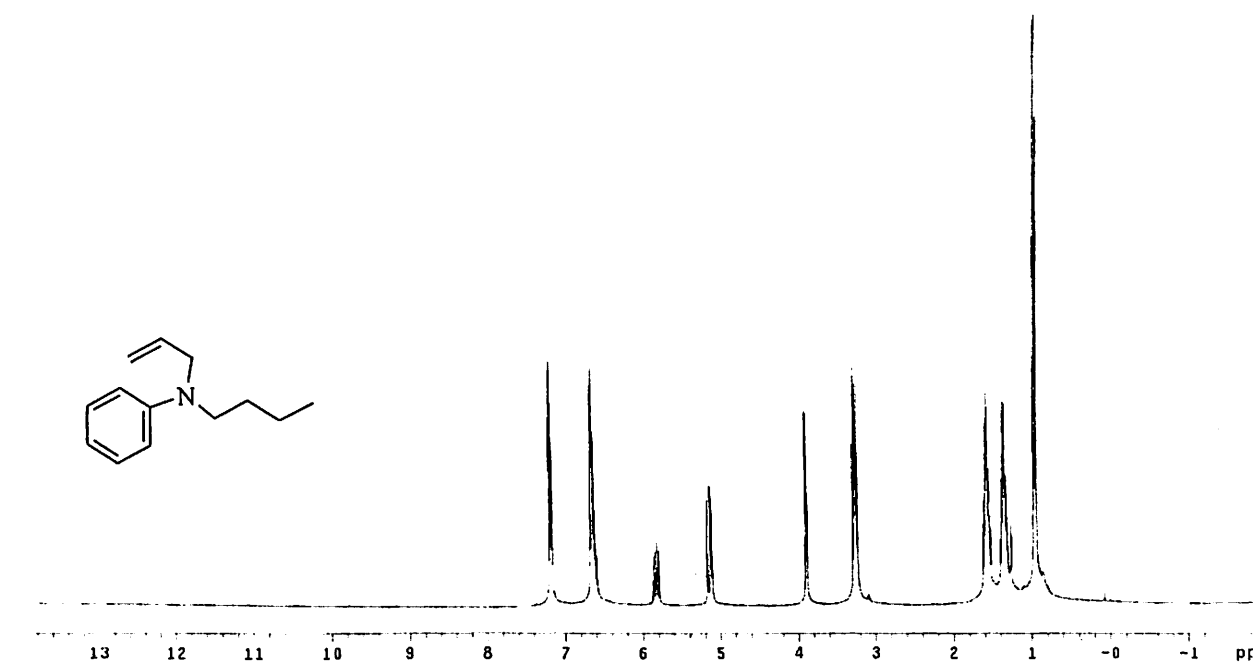
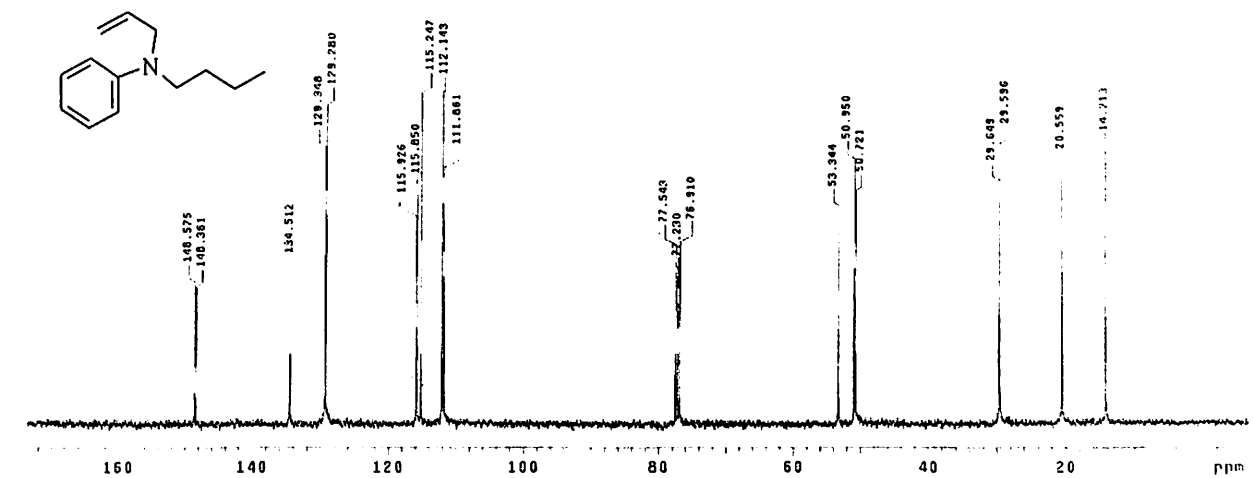
Butyl-(4-nitro-benzyl)-phenyl-amine (22l) ¹H NMR (400 MHz, CDCl₃):

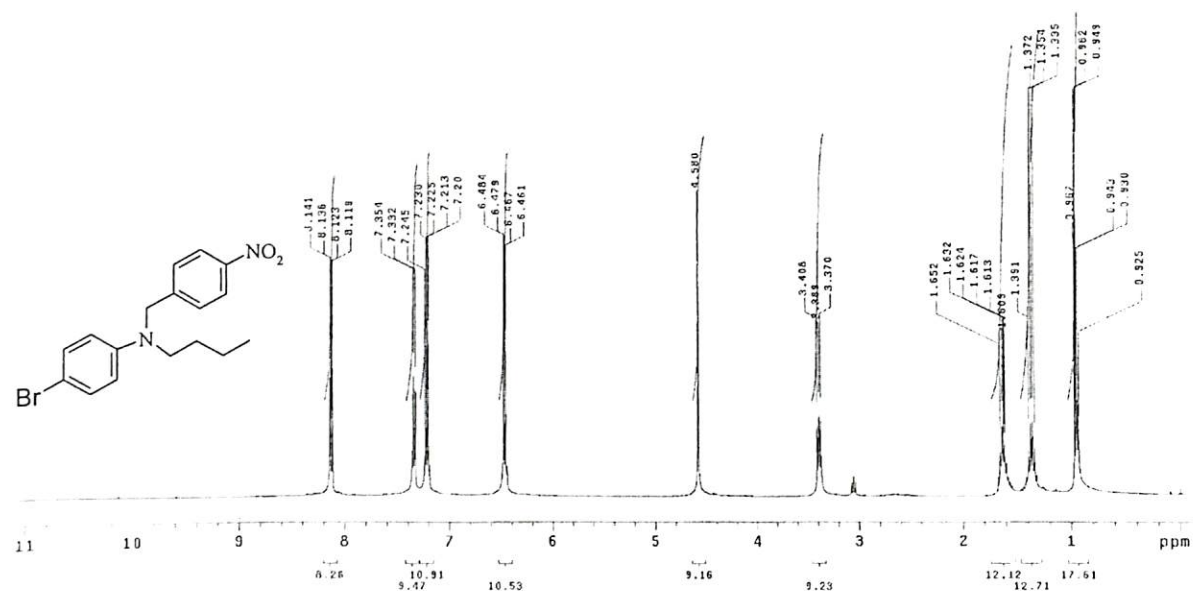
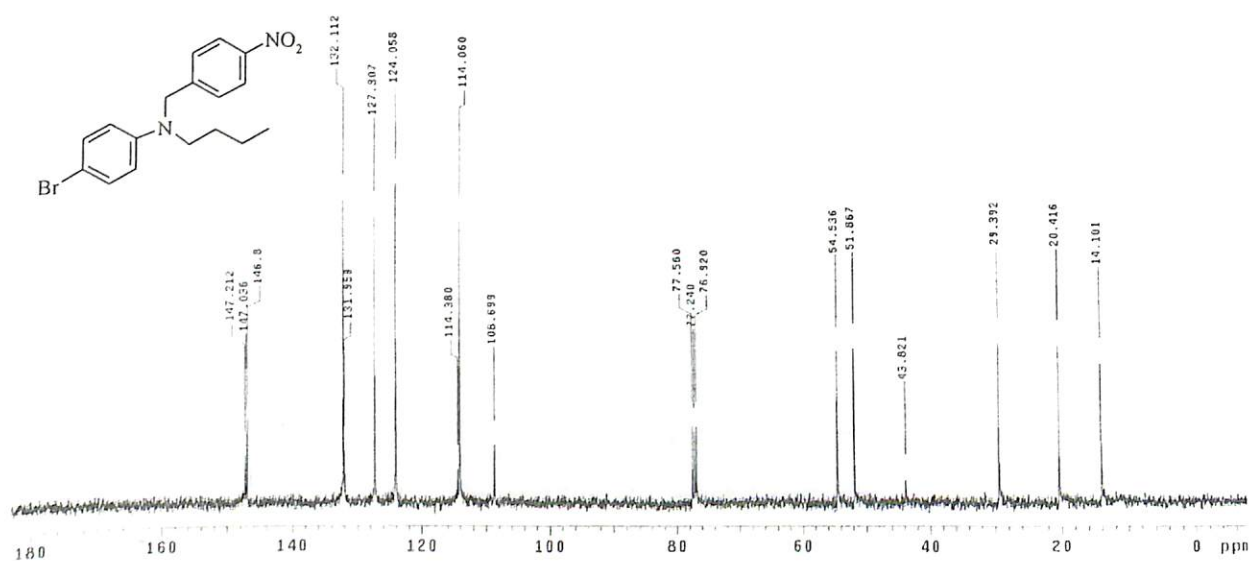
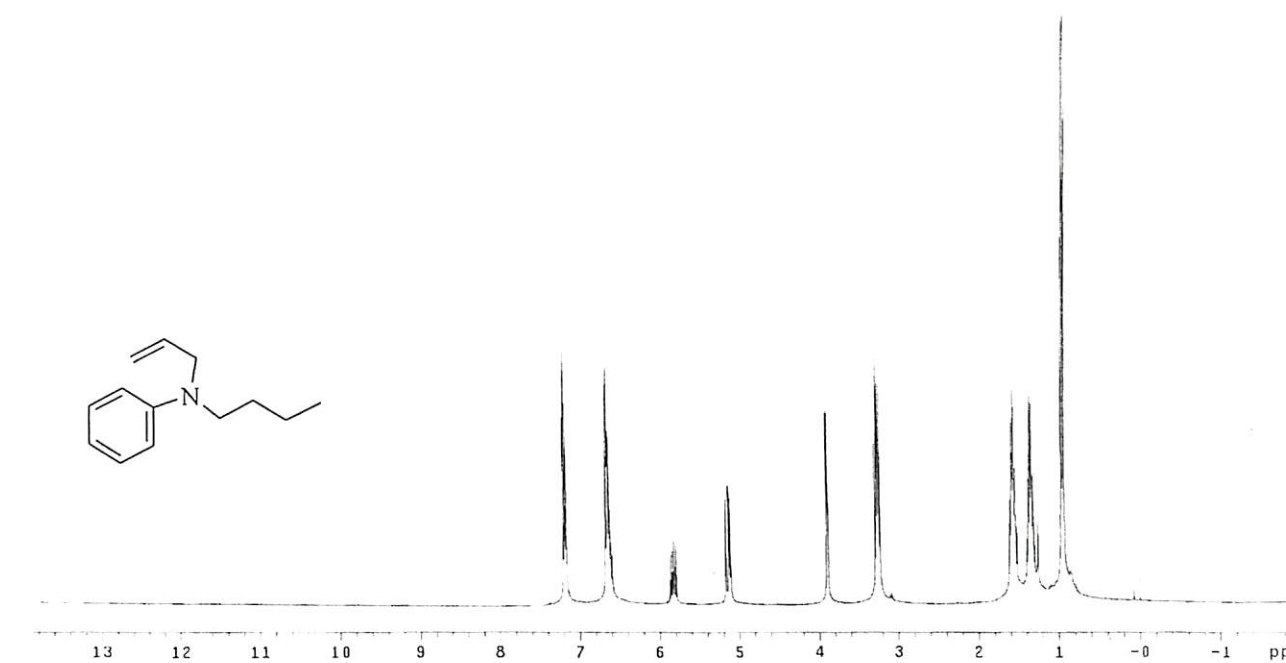
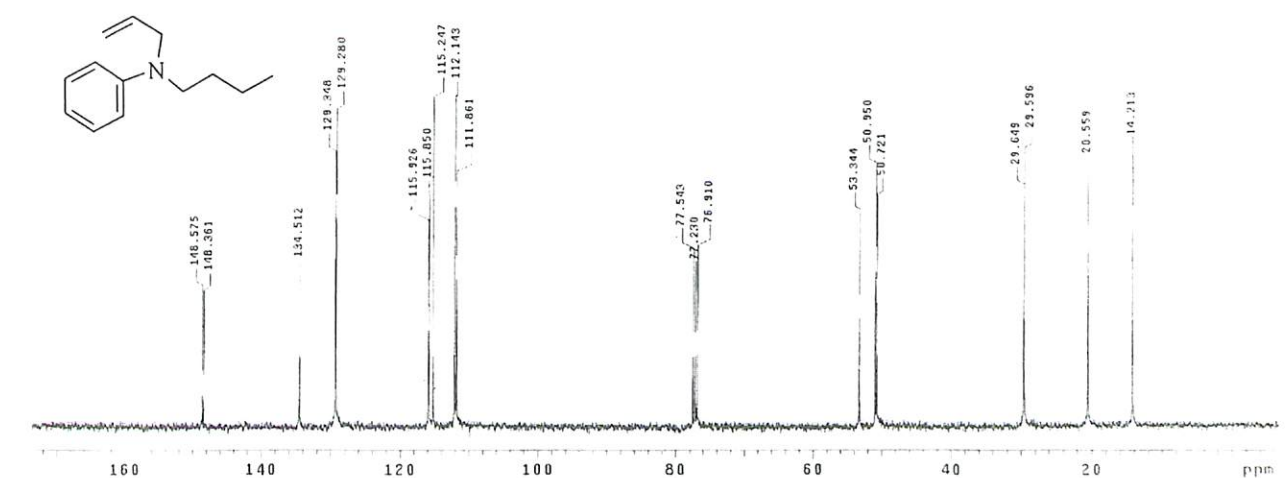


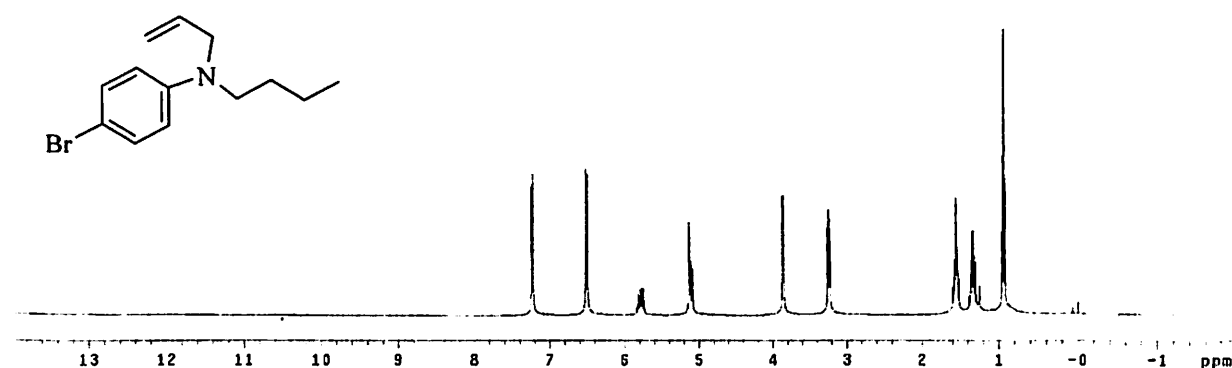
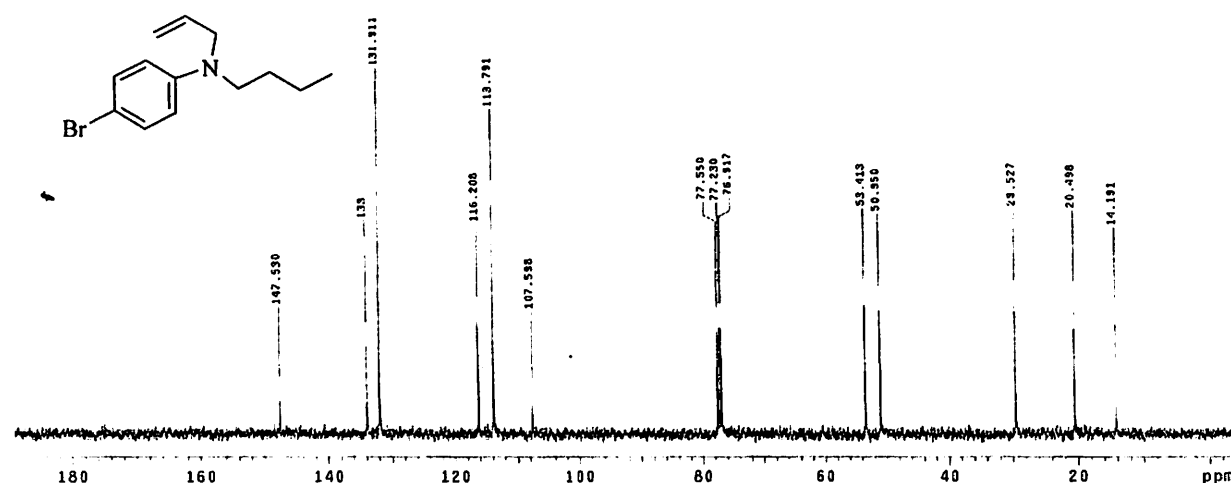
Butyl-(4-nitro-benzyl)-phenyl-amine (22l) ¹³C NMR (100MHz, CDCl₃):



(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l) ^1H NMR (400 MHz, CDCl_3):(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l) ^{13}C NMR (100MHz, CDCl_3):Allyl-phenyl-butyl-amine (22m) ^1H NMR (400 MHz, CDCl_3):Allyl-phenyl-butyl-amine (22m) ^{13}C NMR (100MHz, CDCl_3):

(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l) ^1H NMR (400 MHz, CDCl_3):(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l) ^{13}C NMR (100MHz, CDCl_3):Allyl-phenyl-butyl-amine (22m) ^1H NMR (400 MHz, CDCl_3):Allyl-phenyl-butyl-amine (22m) ^{13}C NMR (100MHz, CDCl_3):

(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l) ^1H NMR (400 MHz, CDCl_3):(4-Bromo-phenyl)-butyl-(4-nitro-benzyl)-amine (27l) ^{13}C NMR (100MHz, CDCl_3):Allyl-phenyl-butyl-amine (22m) ^1H NMR (400 MHz, CDCl_3):Allyl-phenyl-butyl-amine (22m) ^{13}C NMR (100MHz, CDCl_3):

Allyl-(4-bromo-phenyl)-butyl-amine (27m) ^1H NMR (400 MHz, CDCl_3):Allyl-(4-bromo-phenyl)-butyl-amine (27m) ^{13}C NMR (100MHz, CDCl_3):

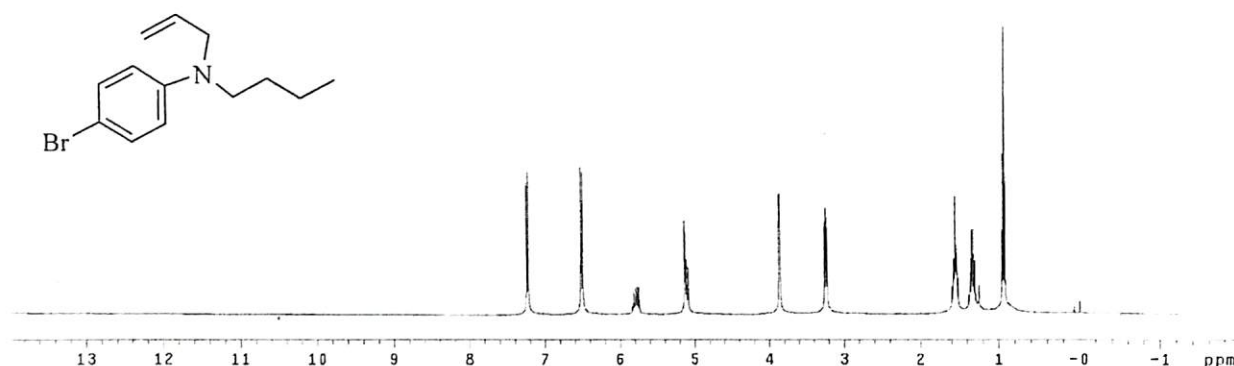
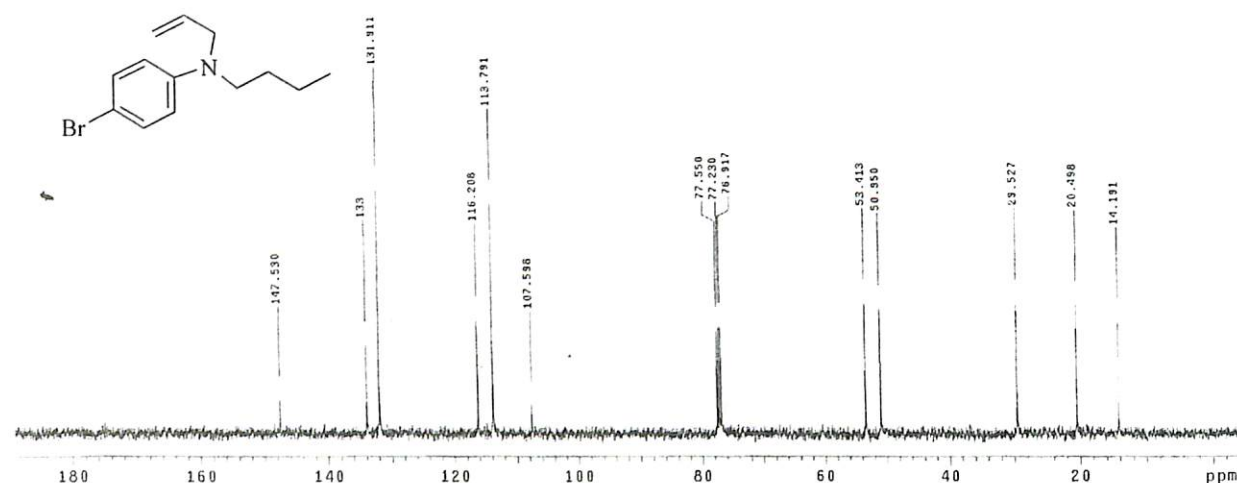
IIA. Introduction

Modern life is dependent upon chemicals in a variety of ways as such it is almost impossible to live without them in the present days. Mankind's ever growing demand for energy and raw materials is gradually pushing natural resources to their limits, giving rise to more environmental problems. Synthesis of new materials, dyes, agrochemicals and pharmaceuticals has certainly contributed to the increase of the life expectancy. In this regards, chemistry has played a contradictory role. Manufacturing process lead to millions of tons of waste, as a consequence, the role of chemistry is not generally accepted by the government or the public; chemistry is actually consider by many as the cause of the problem. To ensure compatibility with conservation of global environment, chemical processes are required to be changed to "Green processes", so as to create new products, processes and services that achieve social, economical and environmental benefits. These are expected to aims at development of highly effective catalytic systems and catalysts suitable for green conditions that minimizes the energy requirements and generates substances that possess little or no toxicity to human health and the environment.

Inspite of the spectacular success, organic synthesis has still a long way to go before achieving its ultimate goals, *i.e.*, being as or even more efficient that Mother Nature in terms of selectivity and capability of producing high yields of structurally varied complex molecules using processes which are simple, cheap, catalytic and which do not destroy our environment. Efficiency and selectivity are essential characteristic of good synthetic methods and it is now becoming a major challenge for organic chemists.

IIA.1. Importance of Bromine and Brominated Products

Bromo-organic compounds play a vital role in life processes. Numerous natural product are isolated which contained bromine, are produced by marine and terrestrial plants, bacteria, fungi, insects, marine animals and some higher animals, numbering nearly 1500 compounds.¹ The first bromo organic compound, tyrian or royal purple was extracted from a Mediterranean sea mollusk and used as dyes.¹ Laurencin, α -synderol, β -synderol etc. are most important bioactive natural bromine

Allyl-(4-bromo-phenyl)-butyl-amine (27m) ^1H NMR (400 MHz, CDCl_3):Allyl-(4-bromo-phenyl)-butyl-amine (27m) ^{13}C NMR (100MHz, CDCl_3):

IIA. Introduction

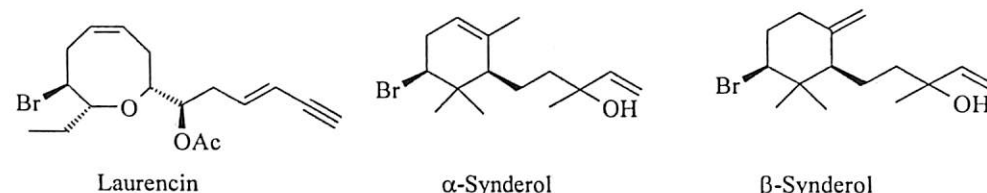
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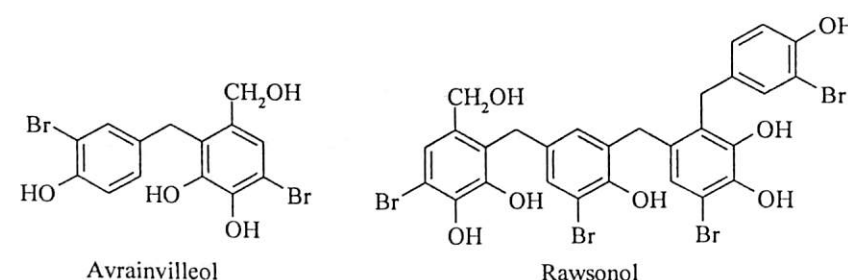
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containing cyclic terpenes (Scheme IIA.1.1).² Several halogenated aromatic compounds have been used as intermediates for a natural products and bioactive materials.^{1,3}



Scheme IIA.1.1

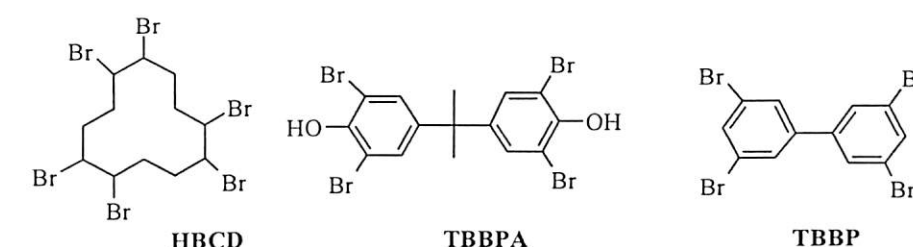
The potent feeding deterrent avrainvilleol found in the tropical green alga *Avrainvillea longicaulis* and *Avrainvillea rawsoni* has yielded the HMGCoA reductase inhibitor rawsonol (Scheme IIA.1.2).¹



Scheme IIA.1.2

Nowadays bromine has found diverse applications. Bromine can be used as disinfectants for swimming pool and cooling tower water. It is used for the disinfection of drinking water in emergency. The first known application of a bromine-containing product is the color purple dye. These substances are produced by purple snails and were used by the Romans to paint their clothes purple. In industry and agriculture it is used on a large scale to produce bromine-containing substances. Bromine was used mainly to produce ethylene dibromide; a main constituent of lead-containing fuel. However, because of its damaging effects on the environment, this product is no longer used. Bromine is also used in the manufacture of fumigants, brominated flame-retardants, water purification compounds, dyes, medicines, sanitizers, inorganic bromides for photography etc. It is also used as intermediates in organic synthesis where it is preferred to iodine due to its much lower cost. Bromine is also used to make brominated vegetable oil, which is used as an emulsifier in many citrus-flavored soft drinks.⁴ The largest use and most important life safety benefit of bromine is in

flame retardants. Tetrabromobisphenol-A (TBBPA), hexabromocyclodod brominated biphenyls (PBB) etc. are important fire retardants (Scheme IIA.1.3).¹



Scheme IIA.1.3

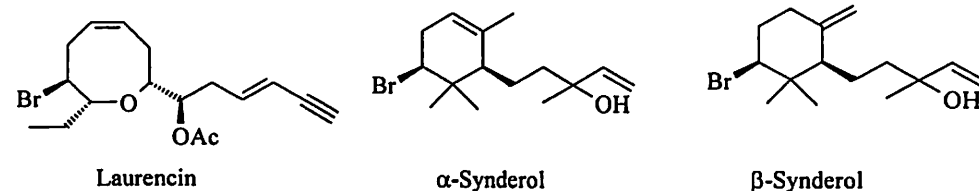
The reactivity of bromine compounds in the nucleophilic substitution is greater than the corresponding chlorine derivatives, owing to the difference in the bond energies (C-Br 276 kJ/mol vs. C-Cl 328 kJ/mol). The higher reactivity is the main advantage of using bromo compounds for carbon-carbon bond formation via cross-coupling reactions such as Stille-Suzuki,⁵ Heck,⁶ and Sonogashira⁷ or carbon-heteroatom bond formation via aromatic functionalization protocols.⁸ The development of modern coupling reactions such as Tamao-Kumada, Suzuki-Mayaura, Migita-Kosugi-Stille, Negishi, Hiyama-Hatanaka, and Mizorogi-Heck reactions has greatly increased the demand for brominated aromatics as starting materials.^{5b}

IIA.1.2. Methods for Bromination

In general molecular bromine is used for the bromination of organic substrates. Despite the wide spread use of molecular bromine as electrophilic reagent it is toxic, difficult to handle, low-boiling point and lachrymatory liquid causing severe burns on contact with skin.⁹ Moreover, due to its oxidizing tendency, attempted bromination of complex organic substrate can cause undesired competing oxidation processes.¹⁰

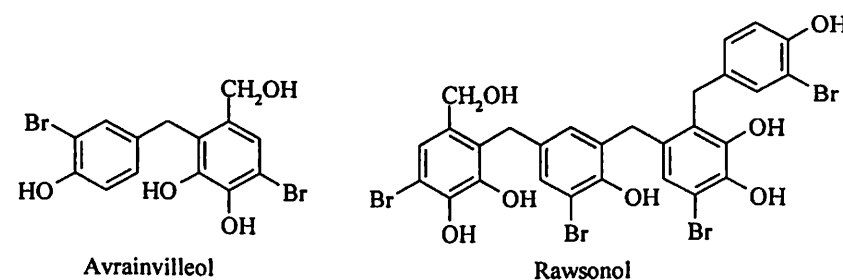
In order to overcome the problems associated with the molecular bromine, alternative strategies have been devised to generate bromine by the oxidation of bromide in the reaction medium. The oxidizing agents and the bromide source used for the process include HBr-*tert*-butylhydroperoxide (TBHP),¹¹ HBr-DMSO,¹² HBr-NaBO₃,¹³ BuOBr-Zeolite,¹⁴ NaBr-dimethyldioxirane,¹⁵ NaBr-NaClO₂/Mn(acac)₃/moist montmorillonite,¹⁶ LiBr-ceric ammonium nitrate(CAN),¹⁷ LiBr-(NH₄)₂S₂O₈,¹⁸ LiBr-2-iodoxybenzoic acid (IBX),¹⁹ KBr-H₂O₂-zeolites,²⁰ KBr-NaBO₃,²¹ KBr-KBrO₃,²² and LDH-WO₄/H₂O₂-Br₂²³ etc.

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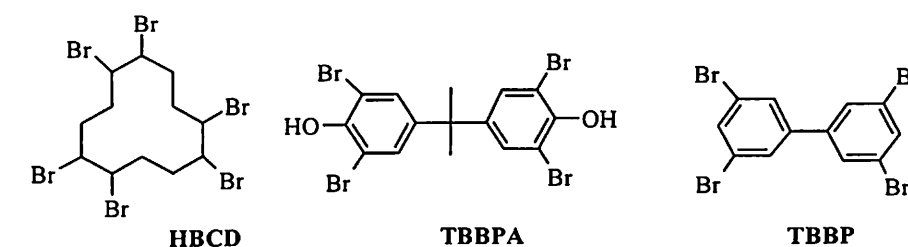
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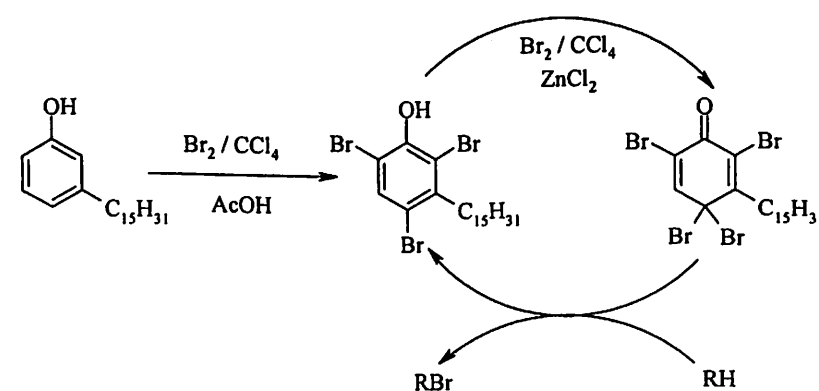
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In order to overcome the problems associated with the molecular bromine, alternative strategies have been devised to generate bromine by the oxidation of bromide in the reaction medium. The oxidizing agents and the bromide source used for the process include HBr-*tert*-butylhydroperoxide (TBHP),¹¹ HBr-DMSO,¹² HBr-NaBO₃,¹³ BuOBr-Zeolite,¹⁴ NaBr-dimethyldioxirane,¹⁵ NaBr-NaClO₂/Mn(acac)₃/moist montmorillonite,¹⁶ LiBr-ceric ammonium nitrate(CAN),¹⁷ LiBr-(NH₄)₂S₂O₈,¹⁸ LiBr-2-iodoxybenzoic acid (IBX),¹⁹ KBr-H₂O₂-zeolites,²⁰ KBr-NaBO₃,²¹ KBr-KBrO₃,²² and LDH-WO₄/H₂O₂-Br₂²³ etc.

N-Bromo succinamide (NBS) is a solid and easy to handle brominating agent.²⁴ Alkylated aromatic compounds are either brominated in the side chain with NBS in the presence of benzoyl peroxide (Wohl- Ziegler reaction)²⁵ or in the aromatic ring in the absence of any radical initiators.²⁶ The nuclear bromination of aromatic compounds are favored in polar solvents like N,N'-dimethylformamide (DMF), CH₃CN etc.²⁷ Methoxy benzoic acid can be brominated to *p*-methoxybenzoic acid in an aqueous NaOH using NBS.²⁸ NBS is also used for the bromination of activated aromatics in the presence of acidic catalysts such as *p*-TsOH, SiO₂, HZMS-5 zeolite, amberlyst, HCl, HBF₄ Et₂O etc.²⁹ Room temperature ionic liquids are used as a green recyclable reaction media for the α -monohalogenation of 1,3-diketones, β -keto esters, and cyclic ketones with N-halosuccinimides in excellent yields in the absence of a catalyst.³⁰

3-Dibromo-5,5-dimethylhydantoin (DBDMH) is another useful brominating reagent and is a suitable alternative to n-bromosuccinamide.³¹ A variety of aromatic compounds with both activating and deactivating substituents were efficiently brominated with sodium monobromoisocyanurate (SMBI). This reagent is reported to be superior to NBS.³²

Bromochromates, such as pyridinium bromochromate (PBC),³³ quinolinium bromochromate (QBC)³⁴ and γ -picolinium bromochromate (γ -PBC)³⁵ are another class of bromineless brominating agent. Although bromochromates works well towards bromination but are inherently associated with strong oxidizing properties and the presence of the toxic metal chromium makes it further unsuitable for large scale reactions.



Scheme IIA.1.2.1

Very recently, 2,4,4,6-tetrabromo-3-n-pentadecyl-2,5-cyclohexadienone (TBPCO) has been synthesized and used as a new efficient, convenient and environmentally friendly brominating agent (Scheme IIA.1.2.1).³⁶

A facile bromination of various organic substrates has been demonstrated using a bromate reagent prepared from the alkali intermediate of the conventional bromination process. The reagent is acidified *in situ* to generate HOBr as the reactive species which effects the bromination. By obtaining the present reagent from the liquid bromine precursor, the twin advantages of avoiding liquid bromine and producing the reagent in a cost-effective manner are realized.³⁷

IIA.1.3. Organic Tribromides

Organic ammonium tribromides are attractive solid brominating agents. These crystalline stable solids are convenient source of bromine owing to the ease in maintenance of their desired stoichiometry and the ease in storage, transportation and handling. Several organic tribromides have been reported in the literature (Figure IIA.1.3.1), which includes tetramethylammonium tribromide (TMATB), tetrabutylammonium tribromide (TBATB), tetraethylammonium tribromide (TEATB), cetyltrimethylammonium tribromide (CTMATB), pyridine hydrobromide perbromide (PHPB), phenyltrimethylammonium tribromide (PTATB), benzyl trimethylammonium tribromide, 1,8-diazabicyclo [5.4.0]-undec-7-ene hydrobromide perbromide (DBUHBr₃), pentylpyridinium tribromide (PPTB), 1-benzyl-4-aza-1-azonia-bicyclo [2.2.2] octane tribromide and 1-butyl-3-methylimidazoliumtribromide ([bmim] Br₃).

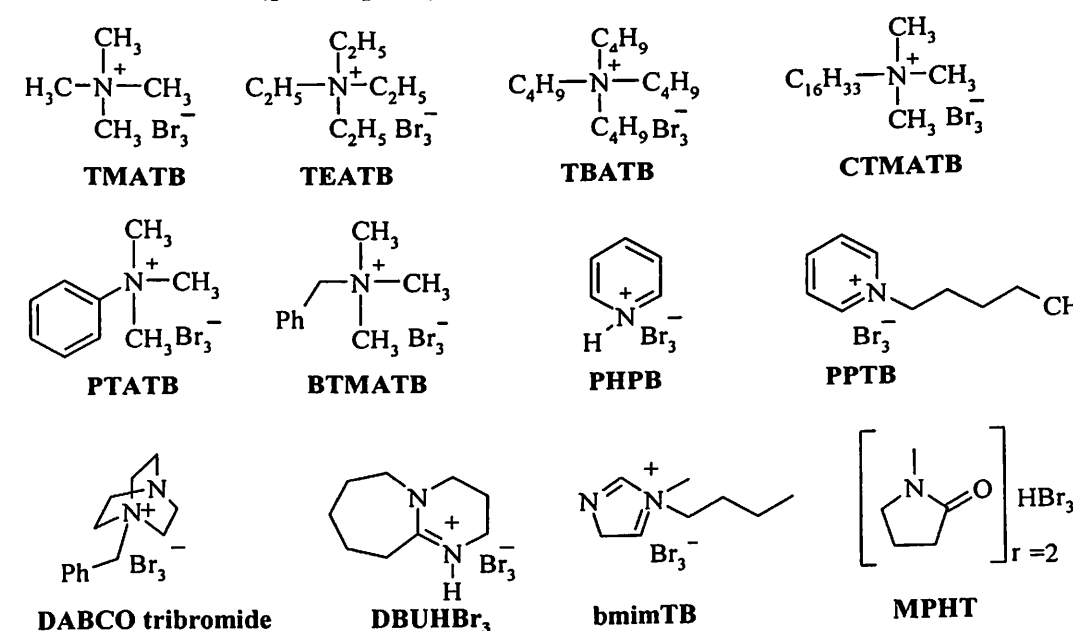
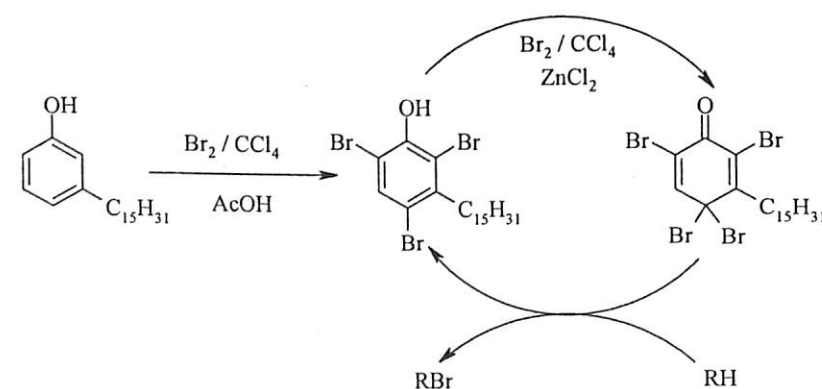


Figure IIA.1.3.1

N-Bromo succinamide (NBS) is a solid and easy to handle brominating agent.²⁴ Alkylated aromatic compounds are either brominated in the side chain with NBS in the presence of benzoyl peroxide (Wohl- Ziegler reaction)²⁵ or in the aromatic ring in the absence of any radical initiators.²⁶ The nuclear bromination of aromatic compounds are favored in polar solvents like N,N'-dimethylformamide (DMF), CH₃CN etc.²⁷ Methoxy benzoic acid can be brominated to *p*-methoxybenzoic acid in an aqueous NaOH using NBS.²⁸ NBS is also used for the bromination of activated aromatics in the presence of acidic catalysts such as *p*-TsOH, SiO₂, HZMS-5 zeolite, amberlyst, HCl, HBF₄ Et₂O etc.²⁹ Room temperature ionic liquids are used as a green recyclable reaction media for the α -monohalogenation of 1,3-diketones, β -keto esters, and cyclic ketones with N-halosuccinimides in excellent yields in the absence of a catalyst.³⁰

3-Dibromo-5,5-dimethylhydantoin (DBDMH) is another useful brominating reagent and is a suitable alternative to *n*-bromosuccinamide.³¹ A variety of aromatic compounds with both activating and deactivating substituents were efficiently brominated with sodium monobromoisocyanurate (SMBI). This reagent is reported to be superior to NBS.³²

Bromochromates, such as pyridinium bromochromate (PBC),³³ quinolinium bromochromate (QBC)³⁴ and γ -picolinium bromochromate (γ -PBC)³⁵ are another class of bromineless brominating agent. Although bromochromates works well towards bromination but are inherently associated with strong oxidizing properties and the presence of the toxic metal chromium makes it further unsuitable for large scale reactions.



Scheme IIA.1.2.1

Very recently, 2,4,4,6-tetrabromo-3-*n*-pentadecyl-2,5-cyclohexadienone (TBPCO) has been synthesized and used as a new efficient, convenient and environmentally friendly brominating agent (Scheme IIA.1.2.1).³⁶

A facile bromination of various organic substrates has been demonstrated using a bromate reagent prepared from the alkali intermediate of the conventional bromination process. The reagent is acidified *in situ* to generate HOBr as the reactive species which effects the bromination. By obtaining the present reagent from the liquid bromine precursor, the twin advantages of avoiding liquid bromine and producing the reagent in a cost-effective manner are realized.³⁷

IIA.1.3. Organic Tribromides

Organic ammonium tribromides are attractive solid brominating agents. These crystalline stable solids are convenient source of bromine owing to the ease in maintenance of their desired stoichiometry and the ease in storage, transportation and handling. Several organic tribromides have been reported in the literature (Figure IIA.1.3.1), which includes tetramethylammonium tribromide (TMATB), tetrabutylammonium tribromide (TBATB), tetraethylammonium tribromide (TEATB), cetyltrimethylammonium tribromide (CTMATB), pyridine hydrobromide perbromide (PHPB), phenyltrimethylammonium tribromide (PTATB), benzyl trimethylammonium tribromide, 1,8-diazabicyclo [5.4.0]-undec-7-ene hydrobromide perbromide (DBUHBr₃), pentylpyridinium tribromide (PPTB), 1-benzyl-4-aza-1-azonia-bicyclo [2.2.2] octane tribromide and 1-butyl-3-methylimidazoliumtribromide ([bmim] Br₃).

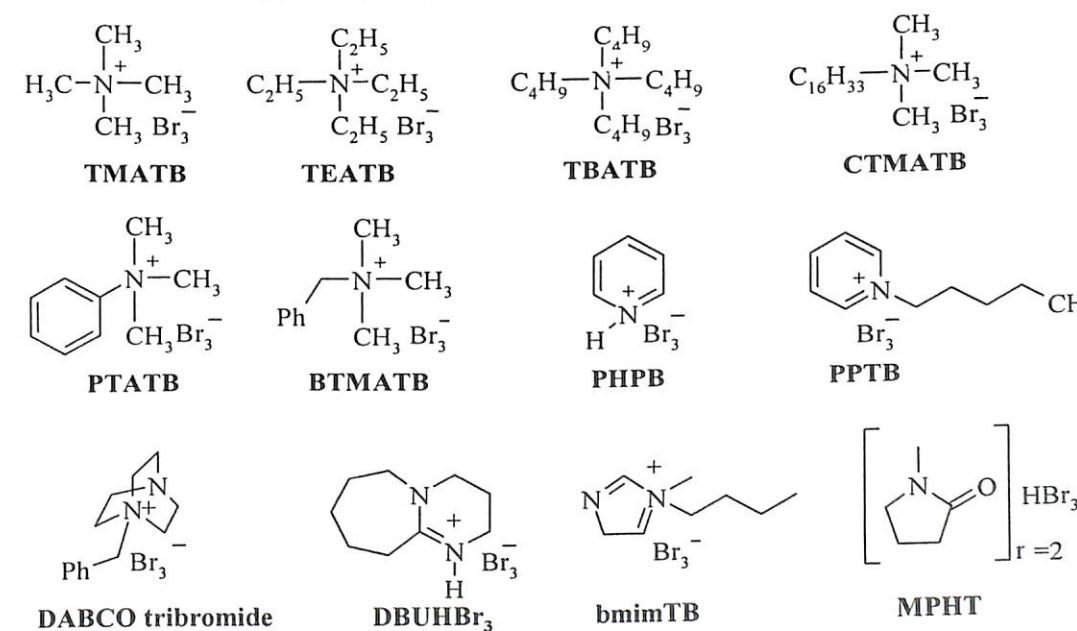
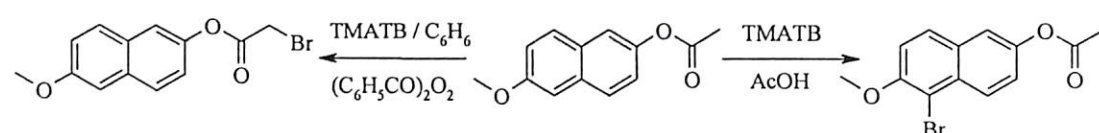


Figure IIA.1.3.1

IIA.1.3.1. Bromination Using Tribromides

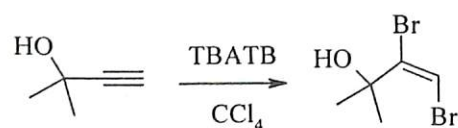
Chattway and Höfle were the first to report the preparation of tetramethylammonium tribromide (TMATB).³⁸ It was obtained by treating tetramethylammonium bromide with bromine in acetic acid. The product TMATB was found to contain 50.9% of active bromine. Its brominating property was studied by Avramoff and coworkers. TMATB furnished the sole nuclear bromination product, 2-acetyl-5-bromo-6-methoxynaphthalene when reacted with 2-acetyl-6-methoxy-naphthalene in acetic acid but gave α -brominated product with change in reaction conditions (Scheme IIA.1.3.1.1).³⁹



Scheme IIA.1.3.1.1

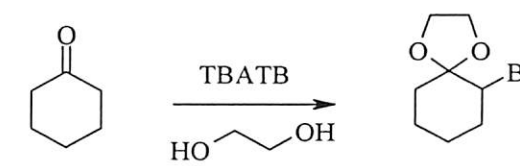
Tetra-*n*-butylammonium tribromide (TBATB) was proved to be an excellent brominating agent as reported by Buckles group.⁴⁰ Berthelot and coworkers have studied extensively on the bromination of different organic compounds with TBATB. Phenols and amines have been brominated with TBATB to give the corresponding *p*-bromo product in CHCl_3 . A mechanism involving electrophilic substitution by the tribromide has been suggested to account for the monobromination at the para position of phenols and amines in aprotic and non-basic solvents.⁴¹ Chaudhuri *et al.* has developed an environmentally benign route for the preparation of TBATB using peroxovanadium (V)-mediated biomimetic oxidation of bromide circumventing the use of Br_2 or HBr .⁴²

Stereoselective bromination of alkynes by TBATB has also been reported. Unlike the other reported methods using bromine, TBATB in CCl_4 gives the (*E*)-isomer exclusively (Scheme IIA.1.3.1.2).⁴³



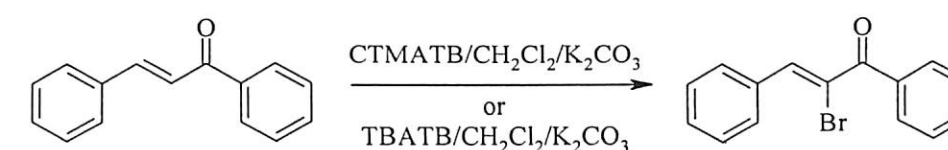
Scheme IIA.1.3.1.2

TBATB has been shown to be a convenient reagent for α -bromination of ketones, but when reacted in the presence of ethylene glycol simultaneously keto protection was observed (Scheme IIA.1.3.1.3).⁴⁴



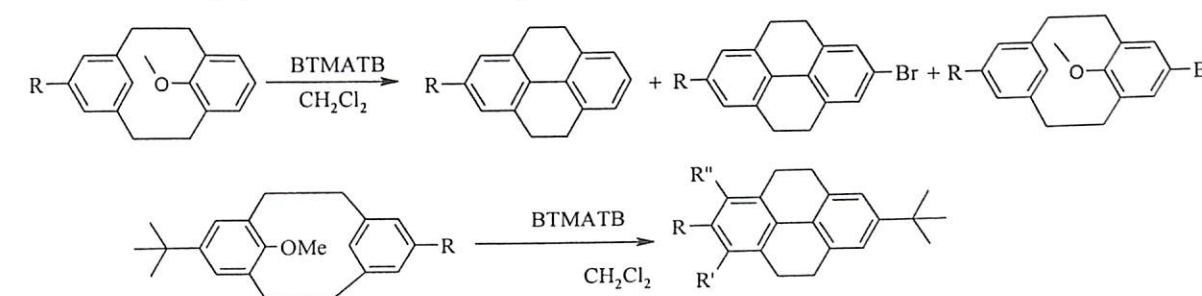
Scheme IIA.1.3.1.3

Khan *et al.* has reported a convenient and useful method for preparation of various acyclic and cyclic α -bromo enones from the corresponding enones using TBATB and CTMATB. The dibromoderivative of enone undergoes elimination in the presence of K_2CO_3 giving α -bromo enones (Scheme IIA.1.3.1.4).⁴⁵



Scheme IIA.1.3.1.4

Benzyl trimethylammonium tribromide (BTMATB) is one of the extensively used tribromide reagent for the bromination of various organic compounds. It has been used for bromination of phenols, aromatic amines and ketones.⁴⁶ When 8-methoxy [2.2]metacyclophanes was treated with BTMATB in dichloromethane, the transannular reaction products, tetrahydropyrene and 2-bromo-4,5,9,10-tetrahydropyrene are obtained along with 5-bromo-8-methoxy[2.2]metacyclophanes. Under the identical conditions 5-*tert*-butyl-8-methoxy[2.2] metacyclophanes gave tetrahydropyrene derivatives exclusively (Scheme IIA.1.3.1.5).⁴⁷

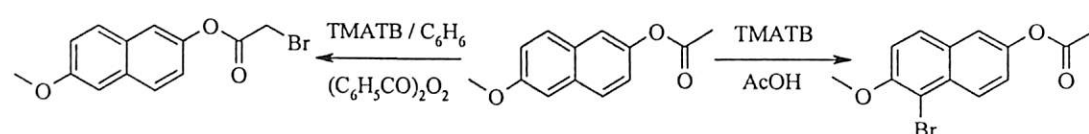


Scheme IIA.1.3.1.5

Phenyl trimethylammonium tribromide (PTATB) is a good source of bromine when dissolved in THF and its reactivity is different from molecular bromine. It is found to be much less electrophilic and is less reactive towards aromatic rings and double bonds as compared to molecular bromine. α -

IIA.1.3.1. Bromination Using Tribromides

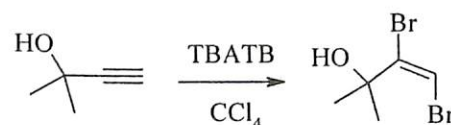
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Scheme IIA.1.3.1.1

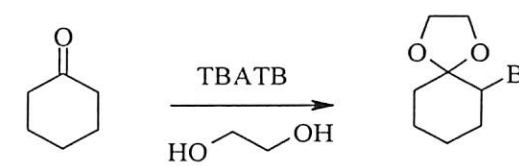
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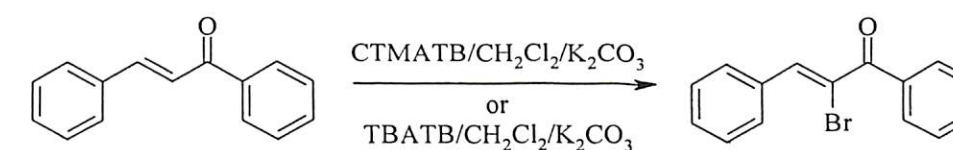
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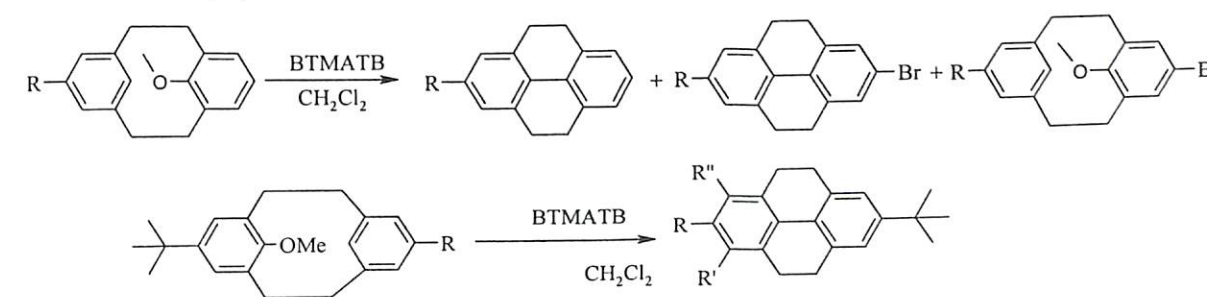
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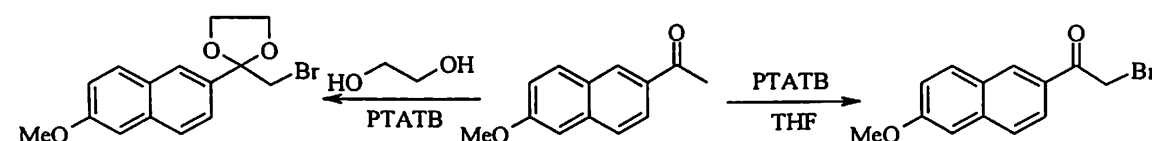


Scheme IIA.1.3.1.5

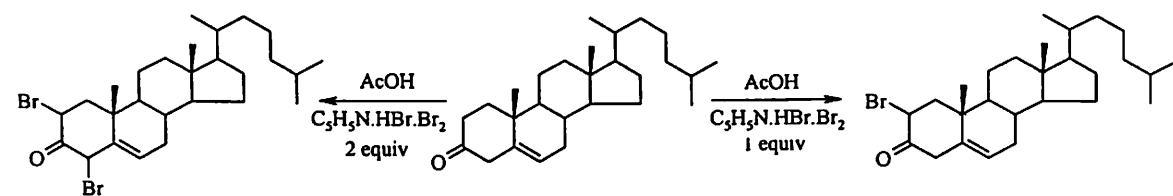
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Bromination of ketones are achieved preferentially as compared to ring bromination using (PTATB)

Scheme IIA.1.3.1.6.⁴⁸



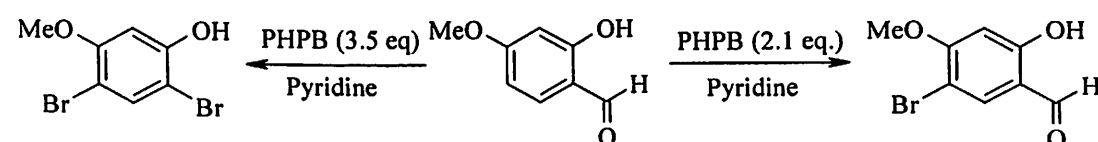
Scheme IIA.1.3.1.6



Scheme IIA.1.3.1.7

Djerassi and Scholz introduced another brominating agent, pyridine hydrobromide perbromide ($C_5H_5N.HBr.Br_2$ or PHPB) which is prepared using equimolar amounts of bromine, pyridine and HBr (48% aq. solution). The red prismatic crystals of PHPB with a melting point of 134 °C were crystallized from acetic acid with 45% available bromine.⁴⁹ PHPB has been used for numerous brominations including selective bromination of aromatic ethers, bromination of trans-2e,3e-diarylcyclohexanones and anilines.⁵⁰ Using PHPB monobrominated product, 2-bromo cholestanone and the dibromo derivative, 2,4-dibromo cholestanone were obtained when used in 1 and 2 equivalents respectively with cholestanone, Scheme IIA.1.3.1.7.

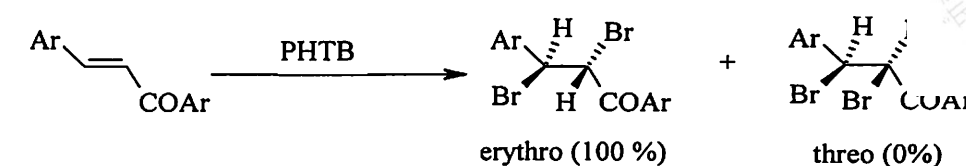
The reaction of o-hydroxy or o-methoxy substituted aromatic aldehydes with PHPB in pyridine gives aromatic bromination product along with product arising from *ipso* bromodeformylation (Scheme IIA.1.3.1.8).⁵¹



Scheme IIA.1.3.1.8

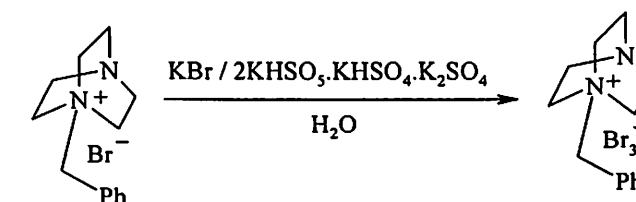
Tanaka and his coworkers have shown that bromination of stilbenes and chalcone proceeds efficiently and stereoselectively in the presence PHPB in an aqueous medium Scheme IIA.1.3.1.9.⁵²

The product obtained can be isolated very easily by just filtration.



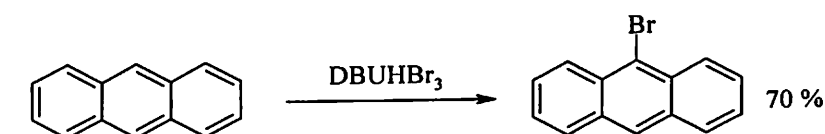
Scheme IIA.1.3.1.9

Synthesis of another tribromide reagent, 1-benzyl-4-aza-1-azonia-bicyclo [2.2.2] octane tribromide obtained by the addition of an aqueous solution of oxone[®] to a solution of 1-benzyl-4-aza-1-azonia-bicyclo[2.2.2]octane bromide and KBr has been shown by Hajipour *et al.* (Scheme IIA.1.3.1.10).⁵³ This is a reactive but selective reagent for the bromination of aniline in the presence of methanol and $CaCO_3$.



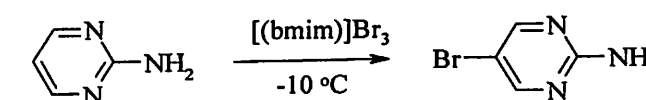
Scheme IIA.1.3.1.10

Muathen has reported the synthesis of a stable tribromide, 1,8-diazabicyclo[5.4.0]undec-7-ene hydrotribromide (DBUHBr₃). It can be readily obtained by the action of an equimolar amount of bromine with DBU in the presence of HBr in acetic acid. This reagent efficiently brominates various organic substrates including ring bromination of anthracene (Scheme IIA.1.3.1.11).⁵⁴



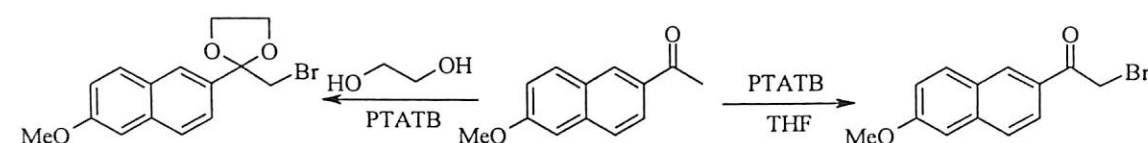
Scheme IIA.1.3.1.11

Chen group has reported a ionic liquid type tribromide, 1-butyl-3-methylimidazolium tribromide [(bmim)Br₃], which is found to be an efficient reagent for the regioselective bromination of anilines, Scheme IIA.1.3.1.12.⁵⁵

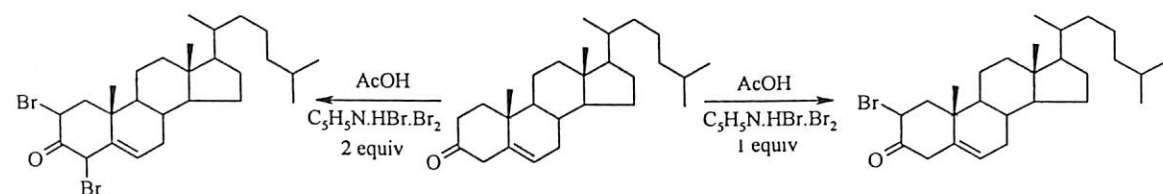


Scheme IIA.1.3.1.12

Bromination of ketones are achieved preferentially as compared to ring bromination using (PTATB) Scheme IIA.1.3.1.6.⁴⁸



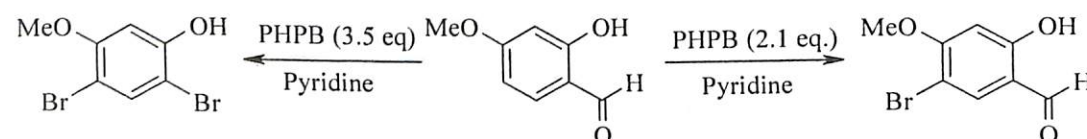
Scheme IIA.1.3.1.6



Scheme IIA.1.3.1.7

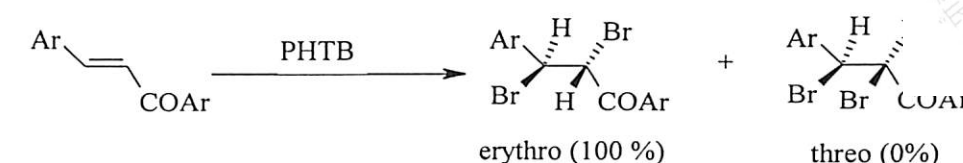
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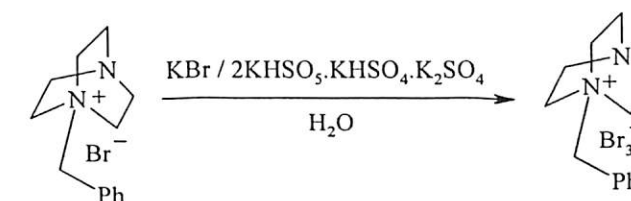
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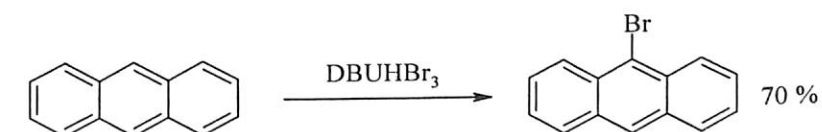
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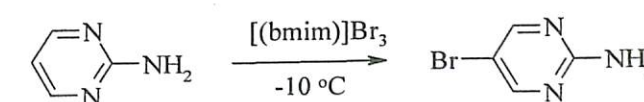
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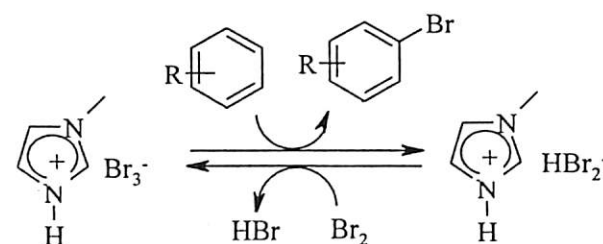
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Chen group has reported a ionic liquid type tribromide, 1-butyl-3-methylimidazolium tribromide [(bmim)Br₃], which is found to be an efficient reagent for the regioselective bromination of anilines, Scheme IIA.1.3.1.12.⁵⁵



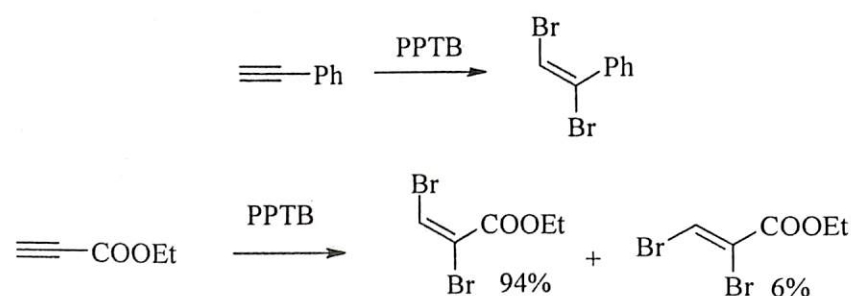
Scheme IIA.1.3.1.12

Chiappe *et al.* has described the bromination of aromatic compounds with 3-methylimidazolium tribromide [(Hmim)Br₃]. The reagent 3-methylimidazolium tribromide [(Hmim)Br₃] has been prepared from the corresponding bromide and molecular bromine (Scheme IIA.1.3.1.13). The red solid thus obtained (m.p. 70 °C) is stable, easy to handle and can be stored in the dark for several months without any degradation.⁵⁶



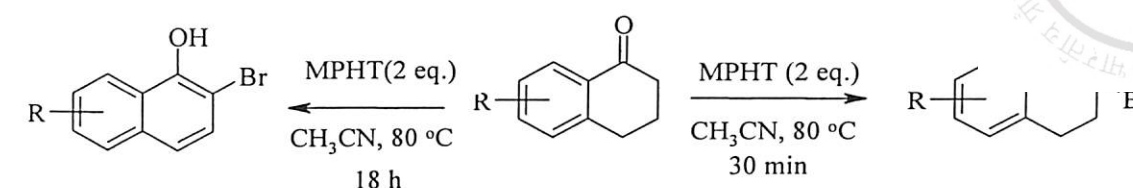
Scheme IIA.1.3.1.13

Salazar *et al.* has reported the synthesis of a room temperature ionic liquid tribromide, pentylpyridinium tribromide (PPTB), upon addition of an equimolar amount of bromine to a solid crushed pentylpyridinium bromide. This reagent served as a vapor pressure free bromine analogue for bromination of ketones, aromatics, alkenes and alkynes. Dibromination of phenylacetylene afforded one sole isomer in excellent yield where as ethylpropyolate led to a mixture of *cis-trans* isomers, Scheme IIA.1.3.1.14.⁵⁷



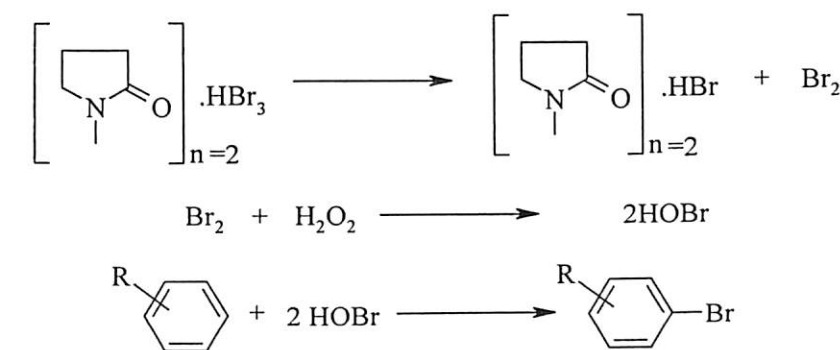
Scheme IIA.1.3.1.14

Provot group have investigated the reaction of the N-methylpyrrolidin-2-one hydrotribromide (MPHT) with substituted-1-tetralones. This reagent was proved to be successful for selective α,α -dibromination of tetralones. Moreover under base-free conditions and longer reaction time, several 2-bromo-1-naphthols were obtained from tetralones in one-pot sequence in good to excellent yields, Scheme IIA.1.3.1.15.⁵⁸



Scheme IIA.1.3.1.15

A regioselective and highly efficient method for the bromination of various aromatic compounds using *N*-methylpyrrolidin-2-one hydrotribromide (MPHT) and aqueous hydrogen peroxide has been reported. The use of MPHT alone as brominating agent gave poor yields while the addition of aqueous hydrogen peroxide enhanced the reaction rate and improves yields, Scheme IIA.1.3.1.16.⁵⁹



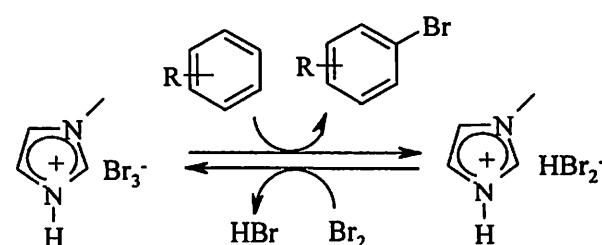
Scheme IIA.1.3.1.16

In addition to serving as useful brominating agents, these reagents has also been used for several other organic transformations including oxidation, cyclization, azidation of alkenes and preparation of primary amines from amides following Hoffman method.

IIA.1.3.2. Oxidation Reactions Using Tribromides

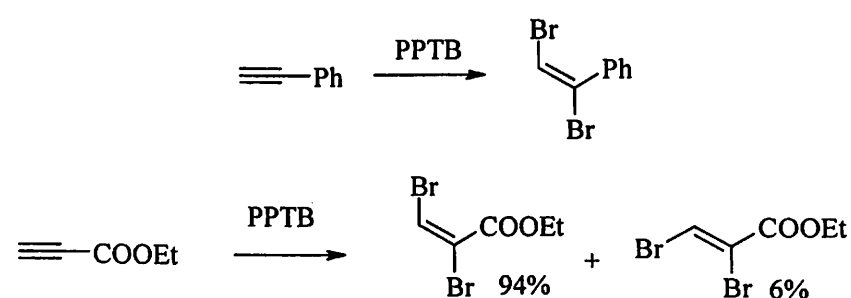
Organic ammonium tribromides being bromine equivalent has oxidizing properties similar to molecular bromine. Numerous reports are known in the literature for the oxidation of alcohols to carbonyl compounds using tribromides.⁶⁰ Organic tribromides have been used for the oxidation of phenols. Oxidation of phenols, such as 1,4-benzenediols and 2,6-di-*tert*-butyl-*p*-methylphenol with benzyltrimethylammonium tribromide in CH₂Cl₂-H₂O yields corresponding *p*-benzoquinone as the exclusive product.⁶¹ On the other hand, the reaction of 1,4-benzenediols with a large excess of the reagent gave poly bromo-substituted 2,5-cyclohexadiene-1,4-diones in good yields.⁶²

Chiappe *et al.* has described the bromination of aromatic compounds with 3-methylimidazolium tribromide [(Hmim)Br₃]. The reagent 3-methylimidazolium tribromide [(Hmim)Br₃] has been prepared from the corresponding bromide and molecular bromine (Scheme IIA.1.3.1.13). The red solid thus obtained (m.p. 70 °C) is stable, easy to handle and can be stored in the dark for several months without any degradation.⁵⁶



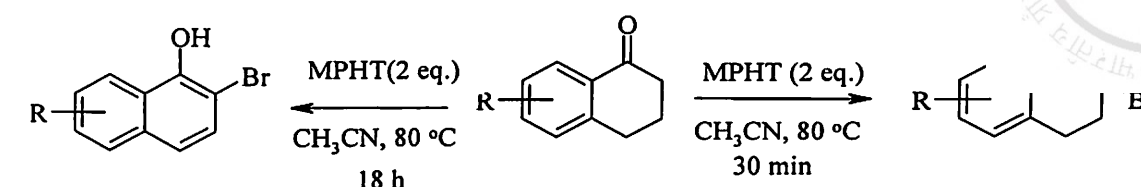
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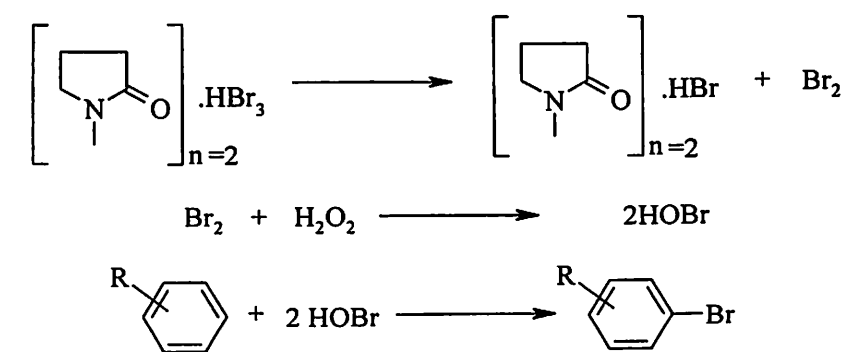
Scheme IIA.1.3.1.14

Provot group have investigated the reaction of the N-methylpyrrolidin-2-one hydrotribromide (MPHT) with substituted-1-tetralones. This reagent was proved to be successful for selective α,α -dibromination of tetralones. Moreover under base-free conditions and longer reaction time, several 2-bromo-1-naphthols were obtained from tetralones in one-pot sequence in good to excellent yields, Scheme IIA.1.3.1.15.⁵⁸



Scheme IIA.1.3.1.15

A regioselective and highly efficient method for the bromination of various aromatic compounds using *N*-methylpyrrolidin-2-one hydrotribromide (MPHT) and aqueous hydrogen peroxide has been reported. The use of MPHT alone as brominating agent gave poor yields while the addition of aqueous hydrogen peroxide enhanced the reaction rate and improves yields, Scheme IIA.1.3.1.16.⁵⁹



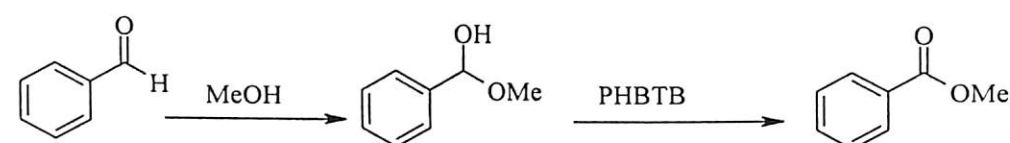
Scheme IIA.1.3.1.16

In addition to serving as useful brominating agents, these reagents has also been used for several other organic transformations including oxidation, cyclization, azidation of alkenes and preparation of primary amines form amides following Hoffman method.

IIA.1.3.2. Oxidation Reactions Using Tribromides

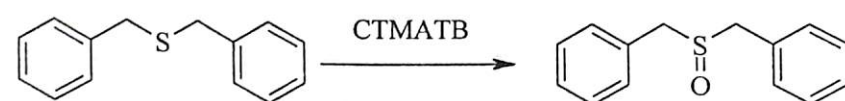
Organic ammonium tribromides being bromine equivalent has oxidizing properties similar to molecular bromine. Numerous reports are known in the literature for the oxidation of alcohols to carbonyl compounds using tribromides.⁶⁰ Organic tribromides have been used for the oxidation of phenols. Oxidation of phenols, such as 1,4-benzenediols and 2,6-di-*tert*-butyl-*p*-methylphenol with benzyltrimethylammonium tribromide in CH₂Cl₂-H₂O yields corresponding *p*-benzoquinone as the exclusive product.⁶¹ On the other hand, the reaction of 1,4-benzenediols with a large excess of the reagent gave poly bromo-substituted 2,5-cyclohexadiene-1,4-diones in good yields.⁶²

An oxidative esterification of aldehyde to esters using pyridinium hydrobromide perbromide (PHPB) and various alcohols is reported by Sayama in water at room temperature. A variety of aldehydes and alcohols were converted to their corresponding esters. This reaction proceeds via a hemiacetal intermediate, Scheme IIA.1.3.2.1.⁶³



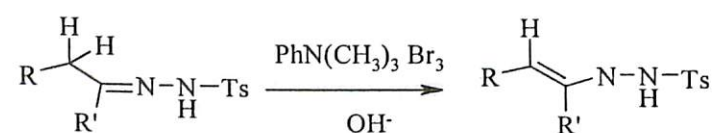
Scheme IIA.1.3.2.1

An efficient method for the large-scale synthesis of symmetrical disulfides and diselenides was developed involving oxidative coupling of corresponding thiols and selenols using bipyridinium hydrobromide perbromide or benzyl trimethyl ammonium tribromide (BTMATB).⁶⁴ Tribromides are convenient reagents for the oxidation of sulphide to sulfoxides (Scheme IIA.1.3.2.2). Various tribromides that have been used include CTMATB, PTMATB, BTMATB and PHBPB.⁶⁵



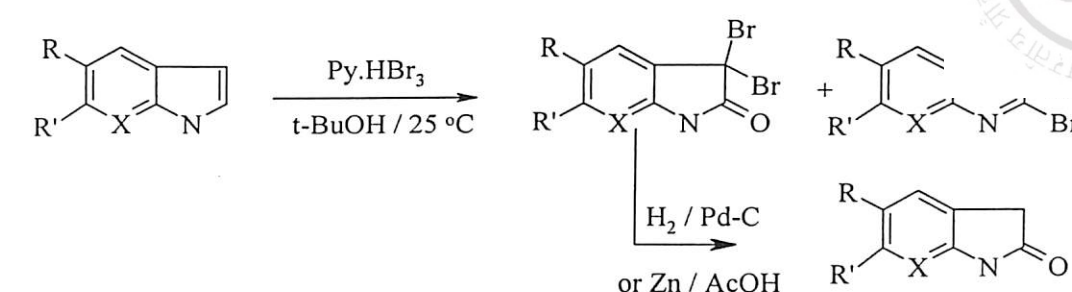
Scheme IIA.1.3.2.2

Tosylhydrazones of enolizable ketone undergo oxidative elimination to tosylazoalkenes under mild basic conditions using phenyl trimethylammonium tribromide, Scheme IIA.1.3.2.3.⁶⁶



Scheme IIA.1.3.2.3

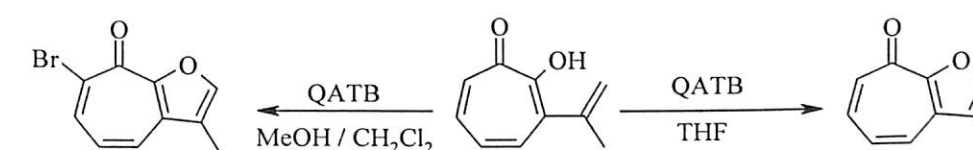
Marfat and his coworkers have developed a two step process for the synthesis oxindoles involving oxidation of indoles using pyridinium hydro bromide perbromide into an intermediate dibromo compound followed by reduction with H₂ / Pd-C or Zn / AcOH to give oxindoles, Scheme IIA.1.3.2.4.⁶⁷



Scheme IIA.1.3.2.4

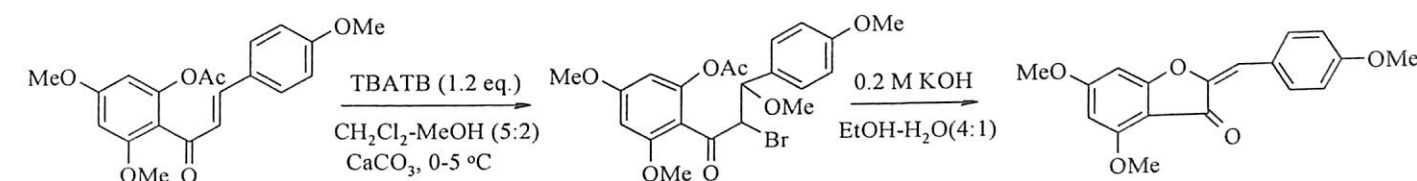
IIA.1.3.3. Cyclization Reactions Using Tribromides

Tribromides are excellent reagents for brominative and oxidative cyclizations. Treatment of 3-isopropenyltropolone with quaternary ammonium tribromide (QATB) in THF afforded 3-methyl-8H-cyclohepta[b]furan-8-one. The same reaction in MeOH-CH₂Cl₂ gave 7-bromo-3-methyl-8H-cyclohepta[b]furan-8-one as shown in Scheme IIA.1.3.3.1.⁶⁸



Scheme IIA.1.3.3.1

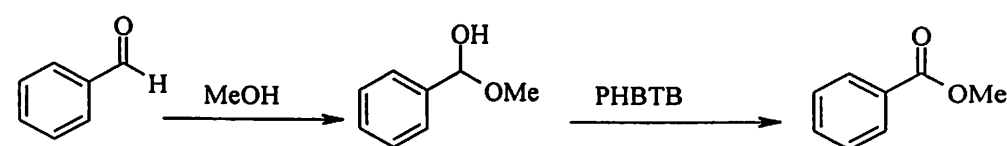
An environmentally benign synthesis of aurones and flavones from 2'-acetoxychalcones using tetrabutylammonium tribromide has been reported by Khan *et al.*⁶⁹ The bromination step is the decisive step which directs the formation of flavone and aurone, Scheme IIA.1.3.3.2.⁶⁹



Scheme IIA.1.3.3.2

Sharpless *et al.* has identified phenyl trimethylammonium tribromide (PTAB) as catalyst for aziridination of alkenes in presence of anhydrous Chloramine- T. The mechanism involves the reaction of olefins with bromonium ion, which undergoes benzylic opening with TsNHCl to give the key intermediate. The latter undergoes attack of Br⁻ on N-Cl bond generating anion. Expulsion of

An oxidative esterification of aldehyde to esters using pyridinium hydrobromide perbromide (PHPB) and various alcohols is reported by Sayama in water at room temperature. A variety of aldehydes and alcohols were converted to their corresponding esters. This reaction proceeds via a hemiacetal intermediate, Scheme IIA.1.3.2.1.⁶³



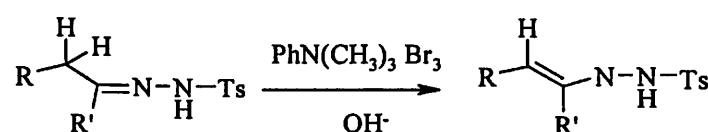
Scheme IIA.1.3.2.1

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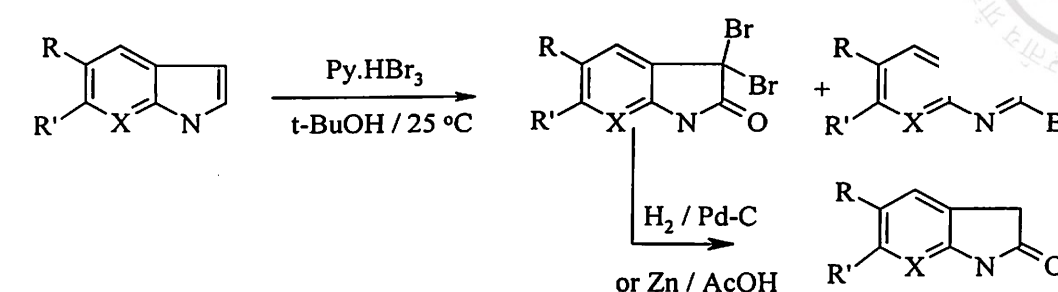
Scheme IIA.1.3.2.2

Tosylhydrazones of enolizable ketone undergo oxidative elimination to tosylazoalkenes under mild basic conditions using phenyl trimethylammonium tribromide, Scheme IIA.1.3.2.3.⁶⁶



Scheme IIA.1.3.2.3

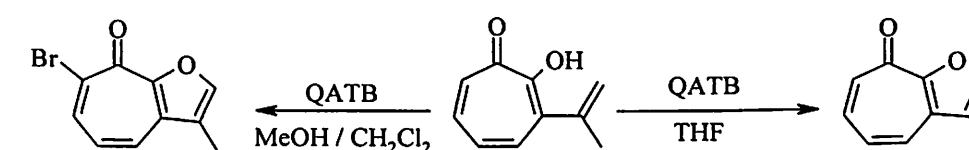
Marfat and his coworkers have developed a two step process for the synthesis oxindoles involving oxidation of indoles using pyridinium hydro bromide perbromide into an intermediate dibromo compound followed by reduction with H₂ / Pd-C or Zn / AcOH to give oxindoles, Scheme IIA.1.3.2.4.⁶⁷



Scheme IIA.1.3.2.4

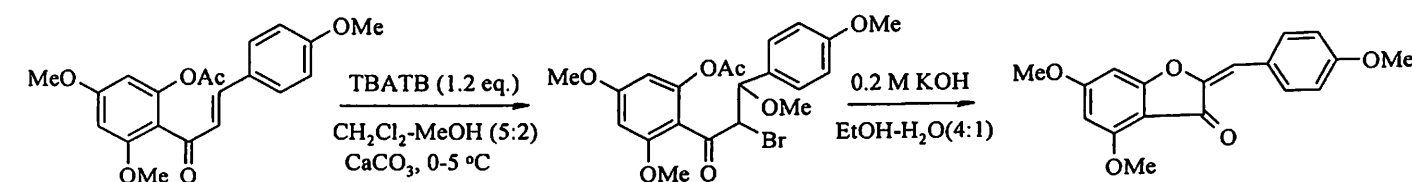
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Scheme IIA.1.3.3.1

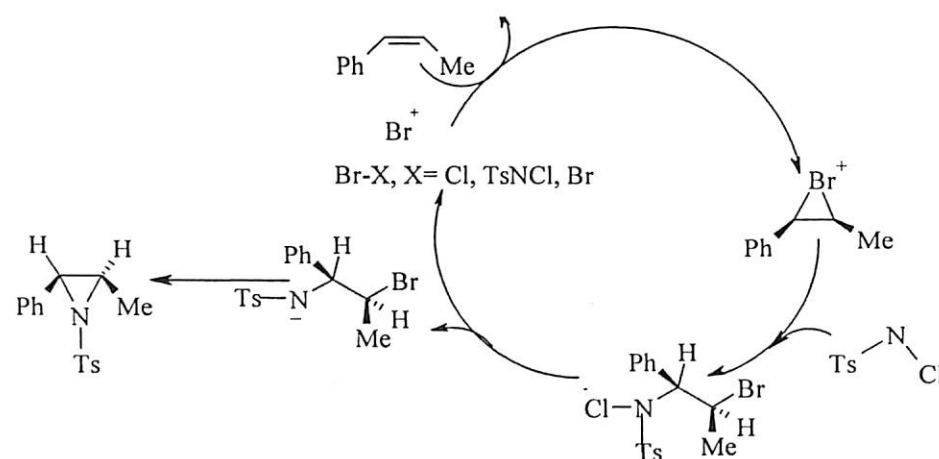
An environmentally benign synthesis of aurones and flavones from 2'-acetoxychalcones using tetrabutylammonium tribromide has been reported by Khan *et al.*⁶⁹ The bromination step is the decisive step which directs the formation of flavone and aurone, Scheme IIA.1.3.3.2.⁶⁹



Scheme IIA.1.3.3.2

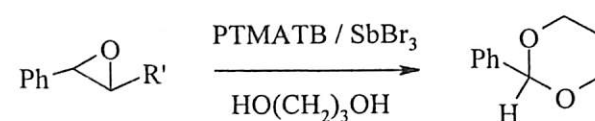
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bromine from anion yields the final aziridine. Subsequently, other triomides such as PHBPB, MHTB has been used for this transformation, Scheme IIA.1.3.3.3.⁷⁰



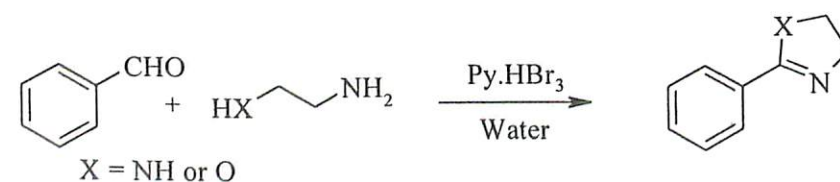
Scheme IIA.1.3.3.3

Trans-stilbene oxide was oxidatively converted to 2-phenyl-1,3-dioxanes with phenyltrimethylammonium tribromide (PTMATB) in the presence of various 1,3-diols and a catalytic amount of SbBr₃ in DMSO at room temperature. Under the similar reaction conditions aromatic 1,2-diol such as hydrobenzoin was converted to 2-aryl-1,3-dioxane derivatives, Scheme IIA.1.3.3.4.⁷¹



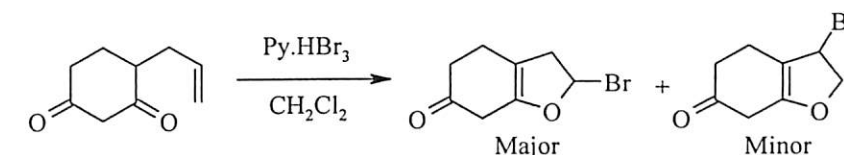
Scheme IIA.1.3.3.4

Various 2-oxazolines were prepared from aromatic aldehydes and 2-aminoethanol with pyridinium hydrobromide perbromide in water at room temperature. 2-Imidazolines were also obtained in good yields from aromatic aldehydes and ethylene diamine (Scheme IIA.1.3.3.5) under the identical reaction conditions.⁷²



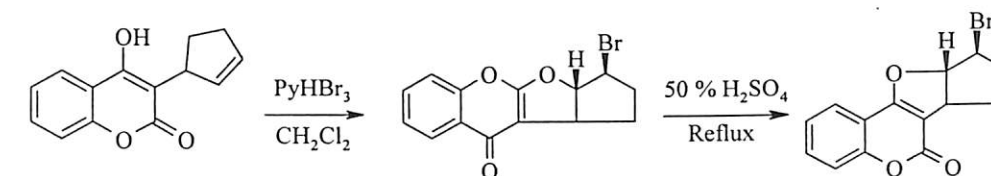
Scheme IIA.1.3.3.5

Reaction of α -allyl-1,3-cyclohexanediones with pyridinium hydrobromide perbromide in dichloromethane afforded a mixture of 2-bromomethyltetrahydrobenzofuran-5-ones (major) and 2-bromomethyltetrahydrobenzopyran-5-ones (minor) products (Scheme IIA.1.3.3.6).⁷³



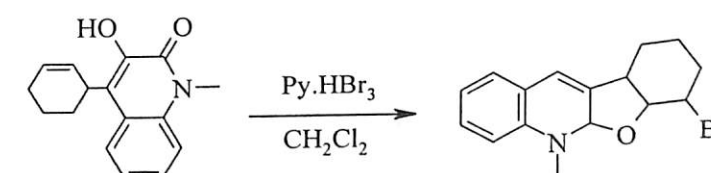
Scheme IIA.1.3.3.6

4-Hydroxy[1]benzopyran-2-one or its acetate, on treatment with pyridine hydrobromide perbromide in dichloromethane at 0-5 °C, gave fused furochromone in 90% yield. These heterocycles undergoes rearrangement to furnish fused furocoumarin in 87% yield (Scheme IIA.1.3.3.7).⁷⁴



Scheme IIA.1.3.3.7

Treatment of 4-cyclohex-2-enyl-3-hydroxy-1-methyl-1H-quinolin-2-one with pyridine hydrobromide perbromide in dichloromethane at 0-5 °C afforded benzofluorene product in excellent yield, Scheme IIA.1.3.3.8.⁷⁵



Scheme IIA.1.3.3.8

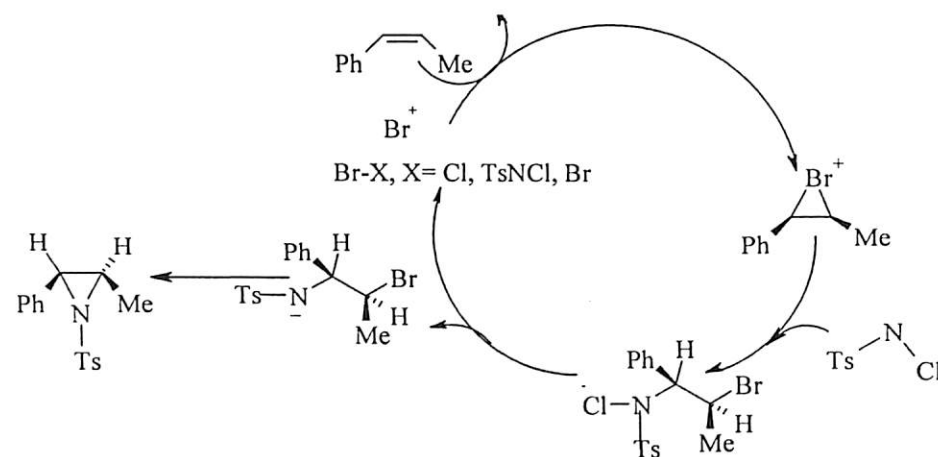
IIA.1.3. 4. Tribromides as Generator of HBr

Reaction of benzyltrimethyl ammonium tribromide in methanol is reported to releases HBr as shown in Scheme IIA.1.3.4.1.⁷⁶



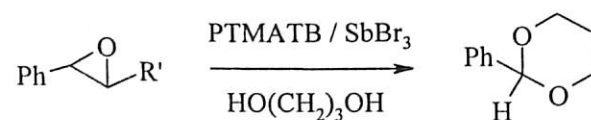
Scheme IIA.1.3.4.1

bromine from anion yields the final aziridine. Subsequently, other triomides such as PHBPB, MHTB has been used for this transformation, Scheme IIA.1.3.3.3.⁷⁰



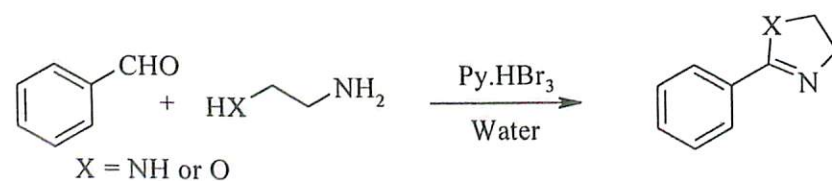
Scheme IIA.1.3.3.3

Trans-stilbene oxide was oxidatively converted to 2-phenyl-1,3-dioxanes with phenyltrimethylammonium tribromide (PTMATB) in the presence of various 1,3-diols and a catalytic amount of SbBr₃ in DMSO at room temperature. Under the similar reaction conditions aromatic 1,2-diol such as hydrobenzoin was converted to 2-aryl-1,3-dioxane derivatives, Scheme IIA.1.3.3.4.⁷¹



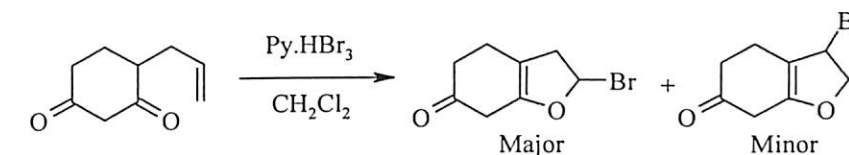
Scheme IIA.1.3.3.4

Various 2-oxazolines were prepared from aromatic aldehydes and 2-aminoethanol with pyridinium hydrobromide perbromide in water at room temperature. 2-Imidazolines were also obtained in good yields from aromatic aldehydes and ethylene diamine (Scheme IIA.1.3.3.5) under the identical reaction conditions.⁷²



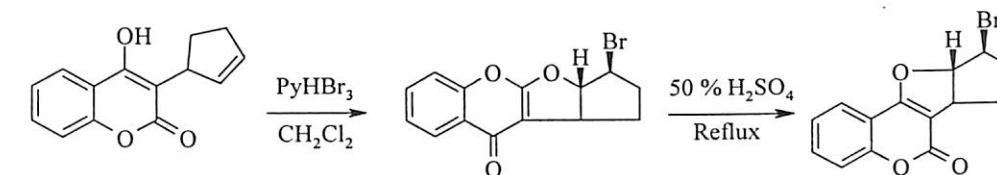
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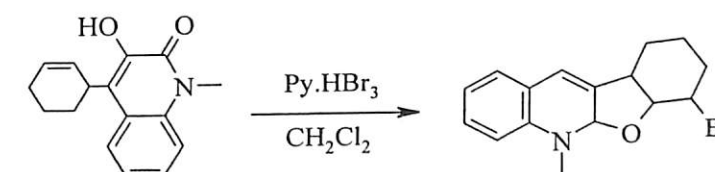
Scheme IIA.1.3.3.6

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Scheme IIA.1.3.3.7

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Scheme IIA.1.3.3.8

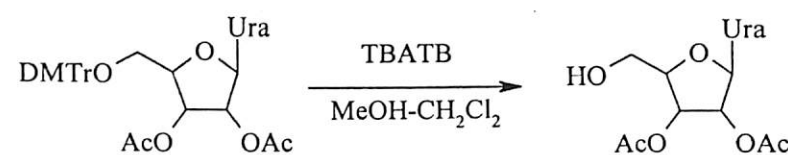
IIA.1.3. 4. Tribromides as Generator of HBr

Reaction of benzyltrimethyl ammonium tribromide in methanol is reported to releases HBr as shown in Scheme IIA.1.3.4.1.⁷⁶



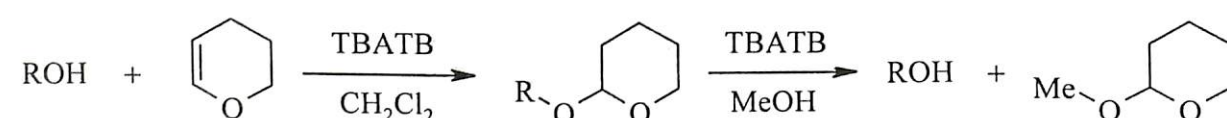
Scheme IIA.1.3.4.1

During last one decade, our group has exploited the acidic property of various tribromides for various useful organic transformations. Tetrabutyl ammonium tribromide (TBATB)-MeOH is an efficient and chemoselective reagent for the cleavage of *tert*-butyldimethylsilyl (TBDMS) ether, Scheme IIA.1.3.4.2.⁷⁷ The solvent dependent study of the cleavage of TBDMS ethers with TBATB highlighted the possibility of tuning the acidity of TBATB in various solvents. Its acidity can be tuned from highly acidic pH to near neutral pH in various organic solvents. It has been inferred that TBATB can readily differentiate THP over TBDMS and TBDMS over TBDPS. The apparent order of stability obtained is phenolic TBDMS > 1° OTBDPS > 2° OTBDMS > 2° OTHP > 1° OTHP > 1° OTBDMS > 1° ODMTr.⁷⁷



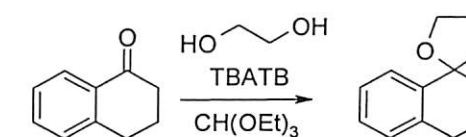
Scheme IIA.1.3.4.2

Alcohols are tetrahydropyranylated rapidly in high yields in the presence of a catalytic amount of TBATB in dichloromethane at room temperature. Depyranylation to their parent alcohol is achieved in quantitative yields by merely changing the solvent to methanol, Scheme IIA.1.3.4.3.⁷⁸



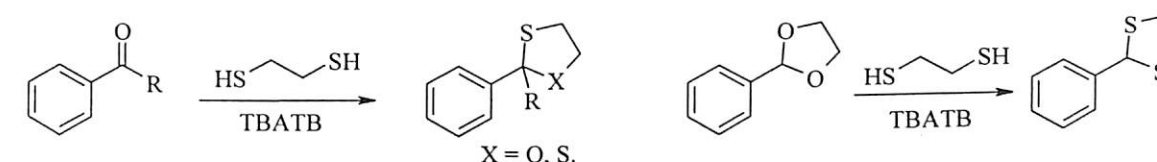
Scheme IIA.1.3.4.3

Our group has also explored the role of tetrabutyl ammonium tribromide (TBATB) as an efficient generator of HBr in the chemoselective acetalization of carbonyl compounds, Scheme IIA.1.3.4.4.⁷⁹ Acyclic and cyclic acetals of various carbonyl compounds were obtained in excellent yields under a mild reaction conditions in the presence of trialkyl orthoformate and a catalytic amount of TBATB in absolute alcohol. Chemoselective acetalization of an aldehyde in the presence of ketone, unsymmetrical acetal formation, the stability of acid sensitive protecting groups and no bromination was observed for substrates amenable to bromination.⁷⁹



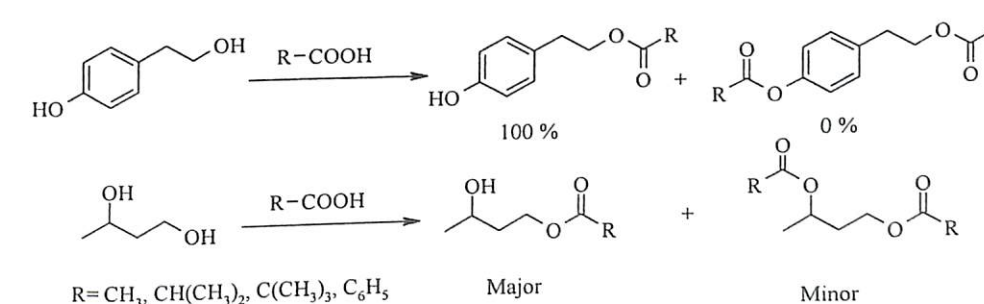
Scheme IIA.1.3.4.4

Thioacetals and thioketals of various aldehydes and ketones were obtained directly from carbonyl compounds or by a transthioacetalization process from cyclic *O,O*-acetals in the presence of dithiols and a catalytic amount of TBATB, Scheme IIA.1.3.4.5.⁸⁰ Chemoselective thioacetalization of aromatic aldehyde containing an electron-donating group in the presence of an aldehyde containing an electron-withdrawing group, aldehydes in presence of ketones, aliphatic cyclic ketones in presence of aromatic ketones and less hindered ketones in presence of more hindered ketones have been achieved. A cyclic acetal containing an electron-donating group has been chemoselectively trans-thioacetalized in the presence of an acetal having an electron-withdrawing substituent.⁸⁰



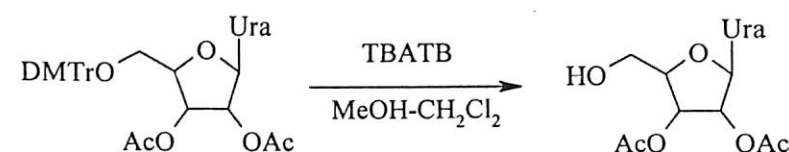
Scheme IIA.1.3.4.5

The direct condensation of various carboxylic acids and alcohols was achieved efficiently at refluxed temperature under a solvent free condition using a catalytic amount of TBATB. Chemoselective acylation of primary alcohols in the presence of secondary alcohols and phenols has been achieved. Steric factors in carboxylic acids played a crucial role during chemoselective acylation of diols, Scheme IIA.1.3.4.6.⁸¹



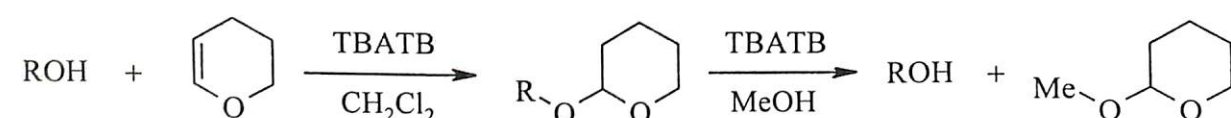
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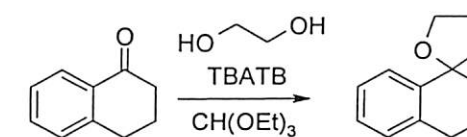
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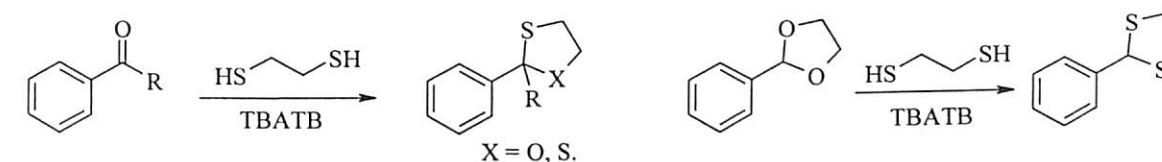
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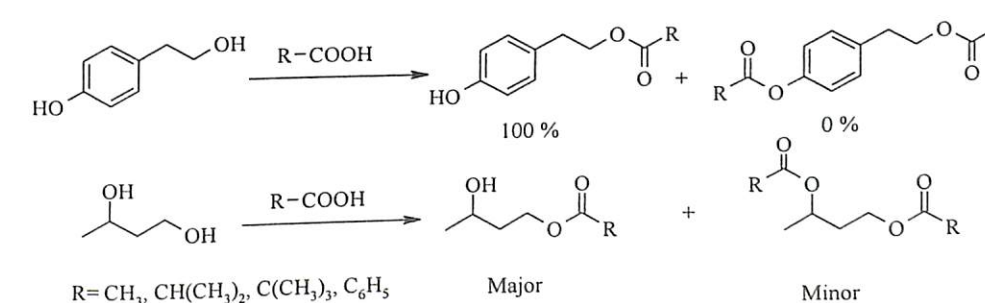
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Scheme IIA.1.3.4.5

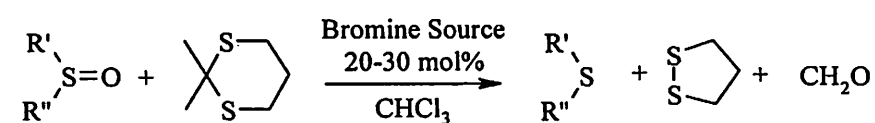
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Scheme IIA.1.3.4.6

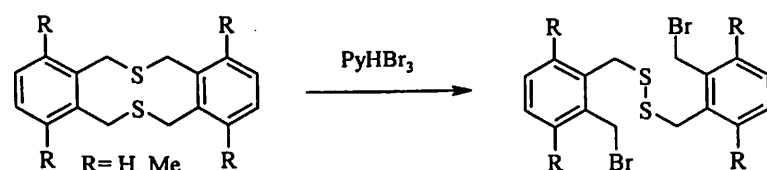
IIA.1.3.5. Miscellaneous Reactions of Tribromides

A new, mild and novel method is described for the efficient deoxygenation of sulfoxides to their corresponding sulfides with 1,3-dithiane at room temperature in the presence of catalytic amount of bromine or its equivalent as the source of electrophilic bromine (Scheme IIA.1.3.5.1).⁸²



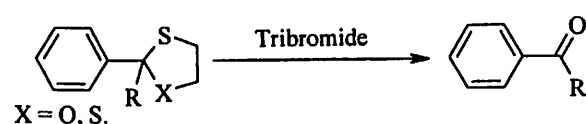
Scheme IIA.1.3.5.1

5,7,12,14-Tetrahydrodibenzo[c,h][1,6]dithieins underwent bromolytic ring cleavage on treatment with pyridinium hydrobromide perbromide to dibromo disulfides (Scheme IIA.1.3.5.2).⁸³



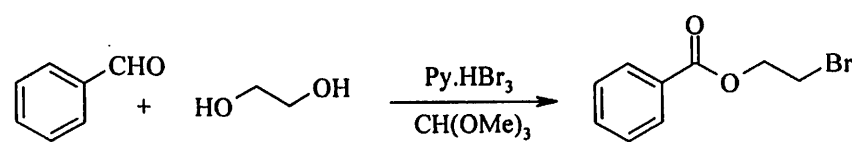
Scheme IIA.1.3.5.2

Oxidative deprotection of dithioacetal and oxo-thioacetal to corresponding carbonyl compound has been reported using TBATB, CTMATB and N-Benzyl-DABCO-tribromide (Scheme IIA.1.3.5.3).^{80b,c,84}



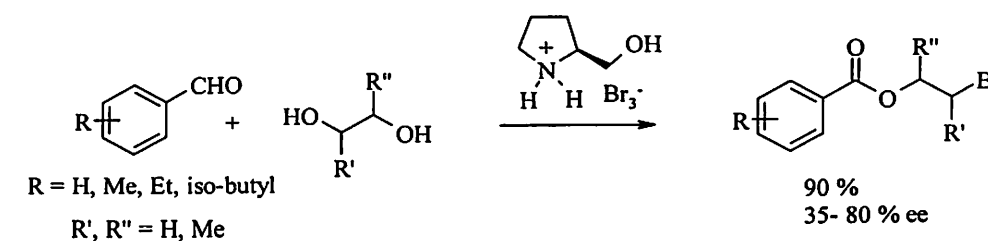
Scheme IIA.1.3.5.3

The synthesis of ω-bromoesters was achieved by treating the aromatic aldehydes and diols in the presence of pyridinium hydrobromide perbromide and trimethyl orthoformate (Scheme IIA.1.3.5.4).⁸⁵



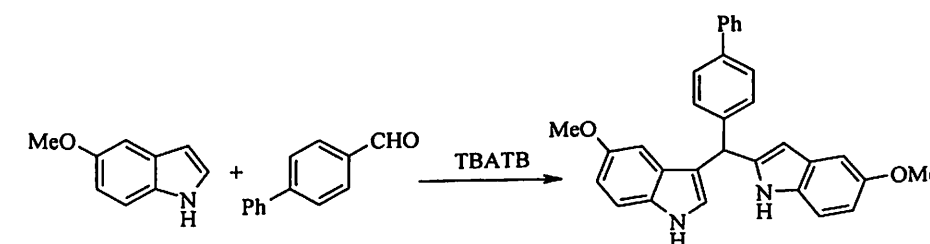
Scheme IIA.1.3.5.4

For the first time chiral ionic liquid tribromides have been directly prolinol by a simple and convenient method in excellent yields. The application of these reagents and solvents for the chemoselective, regioselective, and stereoselective synthesis of 1,2- or 1,3-bromoesters from aromatic aldehydes and 1,2- or 1,3-diols at room temperature has been studied. Good to excellent yields and moderate enantiomeric excesses were obtained under these reaction conditions (Scheme IIA.1.3.5.5).⁸⁶



Scheme IIA.1.3.5.5

Biologically important bis-indolyl methanes are synthesized by electrophilic substitution reaction of indoles with various aldehydes in the presence of a catalytic amount of TBATB in good yields (Scheme IIA.1.3.5.6).⁸⁷



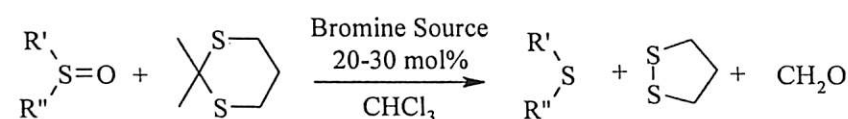
Scheme IIA.1.3.5.6

IIA.2. Benzothiazoles

Benzothiazoles (BTs), a group of xenobiotic compounds containing a phenyl ring fused with a thiazole ring are manufactured worldwide for variety of applications. Benzothiazoles exhibiting various biological activities are found in variety of natural products and hence are important targets in the drug discovery.⁸⁸ Derivatives of benzothiazoles are broadly found in bioorganic and medicinal chemistry with applications in drug discovery and development for the treatment of diabetes,⁸⁹ epilepsy,⁹⁰ inflammation,⁹¹ analgesia,⁹² amyotrophic lateral sclerosis,⁹³ tuberculosis,⁹⁴ antitumour,⁹⁵

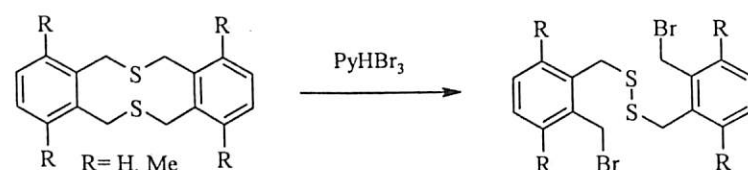
IIA.1.3.5. Miscellaneous Reactions of Tribromides

A new, mild and novel method is described for the efficient deoxygenation of sulfoxides to their corresponding sulfides with 1,3-dithiane at room temperature in the presence of catalytic amount of bromine or its equivalent as the source of electrophilic bromine (Scheme IIA.1.3.5.1).⁸²



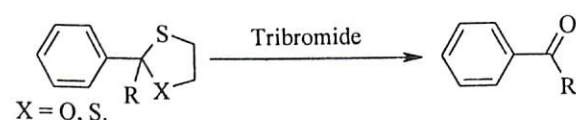
Scheme IIA.1.3.5.1

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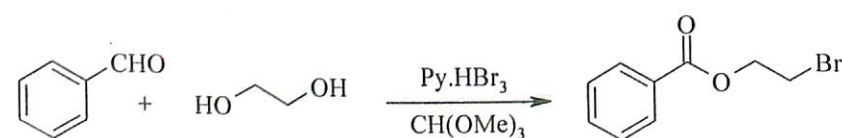
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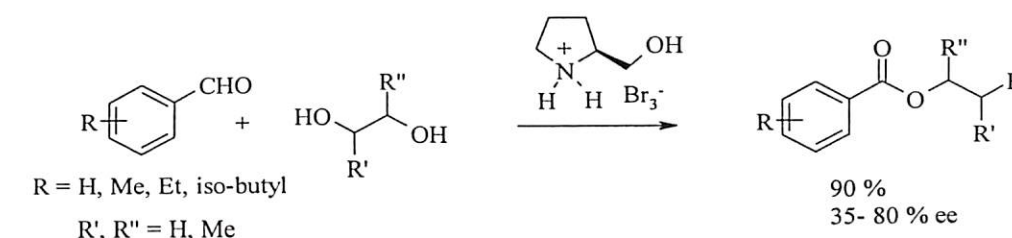
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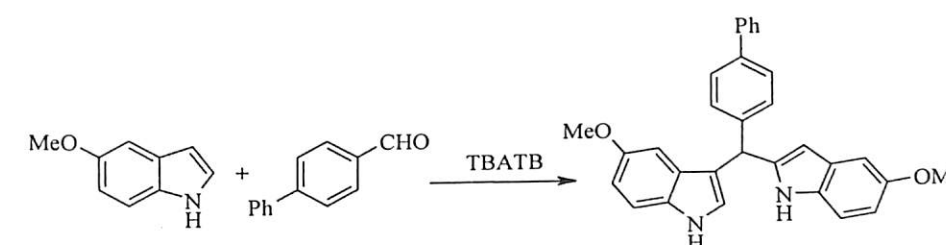
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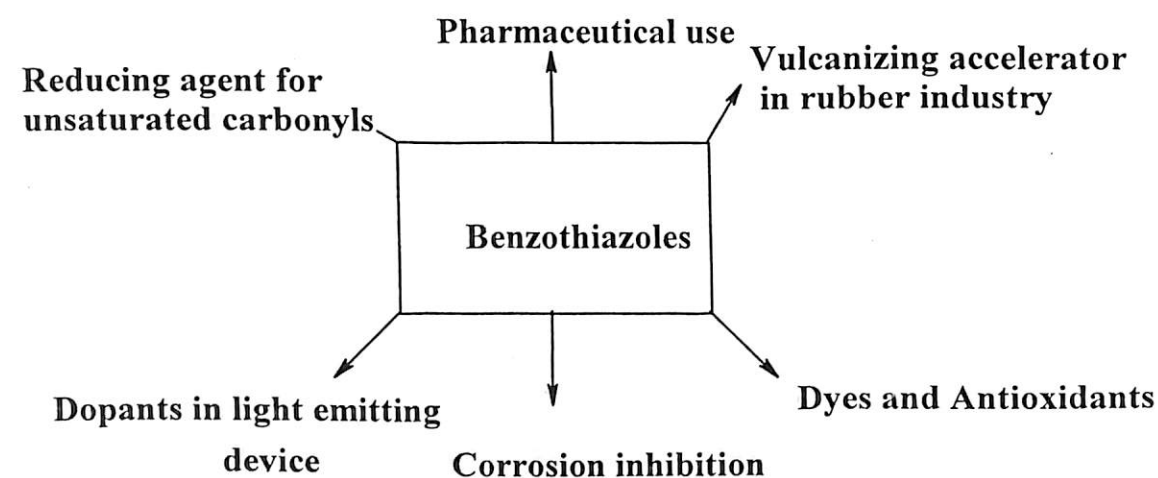


Scheme IIA.1.3.5.6

IIA.2. Benzothiazoles

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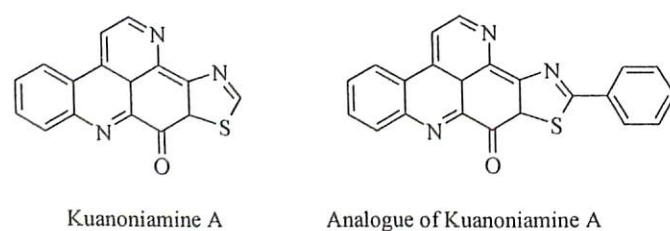
antimicrobial,⁹⁶ anti-viral⁹⁷ and plant growth regulation.⁹⁸ Derivatives of benzothiazoles also exhibit wide spectrum of biological activity such as Ca^{2+} channel antagonist,⁹⁹ inhibitor of enzymes such as aldose reductase,¹⁰⁰ monoamine oxidase,¹⁰¹ cyclooxygenase,¹⁰² proteases,¹⁰³ H^+ - K^+ ATPase,¹⁰⁴ carbonic anhydrase¹⁰⁵ and HCV helicase¹⁰⁶



Scheme IIA.2.1. Applications of benzothiazoles.

Other useful industrial applications are antioxidants,¹⁰⁷ vulcanization accelerators in rubber industries,¹⁰⁸ as dopant in a light emitting organic electroluminescent device¹⁰⁹ and photo sensitizers in the photo degradation of polyvinyl chloride (PVC).¹¹⁰ Apart from these, benzothiazoles also served as an important intermediates for the synthesis of natural products and reducing agents for the reduction of α, β -unsaturated carbonyl compounds.¹¹¹ Industrial applications of benzothiazoles is summarized in Scheme IIA.2.1.

Some of the naturally occurring benzothiazoles has also been isolated. As an example, analogues of Kuanoniamine A which constitute a group of marine alkaloids exhibit good pharmacological activity (Scheme IIA.2.2).¹¹²



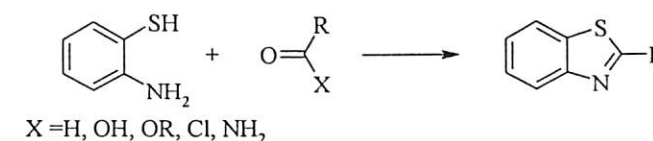
Scheme IIA.2.2

IIA.2. 1. Methods for Syntheses of Benzothiazoles

Several procedures has been developed for the synthesis of benzothiazoles which can be broadly classified into following five category:

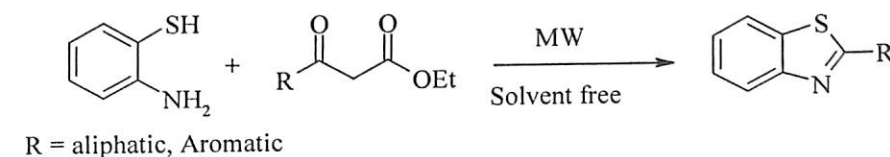
- Condensation of 2-amino thiophenol with carbonyl compounds.
- Oxidative cyclization of thioamides or thioureas.
- Intramolecular nucleophilic aromatic substitution of 2-halo thioamides.
- Radical cyclization and
- Miscellaneous methods.

IIA.2. 1. 1. Condensation of 2-Amino Thiophenol with Carbonyl Compounds



Scheme IIA.2.1.1.1.

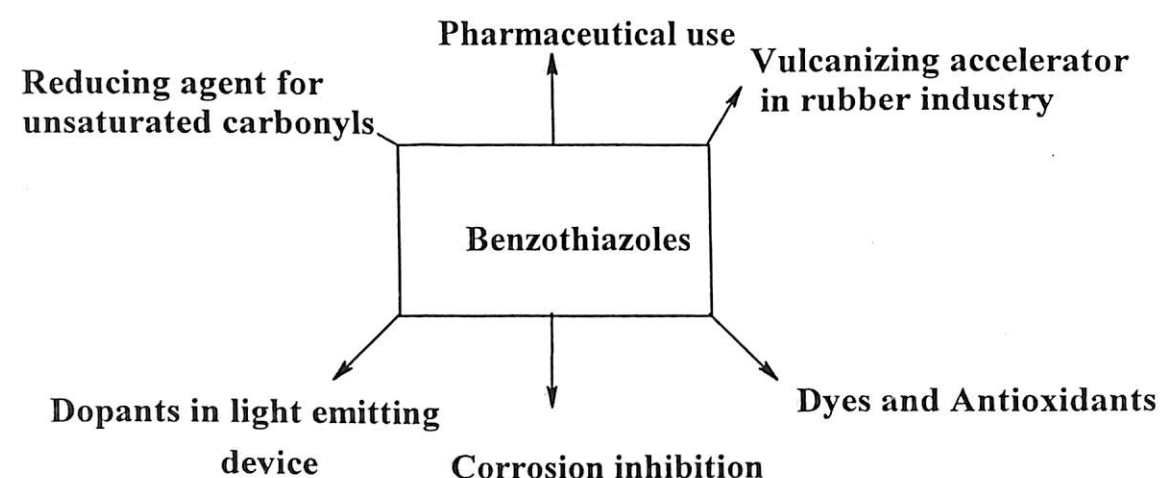
Condensation of 2-amino thiophenol with carbonyl compounds such as aldehydes, acids or esters in the presence of acidic catalyst is one of the method for the construction of bezothiazoles, Scheme IIA.2.1.1.1. Reagents used for this condensation are iodine,¹¹³ silica gel supported sodium hydrogen sulfate,¹¹⁴ zirconium(IV) compound / CuSO_4 ,¹¹⁵ silica or montomorillonite clay under microwave,¹¹⁶ poly phosphoric acid,¹¹⁷ P_2O_5 - MeSO_3H ,¹¹⁸ SOCl_2 ,¹¹⁹ $\text{NMP-K}_2\text{CO}_3$ ¹²⁰ and $\text{Sc}(\text{OTf})_3$.¹²¹



Scheme IIA.2.1.1.2

Eco-friendly direct solvent-free reactions of 2-amino thiophenol and aromatic or aliphatic β -keto esters with microwave irradiation produced 2-substituted benzothiazoles in excellent yields. The formation of benzothiazoles probably involves the nucleophilic addition of the thiol group to the keto group of the β -keto ester with subsequent elimination of AcOEt to from the resulting adduct. The adduct then undergoes an intramolecular addition of the ortho-amino group to the carbonyl group to

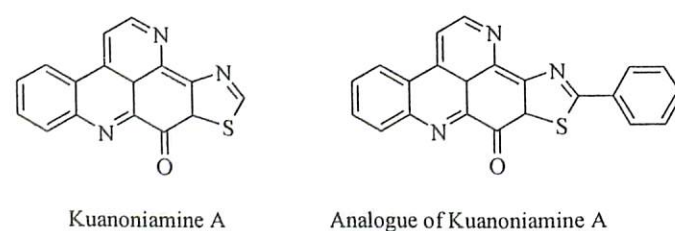
antimicrobial,⁹⁶ anti-viral⁹⁷ and plant growth regulation.⁹⁸ Derivatives of benzothiazoles also exhibit wide spectrum of biological activity such as Ca^{2+} channel antagonist,⁹⁹ inhibitor of enzymes such as aldose reductase,¹⁰⁰ monoamine oxidase,¹⁰¹ cyclooxygenase,¹⁰² proteases,¹⁰³ $\text{H}^+ - \text{K}^+$ ATPase,¹⁰⁴ carbonic anhydrase¹⁰⁵ and HCV helicase¹⁰⁶



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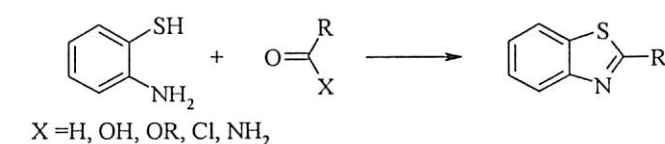
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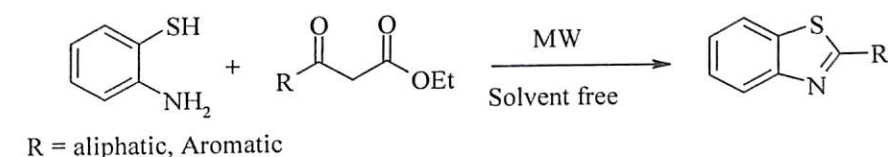
- Condensation of 2-amino thiophenol with carbonyl compounds.
- Oxidative cyclization of thioamides or thioureas.
- Intramolecular nucleophilic aromatic substitution of 2-halo thioamides.
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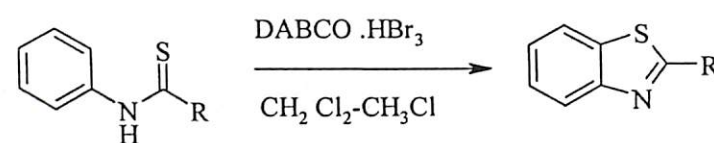
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give an adduct from which water is eliminated to afford the 2-substituted benzothiazoles (Scheme IIA.2.1.1.2).¹²²

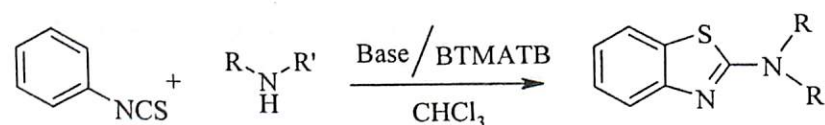
IIA.2.1.2. Oxidative Cyclization of Thioamides or Thioureas

Hugerschhoff reaction involves the reaction of molecular bromine with aryl thiourea to produce 2-amino benzothiazoles (Scheme IIA.2.1.2.1.)¹²³



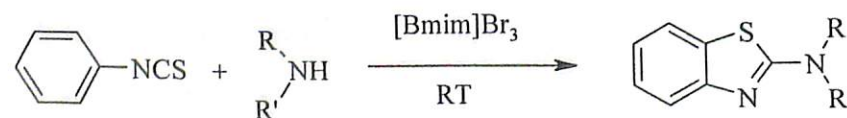
Scheme IIA.2.1.2.1

Recently, solid brominating agent such as N-benzyl-DABCO tribromide and benzyltrimethyl ammonium tribromide (BTMATB) have been utilized as an alternative electrophilic bromine source for the efficient oxidative cyclization of thiobenzanilides and thioureas to their corresponding 2-substituted benzothiazoles under mild conditions.¹²⁴ The later reagent have been used for the one-pot synthesis of 2-amino benzothiazoles from either aryl isothiocyanates and amines or tetrabutyl ammonium thiocyanate and amines, Scheme IIA.2.2.3.



Scheme IIA.2.1.2.2

Le *et al.* has described one-pot direct synthesis of 2-aminobenzothiazoles from phenyl isothiocyanate and amines using 1-butyl-3-methylimidazolium tribromide ([Bmim]Br₃) in ionic liquid 1-butyl-3-methyl-imidazolium tetrafluoroborate ([Bmim]BF₄), Scheme IIA.2.1.2.3.¹²⁶

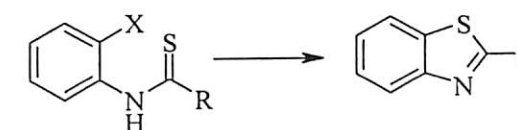


Scheme IIA.2.1.2.4

Using the method of Jacobson employing (K₃[Fe(CN)₆]), several ; oxidative cyclization of thioamides or thioureas to 2-substituted benzothiazoles.

IIA.2.1.3. Intramolecular Nucleophilic Aromatic Substitution of 2-Halo Thioamides or Thioureas

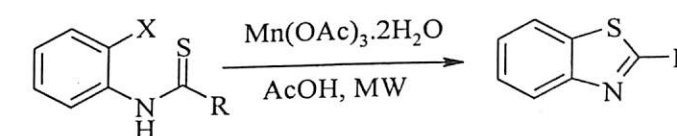
Benzothiazoles can also be synthesized by intramolecular cyclization of 2- halo thiomides or thioureas (Scheme IIA.2.1.3.1) in presence of bases like t-BuOK, NaH-NMP¹²⁷ or metal catalysts (Pd, Cu, Ni).¹²⁸



Scheme IIA.2.1.3.1

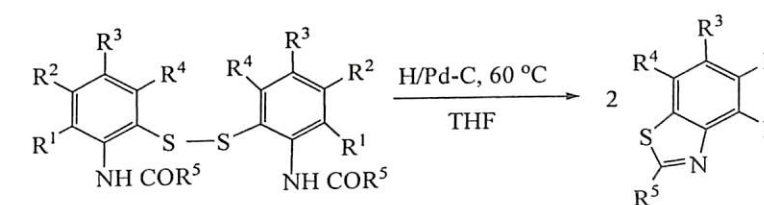
IIA.2.1.4. Radical Cyclization of 2-Halo Thioamide or Thioureas

Radical cyclization of 2-halo thioamides or thioureas leads to the formation of benzothiazoles in presence radical initiators like Bu₃SnH, AIBN or Mn(OAc)₃, Scheme IIA.2.1.4.1.¹²⁹



Scheme IIA.2.1.4.1

IIA.2.1.5. Miscellaneous Methods



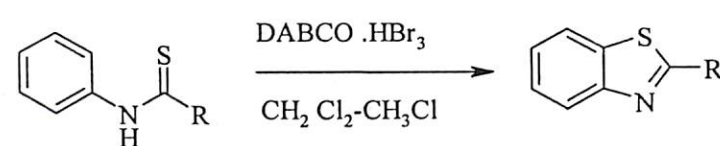
Scheme IIA.2.1.5.1

Benzothiazole derivatives are prepared via reductive cyclization of nitrodisulfides with nitriles promoted by samarium diiodide (SmI₂) or by catalytic hydrogenation (H₂/Pd/C) under mild and neutral conditions to give the required product in good yields, Scheme IIA.2.1.5.1.¹³⁰

give an adduct from which water is eliminated to afford the 2-substituted benzothiazoles (Scheme IIA.2.1.1.2).¹²²

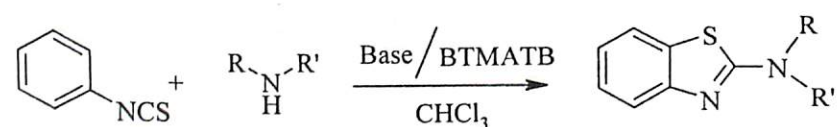
IIA.2.1. 2. Oxidative Cyclization of Thioamides or Thioureas

Hugerschoff reaction involves the reaction of molecular bromine with aryl thiourea to produce 2-amino benzothiazoles (Scheme IIA.2.1.2.1.)¹²³



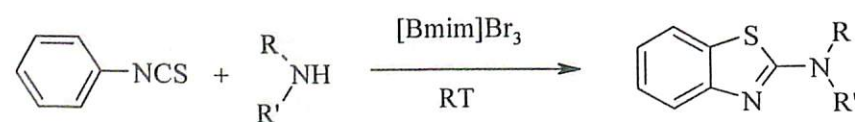
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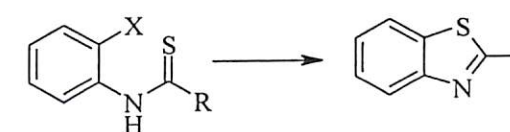


Scheme IIA.2.1.2.4

Using the method of Jacobson employing (K₃[Fe(CN)₆]), several oxidative cyclization of thioamides or thioureas to 2-substituted benzothiazoles

IIA.2.1.3. Intramolecular Nucleophilic Aromatic Substitution of 2-Halo Thioamides or Thioureas

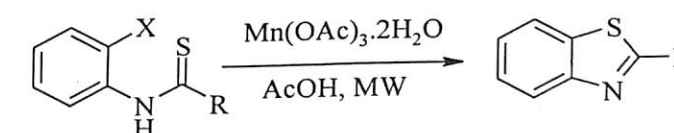
Benzothiazoles can also be synthesized by intramolecular cyclization of 2-halo thiomides or thioureas (Scheme IIA.2.1.3.1) in presence of bases like t-BuOK, NaH-NMP¹²⁷ or metal catalysts (Pd, Cu, Ni).¹²⁸



Scheme IIA.2.1.3.1

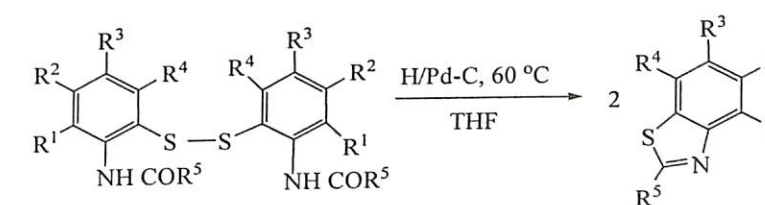
IIA.2.1.4. Radical Cyclization of 2-Halo Thioamide or Thioureas

Radical cyclization of 2-halo thioamides or thioureas leads to the formation of benzothiazoles in presence radical initiators like Bu₃SnH, AIBN or Mn(OAc)₃, Scheme IIA.2.1.4.1.¹²⁹



Scheme IIA.2.1.4.1

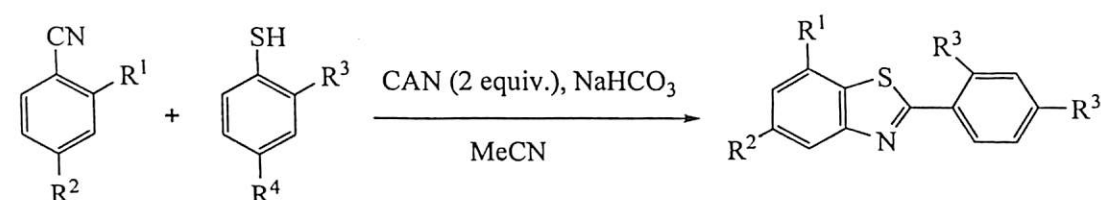
IIA.2.1.5. Miscellaneous Methods



Scheme IIA.2.1.5.1

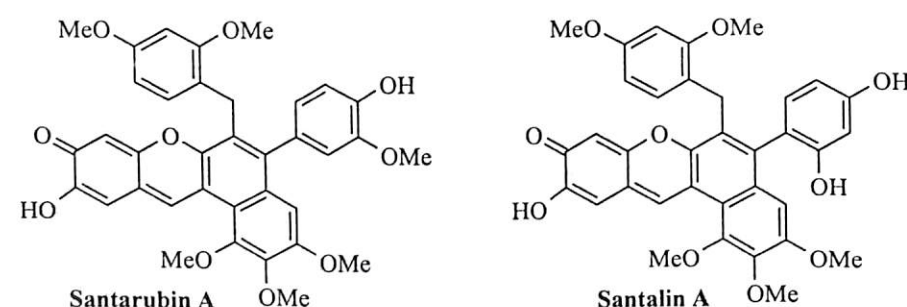
Benzothiazole derivatives are prepared via reductive cyclization of nitrodisulfides with nitriles promoted by samarium diiodide (SmI₂) or by catalytic hydrogenation (H₂/Pd/C) under mild and neutral conditions to give the required product in good yields, Scheme IIA.2.1.5.1.¹³⁰

Ceric ammonium nitrate (CAN) mediated cyclization of the intermediate radical formed after initial oxidative coupling between thiophenols and aromatic nitriles leads to the synthesis of a wide range of 2-aryl benzothiazoles, Scheme IIA.2.1.4.2.¹³¹



Scheme IIA.2.1.4.2

IIA.3. Xathene Derivatives



Scheme IIA.3.1.

Xanthene, also known as 9H-xanthene or 10H-9-oxaanthracene are present in nature and have found diverse applications in organic synthesis. A number of xanthene based compounds are isolated from natural sources. Santalins and santarubins are the red colouring matters of the heartwoods of some Asian and African pterocarpus species which contains xanthene moiety (Scheme IIA.3.1).¹³²

IIA.3.1. Applications of Xanthene Derivatives

IIA.3.1.1. Dyes

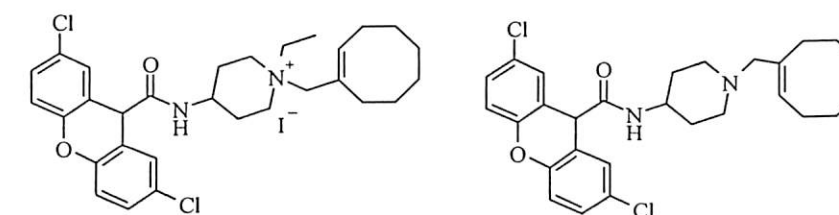
Dyes such as fluorescein, eosins and rhodamines all possess xanthene skeleton. Xanthenes are important class of compounds that find its application as dyes, fluorescent materials for visualization of biomolecules and in laser technologies due to their useful spectroscopic properties.¹³³ Upon

oxidation xanthenes can be converted to corresponding xanthylium salts which are fluorescent materials.¹³⁴

IIA.3.1.2. Pharmaceutical Applications

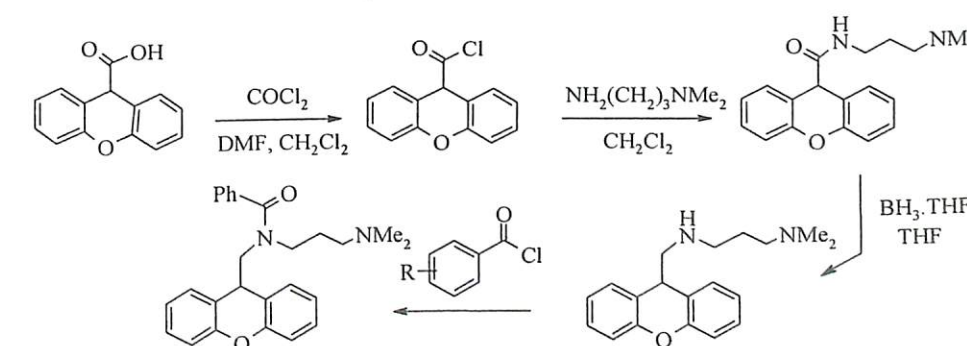
Several pharmaceutically important compounds possess xanthene moieties. They exhibit important biological activities such as anti-inflammatory effects¹³⁵ and antiviral activity.¹³⁶ The alkyl diphenylacetyl, 9H-xanthene and 9H-thioxanthene-carbonyl carbamates behave as selective positive allosteric modulators in rat and human mGlu1 receptor.¹³⁷ Wichmann group has found that these compounds do not directly activate mGlu1 receptors but markedly potentiate agonist stimulated responses increasing potency and maximum efficacy.¹³⁸

Xanthene carboximide derivatives (Scheme IIA.3.1.2.1) possess CCR1 receptor binding affinity and hence used as CCR1 receptor antagonists.¹³⁹



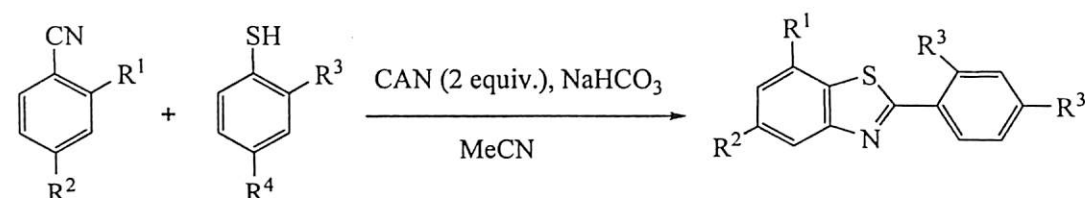
Scheme IIA.3.1.2.1

Chibale's group has designed and synthesized chloroquine-resistant *Plasmodium falciparum* based on the 9H-xanthene tricyclic scaffolds, Scheme IIA.3.1.2.2. The compound contains a common hydrophobic tricyclic 9H-xanthene moiety and an alkyl side chain with two amino groups, one of which is a tertiary substituted terminal amine separated by three carbons and differing only in the chemical nature of the intermediate nitrogen atom.¹⁴⁰



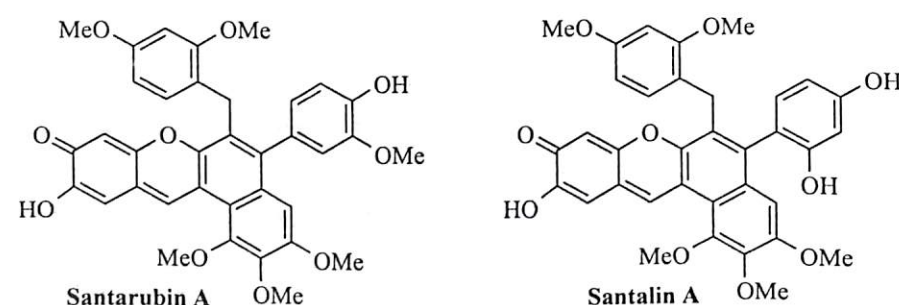
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IIA.3.1. Applications of Xanthene Derivatives

IIA.3.1.1. Dyes

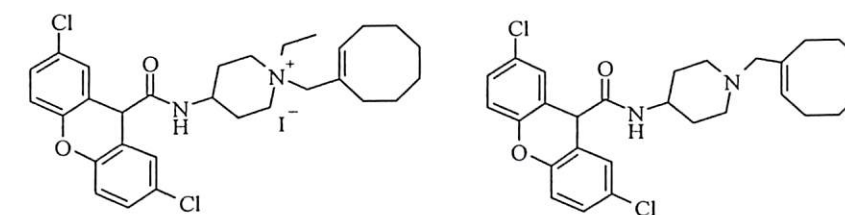
Dyes such as fluorescein, eosins and rhodamines all possess xanthene skeleton. Xanthenes are important class of compounds that find its application as dyes, fluorescent materials for visualization of biomolecules and in laser technologies due to their useful spectroscopic properties.¹³³ Upon

oxidation xanthenes can be converted to corresponding xanthylium salts which are fluorescent materials.¹³⁴

IIA.3.1.2. Pharmaceutical Applications

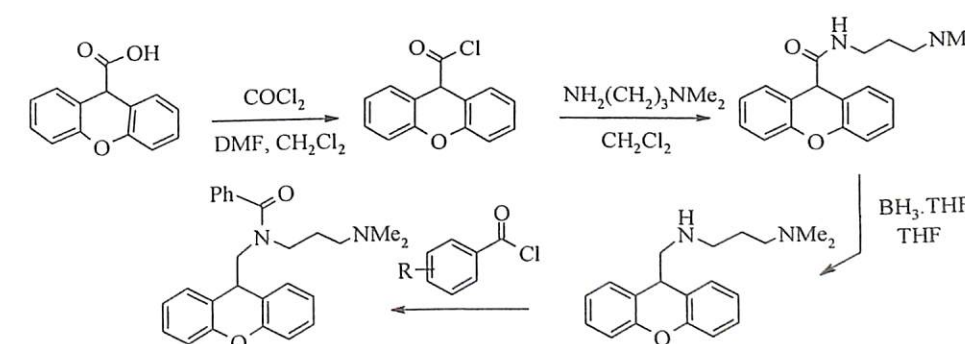
Several pharmaceutically important compounds possess xanthene moieties. They exhibit important biological activities such as anti-inflammatory effects¹³⁵ and antiviral activity.¹³⁶ The alkyl diphenylacetyl, 9H-xanthene and 9H-thioxanthene-carbonyl carbamates behave as selective positive allosteric modulators in rat and human mGlu1 receptor.¹³⁷ Wichmann group has found that these compounds do not directly activate mGlu1 receptors but markedly potentiate agonist stimulated responses increasing potency and maximum efficacy.¹³⁸

Xanthene carboximide derivatives (Scheme IIA.3.1.2.1) possess CCR1 receptor binding affinity and hence used as CCR1 receptor antagonists.¹³⁹



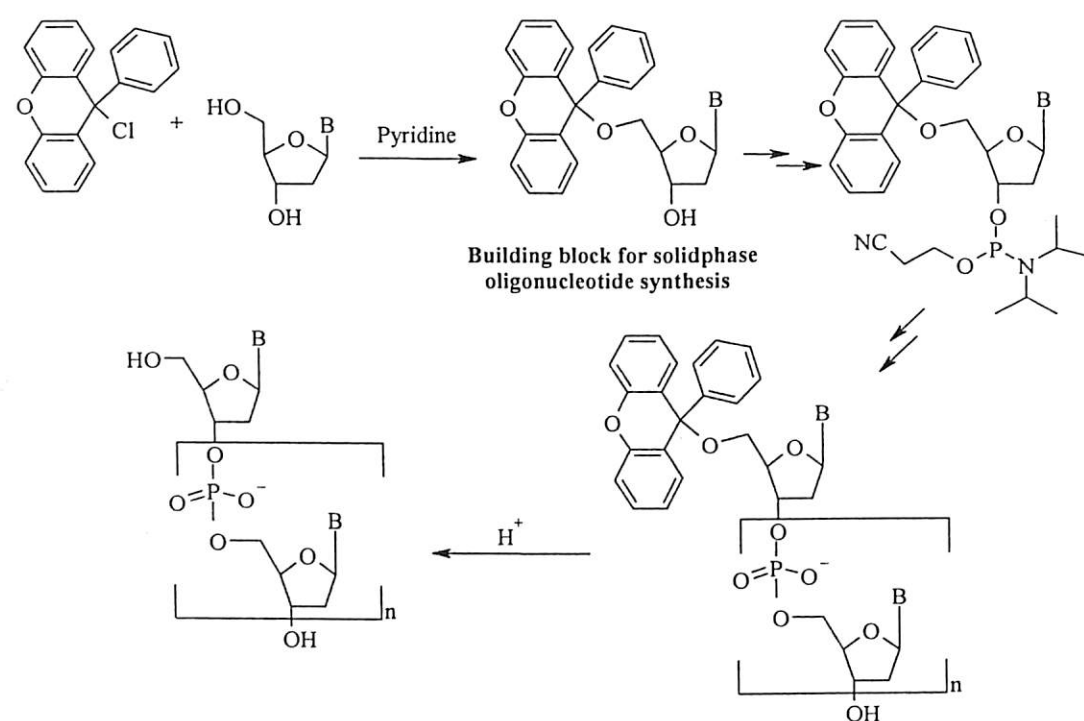
Scheme IIA.3.1.2.1

Chibale's group has designed and synthesized chloroquine-resistant *Plasmodium falciparum* based on the 9H-xanthene tricyclic scaffolds, Scheme IIA.3.1.2.2. The compound contains a common hydrophobic tricyclic 9H-xanthene moiety and an alkyl side chain with two amino groups, one of which is a tertiary substituted terminal amine separated by three carbons and differing only in the chemical nature of the intermediate nitrogen atom.¹⁴⁰



Scheme IIA.3.1.2.2

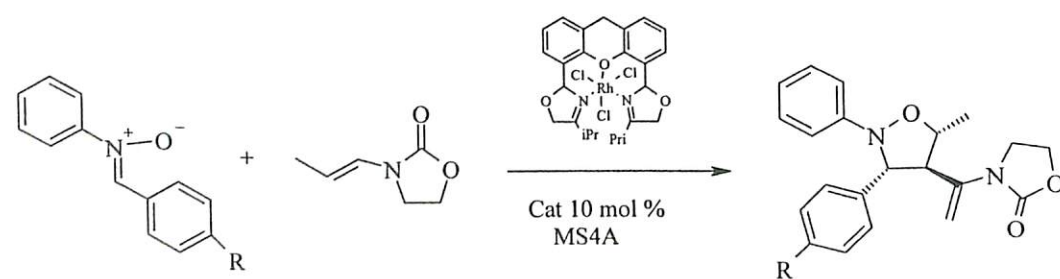
IIA.3.1.3. Applications in Organic Synthesis



Scheme IIA.3.1.3.1

Reese group has developed 9-phenylxanthene derivatives as protecting groups for alcohols especially for the protection of the 5'-hydroxy functions of 2'-deoxy ribonucleosides in solid phase oligonucleotide synthesis. The 9-phenyl xanthene-9-yl group undergoes hydrolytic cleavage in acetic acid-water (4:1) solution at room temperature (Scheme IIA.3.1.3.1).¹⁴¹

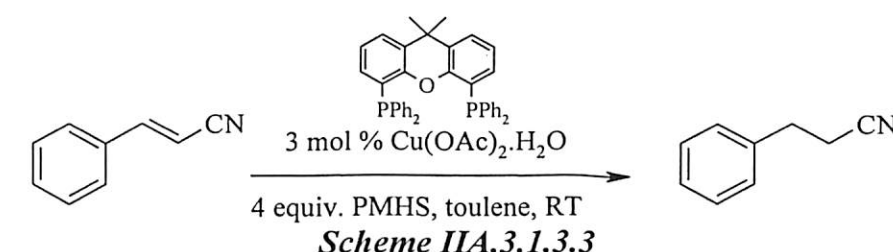
Iwasa *et al.* has demonstrated the 1,3 dipolar addition of nitrones with alkenes in presence rhodium xanthene complex (Scheme IIA.3.1.3.2).¹⁴²



Scheme IIA.3.1.3.2

α,β -Unsaturated nitriles are chemoselectively reduced to the corresponding saturated nitriles in high yields using a Cu-xantphosphorous complex as a catalyst in the presence of

polymethylhydrosiloxane (PMHS) as the stoichiometric reducing agent and (Scheme IIA.3.1.3.3).¹⁴³

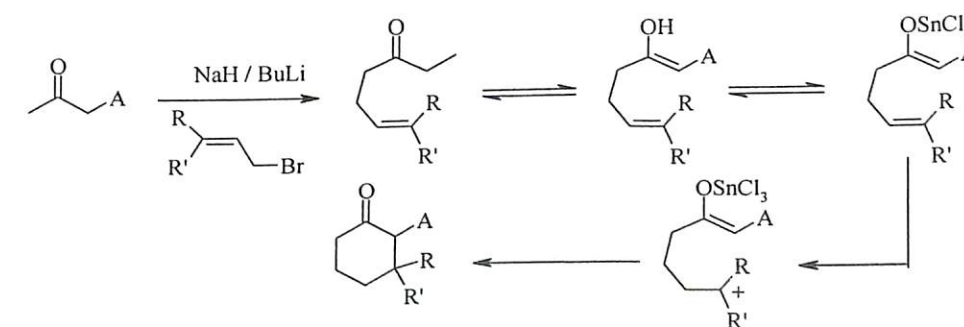


IIA.3.1.4. Applications in Supramolecular Chemistry

Xanthene derivatives are known to form supramolecular structures in solid state. 9-Aryl-9H-xanthene-9-ols have been used as host-guest chemistry. Derivatives of xanthene such as 9-(4-methoxyphenyl)-9H-xanthene-9-ol and 9-(3-methoxyphenyl)-9H-xanthene-9-ol compounds are found to form inclusion compounds with aniline.^{144a} The host 9-(3-chlorophenyl)-9H-xanthene-9-ol forms inclusion compounds with benzene, toluene, *p*-xylene and pyridine.^{144b} Rebek Jr. group has synthesized various xanthene derivatives and used it as supramolecular scaffolds.¹⁴⁵

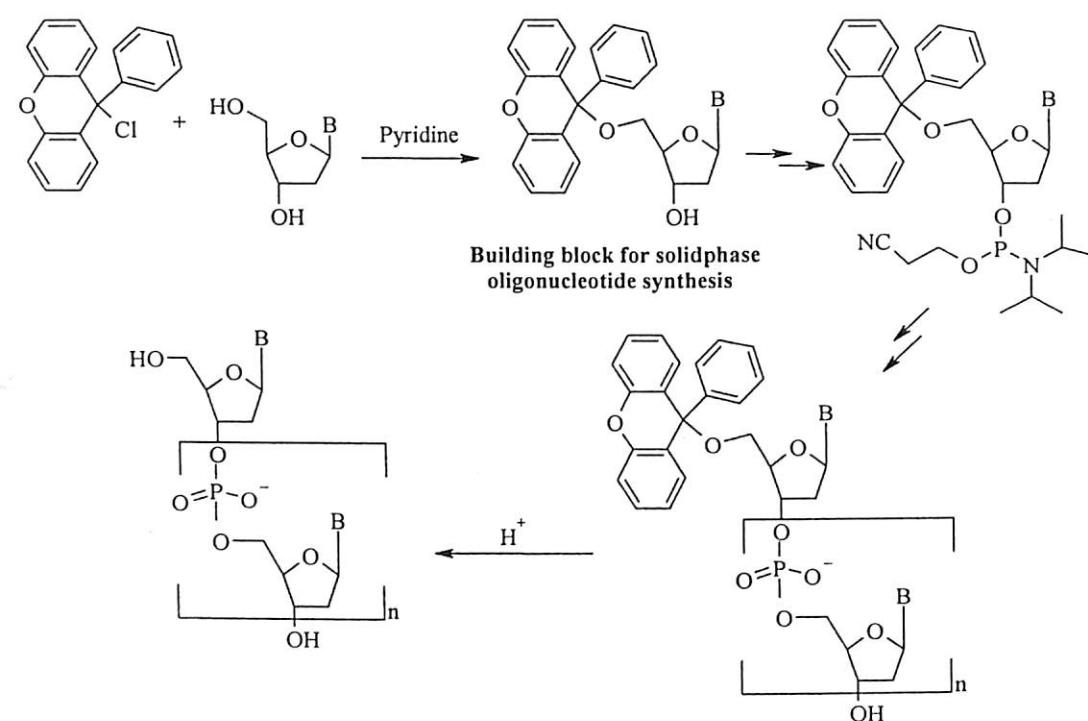
IA.3.2. Alkylation of Ketone

Carbon-carbon bond forming reactions lie at the heart of the organic synthesis. As such, many methods have been developed to accomplish this key construction. One of the most common approaches to the extension of carbon framework involves the carbonyl alkylation reactions, usually accomplished by the reaction of alkyl halides or alcohols in the presence of basic or acidic medium with ketones or enols.¹⁴⁶



Scheme IIA.3.2.1

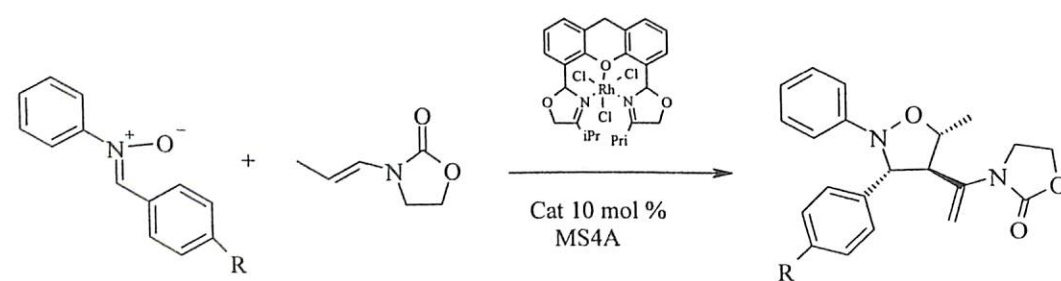
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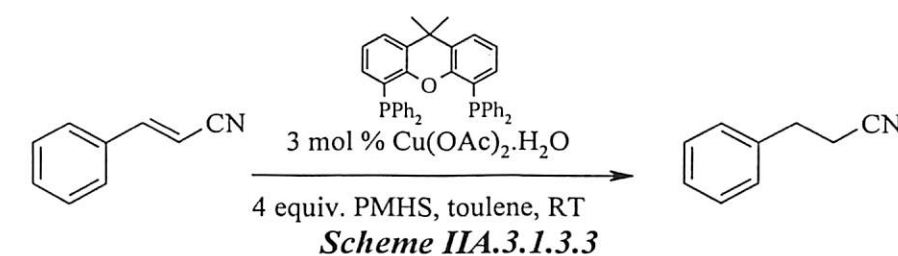
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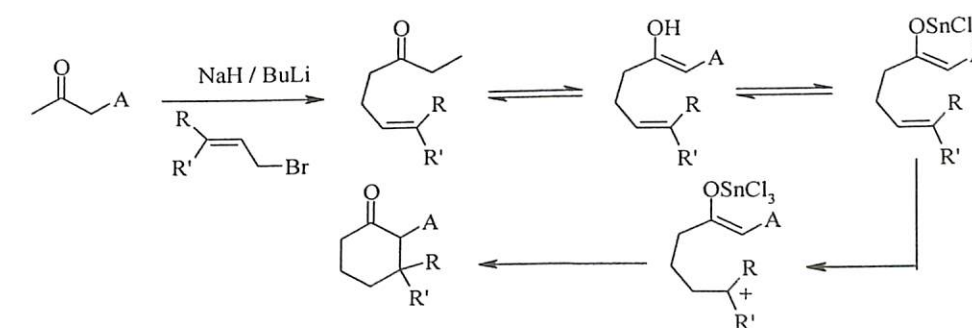


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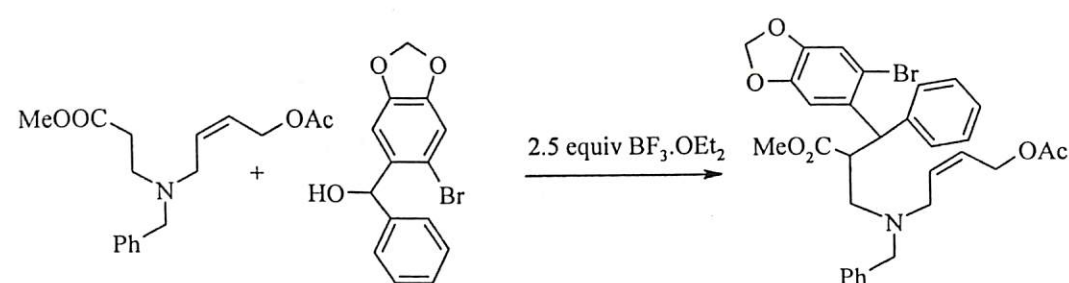
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Scheme IIA.3.2.1

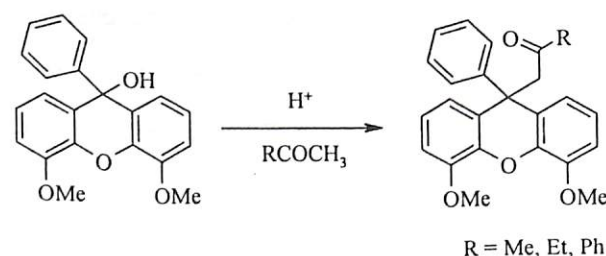
Reetz and coworker reported the intramolecular α -*tert*-alkylation of carbonyl compounds using SnCl_4 as catalyst. According to their speculation, O-stannylation of the enolized form of the enone generate intermediate which on protonation of olefin with HCl results in cyclization of the cation (Scheme IIA.3.2.1).¹⁴⁷

Benzhydrylation of activemethylene compounds were accomplished by treating the active methylene compounds with benzhydryl alcohols in an acid medium. This procedure was successfully applied for the synthesis of the anticancer agent podophyllotoxin by benzhydrylation of malonamide Scheme IIA.3.2.2.¹⁴⁸

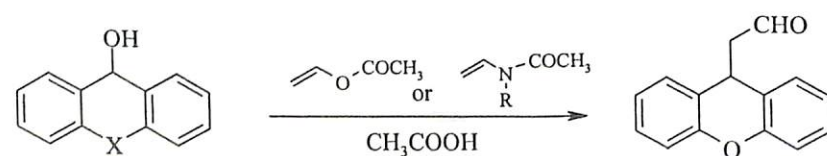


Scheme IIA.3.2.2

Wada *et al.* has reported C–C bond formation of xanthene derivatives. In an acidic medium 1,8-dimethoxy-9-phenylxanthene-9-ol reacts with acetone to give 1,8-dimethoxy-9-phenylxanthene-9-yl-methyl methyl ketone. Analogous reactions were observed for ethyl methyl ketone and acetophenone but not for diethyl ketone (Scheme IIA.3.2.3).¹⁴⁹



Scheme IIA.3.2.3



Scheme IIA.3.2.3

Prashad group has described the synthesis of 9H-xanthene-9-carboxaldehyde, 9H-thioxanthene-9-carboxaldehyde and 9,10-dihydro-10-methyl-9-acridinecarboxaldehyde by a novel two carbon

homologation of xanthidrol, thioxanthidrol and 9,10-dihydro-10-methyl-vinylacetamide or ethyl vinyl ether as acetaldehyde anion equivalents. (Scheme IIA.4.1.1).¹⁵¹

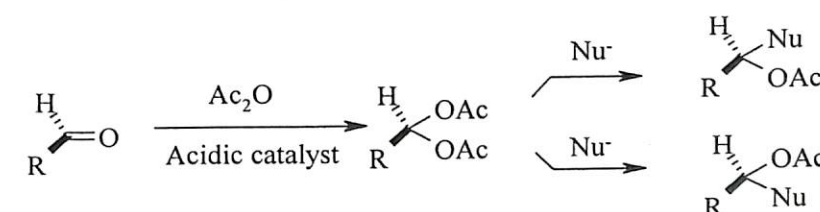
IIA.4. Diacylates (Acylals or *gem*-Diacetates)

The geminal-diacetates also known as “acylals” or 1,1-diacetates are addition products of acid anhydrides with aldehydes. Due to the remarkable stability of *gem*-diacylates towards a variety of reaction conditions, and their easy of preparation, they are gaining importance in organic synthesis as an alternative to cyclic and acyclic acetals for the protection of aldehydes.¹⁵¹

IIA.4.1. Synthetic Applications of Acylals

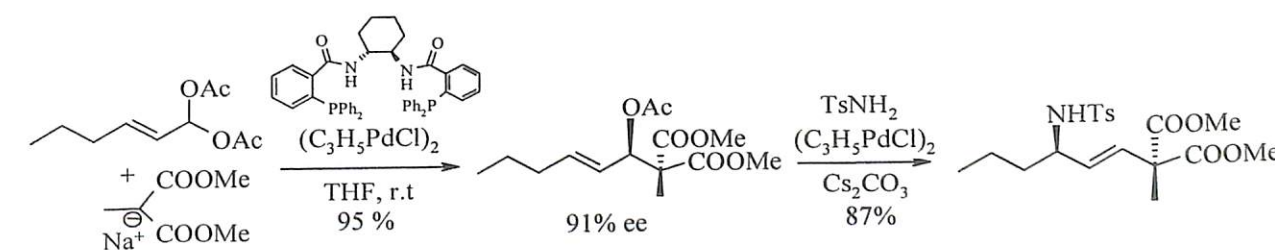
The ambient nature of *gem*-diacylates makes them synthetically important precursors of 1-acetoxy dienes,¹⁵² 2,2-dichlorovinyl acetate for Diels-Alder reactions.¹⁵³ Compounds bearing the *gem*-diacylate functionality are used as cross-linking agents for cellulose in cotton¹⁵⁴ and activators in the composition of bleaching mixtures for wine-stained fabrics.¹⁵⁵

gem-Diacetates constitute an unusual type of substrate for desymmetrization. Two acetates are prochiral and substitution of either one selectively is equivalent to nucleophilic asymmetric addition to one of the prochiral faces of the aldehyde (Scheme IIA.4.1.1).¹⁵⁶



Scheme IIA.4.1.1

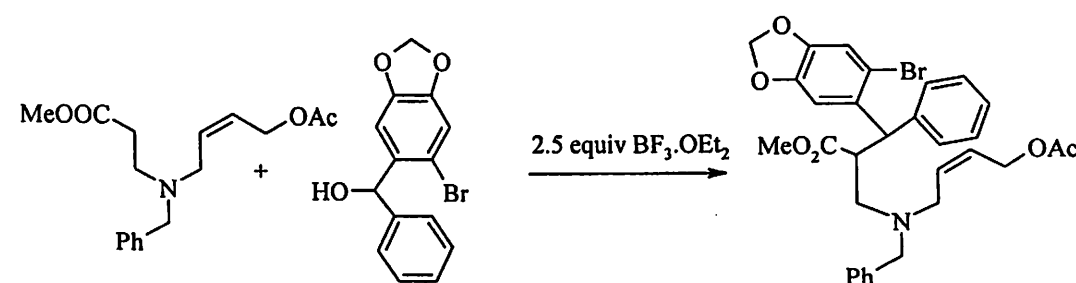
The acylals derived from α,β -unsaturated aldehydes are useful synthetic intermediates. The *gem*-diacylate underwent smooth alkylation to give malonate of high *ee* (Scheme IIA.4.1.2).¹⁵⁷



Scheme IIA.4.1.2

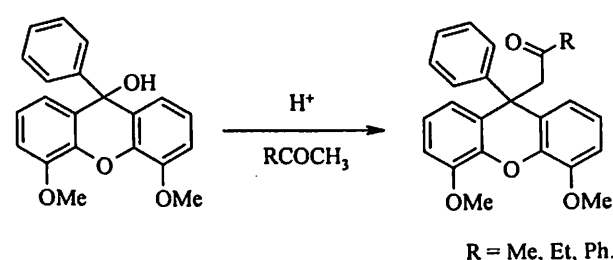
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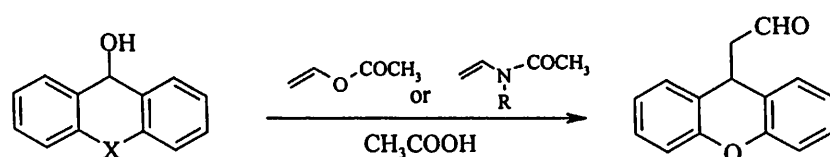


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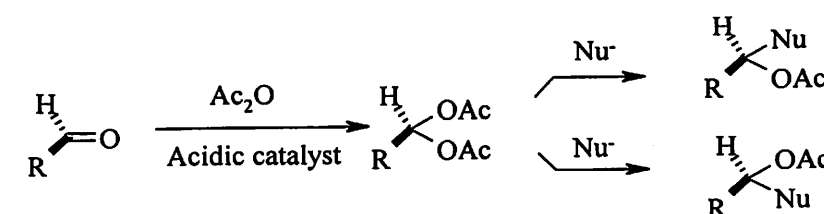
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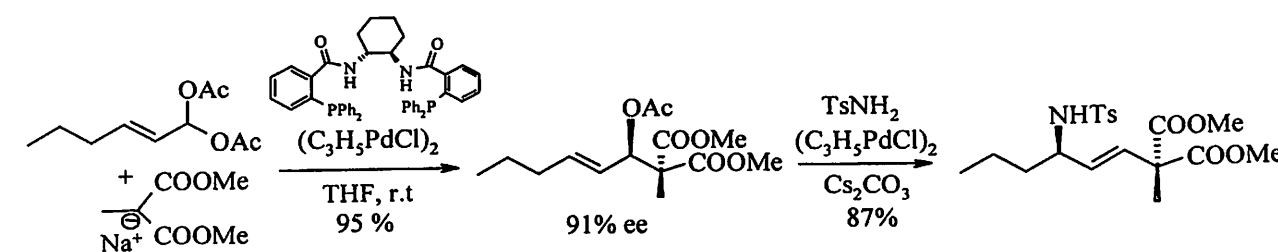
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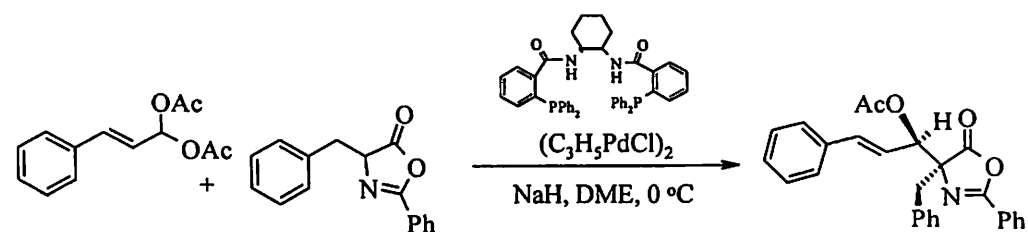
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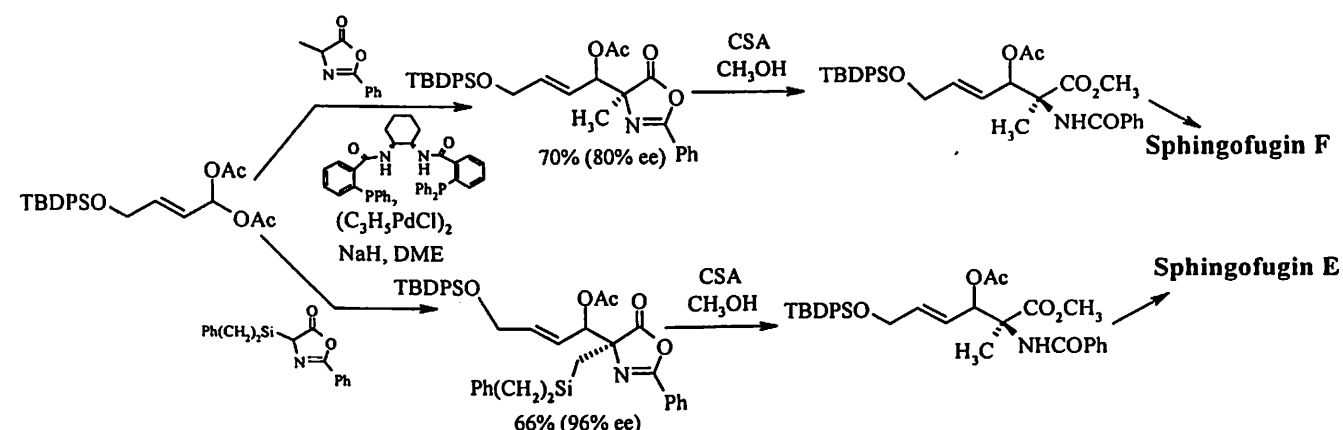


Scheme IIA.4.1.2

Gem-diacrylate of α,β -unsaturated aldehydes are interesting prochiral allyl partners. They react with oxazolones derivatives to generate novel serine analogues, Scheme IIA.4.1.1.3.¹⁵⁶



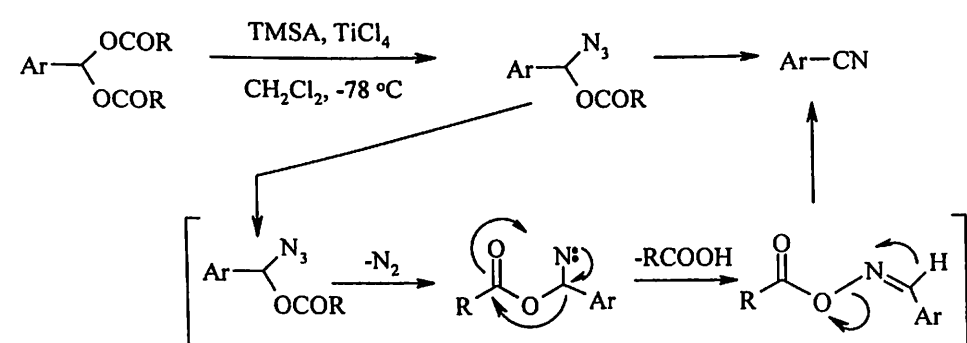
Scheme IIA.4.1.3



Scheme IIA.4.1.4

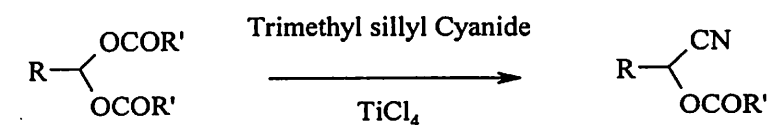
Acylates derived from α,β -unsaturated aldehydes are valuable precursors in the synthesis of sphingofungins and related compounds like myriocin and mycostericin, Scheme IIA.4.1.4.¹⁵⁸

Sydnes *et al.* has synthesized aliphatic and aromatic nitrile by treating acylals derived from aliphatic and aromatic aldehydes with trimethylsilyl azide in the presence of titanium (IV) chloride. The proposed mechanism for the reaction is shown in Scheme IIA.4.1.5.¹⁵⁹



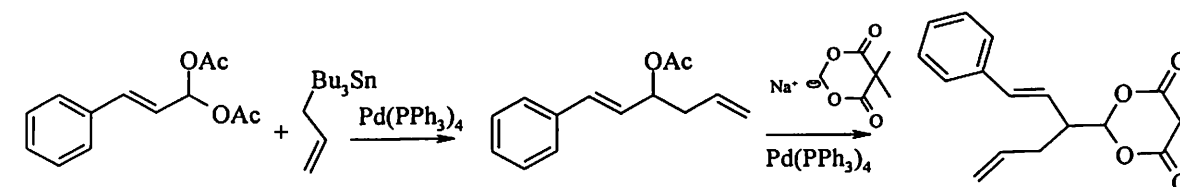
Scheme IIA.4.1.5

Cyanohydrin esters have been prepared in good yield by treating the aliphatic aldehydes with KCN in DMSO at room temperature. However, treatment with trimethylsilyl cyanide and titanium (IV) chloride afforded cyanohydrin esters in good to excellent yields from both aliphatic and aromatic aldehydes, Scheme IIA.4.1.6.¹⁶⁰



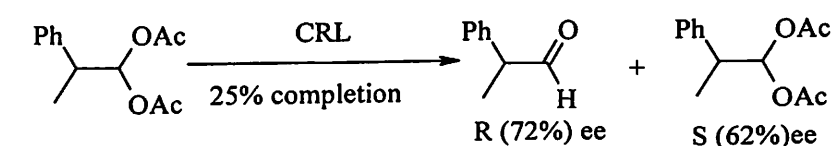
Scheme IIA.4.1.6

Another C-C and C-O bond formation is reported by Heerden group using the Pd(0)-catalyzed substitution of allylic 1,1-diacetates by both carbon and oxygen nucleophiles. The products isolated resulted from either single or double substitution reactions, Scheme IIA.4.1.7.¹⁶¹



Scheme IIA.4.1.7

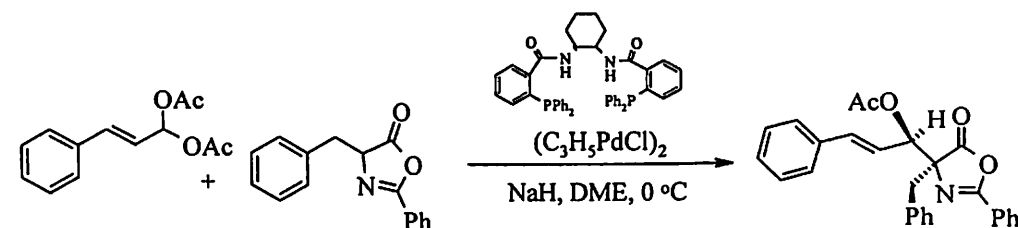
Smonou group has reported a method for the optical resolution of aldehydes through lipase-catalyzed hydrolysis of corresponding acylals. The optical resolution of 2-phenylpropionaldehyde, by enzymatic hydrolysis of the corresponding acylal, with *Candida rugosa* lipase (CRL), gave enantioselectivity of 72 % (% ee) when the reaction is 25 % completion, Scheme IIA.4.1.8.¹⁶²



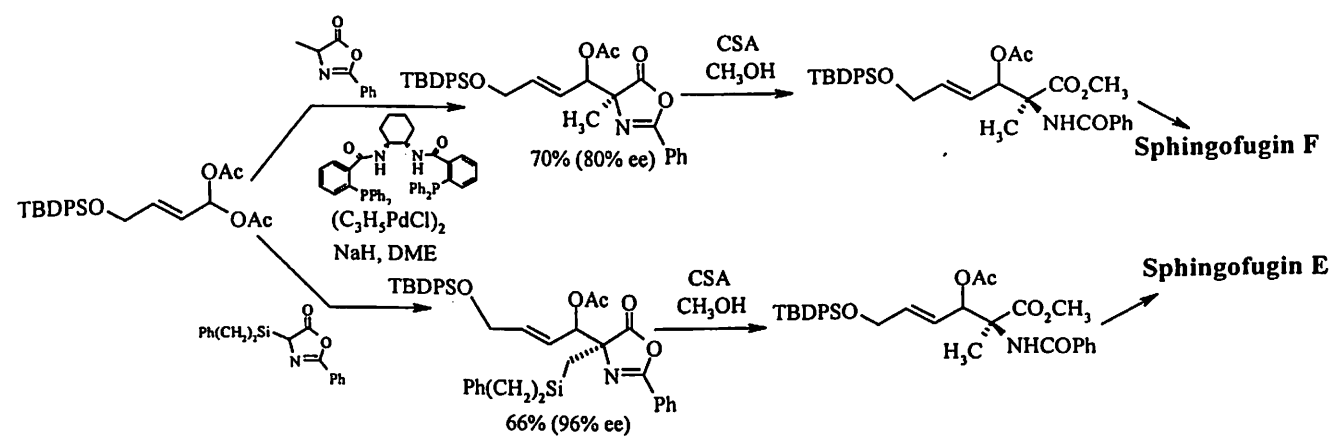
Scheme IIA.4.1.8

Yadav *et al.* has reported a mild and selective method for the synthesis of homoallylic acetates through the allylation of *gem*-diacetates using indium metal and allyl bromide in an aqueous medium, Scheme IIA.4.1.9.¹⁶³

Gem-diacylate of α,β -unsaturated aldehydes are interesting prochiral allyl partners. They react with oxazolones derivatives to generate novel serine analogues, Scheme IIA.4.1.1.3.¹⁵⁶



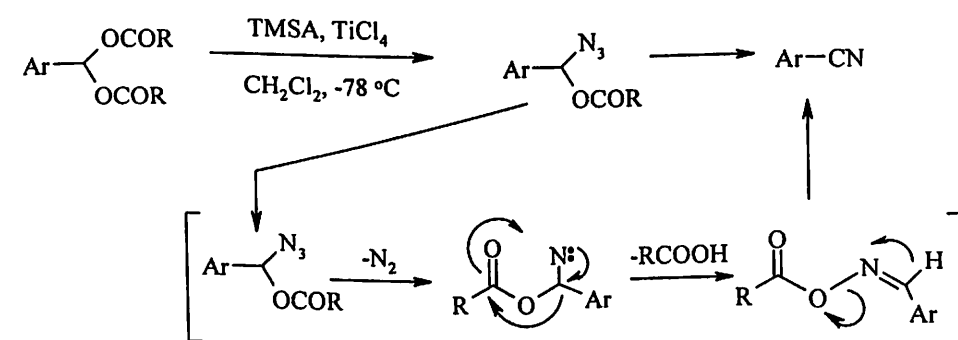
Scheme IIA.4.1.1.3



Scheme IIA.4.1.1.4

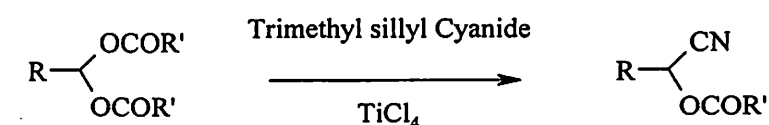
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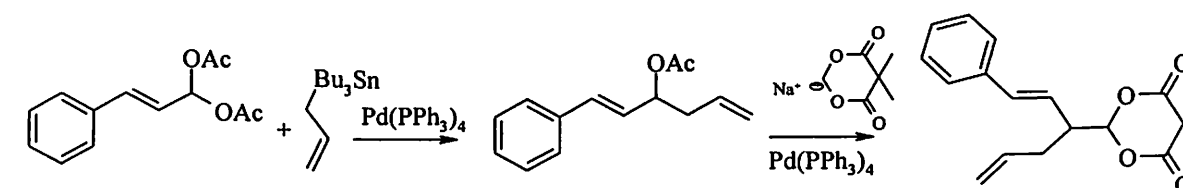
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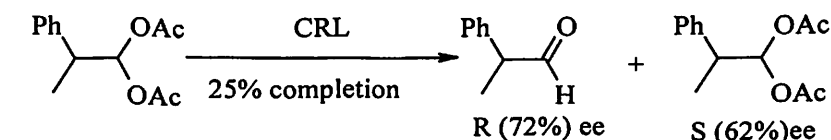
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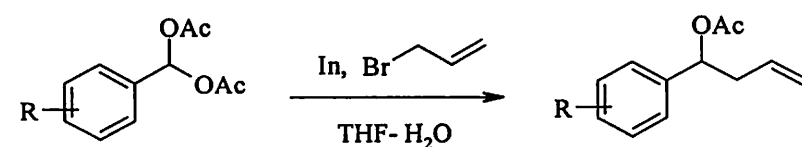
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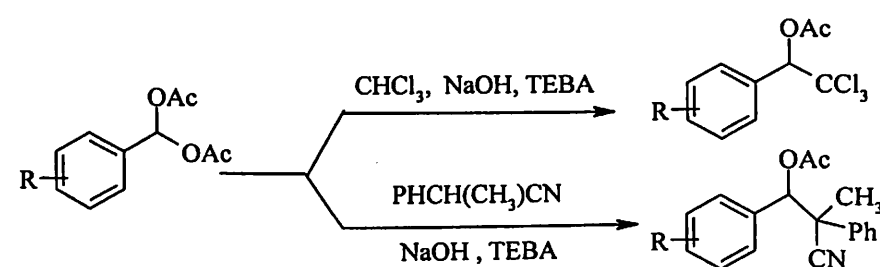
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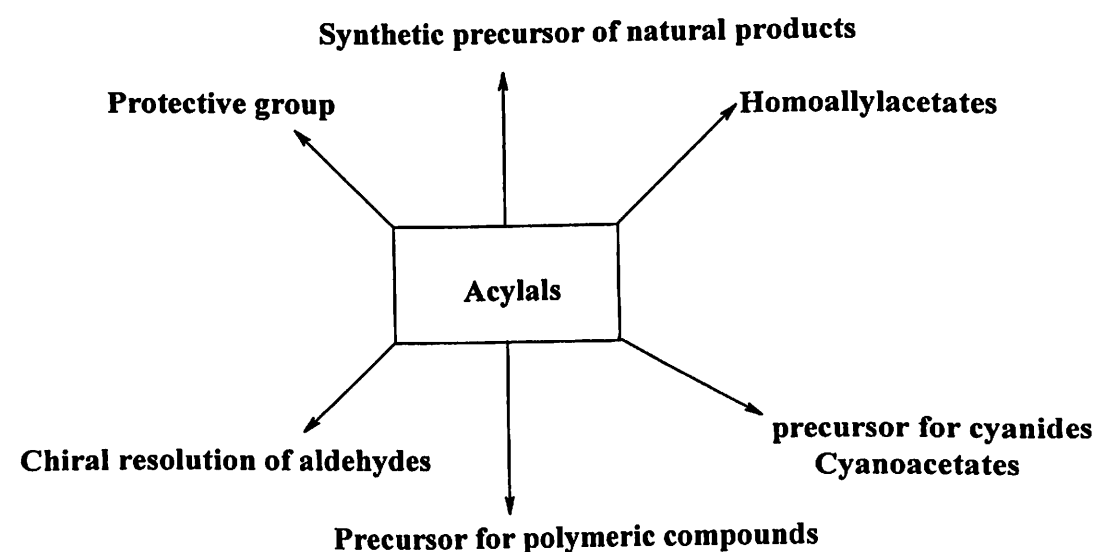
Scheme IIA.4.1.9

Nucleophilic substitution reaction of acylals with carbinions generated by the reaction of base with CHCl₃, CHBr₃ or PhCH(CH₃)CN is reported under a biphasic medium. Only one acetate group is replaced giving valuable synthetic intermediates, Scheme IIA.4.1.10.¹⁶⁴



Scheme IIA.4.1.10

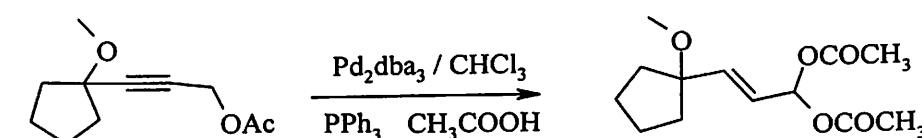
A summary of usefulness of *gem*-diacetate is shown in Scheme IIA.4.1.11



Scheme IIA.4.1.11

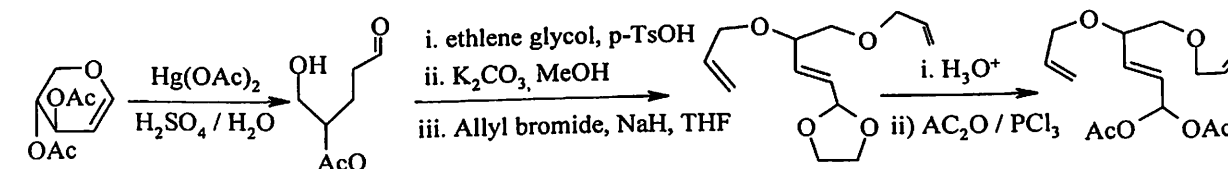
IIA.4.2. Methods of Preparation of Acylals

Numerous methods are available in the literature for the conversion of an aldehydic carbonyl group to the corresponding *gem*-diacetate with acetic anhydride. Some of the reagents and catalyst that have been employed include H₂SO₄,¹⁶⁵ HClO₄,¹⁶⁶ H₃PO₄,¹⁶⁷ CH₃SO₃H,¹⁶⁸ PCl₃,¹⁶⁹ FeSO₄.XH₂O,¹⁷⁰ I₂,¹⁷¹ TMSCl-NaI,¹⁷² NBS,¹⁷³ CAN,¹⁷⁴ InX₃ (X = Cl, Br),¹⁷⁵ WCl₆,¹⁷⁶ LiBF₄,¹⁷⁷ Zn(BF₄)₂,¹⁷⁸ ZrCl₄,¹⁷⁹ CoCl₂,¹⁸⁰ NH₂SO₃H,¹⁸¹ Bi(OTf)₃.XH₂O,¹⁸² Sc(OTf)₃,¹⁸³ LiOTf,¹⁸⁴ Cu(OTf)₂,¹⁸⁵ FeCl₃,¹⁸⁶ and sulfated zirconia.¹⁸⁷ Some solid acidic catalysts, e.g. NafionH,¹⁸⁸ zeolite,¹⁸⁹ Montmorillonite clay,¹⁹⁰ graphite,¹⁹¹ Fe³⁺ on Montmorillonite,¹⁹² PVC-FeCl₃,¹⁹³ Wells-Dawson acid,¹⁹⁴ Zirconium sulphenyl phosphonate,¹⁹⁵ AlPW₁₂O₄₀,¹⁹⁶ Amberlite15,¹⁹⁷ has been developed for this purpose. Recently, diacylation of aldehydes have been achieved in ionic liquids.¹⁹⁸ Very recently several other acidic reagents such as Cu(BF₄)₂,¹⁹⁹ Bi(NO₃)₃,²⁰⁰ LiCl,²⁰¹ (Ce₂(SO₄)₃.4H₂O),²⁰² Zn(OTf)₂.6H₂O,²⁰³ In(OTf)₃,²⁰⁴ bromodimethylsulphonium bromide,²⁰⁵ acetonitriltriphenylphosphonium bromide (ATPB),²⁰⁶ SiO₂-HClO₄,²⁰⁷ FeCl₃-SiO₂,²⁰⁸ zinc-Montmorillonite,²⁰⁹ TiO₂/SO₄²⁻-solid superacid,²¹⁰ have been utilized for this purpose. Trost and his coworkers have developed an excellent method for the synthesis *gem*-diacylates derived from α,β-unsaturated aldehydes using FeCl₃ as catalyst. They have also demonstrated the preparation α,β-unsaturated acylals from propargylic acetates using Pd catalyst, Scheme IIA.4.2.1.^{157,158}

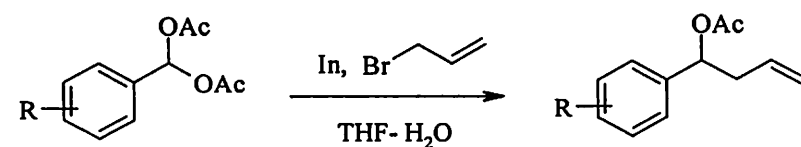


Scheme IIA.4.2.1

Holzappel group has synthesized the carbohydrate derived allylic *gem*-diacetates from cyclic acetals instead of aldehyde in one pot using acetic anhydride and PCl₃, Scheme IIA.4.2.2.²¹¹

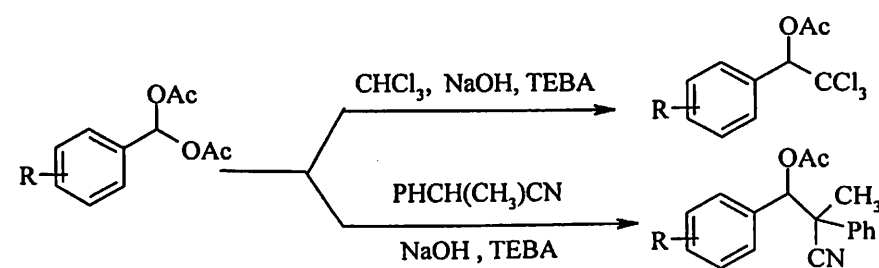


Scheme IIA.4.2.2



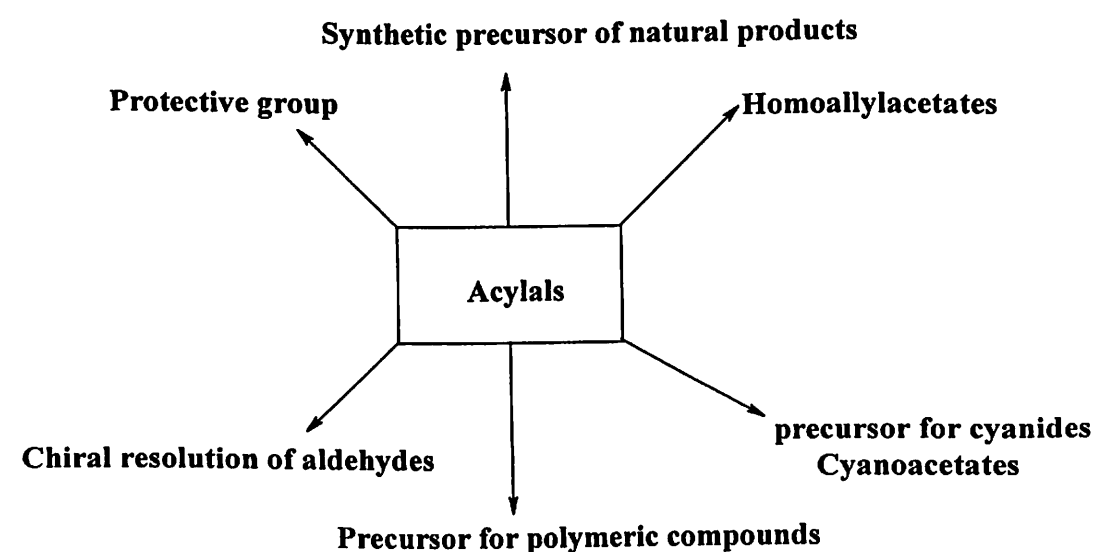
Scheme IIA.4.1.9

Nucleophilic substitution reaction of acylals with carbinions generated by the reaction of base with CHCl_3 , CHBr_3 or $\text{PhCH}(\text{CH}_3)\text{CN}$ is reported under a biphasic medium. Only one acetate group is replaced giving valuable synthetic intermediates, Scheme IIA.4.1.10.¹⁶⁴



Scheme IIA.4.1.10

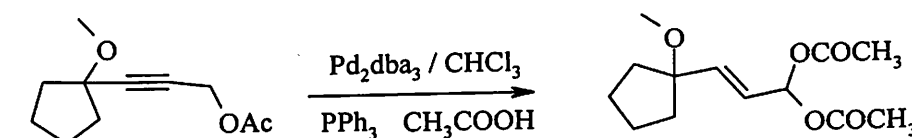
A summary of usefulness of *gem*-diacetate is shown in Scheme IIA.4.1.11



Scheme IIA.4.1.11

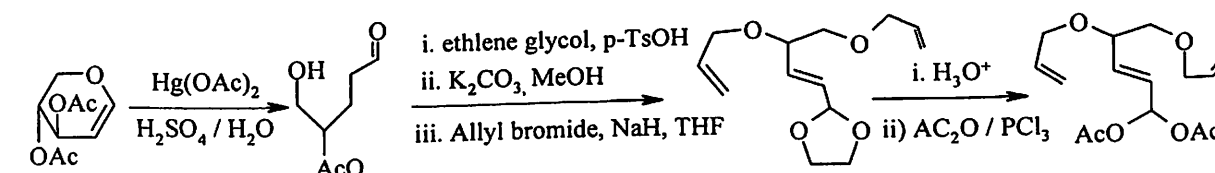
IIA.4.2. Methods of Preparation of Acylals

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Scheme IIA.4.2.1

Holzappel group has synthesized the carbohydrate derived allylic *gem*-diacetates from cyclic acetals instead of aldehyde in one pot using acetic anhydride and PCl_3 , Scheme IIA.4.2.2.²¹¹



Scheme IIA.4.2.2

Although several methods are known for their synthesis, only few methods are reported in the literature for the deprotection of diacylates to their corresponding aldehydes. The reagents used for the deprotection are H_2SO_4 ,^{165c} HCl ,²¹² CAN on silica gel,²¹³ BiCl_3 ,²¹⁴ CBr_4 ,²¹⁵ $\text{CeCl}_3 \cdot 7\text{H}_2\text{O}/\text{NaI}$,²¹⁶ KSF ,²¹⁷ Montmorillonite K-10,²¹⁸ neutral alumina under microwave irradiation,²¹⁹ phenoxide²²⁰ and envirocat EPZG.²²¹ Some of the reagents that are capable of promoting acylation can also cause cleave to the parent aldehyde upon changing the reaction conditions. These reagents are ZrCl_4 ,¹⁷⁹ zeolite,^{189b} graphite,¹⁹¹ zirconium sulphenyl phosphonate,¹⁹⁵ acidic alumina,²²² silica sulphate,²²³ $\text{P}_2\text{O}_5/\text{SiO}_2$,²²⁴ InBr_3 -[bmim] PF_6 ²²⁵ and InBr_3 -poly(ethylene glycol) (PEG).²²⁶

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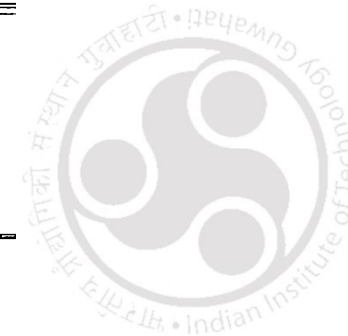
IIB. Present Work

IIB.1. A New Recyclable Ditribromide Reagent for Bromination under Solvent Free Condition

Bromination of aromatic substrates has received significant interest in recent years¹ owing to the increasing commercial importance of bromoorganics in the synthesis of a large number of natural products as well as in the manufacture of pharmaceuticals, intermediates for agrochemicals, and other specialty chemicals. Numerous industrially valuable products such as pesticides, insecticides, herbicides, fire retardants, and other new materials carry bromo functionality.² These halides also undergo carbon-carbon bond formation via cross-coupling reactions such as Stille-Suzuki,³ Heck,⁴ and Sonogashira⁵ or carbon-heteroatom bond formation via aromatic functionalization protocols.⁶

Traditional methods of bromination involve the direct or indirect use of elemental bromine under harsh reaction conditions.⁷ To achieve higher efficiency and selectivity, the conventional reagent bromine has been employed with a variety of new techniques including phase vanishing methodology and fluorous solvent.⁸ However, handling of bromine is cumbersome due to its hazardous nature, thus special care is required for its storage and transport. Moreover, bromination of aromatic substrates with elemental bromine involving an electrophilic aromatic substitution reaction with the formation of HBr as a byproduct effectively reduces the atom efficiency to 50 %. The generated HBr waste must be neutralized before it can be discharged as an effluent. To overcome these problems some environmentally safer procedures have been envisioned to involve the *in situ* preparation of positive bromonium species by oxidation of bromide ion with suitable oxidants under various homogeneous and heterogeneous reaction conditions.⁹

Bromine free bromination with stable crystalline organic ammonium tribromide like tetrabutyl,¹⁰ tetramethyl,^{11b} cetyl,^{9g} benzyltrimethyl,^{9g,12} pentylpyridinium,¹³ pyridinium,¹⁴ and DBU¹⁵ has gained considerable interest. Tribromides are more suitable than the liquid bromine because of their crystalline nature, hence easy for their storage, transport, and maintenance of desired stoichiometry. Preparations of these reagents involve organic ammonium bromide and molecular bromine in most cases, thus an indirect use of toxic molecular bromine. Recently, organic ammonium tribromide has been prepared in an environmentally benign way by the reaction of V₂O₅, aqueous H₂O₂, and KBr.^{9g} However, this method generates some heavy metal as toxic waste.^{9g} Other problems



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IIB. Present Work

IIB.1. A New Recyclable Ditribromide Reagent for Bromination under Solvent Free Condition

Bromination of aromatic substrates has received significant interest in recent years¹ owing to the increasing commercial importance of bromoorganics in the synthesis of a large number of natural products as well as in the manufacture of pharmaceuticals, intermediates for agrochemicals, and other specialty chemicals. Numerous industrially valuable products such as pesticides, insecticides, herbicides, fire retardants, and other new materials carry bromo functionality.² These halides also undergo carbon-carbon bond formation via cross-coupling reactions such as Stille-Suzuki,³ Heck,⁴ and Sonogashira⁵ or carbon-heteroatom bond formation via aromatic functionalization protocols.⁶

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associated with these reagents are the use of expensive organic ammonium cations and the use of 1/3 of its total bromine for an aromatic electrophilic substitution type reaction and 2/3 bromine towards addition to C-C multiple bonds. Some of the organic ammonium tribromides have phase transfer property, hence substantial amount gets extracted along with the organic products in an organic solvent during work up, thereby making the purification tedious and the method expensive for large-scale reaction. Recovery and recycling of expensive organic ammonium cations is also poor after the reaction. Pyridinium tribromide or pyridinium hydrobromide perbromide is not so stable compared to other organic ammonium tribromides and is reported to have three different bromine composition with different melting points.^{14d} In order to overcome the problems of phase transfer property, poor stability, regio and stereo selectivity, recovery and recycling of the spent reagent we have synthesized a novel ditribromide reagent. The new reagent has higher bromine content per molecule, better bromination efficiency and selectivity, is devoid of phase transfer property and the spent reagent can be recovered and regenerated easily. In this manuscript we wished to report the preparation of a new ditribromide reagent, development of a solvent, metal and ionic-liquid free bromination protocol and recovery and recycling of the reagent.

The reagent was prepared by refluxing pyridine (2 equiv) with 1,2-dibromoethane (1 equiv). The resultant 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) solid was treated with KBr (4.5 equiv) followed by oxidation of bromide to bromine using an aqueous solution of Oxone® (1 equiv). The standard electrode potential (E°) of Oxone® being (-1.44 V) is high enough for the oxidation of bromide to bromine. Oxone® has been utilized for the oxidative bromination of aromatic compounds using NH_4Br .^{9k} The orange precipitate of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) was filtered (88 % yield) and was recrystallized in acetonitrile to obtain large crystals as shown in Figure IIB.1.1. The compound has been characterized by spectral and analytical data. This new reagent is highly soluble in acetonitrile. Conductivity measurements of the reagent in acetonitrile showed the presence of 2 : 2 complex. In order to reconfirm the stoichiometry and investigate factors that control the intramolecular interactions over the crystal engineering, the X-ray crystal structure of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) was determined (Figure IIB.1.2).

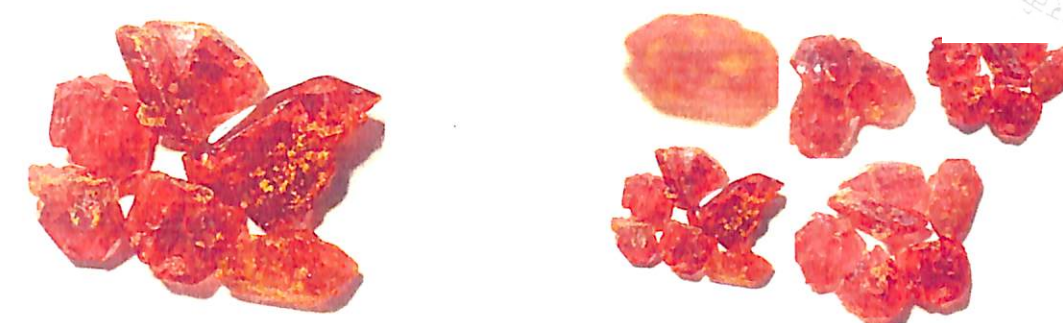


Figure IIB.1.1. Crystals of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT)

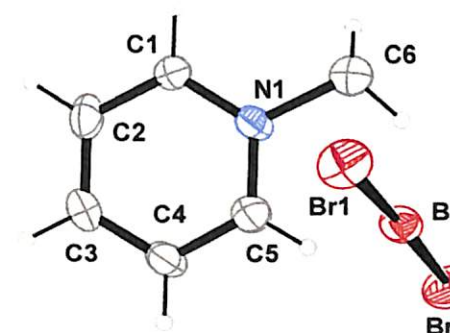


Figure IIB.1.2. ORTEP diagram of EDPBT with atomic numbering scheme

It crystallized in the space group monoclinic $P2(1)/c$. The ORTEP diagram with atomic numbering scheme is shown in Figure IIB.1.2. In the asymmetric unit only one half of the molecule is present. The two pyridinium rings are nearly planar and are parallel to each other. Each tribromide is nearly linear with a bond angle of 176.82° between $\text{Br}_2\text{-Br}_1\text{-Br}_3$. This crystalline compound of EDPBT (Figure IIB.1.1) is stable for several months at room temperature without loss of its activity.

This new reagent, 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) is soluble in polar aprotic solvents (acetonitrile, DMSO, DMF etc.), sparingly soluble in polar protic solvents (methanol, ethanol, acetic acid etc.) but is insoluble in non-polar aprotic solvents (dichloromethane, chloroform, ethyl acetate, toluene etc.). On the other hand its precursor 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) is insoluble in most organic solvents but is highly soluble in water, indicating the absence of phase transfer property, thus, facilitating efficient recovery of 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) and the separation of brominated products. This property attests the superiority of this reagent which other known organic ammonium tribromides lack.

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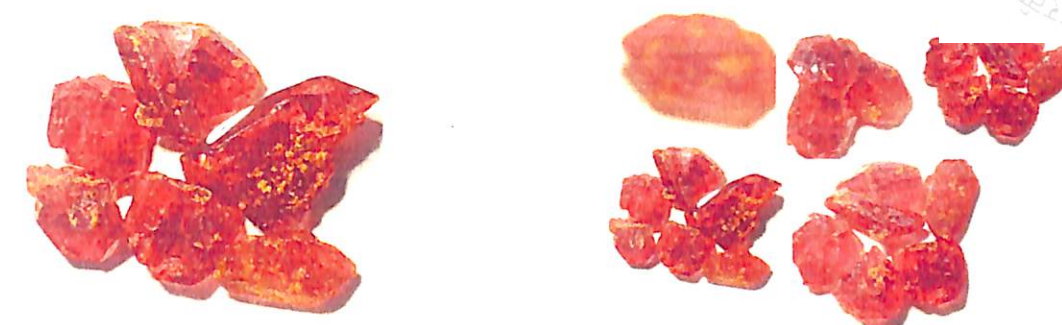


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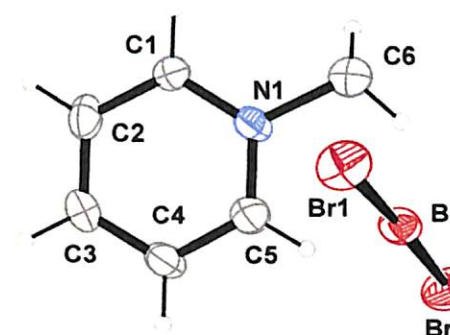


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When this solvent free methodology was applied to phenol **35** and aniline **36** both gave regioselectively *p*-bromophenol **35n** and *p*-bromoaniline **36n** respectively, which is otherwise difficult to achieve with other reagents. Regioselective bromination of phenol and aniline is an important protocol in organic synthesis because of their versatile synthetic intermediates for a considerable number of useful transformations. In an aromatic electrophilic substitution reaction *p*-orientation is favored over *o*-orientation due to stereo-electronic effects. Exclusive regioselective bromination of phenol **35** and aniline **36** has been achieved with supported reagents,^{8c,i} in solid phase reaction,^{13a} under controlled *in situ* generation of electrophilic bromonium ion^{9f,r,10a} or by using special reagents and conditions.^{8d,9x} The reagent 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) is an excellent bromine carrier and releases bromine only in contact with the substrate. Moreover due to use of the reagent in stoichiometric amount (0.5 eq.), no polybromination occurred with 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT). It may be noted here that some acidic fumes evolved during reaction with aromatic phenols and amines, which can however be

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Table IIB.1.1. Bromination^a of Organic Substrates Using EDPBT Under Solvent Free Condition

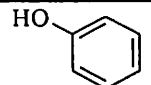
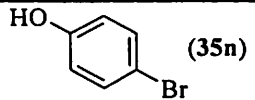
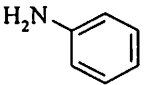
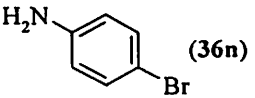
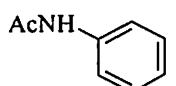
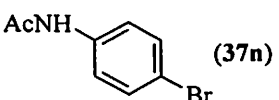
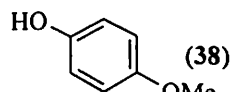
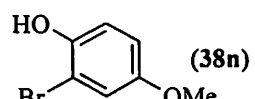
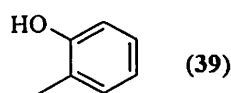
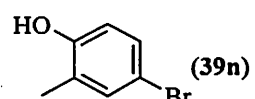
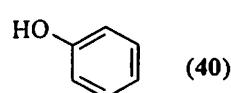
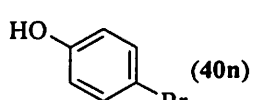
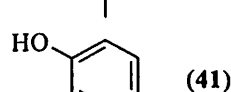
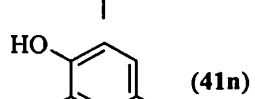
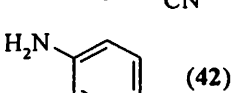
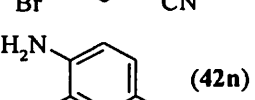
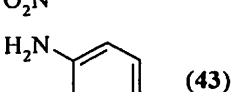
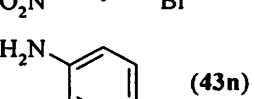
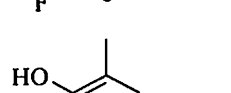
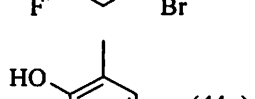
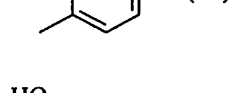
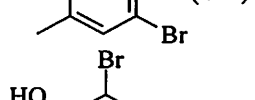
Substrate	Product	Time (min)	Yield ^b
 (35)	 (35n)	30	85
 (36)	 (36n)	30	85
 (37)	 (37n)	30	95
 (38)	 (38n)	30	92
 (39)	 (39n)	30	93
 (40)	 (40n)	30	92
 (41)	 (41n)	30	93
 (42)	 (42n)	30	96
 (43)	 (43n)	30	92
 (44)	 (44n)	30	95
 (45)	 (45n)	30	95

Table Contd....

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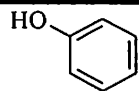
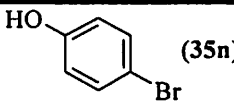
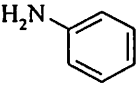
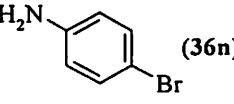
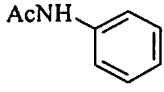
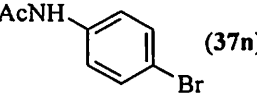
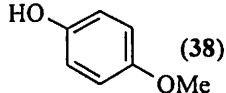
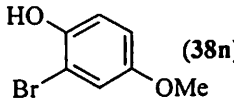
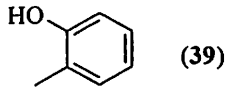
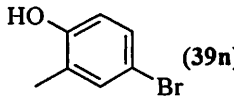
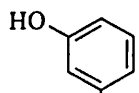
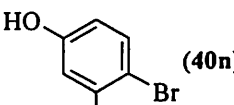
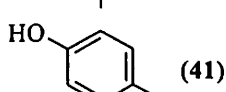
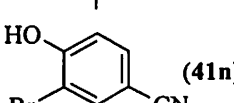
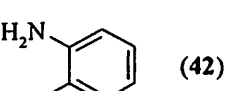
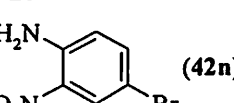
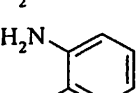
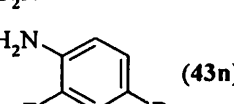
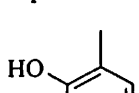
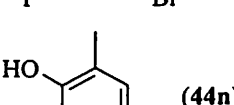
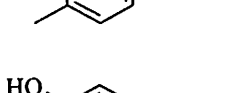
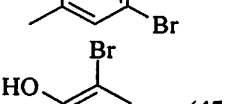
Substrate	Product	Time (min)	Yield ^b
 (35)	 (35n)	30	85
 (36)	 (36n)	30	85
 (37)	 (37n)	30	95
 (38)	 (38n)	30	92
 (39)	 (39n)	30	93
 (40)	 (40n)	30	92
 (41)	 (41n)	30	93
 (42)	 (42n)	30	96
 (43)	 (43n)	30	92
 (44)	 (44n)	30	95
 (45)	 (45n)	30	95

Table Contd....

Substrate	Product	Time (min)	Yield ^b
		30	94
		30	93
		30	94
		30	95

^aReactions were monitored by TLC. ^bIsolated yields

One of the salient features of this methodology is the exclusive regioselective bromination for majority of the substrates (Table IIB.1.1). Acetanilide **37** gave exclusively its *p*-derivative **37n**. When two *o,p*-directing groups are present in an aromatic ring, substituents having higher *o,p*-directing power, influence the incoming bromo group to its para position and if the para position is blocked then to its ortho position as shown for substrates **38–40**. As expected in presence of both a meta and an *o,p*-directing substituents in the same aromatic ring, the *o,p*-directing group controls the incoming bromo group to its para-position and if the para-position is blocked the bromination takes place in the ortho to the *o,p*-directing group as demonstrated for *p*-hydroxybenzonitrile **41**. However, using molecular bromine, a mixture of ortho and para products are obtained for *o*-cresol **39** and *m*-cresol **40**.^{9a} Regioselective bromination has been demonstrated with substrates **41–46** bearing various combination of functional groups. Phenolic substrates bearing benzyloxy carbonyl **47** and benzoyl group **48** survived under the described conditions giving corresponding *o*-bromo products **47n** and **48n** respectively. The fused ring phenolic compound, α -naphthol **49** afforded the expected 2-bromo- α -naphthol **49n**.

Table IIB.1.2. Bromination^a of Organic Substrates Using EDPBT Under Solv

Substrate	Product	Time (min)	Yield ^b
		25	91
		30	88
		30	93
		25	87
		25	95
		30	92
		25	96
		20	87
		25	89

Table Contd....

Substrate	Product	Time (min)	Yield ^b
		30	94
		30	93
		30	94
		30	95

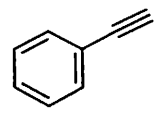
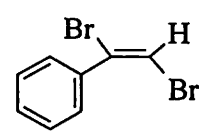
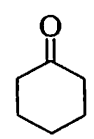
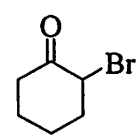
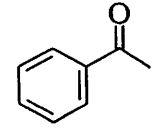
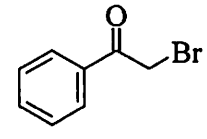
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Substrate	Product	Time (min)	Yield ^b
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		30	88
		30	93
		25	87
		25	95
		30	92
		25	96
		20	87
		25	89

Table Contd....

Substrate	Product	Time (min)	Yield ^b
 (59)	 (59n)	35	84
 (60)	 (60n)	60	80
 (61)	 (61n)	60	85

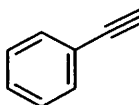
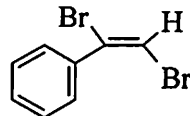
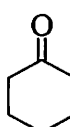
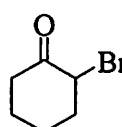
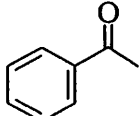
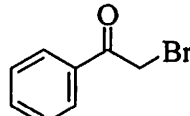
^a Reactions were monitored by TLC. ^b Isolated yields

The versatility of the methodology also lies in the fact that apart from aromatic electrophilic bromination of aromatic amines and phenols in Table IIB.1.1., this reagent also brominated several other functionalities such as ethylenic, acetylinic and carbonyl functions efficiently (Table IIB.1.2.). For example but-2-ene-1,4-diol **50**, hex-2-ene-1-ol **51**, vinyl benzene **52** and 1,1-diphenyl-ethene **53**, containing ethylenic functionality were all brominated to corresponding *trans*-dibromo compounds with just 0.5 equivalent of the reagent by simply grinding the substrate and the reagent in a mortar. The efficacy of the methodology was demonstrated by carrying out bromination of α,β -unsaturated ketones such as 4-phenyl-but-3-en-2-one **54** and 1,3-diphenyl-propenone **55**. Both substrates gave exclusively corresponding *erythro*-dibromo products **54n** and **55n** respectively. Cinnamaldehyde diacylate **56** gave corresponding *erythro*-dibromo product in excellent yield without affecting the acylal functionality under the described conditions. It is also possible to achieve perfect chemoselective bromination of one double bond in a substrate containing two symmetrical double bonds as demonstrated for dibenzylidene acetone **57** with 0.5 equivalent of the reagent. Substrates **58** and **59** containing acetylinic functionality could also be efficiently brominated with this reagent in excellent yields. However, terminal acetylinic substrate **59** gave a mixture of *trans* and *cis* product in the ratio (80 : 20) as obtained from the GC mass analysis. Finally, successful α -bromination of ketones such as cyclohexanone **60** and acetophenone **61** has been demonstrated with this reagent.

Table IIB.1.3. Regioselectivity Phenol, Aniline, *o*-Cresol, *m*-Cresol with Diffe

Reagent / Condition	Phenol (35)	aniline (36)	<i>o</i> -cresol (39)	<i>m</i> -cresol (40)
	% of <i>p</i> -product (isolated yields / GC yields)			
EDPBT / CH ₃ CN	84 / 88	84 / 89	93 / 96	91 / 95
EDPBT / Solid	85 / 89	85 / 90	93 / 96	92 / 96
TEATB / Solid	80 / 86	80 / 89	90 / 95	89 / 95
BTMATB / Solid	80 / 87	80 / 87	90 / 96	88 / 96
CTMATB / Solid	75 / 85	75 / 88	76 / 93	78 / 93
TBATB / Solid	72 / 87	72 / 87	78 / 94	76 / 94

The superiority of this reagent and the methodology with respect to other organoammonium tribromides has been shown by a highly efficient and regioselective bromination of phenol **35**, aniline **36**, *o*-cresol **39** and *m*-cresol **40**. The results are summarized in the Table IIB.1.3. As can be seen from Table IIB.1.3, similar reactivity and regioselectivity was found for EDPBT both in solution (CH₃CN) and in solid phase. Considering green chemistry aspects, the solid phase method is superior as no organic solvent is used in the first stage of the reaction and due to high water solubility of EDPBB only a small amount of organic solvent is required for product extraction. It may be noted here that for substrates giving solid products no organic solvent is used at any stage of the reaction. Other organoammonium tribromides such as tetraethyl (TEATB), benzyltrimethyl (BTMATB), cetyltrimethyl (CTMATB) and tetrabutylammonium (TBATB) are equally effective as far as the chemical conversion is concerned, as monitored by GC. However, excess water washings are required during workup for reaction involving TEATB, BTMATB, CTMATB and TBATB due to their phase transfer property, there by reducing the overall isolated yields. Sometime even after repeated washings, the product is invariably contaminated with organoammonium cations, particularly for CTMATB and TBATB requiring further chromatographic purification for all liquid products there by loss of products as well as ammonium cations. On the other hand due to high water solubility of EDPBB the product obtained using EDPBT is completely free from any contamination of cations,

Substrate	Product	Time (min)	Yield ^b .
 (59)	 (59n)	35	84
 (60)	 (60n)	60	80
 (61)	 (61n)	60	85

^a Reactions were monitored by TLC. ^b Isolated yields

The versatility of the methodology also lies in the fact that apart from aromatic electrophilic bromination of aromatic amines and phenols in Table IIB.1.1., this reagent also brominated several other functionalities such as ethylenic, acetylinic and carbonyl functions efficiently (Table IIB.1.2.). For example but-2-ene-1,4-diol **50**, hex-2-ene-1-ol **51**, vinyl benzene **52** and 1,1-diphenyl-ethene **53**, containing ethylenic functionality were all brominated to corresponding *trans*-dibromo compounds with just 0.5 equivalent of the reagent by simply grinding the substrate and the reagent in a mortar. The efficacy of the methodology was demonstrated by carrying out bromination of α,β -unsaturated ketones such as 4-phenyl-but-3-en-2-one **54** and 1,3-diphenyl-propenone **55**. Both substrates gave exclusively corresponding *erythro*-dibromo products **54n** and **55n** respectively. Cinnamaldehyde diacrylate **56** gave corresponding *erythro*-dibromo product in excellent yield without affecting the acrylal functionality under the described conditions. It is also possible to achieve perfect chemoselective bromination of one double bond in a substrate containing two symmetrical double bonds as demonstrated for dibenzylidene acetone **57** with 0.5 equivalent of the reagent. Substrates **58** and **59** containing acetylinic functionality could also be efficiently brominated with this reagent in excellent yields. However, terminal acetylinic substrate **59** gave a mixture of *trans* and *cis* product in the ratio (80 : 20) as obtained from the GC mass analysis. Finally, successful α -bromination of ketones such as cyclohexanone **60** and acetophenone **61** has been demonstrated with this reagent.

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EDPBT / CH ₃ CN	84 / 88	84 / 89	93 / 96	91 / 95
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TBATB / Solid	72 / 87	72 / 87	78 / 94	76 / 94

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which can be recovered and regenerated efficiently without any significant loss. The active bromine content per molecule of EDPBT is (48 %), which is higher compared to some of the other known tribromides, TEATB (43 %), BTMATB (41 %), CTMATB (30.5 %) and TBATB (33 %).

The most interesting feature of this reagent is that it can be regenerated. To regenerate the reagent from reaction of the type aromatic electrophilic substitution and α -bromination of ketones where exclusive monobromo products were obtained, 1.25 equiv of bromide (KBr) and 2 equiv of Oxone® was added to the aqueous layer containing 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) and two equiv of spent bromide. To regenerate the reagent from the aqueous layer obtained from the bromination of ethylenic and acetylinic compounds, where only EDPBB is present, 2 equiv of KBr was added along with 2 equiv of Oxone®. The recovered reagent is identical in all respects to the parent 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) reagent.

In summary, we have for the first time reported a ditribromide reagent with high active bromine content per molecule, which acts as an excellent bromine carrier capable of brominating an equivalent of the substrate with just half an equivalent of the reagent. The reaction is carried out under a solvent free condition. Selectivities and reactivities were shown to be far superior to any of the reported reagents and methodologies. It has unique features of providing enhanced yields, reduction in synthesis temperatures, shorter process times and environmentally friendly process. The spent reagent EDPBB can be easily recycled hence the process is economically viable for large-scale reaction. In addition to bromination it can be used for several other organic transformations as has been achieved by us with tetrabutylammonium tribromide.¹⁶

IIB.1.1. References

1. Larock, R. C. *Comprehensive Organic Transformations*, 2nd ed.; Wiley, New York, 1999.
2. (a) Gribble, G. W. *Chem. Soc. Rev.* **1999**, 335. (b) Butler, A.; Walker, J. V. *Chem. Rev.* **1993**, 93, 1937. (c) Seevers, R. H.; Counsell, R. E. *Chem. Rev.* **1982**, 82, 575.
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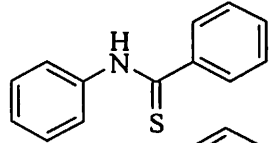
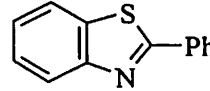
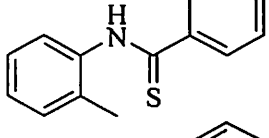
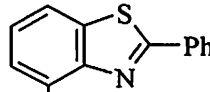
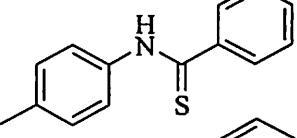
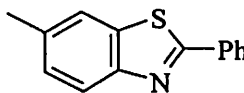
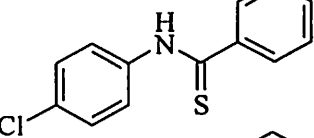
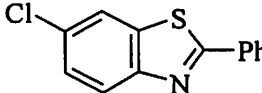
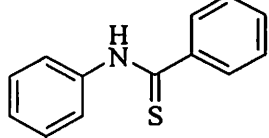
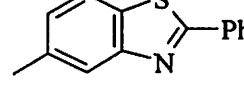
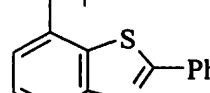
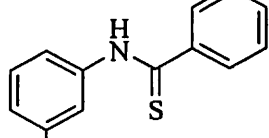
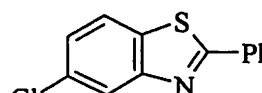
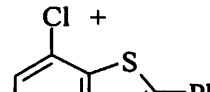
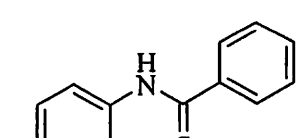
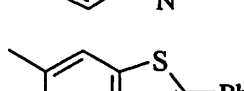
IIB. Present Work

IIB.2. Synthesis of 2-Substituted Benzothiazoles Using 1,1'-(Ethane-1,2-diyl)-Dipyridinium Bistribromide (EDPBT)

Benzothiazoles are found in variety of natural products and are important targets in the drug discovery. Derivatives of benzothiazoles are very important pharmaceutical agents due to the wide spectrum of biological activity exhibited by them. Details of their importance along with the methods of their synthesis are described in sections IIA.2. and IIA.2.1 (IIA.2.1.1-IIA.2.1.5), page 99-104.

Despite the numerous methods reported in the literature, some of the problems of the existing methods are difficulties in work-up, isolation, requirement of inert atmosphere, harsh reaction conditions, use of hazardous reagents and expensive catalysts. The use of copper salts for C-S bond formation also encounters a number of difficulties like high reaction temperatures, functional group incompatibility and requirement for substrates with ortho-carbonyl groups that are both electron-withdrawing and capable of chelating with copper. The reaction in which palladium is used as a catalyst, the removal of the palladium-residues from polar reaction during the later stages of the purification process and its use as pharmaceutical agents poses a serious problem.¹ Although some of these reactions usually proceeds efficiently at room temperature, several drawbacks are associated with the use of liquid bromine, which is toxic and corrosive and can be difficult to manipulate on small scale. It is known that excess bromine will produce the perbromide of amino-benzothiazole, which can then brominate the phenyl ring under the prolonged reaction conditions.² Alternative to liquid bromine is organic ammonium tribromides which are stable crystalline materials, capable of delivering a stoichiometric amount of bromine where small amounts of bromine are necessary for micro scale reactions. We have been utilizing tetrabutylammonium tribromide for bromination³ and for various other organic transformations.⁴ Recently we synthesized a new ditribromide reagent, 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) which is superior to all known tribromides and has several advantages over molecular bromine and other tribromides.⁵ In addition to acting as an excellent brominating agent,⁵ it has been utilized as a catalyst for the acylation of alcohols⁶ for the synthesis of various thiazolidene-2-imine derivatives⁷ and also used in the transformation of dithialane to dithiins.⁸ Here we have utilized 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) as a reagent for the synthesis of various 2-substituted benzothiazoles.

Table IIB.2.1. Formation of 2-Phenylbenzothiazole from Thioamide^a

Substrate	Product ^b	Time (h)	
	 (62o)	20	70
	 (63o)	15	65
	 (64o)	15	65
	 (65o)	20	70
	 (66o)	10	60 ^d
	 (66o')		
	 (67o)	20	60 ^d
	 (67o')		
	 (68o)	10	80

^a Reactions were monitored by TLC. ^b Products were characterized by IR, ¹H and ¹³C NMR. ^c Isolated yields. ^d Mixture of two inseparable isomeric products were obtained.

Various reaction conditions were tried to optimize the reaction condition. One equivalent of the substrate thiobenzanalide **62** and 0.6 equivalent of the reagent 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) in chloroform gave most satisfactory result. A plausible mechanism for the reaction is proposed in Scheme IIB.2.1. EDPBT releases bromine in the reaction medium. The lone

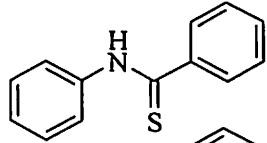
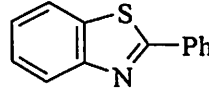
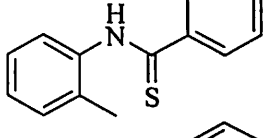
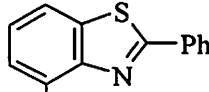
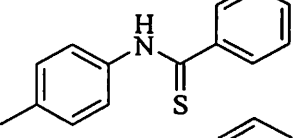
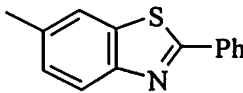
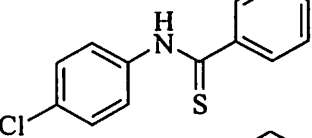
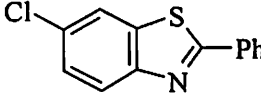
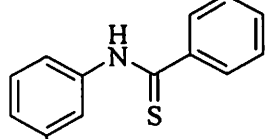
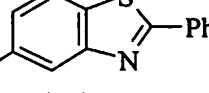
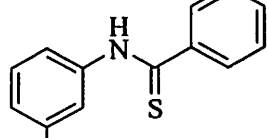
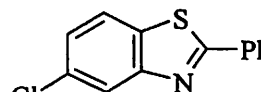
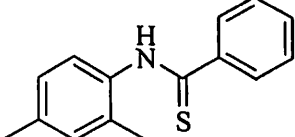
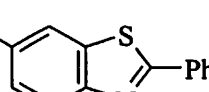
IIB. Present Work

IIB.2. Synthesis of 2-Substituted Benzothiazoles Using 1,1'-(Ethane-1,2-diyl)-Dipyridinium Bistribromide (EDPBT)

Benzothiazoles are found in variety of natural products and are important targets in the drug discovery. Derivatives of benzothiazoles are very important pharmaceutical agents due to the wide spectrum of biological activity exhibited by them. Details of their importance along with the methods of their synthesis are described in sections IIA.2. and IIA.2.1 (IIA.2.1.1-IIA.2.1.5), page 99-104.

Despite the numerous methods reported in the literature, some of the problems of the existing methods are difficulties in work-up, isolation, requirement of inert atmosphere, harsh reaction conditions, use of hazardous reagents and expensive catalysts. The use of copper salts for C-S bond formation also encounters a number of difficulties like high reaction temperatures, functional group incompatibility and requirement for substrates with ortho-carbonyl groups that are both electron-withdrawing and capable of chelating with copper. The reaction in which palladium is used as a catalyst, the removal of the palladium-residues from polar reaction during the later stages of the purification process and its use as pharmaceutical agents poses a serious problem.¹ Although some of these reactions usually proceeds efficiently at room temperature, several drawbacks are associated with the use of liquid bromine, which is toxic and corrosive and can be difficult to manipulate on small scale. It is known that excess bromine will produce the perbromide of amino-benzothiazole, which can then brominate the phenyl ring under the prolonged reaction conditions.² Alternative to liquid bromine is organic ammonium tribromides which are stable crystalline materials, capable of delivering a stoichiometric amount of bromine where small amounts of bromine are necessary for micro scale reactions. We have been utilizing tetrabutylammonium tribromide for bromination³ and for various other organic transformations.⁴ Recently we synthesized a new ditribromide reagent, 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) which is superior to all known tribromides and has several advantages over molecular bromine and other tribromides.⁵ In addition to acting as an excellent brominating agent,⁵ it has been utilized as a catalyst for the acylation of alcohols⁶ for the synthesis of various thiazolidene-2-imine derivatives⁷ and also used in the transformation of dithialane to dithiins.⁸ Here we have utilized 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) as a reagent for the synthesis of various 2-substituted benzothiazoles.

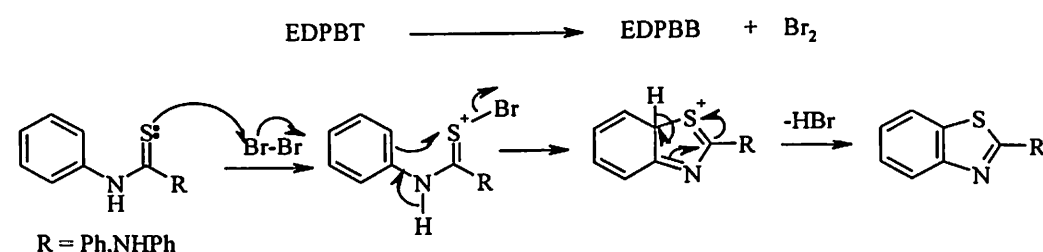
Table IIB.2.1. Formation of 2-Phenylbenzothiazole from Thioamide^a

Substrate	Product ^b	Time (h)	
 (62)	 (62o)	20	70
 (63)	 (63o)	15	65
 (64)	 (64o)	15	65
 (65)	 (65o)	20	70
 (66)	 (66o)	10	60 ^d
 (67)	 (67o)	20	60 ^d
 (68)	 (68o)	10	80

^a Reactions were monitored by TLC. ^b Products were characterized by IR, ¹H and ¹³C NMR. ^c Isolated yields. ^d Mixture of two inseparable isomeric products were obtained.

Various reaction conditions were tried to optimize the reaction condition. One equivalent of the substrate thiobenzanilide **62** and 0.6 equivalent of the reagent 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) in chloroform gave most satisfactory result. A plausible mechanism for the reaction is proposed in Scheme IIB.2.1. EDPBT releases bromine in the reaction medium. The lone

pair of electron on sulfur in thiourea or thioamide attacks the bromine resulting in the acquisition of positive charge by the sulfur atom followed by intramolecular electrophilic substitution reaction facilitated by the lone pair of electron on the nitrogen. This is followed by the rearomatization with the release of HBr as shown in Scheme IIB.2.1.



Scheme IIB.2.1. Mechanism of formation of benzothiazoles

As can be seen from Table IIB.2.1 most of the substrates gave moderate to good yields of their corresponding benzothiazoles. The thiobenzanilide **62** gave good yield of the benzothiazole **62o** when reacted with EDPBT in chloroform at room temperature. Substrate containing substitution at the ortho **63** and para **64** and **65** positions in the ring leads to the formation of one product exclusively. In the case of ortho substituted thioamide **63** only one side of the ring is accessible for the cyclization. For para substituted thioamides **64** and **65** the cyclization can occur on either of the ortho positions of the thioamide since both the positions are equivalent, only one product is obtained. However, in the case of meta substituted thioamides **66** and **67** there are two available positions for possible cyclization *i.e* ortho and para positions with respect to the substituent. It was observed that both the meta substituted substrates **66** and **67** gave both its possible isomers **66o** / **66o'** and **67** / **67o'** respectively in equimolar ratio, as evident from its ^1H and ^{13}C NMR spectrum. When electron donating substituents such as methyl and chloro are present as in the case of **66** and **67** both the positions are electronically favorable. This observation is consistent with the observation made by Jordan *et al* using benzyltrimethyl ammonium tribromide (BTMATB).⁹

Further this methodology was successfully applied for the synthesis of 2-arylmino benzothiazoles from the substituted diaryl thioureas. This reaction works equally well both in acetonitrile and in chloroform medium. We have chosen acetonitrile over chloroform because the former is more environmentally friendly. In an initial reaction diphenyl thiourea **69** (1 mmol) was treated with EDPBT (0.6 mmol) in acetonitrile (5 mL) at room temperature. The product obtained was

70 % after 6 h. However, 90 % conversion could be achieved in 2 h by perform $^{\circ}\text{C}$. The product obtained was precipitated out as its hydrobromide salt of **69p**.

the reaction, acetonitrile was evaporated and the solid residue washed with water to get rid of the spent reagent EDPBB leaving behind the solid hydrobromide salt. The hybromide salt of the product so obtained was treated with a saturated solution of NaHCO_3 (2 mL) and the product extracted with ethyl acetate (2 x 10 mL). Concentration of the organic layer after drying over anhydrous sodium sulphate yields the desired product **69p**. Further purification was achieved by crystallization using a mixture of ethyl acetate and hexane to obtain the pure product. Under the present reaction condition the symmetrical ortho substituted thiourea, 1,3-di-*o*-tolyl-thiourea **70** gave correspond benzothiazole **70p** in good yield. However, reaction of 1,3-di-*m*-tolyl-thiourea **71** yielded a mixture of two inseparable isomeric products **71p** and **71p'** in the ratio 3:1. One of the isomer **71p** preferentially crystallized from the mixture when crystallized from ethyl acetate hexane (8 : 2). The crystal structure of **71p** is shown in the Figure IIB.2.1

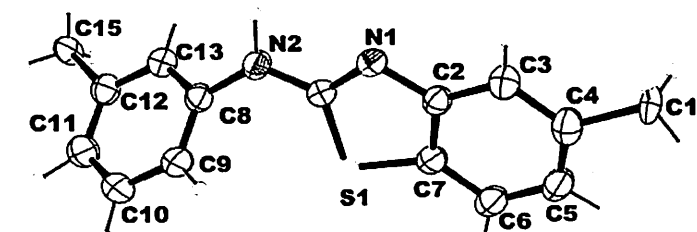
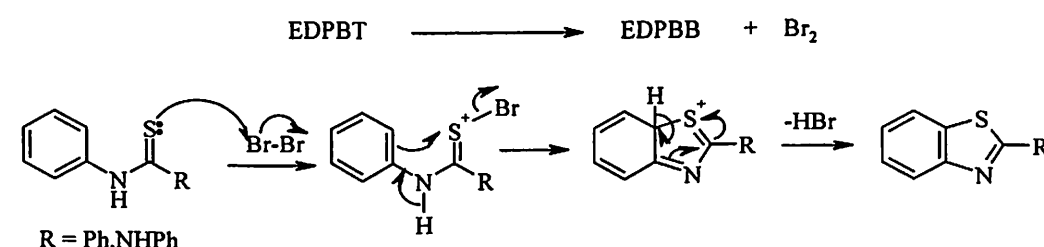


Figure IIB.2.1. Crystal structure of compound (**71p**).

The symmetrical para substituted thioureas such as di-*p*-tolyl thiourea **72**, di-*p*-methoxythiourea **73** were subjected to the present reaction condition to obtain the corresponding aminobenzothiazoles **72p** and **73p** in good yields. Since the ring formation can occur on either side of the thioureas as both the positions are equivalent. In the case of a symmetrical disubstituted thiourea such as 1,3-bis-(2,4-dimethyl-phenyl)-thiourea **74** only one of the position is available for the cyclization, to form benzothiazole **74p** derivative in good yield. When applied to an unsymmetrical diphenylthiourea **75** having a phenyl and a benzyl group the cyclization is towards the phenyl ring giving product **75p** in moderate yield.

pair of electron on sulfur in thiourea or thioamide attacks the bromine resulting in the acquisition of positive charge by the sulfur atom followed by intramolecular electrophilic substitution reaction facilitated by the lone pair of electron on the nitrogen. This is followed by the rearomatization with the release of HBr as shown in Scheme IIB.2.1.



Scheme IIB.2.1. Mechanism of formation of benzothiazoles

As can be seen from Table IIB.2.1 most of the substrates gave moderate to good yields of their corresponding benzothiazoles. The thiobenzanilide **62** gave good yield of the benzothiazole **62o** when reacted with EDPBT in chloroform at room temperature. Substrate containing substitution at the ortho **63** and para **64** and **65** positions in the ring leads to the formation of one product exclusively. In the case of ortho substituted thioamide **63** only one side of the ring is accessible for the cyclization. For para substituted thioamides **64** and **65** the cyclization can occur on either of the ortho positions of the thioamide since both the positions are equivalent, only one product is obtained. However, in the case of meta substituted thioamides **66** and **67** there are two available positions for possible cyclization *i.e* ortho and para positions with respect to the substituent. It was observed that both the meta substituted substrates **66** and **67** gave both its possible isomers **66o** / **66o'** and **67** / **67o'** respectively in equimolar ratio, as evident from its ^1H and ^{13}C NMR spectrum. When electron donating substituents such as methyl and chloro are present as in the case of **66** and **67** both the positions are electronically favorable. This observation is consistent with the observation made by Jordan *et al* using benzyltrimethyl ammonium tribromide (BTMATB).⁹

Further this methodology was successfully applied for the synthesis of 2-arylamino benzothiazoles from the substituted diaryl thioureas. This reaction works equally well both in acetonitrile and in chloroform medium. We have chosen acetonitrile over chloroform because the former is more environmentally friendly. In an initial reaction diphenyl thiourea **69** (1 mmol) was treated with EDPBT (0.6 mmol) in acetonitrile (5 mL) at room temperature. The product obtained was

70 % after 6 h. However, 90 % conversion could be achieved in 2 h by perform $^{\circ}\text{C}$. The product obtained was precipitated out as its hydrobromide salt of **69p** the reaction, acetonitrile was evaporated and the solid residue washed with water to get rid of the spent reagent EDPBB leaving behind the solid hydrobromide salt. The hybromide salt of the product so obtained was treated with a saturated solution of NaHCO_3 (2 mL) and the product extracted with ethyl acetate (2 x 10 mL). Concentration of the organic layer after drying over anhydrous sodium sulphate yields the desired product **69p**. Further purification was achieved by crystallization using a mixture of ethyl acetate and hexane to obtain the pure product. Under the present reaction condition the symmetrical ortho substituted thiourea, 1,3-di-*o*-tolyl-thiourea **70** gave correspond benzothiazole **70p** in good yield. However, reaction of 1,3-di-*m*-tolyl-thiourea **71** yielded a mixture of two inseparable isomeric products **71p** and **71p'** in the ratio 3:1. One of the isomer **71p** preferentially crystallized from the mixture when crystallized from ethyl acetate hexane (8 : 2). The crystal structure of **71p** is shown in the Figure IIB.2.1

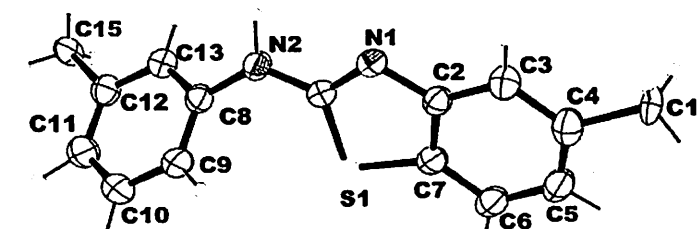


Figure IIB.2.1. Crystal structure of compound (**71p**).

The symmetrical para substituted thioureas such as di-*p*-tolyl thiourea **72**, di-*p*-methoxythiourea **73** were subjected to the present reaction condition to obtain the corresponding aminobenzothiazoles **72p** and **73p** in good yields. Since the ring formation can occur on either side of the thioureas as both the positions are equivalent. In the case of a symmetrical disubstituted thiourea such as 1,3-bis-(2,4-dimethyl-phenyl)-thiourea **74** only one of the position is available for the cyclization, to form benzothiazole **74p** derivative in good yield. When applied to an unsymmetrical diphenylthiourea **75** having a phenyl and a benzyl group the cyclization is towards the phenyl ring giving product **75p** in moderate yield.

Table IIB.2.2. Formation of 2-Phenylbenzothiazole from Thioamide^a

Substrate	Product ^b	Time (h)	Yield (%) ^c
		2	90
		3	85
		4	75
		3	80
		2	78
		3	79
		2	77

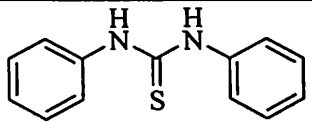
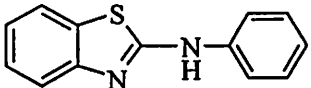
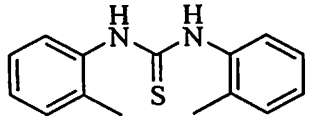
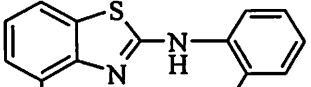
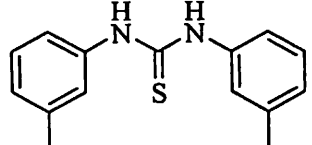
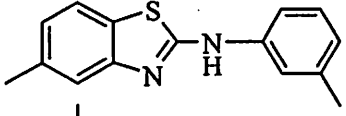
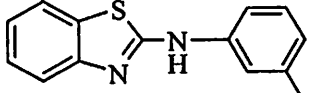
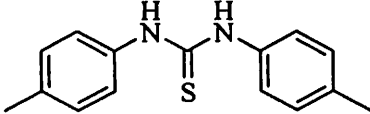
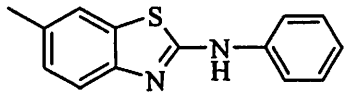
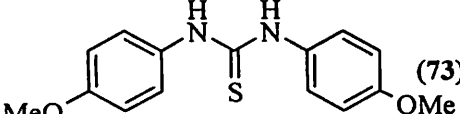
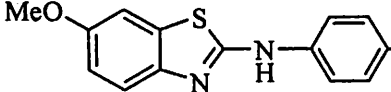
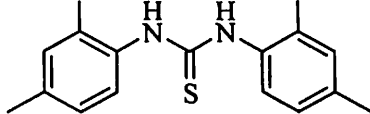
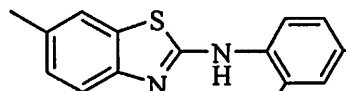
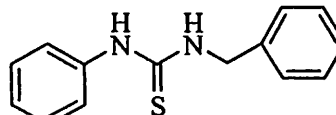
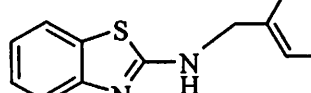
^a Reactions were monitored by TLC. ^b Products were characterized by IR, ¹H and ¹³C NMR. ^c Isolated yields.

In conclusion we have demonstrated an efficient method for the synthesis of 2-substituted benzothiazoles via oxidative cyclization of corresponding thioamides or thioureas using EDPBT as the reagent. The reactions are, in general, very clean giving good to moderate yields of the product. The selectivities in general are good particularly for unsymmetrical substituted thioureas. The spent reagent can be recovered and regenerated.

IIB.2.1. References

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Table IIB.2.2. Formation of 2-Phenylbenzothiazole from Thioamide^a

Substrate	Product ^b	Time (h)	Yield (%) ^c
 (69)	 (69p)	2	90
 (70)	 (70p)	3	85
 (71)	 (71p)	4	75
	 (71p')		
 (72)	 (72p)	3	80
 (73)	 (73p)	2	78
 (74)	 (74p)	3	79
 (75)	 (75p)	2	77

^a Reactions were monitored by TLC. ^b Products were characterized by IR, ¹H and ¹³C NMR. ^c Isolated yields.

In conclusion we have demonstrated an efficient method for the synthesis of 2-substituted benzothiazoles via oxidative cyclization of corresponding thioamides or thioureas using EDPBT as the reagent. The reactions are, in general, very clean giving good to moderate yields of the product. The selectivities in general are good particularly for unsymmetrical substituted thioureas. The spent reagent can be recovered and regenerated.

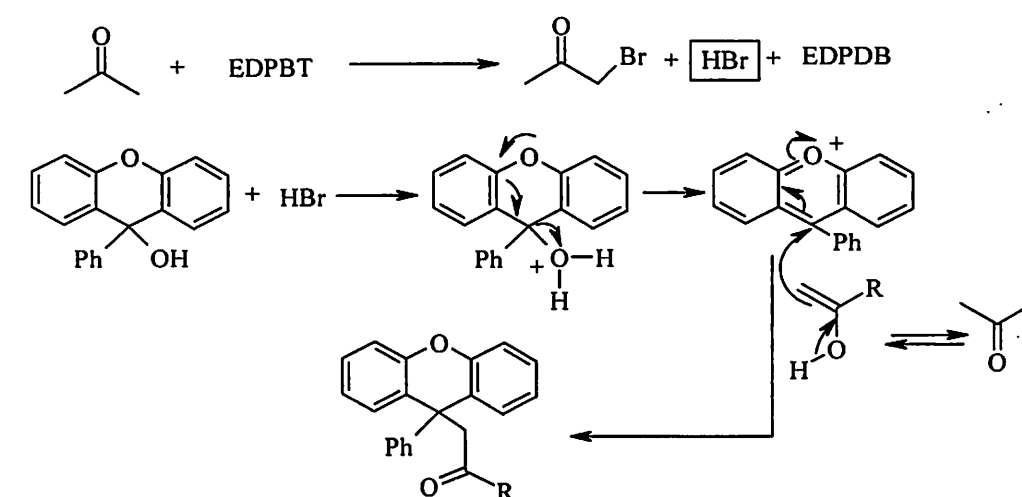
IIB.2.1. References

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IIB.3. Synthesis and Regiochemistry of Enol Addition to Xanthene and its Self Assembled Superstructure in Solid State

Xanthene derivatives are useful pharmaceuticals such as, muscarinic receptor antagonist, mGluR1 enhancer, cancer chemotherapy, trypanothione reductase inhibitor and chemosensitizers against chloroquine-resistant *Plasmodium falciparum*.¹ They are also useful as dyes, photosensitizers, catalysts for asymmetric 1,3-dipolar cycloaddition reactions² and have the propensity to form inclusion compounds with various aromatic compounds.³ Thus syntheses of xanthene derivatives are of immense interest. Intermolecular interactions play a central role in supramolecular chemistry, materials science and biology. Their understanding has allowed, for instance, crystal engineering to evolve and some new related concepts as tecton and synthon are now of common use in the field.⁴ Intermolecular interactions enable us to put molecules into desired positions to create novel functional nanostructures which have received great attention because of their potential applications ranging from electronics to medicine.⁵ The energy range for hydrogen-bond as well as its directionality facilitates the making of highly organized assemblies so that molecular species with functional groups suitable for hydrogen-bond formation constitute a target class of compounds for supramolecular aggregates.⁵ A current topic of hydrogen bond research is directional interactions of the types C-H...Y⁶ and X-H... π .⁷ In crystal structures, these types of weak hydrogen bonds are often found interconnected with 'normal' or other weak hydrogen bonds, forming motifs that are topologically analogous with conventional hydrogen bond patterns. Several authors have taken this as a manifestation of cooperativity phenomena.⁸ A set of weaker hydrogen bonding interactions has also been recognized to play an important role in protein structure and stability.^{4a,7c} This set includes N-H... π , O-H... π , C-H...O and C-H... π . The overall stabilization energy of these interactions is much smaller (not more than a few Kcal/mol), but is still significant. These weak interactions are suggested to constitute one of the important factors in controlling the crystal packing of molecules.⁹ Here we report the synthesis, regiochemistry of a range of xanthene derivatives along with self assembled solid state structures. Various multi carbon homologations **77q-86q** of 9-phenyl-9H-xanthen-9-ol **76** were obtained through a C-C bond formation by reacting it with various enolizable ketones in an acidic medium. In addition to the synthesis and regiochemistry of various addition products we were

interested in the self-assembled superstructure in solid state of 9-phenyl-9H change of supramolecular architect with homologous variation of xanthene deriv



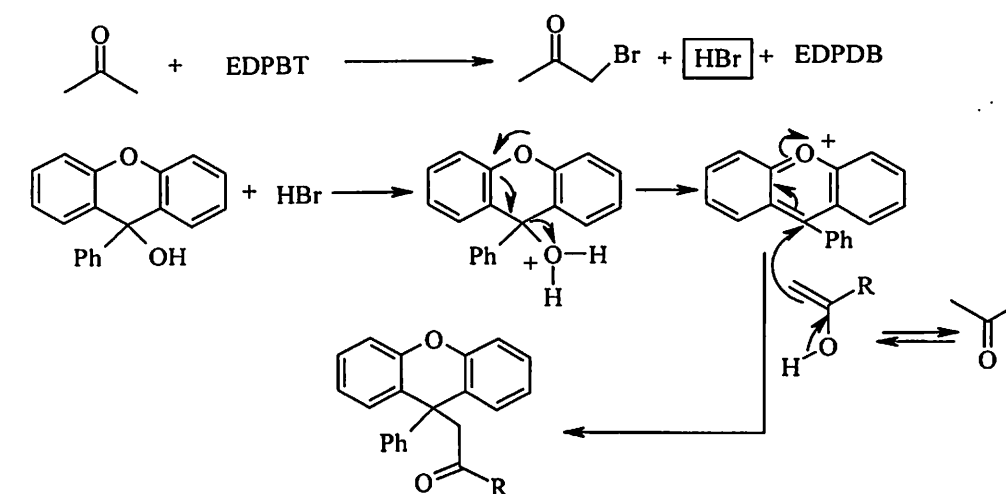
Scheme IIB.3.1. Proposed mechanism of C-C bond formation

Tetrabutyl ammonium tribromide in an organic medium is an excellent source of anhydrous HBr which has been utilized for various important organic transformations in our laboratory.¹⁰ Recently we have developed 1,2-dipyridiniumditribromide-ethane (DPTBE) which is found to be superior to all known organic ammonium tribromides.¹¹ This compound is renamed as 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) and is an excellent catalyst for acylation of alcohols using acetic anhydrides.¹² In an attempt to acetylate 9-phenyl-9H-xanthen-9-ol **76** employing acetic anhydride in acetone and 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) as catalyst¹² gave no trace of acetylated product, rather an unusual three carbon homologation **77q** was observed. Being buoyant by this result we focused our attention to synthesize various analogues. A similar C-C bond formation at the tertiary carbon of 1,8-dimethoxy-9-phenyl-9H-xanthen-9-ol has been observed with 60% aqueous HClO₄ at elevated temperature but only with three enolizable ketones.¹³ Very recently, reaction of xanthidrol, thioxanthidrol and 9,10-dihydro-10-methyl-9-acrydenol with N-vinylacetamide or ethylvinylether as acetaldehyde anion equivalents has also been reported.¹⁴ Formation of the product 1-(9-phenyl-9H-xanthen-9-yl)-propan-2-one **77q** could only be explained through a carbocation intermediate, obtained by the initial reaction of tertiary alcohol **76** with HBr generated by the reaction of EDPBT with acetone, which undergoes nucleophilic attack by the

IIB.3. Synthesis and Regiochemistry of Enol Addition to Xanthene and its Self Assembled Superstructure in Solid State

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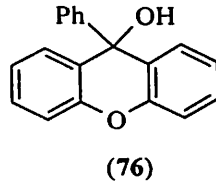
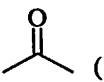
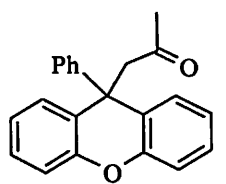
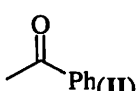
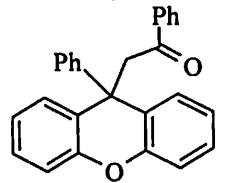
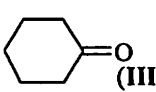
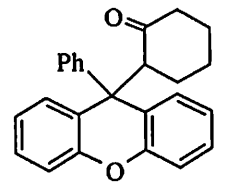
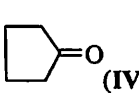
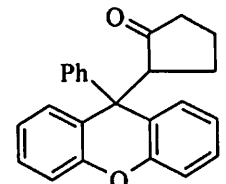
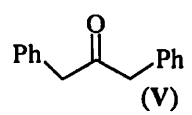
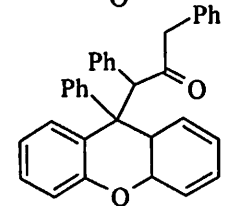


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Table IIB.3.1. C-C Bond Formation at the Tertiary Carbon of Xanthenol with Ketones^a

Substrate	Ketone	Product ^b	Time (h)	Yield (%) ^c
 (76)	 (I)	 (77q)	12	87
	 (II)	 (78q)	24	81
	 (III)	 (79q)	18	80
	 (IV)	 (80q)	18	77
	 (V)	 (81q)	24	72

^aReactions were monitored by TLC. ^bProducts were characterized by IR, ¹H and ¹³C NMR and single crystal XRD analysis. ^cYields of the isolated product.

The scope of the reaction was extended further by replacing acetone with other enolizable ketones such as acetophenone **II** which gave **78q** as the exclusive product. Cyclic aliphatic ketones such as cyclohexanone **III** and cyclopentanone **IV** gave the corresponding addition product **79q** and **80q** respectively in good yields in a relatively shorter reaction time (Table IIB.3.1). Other symmetrical ketone, 1,3-diphenylpropane-2-one **V** also gave the expected product **81q**.

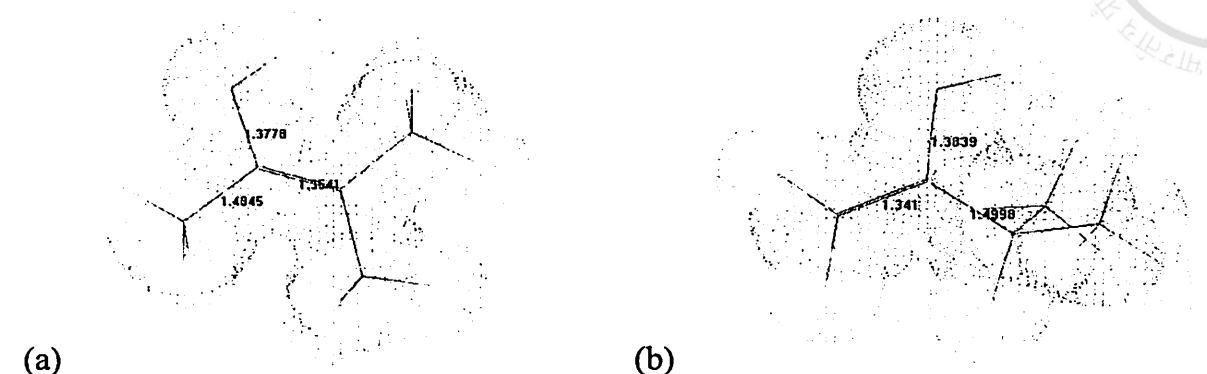


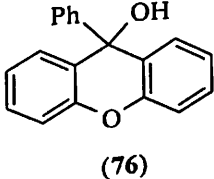
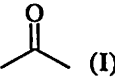
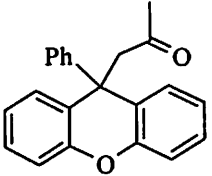
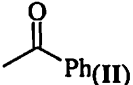
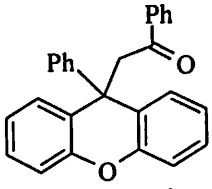
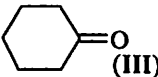
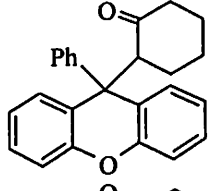
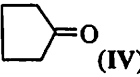
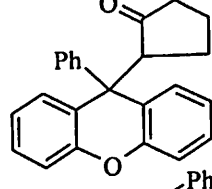
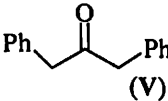
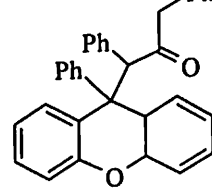
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However, when a similar reaction was performed with an unsymmetrical ketone such as butan-2-one **VI**, the sole product 3-(9-phenyl-9H-xanthen-9-yl)-butan-2-one **82q** obtained was through the attack of methylene carbon rather than methyl carbon (Table IIB.3.2.). In spite of the steric hindrance, the regioselectivity of the product is governed by the formation of stable enol, giving 3-(9-phenyl-9H-xanthen-9-yl)-butan-2-one **82q** exclusively. This observation is however inconsistent with the observation made by others, where the product obtained is by the attack of methyl carbon of butan-2-one.¹³ The difference in observed regiochemistry may be due to a different xanthene system, 1,8-dimethoxy-9H-xanthene-9-ol instead of 9-phenyl-9H-xanthen-9-ol **76**. However, unsymmetrical and one side sterically hindered ketone, 4-methyl-pent-2-one **VII** gave the product 4-methyl-1-(9-phenyl-9H-xanthen-9-yl)-penta-2-one **83q** (Table IIB.3.2) through a kinetically controlled enol. This is in spite of the fact that even though enolization is expected to favor towards a thermodynamically stable form but a large steric factor due to the adjacent isopropyl group (Figure IIB.3.1) the attack is only possible from the less hindered enolizable side.

Neither of the above observations has however been manifested during the reaction of 3-methyl-butane-2-one **VIII** with **76** under an identical condition. Analysis of product showed an oxygen inserted product from the more hindered side of the enolized ketone **VIII** giving the oxygen inserted product **84q** as shown in Table IIB.3.2. This result is unexpected and unprecedented in the literature. This can be explained only if the reaction goes via a radical mechanism. No signal for radical could be detected when reaction was continuously monitored by EPR spectrometer. Later it was found that formation of product **84q** was due to the contamination of corresponding

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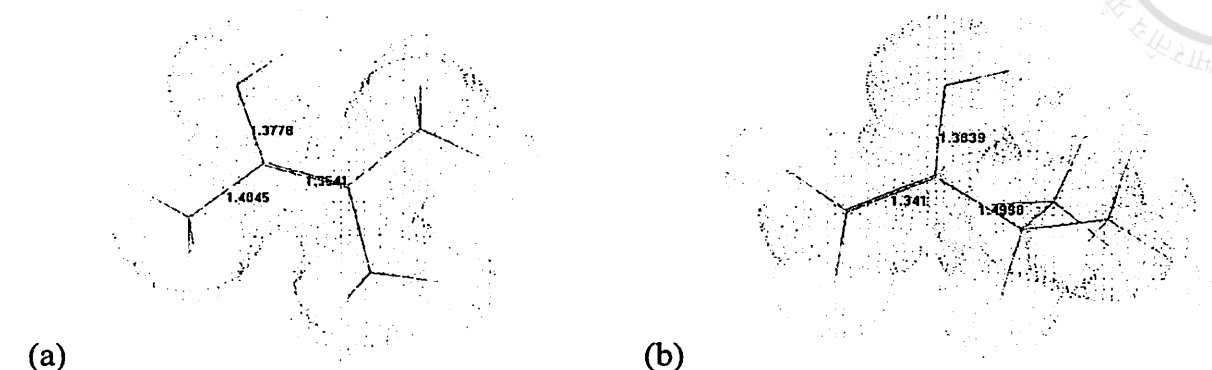


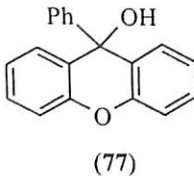
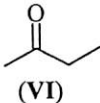
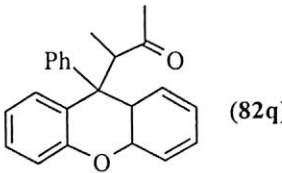
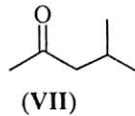
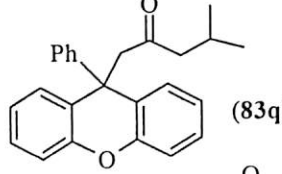
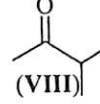
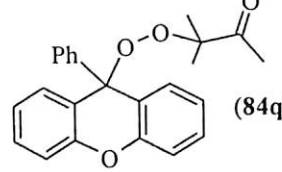
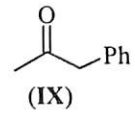
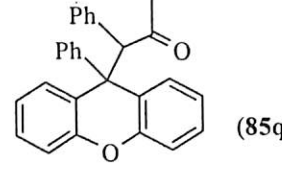
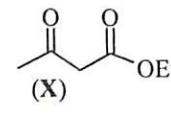
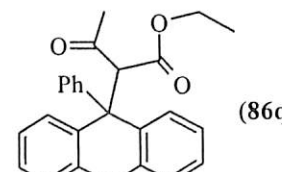
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hydroperoxide obtained by a radical autooxidation at the tertiary carbon of **VIII**. When reaction was performed with a freshly distilled ketone under a nitrogen atmosphere no reaction occurred even after three days. This is because enolization is expected to favor exclusively¹⁰ towards more substituted enol which is sterically unfavorable for attack on xanthenyl carbocation. No kinetically controlled enol addition product was observed due extra ordinary stability of the highly substituted enol of **VIII**.¹⁰

Table IIB.3.2. C-C Bond Formation at the Tertiary Carbon of Xanthenol with Unsymmetrical Ketones^a

Substrate	Ketone	Product ^b	Time / h	Yield (%) ^c
 (77)	 (VI)	 (82q)	24	79
	 (VII)	 (83q)	24	60
	 (VIII)	 (84q) ^d	12	35
	 (IX)	 (85q)	24	78
	 (X)	 (86q)	12	75

^aReactions were monitored by TLC. ^bProducts were characterized by IR, ¹H and ¹³C NMR and single crystal XRD analysis. ^cYields of the isolated product.

Two other unsymmetrical ketones viz. 1-phenylpropan-2-one **IX** and ethyl acetoacetate **X** were reacted with **76**, both gave product (**85q** and **86q**) with regiochemistry corresponding to the

attack by the thermodynamically stable enol. Regiochemistry of the product was by ¹H NMR but also by single crystal X-ray analysis, without which it would have unequivocally elucidate the structure of oxygen inserted product **84q**.

Description of Crystal Structures (76 and 77q-86q)

Single crystal X-ray diffraction studies of all the products **77q-86q** along with its starting compound **76** was carried out. During the course of solid state structural analysis of xanthene **76** and its derivatives **76q-86q** they were found to form self assembled supramolecular architecture in 3D space. Critical investigation of the solid state structure can help us to reveal the effect of variation of alkyl and aryl appendage on the supramolecular assembly / crystal engineering.

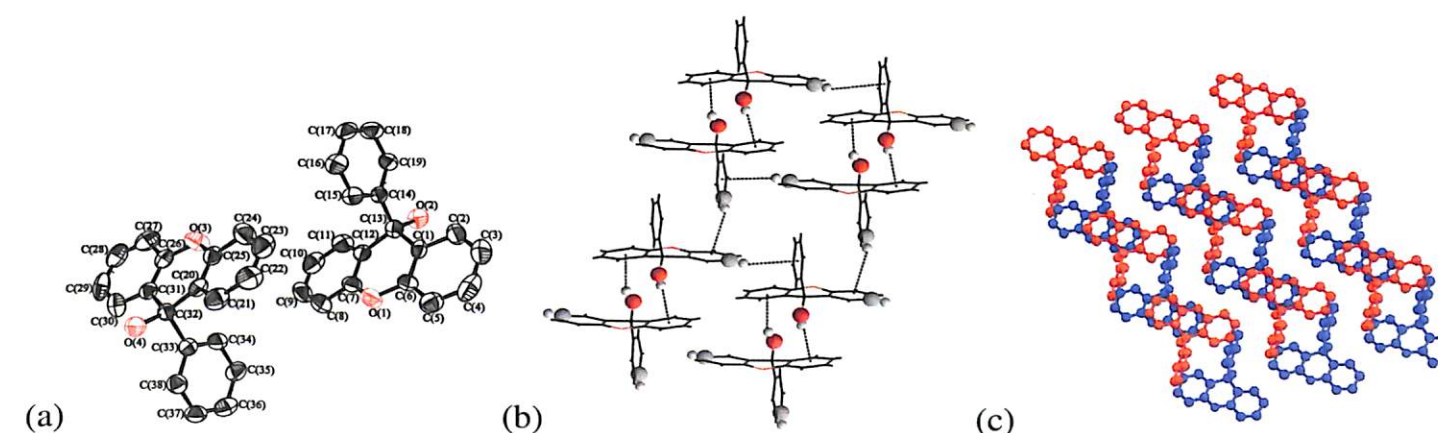
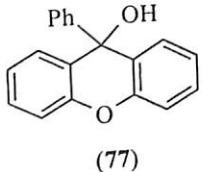
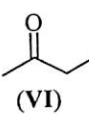
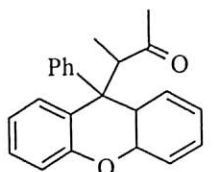
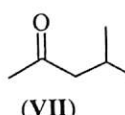
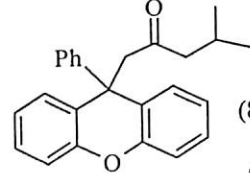
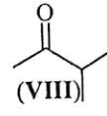
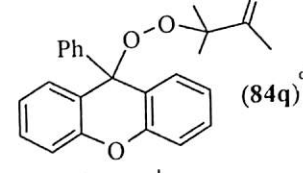
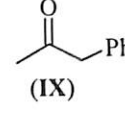
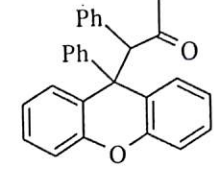
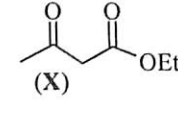
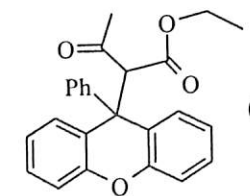


Figure IIB.3.2. (a) ORTEP plot with atom numbering scheme of (**76**). (b) O–H···π and C–H···π hydrogen bond in (**76**) along c-axis, (c) 3D pillared staircase organic network structure in (**76**).

In the asymmetric unit two molecules of **76** crystallizes in the opposite directions (Figure IIB.3.2a). Phenyl ring is orthogonal to the xanthene ring systems. Alcohol oxygen atoms form dimer via strong intermolecular O–H···π (O2–H2A···π = 2.507 Å and O4–H4A···π = 2.407 Å) hydrogen bonding. Each of these dimeric units are interconnected via the formation of C–H···π (C3–H3···π = 3.225 Å, C17–H17···π = 3.450 Å, C29–H29···π = 2.235 Å type of hydrogen bonding (Figure IIB.3.2b), which in turn results the formation of 3D pillared staircase organic network structure (Figure IIB.3.2c). The distance between two parallel staircases is 3.959 Å, while distance between each stair is 7.628 Å. The rectangular boxes of dimensions 8.161 Å x 5.337 Å, formed by the two

hydroperoxide obtained by a radical autooxidation at the tertiary carbon of **VIII**. When reaction was performed with a freshly distilled ketone under a nitrogen atmosphere no reaction occurred even after three days. This is because enolization is expected to favor exclusively¹⁰ towards more substituted enol which is sterically unfavorable for attack on xanthenyl carbocation. No kinetically controlled enol addition product was observed due extra ordinary stability of the highly substituted enol of **VIII**.¹⁰

Table IIB.3.2. C-C Bond Formation at the Tertiary Carbon of Xanthenol with Unsymmetrical Ketones^a

Substrate	Ketone	Product ^b	Time / h	Yield (%) ^c
 (77)	 (VI)	 (82q)	24	79
	 (VII)	 (83q)	24	60
	 (VIII)	 (84q) ^d	12	35
	 (IX)	 (85q)	24	78
	 (X)	 (86q)	12	75

^aReactions were monitored by TLC. ^bProducts were characterized by IR, ¹H and ¹³C NMR and single crystal XRD analysis. ^cYields of the isolated product.

Two other unsymmetrical ketones viz. 1-phenyl-propan-2-one **IX** and ethyl acetoacetate **X** were reacted with **76**, both gave product (**85q** and **86q**) with regiochemistry corresponding to the

attack by the thermodynamically stable enol. Regiochemistry of the product was elucidated by ¹H NMR but also by single crystal X-ray analysis, without which it would have been difficult to unequivocally elucidate the structure of oxygen inserted product **84q**.

Description of Crystal Structures (76 and 77q-86q)

Single crystal X-ray diffraction studies of all the products **77q-86q** along with its starting compound **76** was carried out. During the course of solid state structural analysis of xanthene **76** and its derivatives **76q-86q** they were found to form self assembled supramolecular architecture in 3D space. Critical investigation of the solid state structure can help us to reveal the effect of variation of alkyl and aryl appendage on the supramolecular assembly / crystal engineering.

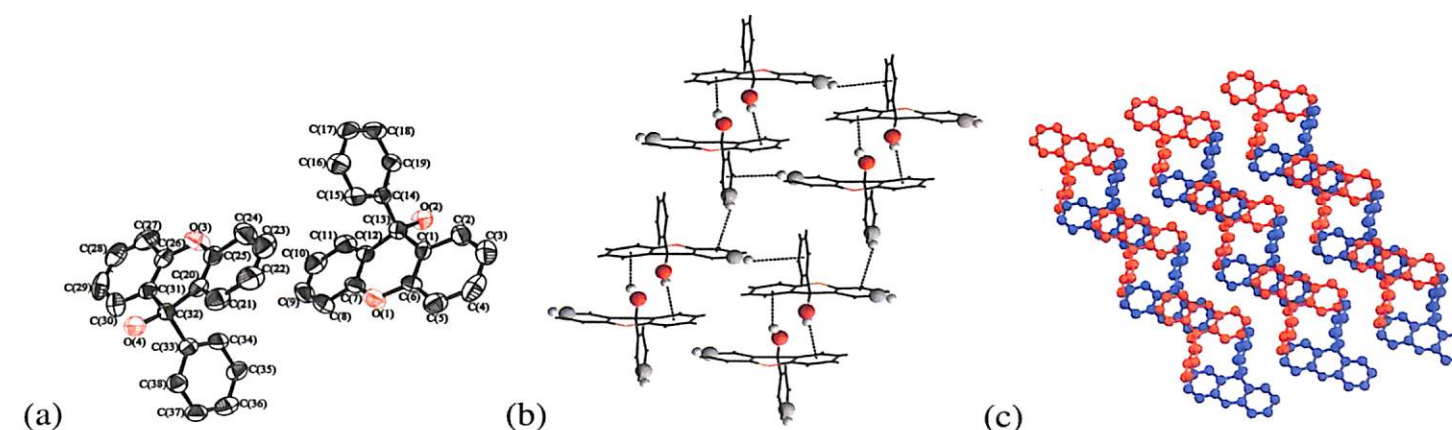


Figure IIB.3.2. (a) ORTEP plot with atom numbering scheme of (**76**). (b) O-H... π and C-H... π hydrogen bond in (**76**) along c-axis, (c) 3D pillared staircase organic network structure in (**76**).

In the asymmetric unit two molecules of **76** crystallizes in the opposite directions (Figure IIB.3.2a). Phenyl ring is orthogonal to the xanthene ring systems. Alcohol oxygen atoms form dimer via strong intermolecular O-H... π (O2-H2A... π = 2.507 Å and O4-H4A... π = 2.407 Å) hydrogen bonding. Each of these dimeric units are interconnected via the formation of C-H... π (C3-H3... π = 3.225 Å, C17-H17... π = 3.450 Å, C29-H29... π = 2.235 Å type of hydrogen bonding (Figure IIB.3.2b), which in turn results the formation of 3D pillared staircase organic network structure (Figure IIB.3.2c). The distance between two parallel staircases is 3.959 Å, while distance between each stair is 7.628 Å. The rectangular boxes of dimensions 8.161 Å x 5.337 Å, formed by the two

oppositely oriented molecules in the asymmetric unit constitute the pillar of the staircase. The hydrogen bond distances and angles are tabulated in Table IIB.3.3.

Table IIB.3.3. Hydrogen Bond Distances and Angles for Compound **76**

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
76	O2–H2A··· π (Centroid ^b)	2.507	3.252	151.62
	O4–H4A··· π (Centroid ^a)	2.470	3.250	159.43
	C3–H3··· π (Centroid ^c)	3.255	3.879	126.28
	C17–H17··· π (Centroid ^d)	3.450	3.968	117.70
	C29–H29··· π (Centroid ^e)	3.235	3.870	127.30

^aCentroid of ring C7–C12, ^bCentroid of ring C20–C25, ^cCentroid of ring C14–C19, ^dCentroid of ring C26–C31,

^eCentroid of ring C33–C38.

Compound **77q** contains two molecules in the asymmetric unit like its starting compound **76**, while **78q** contains one molecule in the asymmetric unit, as terminal methyl is replaced by a phenyl group (Figure IIB.3.3). Pendant phenyl ring is also almost perpendicular to the xanthene ring system.

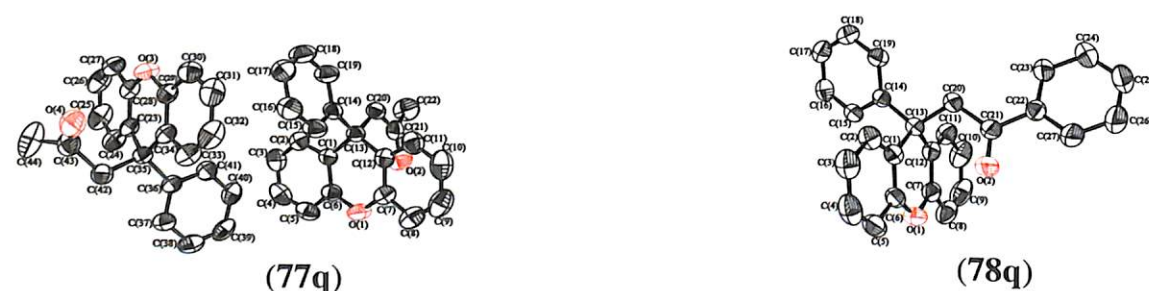


Figure IIB.3.3. An ORTEP view with atom numbering scheme of **77q** and **78q**.

The compound **77q** shows the presence of C–H···O (C3–H3···O4 = 2.892 Å and C39–H39···O3 = 2.478 Å) type hydrogen bonding network to form the linear array along crystallographic *a* axis (Figure IIB.3.4a) involving xanthene oxygen atoms unlike compound **76**. The parallel linear arrays are pointed in the opposite directions and they are connected via C–H··· π (C19–H19··· π = 3.300 Å, C22–H22B··· π = 3.072 Å, C26–H26··· π = 3.348 Å and C34–H34··· π = 3.345 Å) hydrogen bonding. Overall hydrogen bonding network results in the formation of 3D alternate

continuous wave-like tape and discrete box network (Figure IIB.3.4b). One of the asymmetric unit forms the box of dimension 6.580 Å x 5.887 Å. The hydrogen angles are for **77q** and **78q** tabulated in Table IIB.3.4 and Table IIB.3.5 respectively.

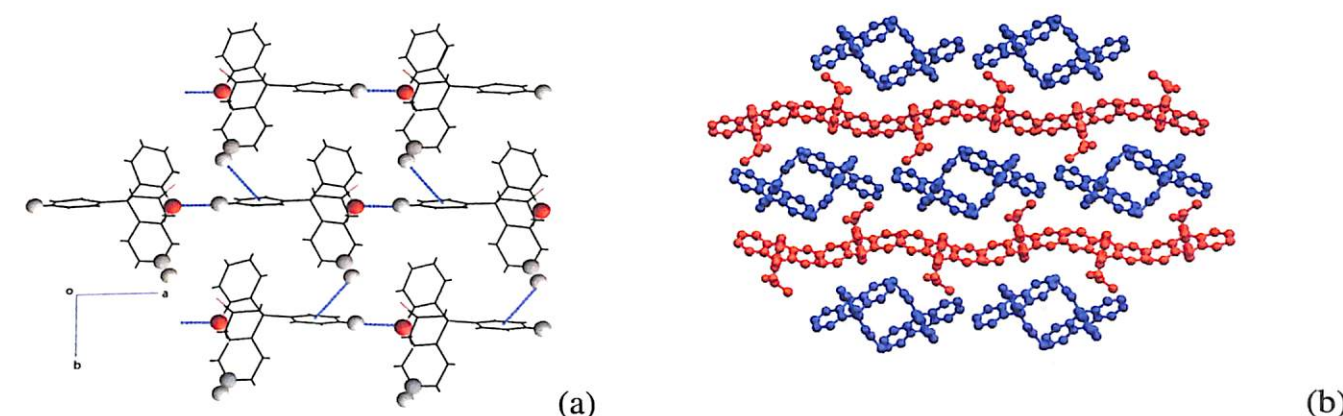


Figure IIB.3.4. (a) Formation C–H···O and C–H··· π hydrogen bonding network in **77q** view along *c* axis., (b) Alternate box and wave-like tape structure in the compound **77q** view along *a* axis.

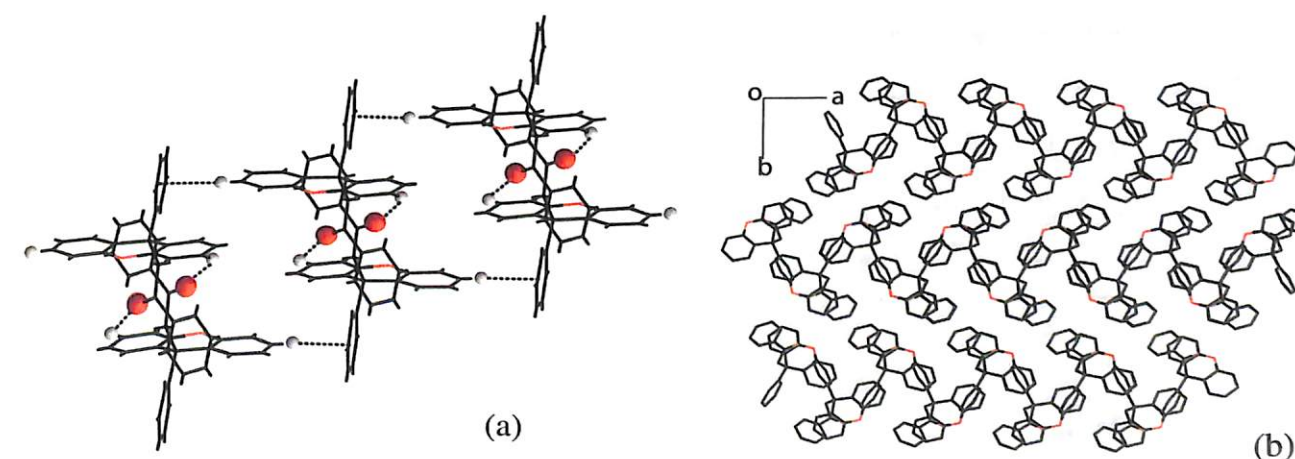


Figure IIB.3.5. (a) C–H···O and C–H··· π hydrogen bonding network in **78q**, (b) Zig-zag tape structure in the compound **78q** along *a* axis

oppositely oriented molecules in the asymmetric unit constitute the pillar of the staircase. The hydrogen bond distances and angles are tabulated in Table IIB.3.3.

Table IIB.3.3. Hydrogen Bond Distances and Angles for Compound **76**

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
76	O2–H2A··· π (Centroid ^b)	2.507	3.252	151.62
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	C3–H3··· π (Centroid ^c)	3.255	3.879	126.28
	C17–H17··· π (Centroid ^d)	3.450	3.968	117.70
	C29–H29··· π (Centroid ^e)	3.235	3.870	127.30

^aCentroid of ring C7–C12, ^bCentroid of ring C20–C25, ^cCentroid of ring C14–C19, ^dCentroid of ring C26–C31,

^eCentroid of ring C33–C38.

Compound **77q** contains two molecules in the asymmetric unit like its starting compound **76**, while **78q** contains one molecule in the asymmetric unit, as terminal methyl is replaced by a phenyl group (Figure IIB.3.3). Pendant phenyl ring is also almost perpendicular to the xanthene ring system.

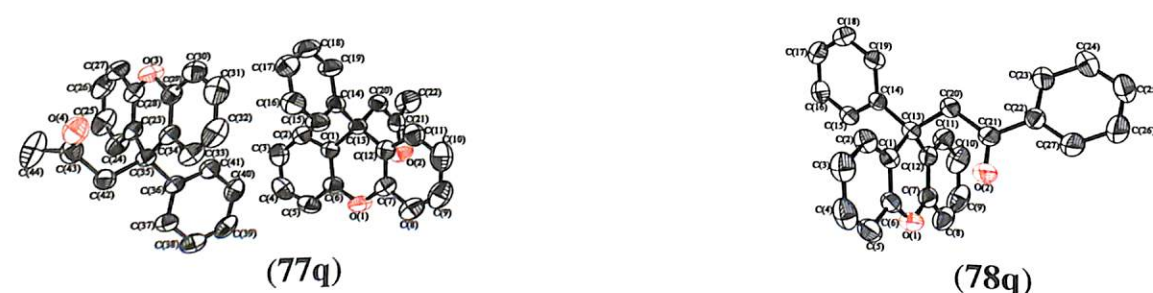


Figure IIB.3.3. An ORTEP view with atom numbering scheme of **77q** and **78q**.

The compound **77q** shows the presence of C–H···O (C3–H3···O4 = 2.892 Å and C39–H39···O3 = 2.478 Å) type hydrogen bonding network to form the linear array along crystallographic *a* axis (Figure IIB.3.4a) involving xanthene oxygen atoms unlike compound **76**. The parallel linear arrays are pointed in the opposite directions and they are connected via C–H··· π (C19–H19··· π = 3.300 Å, C22–H22B··· π = 3.072 Å, C26–H26··· π = 3.348 Å and C34–H34··· π = 3.345 Å) hydrogen bonding. Overall hydrogen bonding network results in the formation of 3D alternate

continuous wave-like tape and discrete box network (Figure IIB.3.4b). One of the asymmetric unit forms the box of dimension 6.580 Å x 5.887 Å. The hydrogen bond angles are for **77q** and **78q** tabulated in Table IIB.3.4 and Table IIB.3.5 respectively.

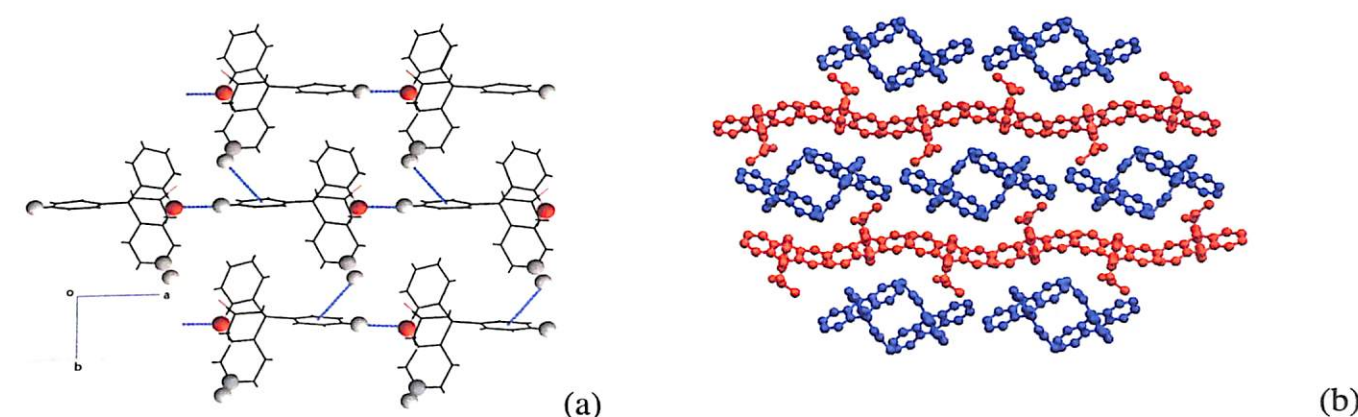


Figure IIB.3.4. (a) Formation C–H···O and C–H··· π hydrogen bonding network in **77q** view along *c* axis., (b) Alternate box and wave-like tape structure in the compound **77q** view along *a* axis.

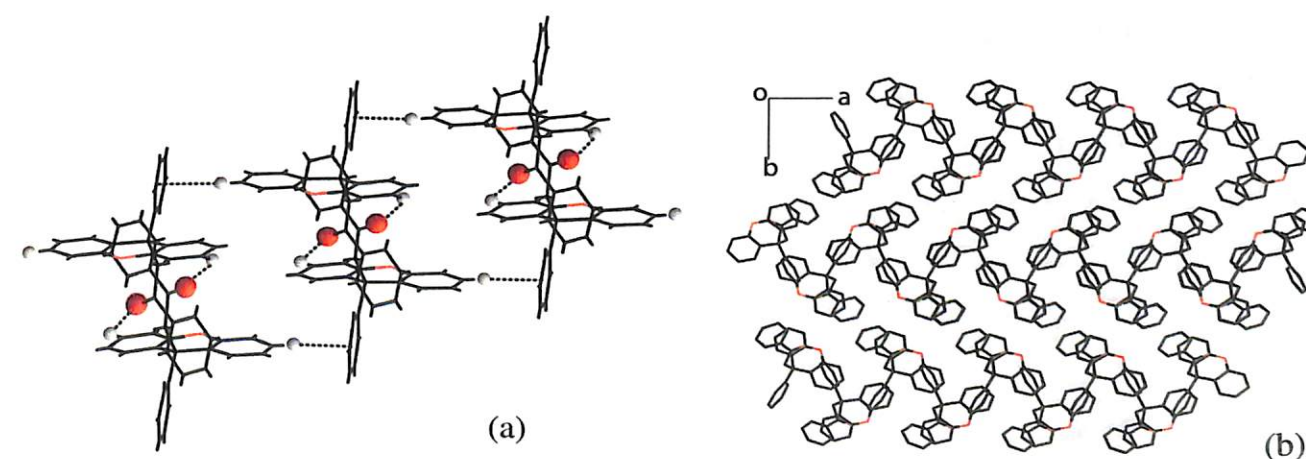


Figure IIB.3.5. (a) C–H···O and C–H··· π hydrogen bonding network in **78q**, (b) Zig-zag tape structure in the compound **78q** along *a* axis

Table IIB.3.4. Hydrogen Bond Distances and Angels for Compound 77q

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
77q	C3–H3···O4	2.892	3.494	123.66
	C39–H39···O3	2.478	3.388	166.10
	C19–H19··· π (Centroid ^a)	3.300	4.051	139.19
	C22–H22B··· π (Centroid ^b)	3.072	3.786	132.37
	C26–H26···π (Centroid ^c)	3.348	3.849	116.10
	C34–H34··· π (Centroid ^d)	3.345	3.849	116.10

^a Centroid of ring C1–C6, ^b Centroid of ring C23–C28, ^c Centroid of ring C36–C41, ^d Centroid of ring C24–C29.

Table IIB.3.5. Hydrogen Bond Distances and Angels for Compound 78q

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
78q	C9–H9···O2	2.888	3.470	121.96
	C4–H4··· π (Centroid ^a)	2.725	3.585	154.20

^a Centroid of ring C14–C19.

The acetophenone adduct **78q** forms staircase via intermolecular C–H···π (C4–H4···π = 2.725 Å) type hydrogen bonding and each staircase is interconnected through C–H···O (C9–H9···O2 = 2.888 Å) type hydrogen bonding through the pendant carbonyl oxygen atoms, while xanthene ring oxygen does not take part here like compound **76** (Figure 5a). Overall results in these extensive hydrogen bonding network is 3D zig-zag tape structure (Figure IIB.3.5b) along crystallographic *a* axis. Adjacent zig-zag tapes are oriented in the opposite directions.

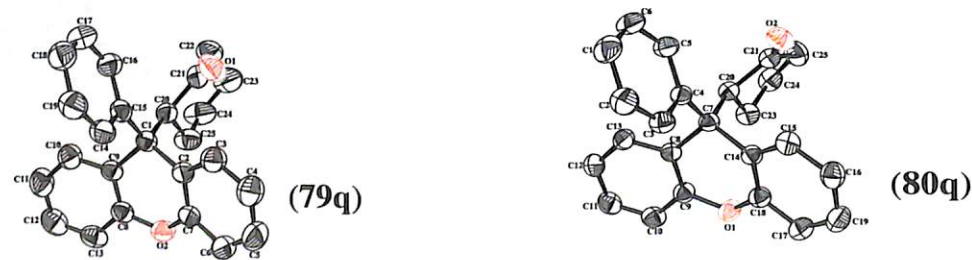


Figure IIB.3.6. An ORTEP view with atom numbering scheme of 79q and 80q.

Incidentally, there is a striking similarity between the structural disposition of cyclohexanone **79q** and cyclopentanone **80q** addition products. For instance, both compounds **79q** and **80q** has similar solid-state structural disposition (Figure IIB.3.6) in space. Pendant phenyl ring and the cyclic ketone make an angle of 112.12° and 114.26° respectively. Compound **79q** form zig-zag linear array along *a* axis via C–H···O type hydrogen bonding (C15–H15···O1 = 2.605 Å) and the adjacent linear arrays are oriented in the opposite direction (Figure IIB.3.7a). An internal comparison of the packing patterns of **79q** and **80q** reveals certain interesting features, for instance, whereas the compound **79q** forms only C–H···O type hydrogen bonding while **80q** shows the presence of C–H···O, C–H···π and π–π type interactions. Unlike **79q**, in compound **80q** both the oxygen atoms form C–H···O hydrogen bonding (C1–H1···O1 = 2.664 Å and C19–H19···O2 = 2.671 Å). Weaker C–H···π interactions are also responsible for the formation of organic network (C5–H5···π (C14–C19) = 3.378 Å and C24–H24a···π (C1–C6) = 3.234 Å). The cyclopentanone adduct **80q** shows the presence of π–π interactions (π (C14–C19)···π (C14–C19) = 4.691 Å). Combination of these interaction results in to a mosaic structural motif (Figure IIB.3.7b). The hydrogen bond distances and angles are for **79q** and **80q** tabulated in Table IIB.3.6 and Table IIB.3.7 respectively.

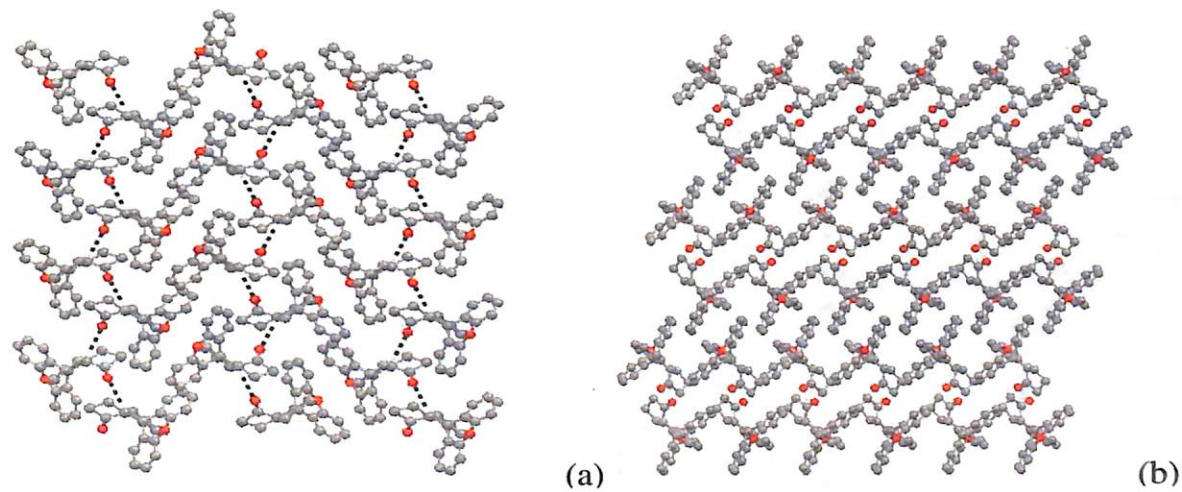


Figure IIB.3.7. (a) Packing of 79q and (b) mosaic structural motif of 80q.

Table IIB.3.6. Hydrogen Bond Distances and Angels for Compound 79q

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
79q	C15–H15···O1	2.605	3.470	121.96

Table IIB.3.4. Hydrogen Bond Distances and Angels for Compound 77q

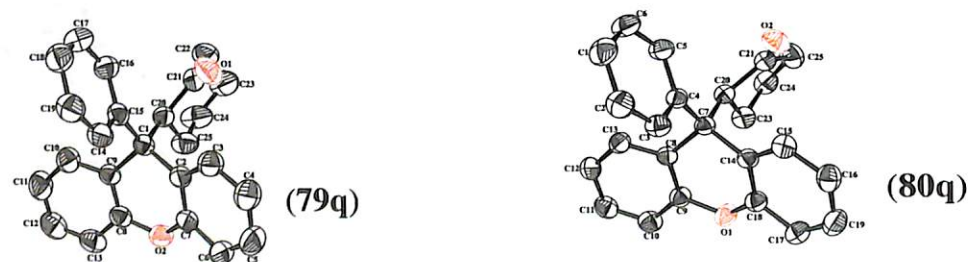
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	C19–H19··· π (Centroid ^a)	3.300	4.051	139.19
	C22–H22B··· π (Centroid ^b)	3.072	3.786	132.37
	C26–H26···π (Centroid ^c)	3.348	3.849	116.10
	C34–H34··· π (Centroid ^d)	3.345	3.849	116.10

^a Centroid of ring C1–C6, ^b Centroid of ring C23–C28, ^c Centroid of ring C36–C41, ^d Centroid of ring C24–C29.**Table IIB.3.5. Hydrogen Bond Distances and Angels for Compound 78q**

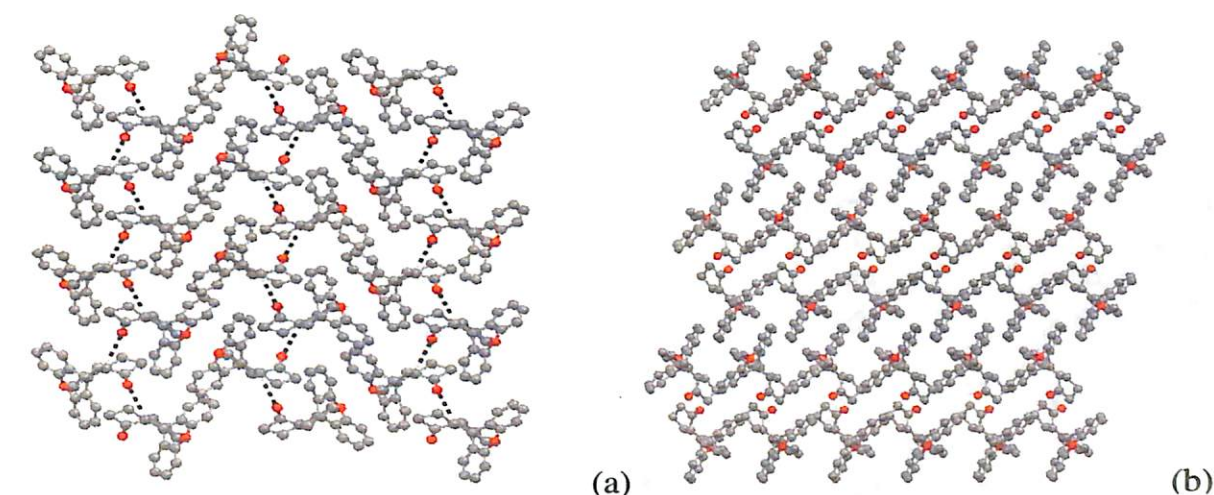
Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
78q	C9–H9···O2	2.888	3.470	121.96
	C4–H4··· π (Centroid ^a)	2.725	3.585	154.20

^a Centroid of ring C14–C19.

The acetophenone adduct **78q** forms staircase via intermolecular C–H···π (C4–H4···π = 2.725 Å) type hydrogen bonding and each staircase is interconnected through C–H···O (C9–H9···O2 = 2.888 Å) type hydrogen bonding through the pendant carbonyl oxygen atoms, while xanthene ring oxygen does not take part here like compound **76** (Figure 5a). Overall results in these extensive hydrogen bonding network is 3D zig-zag tape structure (Figure IIB.3.5b) along crystallographic *a* axis. Adjacent zig-zag tapes are oriented in the opposite directions.

**Figure IIB.3.6. An ORTEP view with atom numbering scheme of 79q and 80q.**

Incidentally, there is a striking similarity between the structural disposition of cyclohexanone **79q** and cyclopentanone **80q** addition products. For instance, both compounds **79q** and **80q** has similar solid-state structural disposition (Figure IIB.3.6) in space. Pendant phenyl ring and the cyclic ketone make an angle of 112.12° and 114.26° respectively. Compound **79q** form zig-zag linear array along *a* axis via C–H···O type hydrogen bonding (C15–H15···O1 = 2.605 Å) and the adjacent linear arrays are oriented in the opposite direction (Figure IIB.3.7a). An internal comparison of the packing patterns of **79q** and **80q** reveals certain interesting features, for instance, whereas the compound **79q** forms only C–H···O type hydrogen bonding while **80q** shows the presence of C–H···O, C–H···π and π–π type interactions. Unlike **79q**, in compound **80q** both the oxygen atoms form C–H···O hydrogen bonding (C1–H1···O1 = 2.664 Å and C19–H19···O2 = 2.671 Å). Weaker C–H···π interactions are also responsible for the formation of organic network (C5–H5···π (C14–C19) = 3.378 Å and C24–H24a···π (C1–C6) = 3.234 Å). The cyclopentanone adduct **80q** shows the presence of π–π interactions (π (C14–C19)···π (C14–C19) = 4.691 Å). Combination of these interaction results in to a mosaic structural motif (Figure IIB.3.7b). The hydrogen bond distances and angles are for **79q** and **80q** tabulated in Table IIB.3.6 and Table IIB.3.7 respectively.

**Figure IIB.3.7. (a) Packing of 79q and (b) mosaic structural motif of 80q.****Table IIB.3.6. Hydrogen Bond Distances and Angels for Compound 79q**

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
79q	C15–H15···O1	2.605	3.470	121.96

Table IIB.3.7. Hydrogen Bond Distances and Angels for Compound 80q

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
80q	C1–H1···O1	2.664	3.363	132.55
	C19–H19···O2	2.671	3.526	153.00
	C5–H5··· π (Centroid ^a)	2.809	3.693	159.31
	C23–H23A··· π (Centroid ^b)	2.899	3.650	133.21
	π (Centroid ^a)···π (Centroid ^a)	4.691		

^a Centroid of ring C14–C19., ^b Centroid of ring C1–C6.

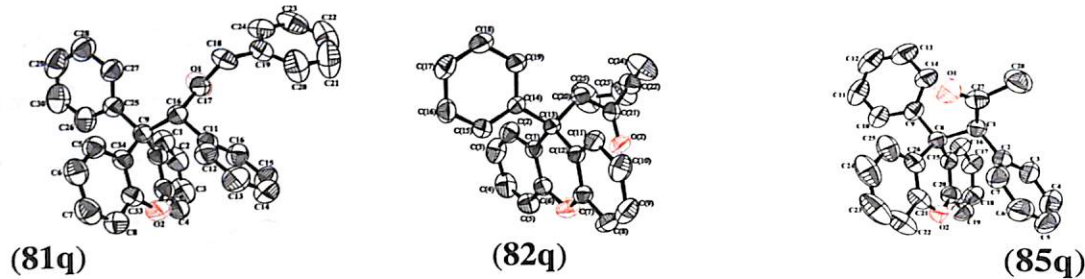


Figure IIB.3.8. An ORTEP view with atom numbering scheme of 81q, 82q and 85q.

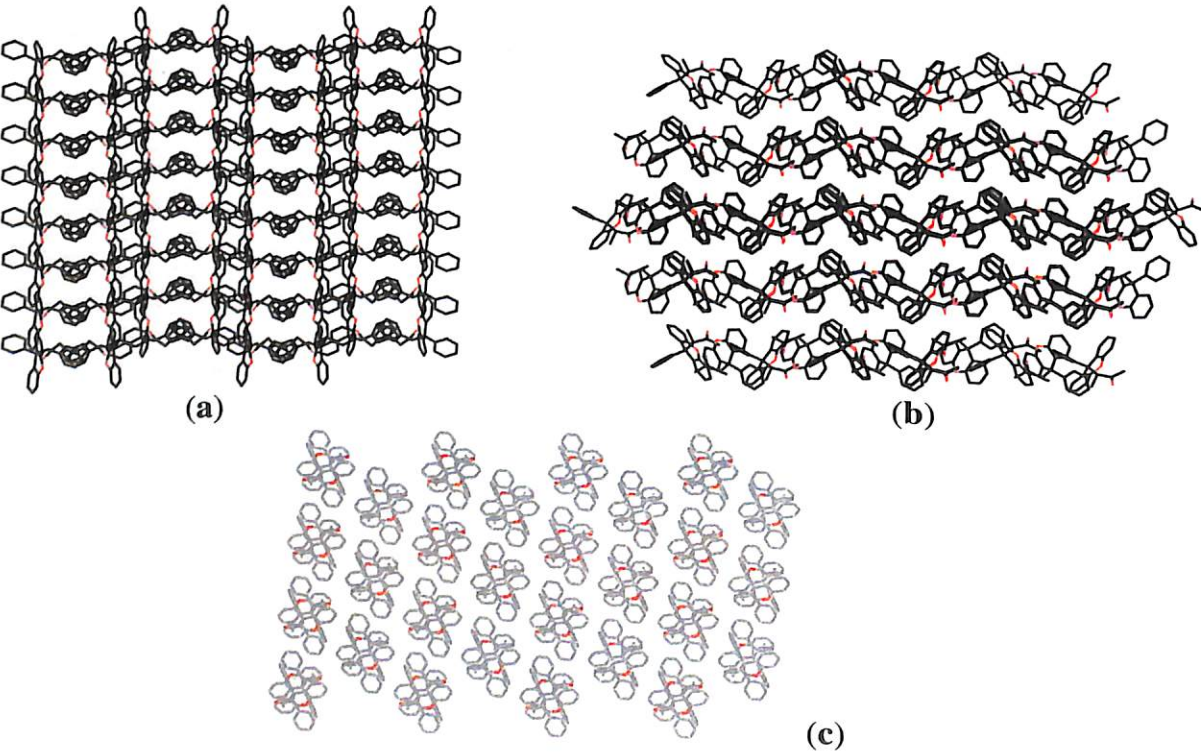


Figure IIB.3.9. (a) 3D Organic net work in 81q, (b) Wave like tape structure in 82q and (c) Flower mosaic structure in 85q.

The ORTEP diagram with atom numbering scheme of compound 81q, is in Figure IIB.3.8. In compound 1,3-diphenyl-propane-2-one adduct 81q containing two phenyl rings one of the pendant phenyl ring (C25–C30) is almost perpendicular to the xanthene unit while the other phenyl ring (C11–C16) is almost parallel to the xanthene unit (Figure IIB.3.8.). Interestingly, it forms both inter and intra-molecular C–H···π type interactions (*inter* C24–H24···π (C1–C32) = 2.997 Å and *intra* C18–H18b···π (C11–C16) = 3.422 Å). It forms ladder like 3D organic network (Figure IIB.3.9a).

Table IIB.3.8. Hydrogen Bond Distances and Angels for Compound 81q

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
81q	C24–H24···π (Centroid ^a)	2.667	3.586	139.40
	C18–H18··· π (Centroid ^b)	3.422	3.814	172.01

^a Centroid of ring C1–C32, ^b Centroid of ring C11–C16

Table IIB.3.9. Hydrogen Bond Distances and Angels for Compound 82q

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
82q	C4–H4···O1	2.894	3.650	139.23
	C16–H16···O2	2.561	3.483	171.45
	C20–H20···O2	2.411	3.347	159.57
	C23–H23C···O2	2.644	3.301	126.06
	C2–H2··· π (Centroid ^a)	3.329	3.814	114.79
	C9–H9··· π (Centroid ^a)	3.250	4.013	146.29
	C11–H11···π (Centroid ^a)	3.413	3.887	114.06

^a Centroid of ring C14–C19.

Table IIB.3.10. Hydrogen Bond Distances and Angels for Compound 85q

Compound	D–H···A	H···A (Å)	D···A (Å)	∠D–H···A (°)
85q.	C23–H23···π (Centroid ^a)	2.647	3.525	157.61
	C24–H24···π (Centroid ^b)	2.861	3.382	116.67

^aCentroid of ring C2–C7, ^b Centroid of ring C21–C26.

Table IIB.3.7. Hydrogen Bond Distances and Angels for Compound 80q

Compound	D-H...A	H...A (Å)	D...A (Å)	∠D-H...A (°)
80q	C1-H1...O1	2.664	3.363	132.55
	C19-H19...O2	2.671	3.526	153.00
	C5-H5... π (Centroid ^a)	2.809	3.693	159.31
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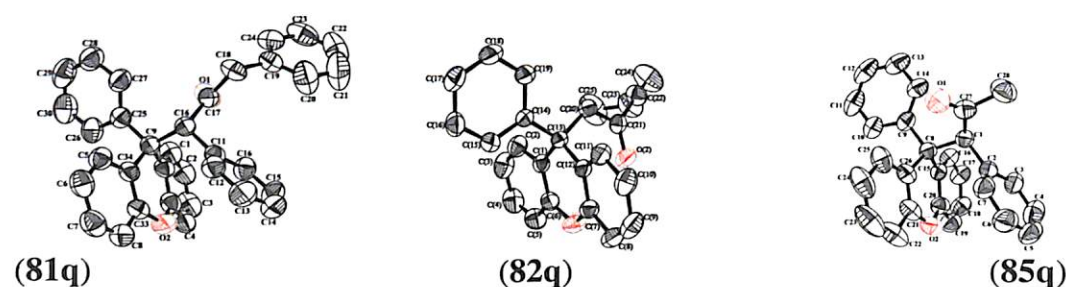
^a Centroid of ring C14–C19., ^b Centroid of ring C1–C6.

Figure IIB.3.8. An ORTEP view with atom numbering scheme of 81q, 82q and 85q.

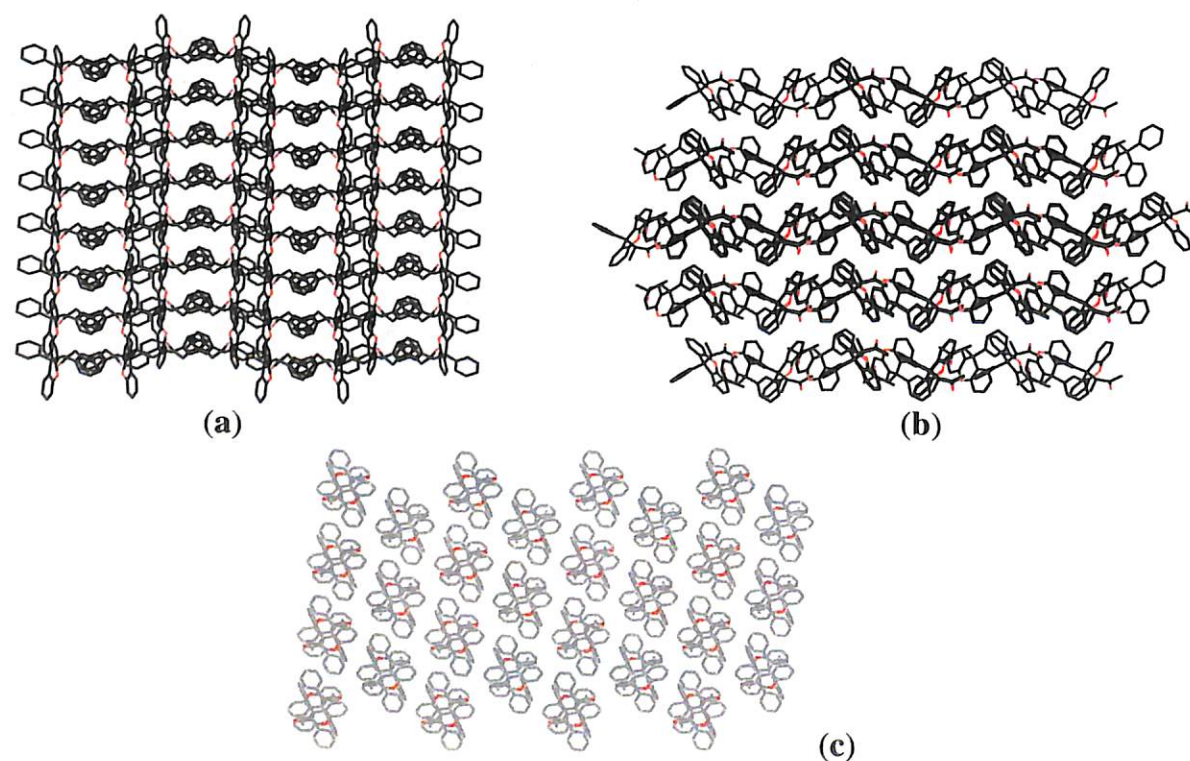


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81q	C24-H24...π (Centroid ^a)	2.667	3.586	139.40
	C18-H18... π (Centroid ^b)	3.422	3.814	172.01

^a Centroid of ring C1–C32, ^b Centroid of ring C11–C16

Table IIB.3.9. Hydrogen Bond Distances and Angels for Compound 82q

Compound	D-H...A	H...A (Å)	D...A (Å)	∠D-H...A (°)
82q	C4-H4...O1	2.894	3.650	139.23
	C16-H16...O2	2.561	3.483	171.45
	C20-H20...O2	2.411	3.347	159.57
	C23-H23C...O2	2.644	3.301	126.06
	C2-H2... π (Centroid ^a)	3.329	3.814	114.79
	C9-H9... π (Centroid ^a)	3.250	4.013	146.29
	C11-H11...π (Centroid ^a)	3.413	3.887	114.06

^a Centroid of ring C14–C19.

Table IIB.3.10. Hydrogen Bond Distances and Angels for Compound 85q

Compound	D-H...A	H...A (Å)	D...A (Å)	∠D-H...A (°)
85q.	C23-H23...π (Centroid ^a)	2.647	3.525	157.61
	C24-H24...π (Centroid ^b)	2.861	3.382	116.67

^a Centroid of ring C2–C7, ^b Centroid of ring C21–C26.

Unlike **81q**, oxygen atom of the carbonyl group in the side arm of **82q** participates in C–H···O type hydrogen bonding network like acetophenone adduct **78q**. In **81q** each carbonyl oxygen atom forms three C–H···O type hydrogen bonds. Two of them form stable six-membered hydrogen bonded ring, which help to form infinite 2D tape structure along *a* axis. Third C–H···O type hydrogen bond forms with adjacent aromatic hydrogen of xanthene unit, with alternate up and down direction with this 2D tape structure. Overall hydrogen bonding results wave like tape structure along crystallographic *c* axis (Figure IIB.3.9b). Similar to that of **81q**, compound **85q** also possess only C–H··· π type interactions, but only inter-molecular interactions (C23–H23··· π (C2–C7) = 3.227 Å). In solid state, it packs as flower like mosaic structure in 3D (Figure IIB.3.9c). The hydrogen bond distances and angles are for **81q**, **82q** and **85q** tabulated in Table IIB.3.8, Table IIB.3.9 and Table IIB.3.10 respectively.

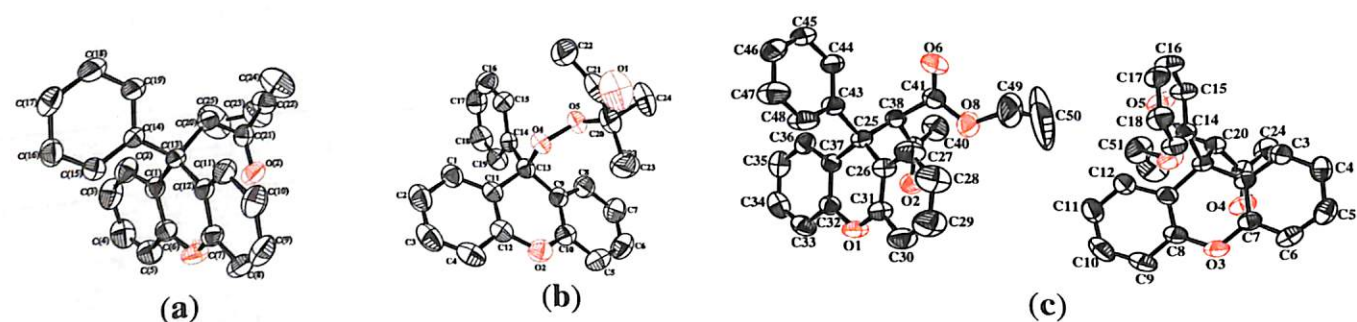


Figure IIB.3.10. An ORTEP view of (a) **83q**, (b) **84q** and (c) **86q**.

The ORTEP diagrams of **83q**, **84q** and **86q** with atomic numbering scheme is shown in Figure IIB.3.10. In **83q** only the pendant carbonyl oxygen atom forms C–H···O type hydrogen bonding which form 1D linear network along crystallographic *c* axis. Each T-shaped molecule assembled in the crystal as a 3D zig-zag tape structure (Figure IIB.3.11a). Compound **84q** interestingly shows the presence of peroxide linkage in the product. Here both the carbonyl oxygen atom as well as the xanthene oxygen atom form C–H···O type hydrogen bonding (C4–H4···O1 = 2.556 Å and C17–H17···O2 = 2.526 Å). Similar to that of compound **81q**, compound **84q** also form relatively stronger intra-molecular C–H··· π type interactions (C23–H23C··· π (C6–C10) = 2.919 Å). Peroxide oxygen atoms do not participate in any such type of interactions. Overall hydrogen bonding results in the formation of brick wall network along *a* axis (Figure IIB.3.11b).

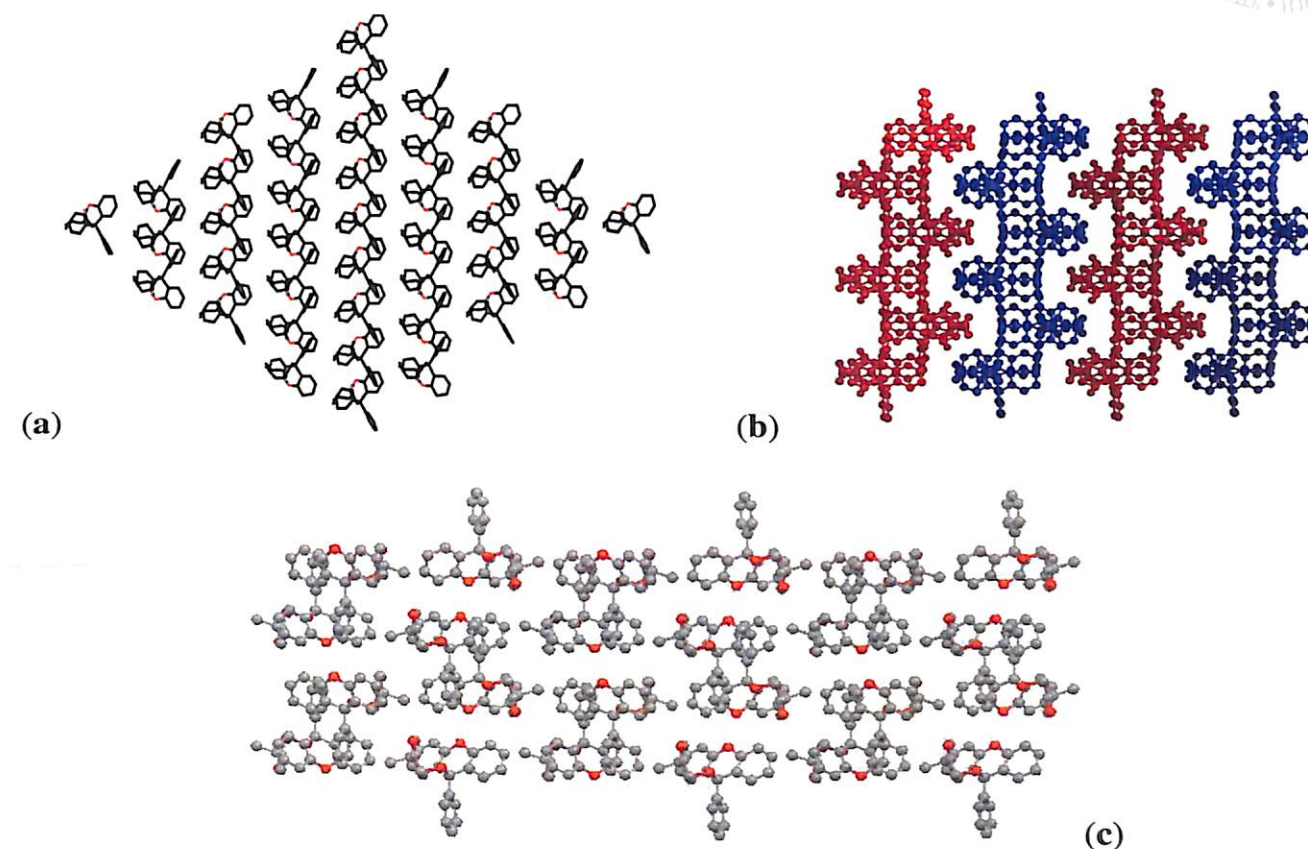


Figure IIB.3.11. (a) 3D zig-zag tape structure in **84q**, (b) Brick wall type net work in **86q**, and (c) Alternate 2D interpenetrating tape structure in **85q**.

Similar to the starting compound **76** and **77q**, compound **86q** the ethylacetoacetate adduct also crystallizes with two molecules in the asymmetric unit (Figure IIB.3.10c). Analogous to the compound **84q**, compound **86q** also shows the presence of C–H···O and C–H··· π type of interactions. Unlike **83q**, in compound **86q** both the oxygen atoms form C–H···O hydrogen bonding (C10–H10···O6 = 2.536 Å, C17–H17···O3 = 2.563 Å, C46–H46···O1 = 2.548 Å and C51–H51a···O6 = 2.689 Å). Weaker C–H··· π interactions are also responsible for the formation of organic network (C40–H40c··· π (C43–C48) = 2.964 Å). Two symmetrically independent molecules in the unit cell form alternate 2D interpenetrating tape structure (Figure IIB.3.11c). The hydrogen bond distances and

Unlike **81q**, oxygen atom of the carbonyl group in the side arm of **82q** participates in C–H···O type hydrogen bonding network like acetophenone adduct **78q**. In **81q** each carbonyl oxygen atom forms three C–H···O type hydrogen bonds. Two of them form stable six-membered hydrogen bonded ring, which help to form infinite 2D tape structure along *a* axis. Third C–H···O type hydrogen bond forms with adjacent aromatic hydrogen of xanthene unit, with alternate up and down direction with this 2D tape structure. Overall hydrogen bonding results wave like tape structure along crystallographic *c* axis (Figure IIB.3.9b). Similar to that of **81q**, compound **85q** also possess only C–H··· π type interactions, but only inter-molecular interactions (C23–H23··· π (C2–C7) = 3.227 Å). In solid state, it packs as flower like mosaic structure in 3D (Figure IIB.3.9c). The hydrogen bond distances and angles are for **81q**, **82q** and **85q** tabulated in Table IIB.3.8, Table IIB.3.9 and Table IIB.3.10 respectively.

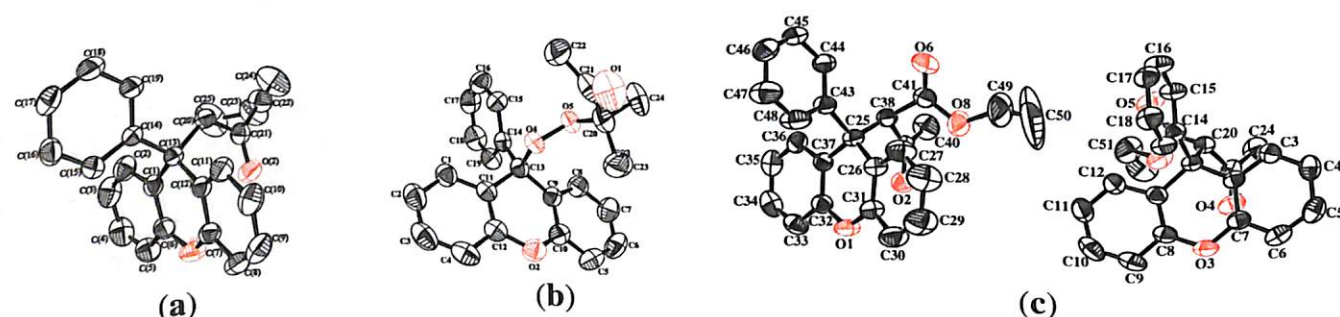


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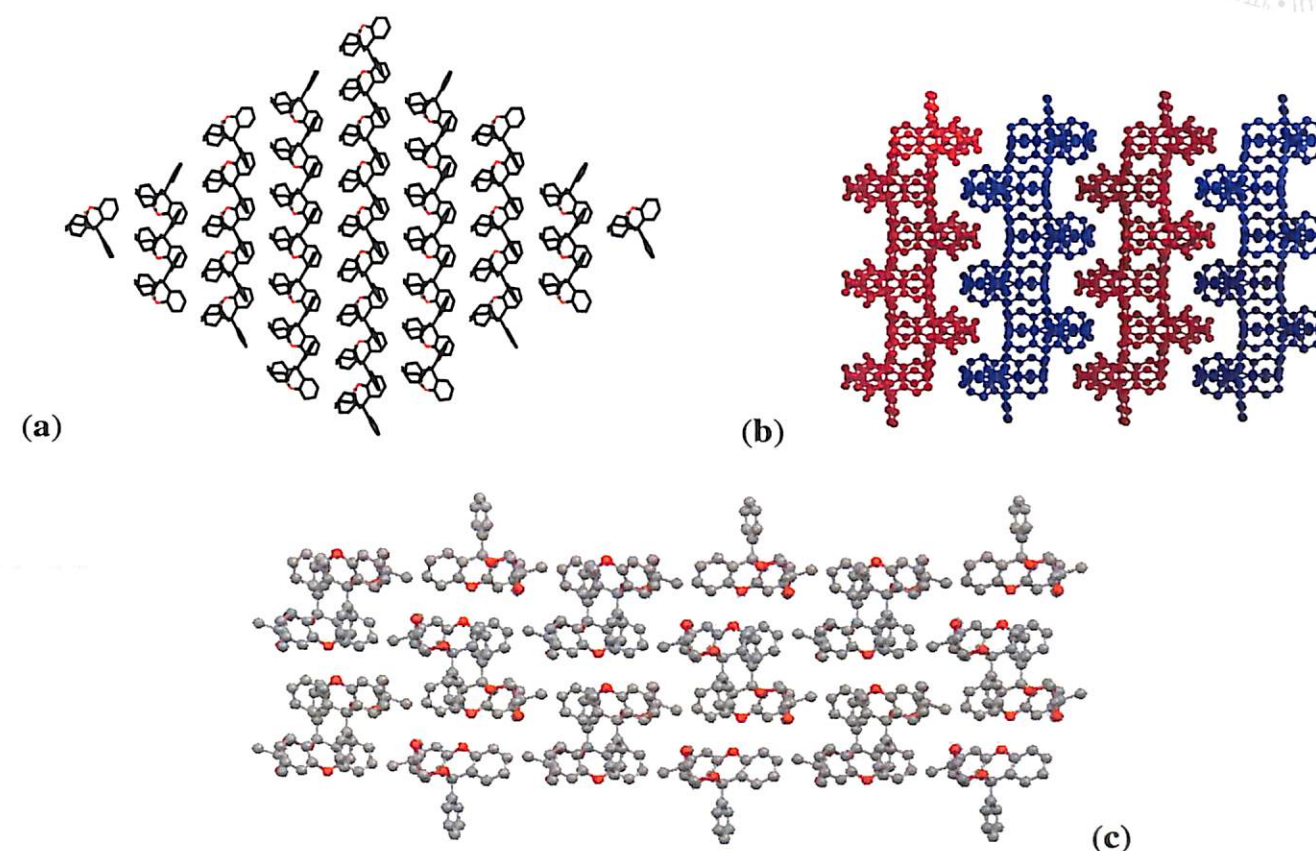


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angles are for **83q**, **84q** and **86q** tabulated in Table IIB.3.11, Table IIB.3.12 and Table IIB.3.13 respectively.

Table IIB.3.11. Hydrogen Bond Distances and Angels for Compound 83q

Compound	D-H...A	H...A (Å)	D...A (Å)	∠D-H...A (°)
83q	C20-H20A...O2	2.440	3.374	161.57
	C25-H25B... π (Centroid ^a)	3.264	4.200	165.5
	C19-H19... π (Centroid ^b)	3.001	3.865	155.13

^a Centroid of ring C1-C6, ^b Centroid of ring C7-C12.

Table IIB.3.12. Hydrogen Bond Distances and Angels for Compound 84q

Compound	D-H...A	H...A (Å)	D...A (Å)	∠D-H...A (°)
84q	C4-H4...O1	2.556	3.405	151.94
	C17-H17... O2	2.525	3.340	146.49
	C26-H26... π (Centroid ^b)	2.816	3.727	158.62

^a Centroid of ring C14-C19,

Table IIB.3.13. Hydrogen Bond Distances and Angels for Compound 86q

Compound	D-H...A	H...A (Å)	D...A (Å)	∠D-H...A (°)
86q	C36-H36...O2	2.637	3.418	142.10
	C17-H17...O3	2.563	3.361	144.14
	C10-H10...O6	2.536	3.453	168.86
	C51-H51A...O2	2.689	3.615	159.60
	C15-H15... π (Centroid ^a)	2.764	3.437	130.04
	C40-H40C... π (Centroid ^b)	2.723	3.649	162.17
	C50-H50C... π (Centroid ^c)	2.891	3.728	175.99
	C50-H50C... π (Centroid ^c)	2.875	3.850	148.48

^aCentroid of ring C1-C6., ^bCentroid of ring C43-C48, ^cCentroid of ring C14-C19

In conclusion, we have achieved multi carbon homologations of xanthene **76** through a C-C bond formation by various enolizable ketones in an acidic medium. In most cases the regiochemistry

of the product is governed by the attack of thermodynamically stable enol. But **1** dominates as in the case of 4-methyl-pent-2-one **VII** product obtained is via a **1** enloate attack. With further increase in steric hindrance as in 3-methyl-butane-2-one **VIII** no reaction takes place. X-ray crystallography of all the products revealed that the pendant arms are disposed in the opposite direction with respect to the core xanthene unit to relieve the steric crowding in the solid state. We have also shown that the systematic variation in the pendant arm of the xanthene derivatives results in the formation of different types of weak interactions as well as different types of self-assembled superstructure. It is also clear that the design strategy should be more widely applicable to investigate these xanthene derivatives as supramolecular building blocks in crystal engineering, which is currently going on in our laboratory.

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IIB.4. Reinvestigation of the Mechanism of *gem*-Diacylation: Chemoselective Conversion of Aldehydes to Various *gem*-Diacylates and Their Cleavage under Acidic and Basic Conditions

The mechanism of the formation of *gem*-diacylate, the addition product of an acid anhydride with an aldehyde, is not yet well understood. *Gem*-diacylate functionalities have served as an interesting protecting group for aldehydes in addition to acetals, oxathioacetals and thioacetals. Unlike the acetal protecting group, which is removed only under acidic conditions, *gem*-diacylates can be removed under either acidic or basic conditions.¹ The *gem*-diacylate of aldehydes are useful precursors for nucleophilic substitution reactions; they are used in the synthesis of acetoxydienes, vinyl acetates and dienes for Diels-Alder reaction and are also used as several industrial intermediates.² Due to the remarkable stability of *gem*-diacetates towards a variety of reaction conditions, and their easy preparation, they are gaining importance in organic synthesis as an alternative to cyclic and acyclic acetals for the protection of aldehydes. They are superior to acetals because, during acetalization of acetals, the water formed in the reaction medium must be removed either by physical or by chemical means using water scavengers such as orthoformates;³ this procedure is not required during *gem*-diacylation of aldehydes.

Numerous methods are available in the literature for the conversion of an aldehydic carbonyl group to the corresponding *gem*-diacetates with acetic anhydride. Some of the reagents and catalysts that have been employed include H₂SO₄,⁴ HClO₄,⁵ H₃PO₄,⁶ CH₃SO₃H,⁷ PCl₃,⁸ FeSO₄.XH₂O,⁹ I₂,¹⁰ TMSCl-NaI,¹¹ NBS,¹² CAN,¹³ InCl₃,¹⁴ WCl₆,¹⁵ LiBF₄,¹⁶ Zn(BF₄)₂,¹⁷ ZrCl₄,¹⁸ CoCl₂,¹⁹ NH₂SO₃H,²⁰ Bi(OTf)₃.XH₂O,²¹ Sc(OTf)₃,²² LiOTf,²³ Cu(OTf)₂,²⁴ FeCl₃,^{1b,25} and sulfated zirconia.²⁶ Some solid acidic catalysts, for example NafionH,²⁷ zeolite,²⁸ montmorillonite clay,²⁹ graphite,³⁰ Fe³⁺ on montmorillonite,³¹ PVC-FeCl₃,³² Wells-Dawson acid,³³ zirconium sulphenyl phosphonate,³⁴ AIPW₁₂O₄₀,³⁵ and amberlite15,³⁶ has also been used for this purpose. Recently, the diacylation of aldehydes has been achieved in ionic liquids.³⁷ However, none of the above mentioned catalysts are capable of protecting as well as deprotecting *gem*-diacetates except CAN,¹³ ZrCl₄,¹⁷ expensive graphite³⁰ and HSZ360 (zeolite).^{28b}

Although some of these methods are excellent in terms of yields but none of them have studied extensively their mechanism, *gem*-diacylation of aldehydes with a range of aliphatic and aromatic anhydrides, their chemoselectivities and relative stabilities of various *gem*-diacylates both

under acidic and basic conditions. Except for acetic anhydride, only two other reactions of aldehydes with other anhydrides, namely butyric, isobutyric and Although there are several methods known for the chemoselective protection of aldehydes over ketones, there is only one method for the chemoselective *gem*-diacylation of different aromatic aldehydes.³⁴ Other problems associated with some of the existing methods are difficulties in workup and isolation, the use of organic solvents, the need for an inert atmosphere, harsh reaction conditions, expensive and stoichiometric amounts of reagents, incompatibility with other protecting groups and failure to protect deactivated substrates and substrates containing an amino functionality. Substrates containing hindered and acid-sensitive groups also fail in many instances. Hence, a practical and more efficient alternative using an inexpensive reagent under solvent-free conditions is of considerable interest. To achieve chemoselective *gem*-diacylation between aldehydes and ketones and between different aldehydes will be useful during a multi-step synthesis. Further, the stability order of various *gem*-diacylates of a substrate towards acidic and basic conditions is yet another interesting aspect in protection / deprotection chemistry. Finally, to have gain insight into the reaction mechanism of such a reaction is crucial to the scientific community.

Solvent-free reactions have gained considerable attention in chemical processes for environmental and economic reasons and their easy workup, high yields and usually faster reaction rates.³⁸ We have been interested in the development of several green chemical processes in aqueous media³⁹ and in exploring the catalytic properties of tetrabutyl ammonium tribromide (TBATB) for various organic transformations.⁴⁰ In this regard, we have found that TBATB is a useful reagent whose acidity can be tuned from highly acidic to near neutral pH in the appropriate organic solvent. This reagent has been proved to be a good catalyst for the chemoselective acetalization of carbonyl compounds,^{40a} pyranlylation / depyranlylation of alcohols^{40b} and thioacetalization and transthioacetalization of carbonyl compounds.^{40f} Now we have utilized tetrabutyl ammonium tribromide (TBATB) to gain further understanding of the mechanism of formation of *gem*-diacylates and the chemoselective preparation of various *gem*-diacylates from structurally different aldehydes and different aliphatic and aromatic anhydrides with a catalytic quantity of this reagent at room temperature under solvent-free conditions. We have also studied the stability order of various *gem*-diacylates under acidic and basic conditions.

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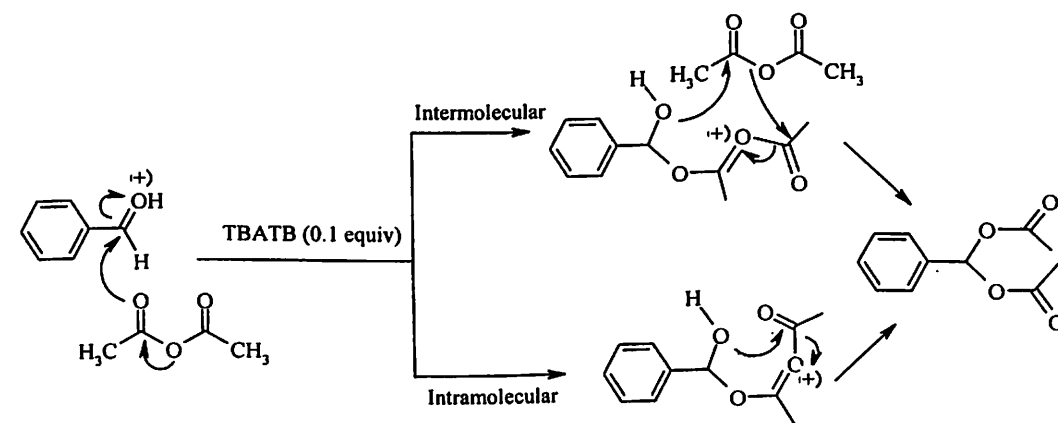
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Although there are several methods known for the chemoselective protection of aldehydes over ketones, there is only one method for the chemoselective *gem*-diacylation of different aromatic aldehydes.³⁴ Other problems associated with some of the existing methods are difficulties in workup and isolation, the use of organic solvents, the need for an inert atmosphere, harsh reaction conditions, expensive and stoichiometric amounts of reagents, incompatibility with other protecting groups and failure to protect deactivated substrates and substrates containing an amino functionality. Substrates containing hindered and acid-sensitive groups also fail in many instances. Hence, a practical and more efficient alternative using an inexpensive reagent under solvent-free conditions is of considerable interest. To achieve chemoselective *gem*-diacylation between aldehydes and ketones and between different aldehydes will be useful during a multi-step synthesis. Further, the stability order of various *gem*-diacylates of a substrate towards acidic and basic conditions is yet another interesting aspect in protection / deprotection chemistry. Finally, to have gain insight into the reaction mechanism of such a reaction is crucial to the scientific community.

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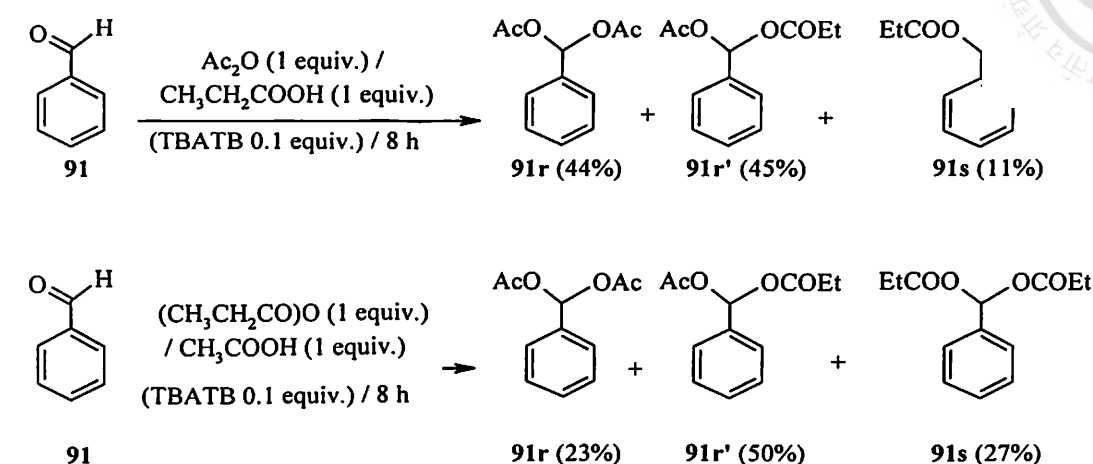
In a typical experimental procedure, a mixture of an aldehyde (5 mmol) and freshly distilled acetic anhydride(15 mmol) was stirred at room temperature in the presence of a catalytic amount of

TBATB (0.5 mmol) for the time required for the completion of the reaction at room temperature. The exact role of the TBATB is not clear, but it is known to release anhydrous HBr in an alcoholic medium, and the medium becomes weakly acidic in a nonpolar aprotic solvent.^{40a-40c} The pH of neat acetic anhydride is 0.1, and this drops to a value of -0.7 on addition of 0.1 equivalents of TBATB. Similarly, the pH of various neat aldehydes drops to a more acidic pH on addition of TBATB. The mechanism of this reaction has been the subject of some controversy.^{19d,41} An intermolecular mechanism has been proposed involving an intermolecular transfer of a second acetate group after initial attack by acetic anhydride.^{1b} To get further insight into the mechanism we have carried out a series of experiments. Two plausible mechanisms could be thought of for *gem*-diacylation, one involving an intramolecular and other an intermolecular transfer of a second acylate group after the initial nucleophilic attack by an anhydride on an aldehydic group, as shown in Scheme IIB.4.1.



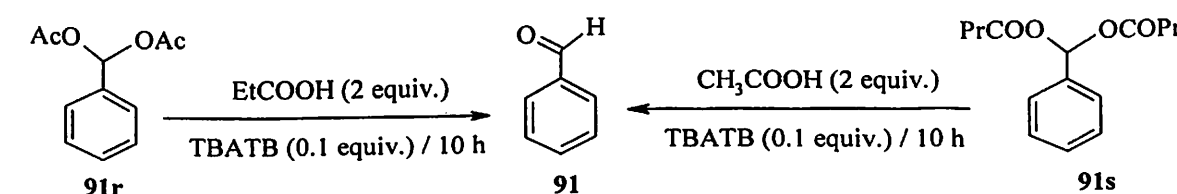
Scheme IIB.4.1. Plausible mechanisms formation of *gem*-diacylate

In order to test this, benzaldehyde (**91**; 1 equiv.) was treated with acetic anhydride (1 equiv.) in the presence of propionic acid (1 equiv.) and TBATB (0.1 equiv.). Analysis of the products by GC showed the formation of *gem*-diacetate **91r**, the mixed acetate-propionate **91r'** and the *gem*-dipropionate **91s**, in the ratio 44 : 45 : 11, respectively, after 8 h, as shown in Scheme IIB.4.2. In another experiment, benzaldehyde (**91**; 1 equiv.) was treated with propionic anhydride (1 equiv.) in the presence of acetic acid (1 equiv.) under identical conditions. The ratio of *gem* dipropionate **91s**, mixed acetatepropionate **91r'** and *gem*-diacetate **91r** obtained was 23 : 50 : 27, respectively, after 8 h, as shown in Scheme IIB.4.2.



Scheme IIB.4.2. Formation of mixed *gem*-diacylate

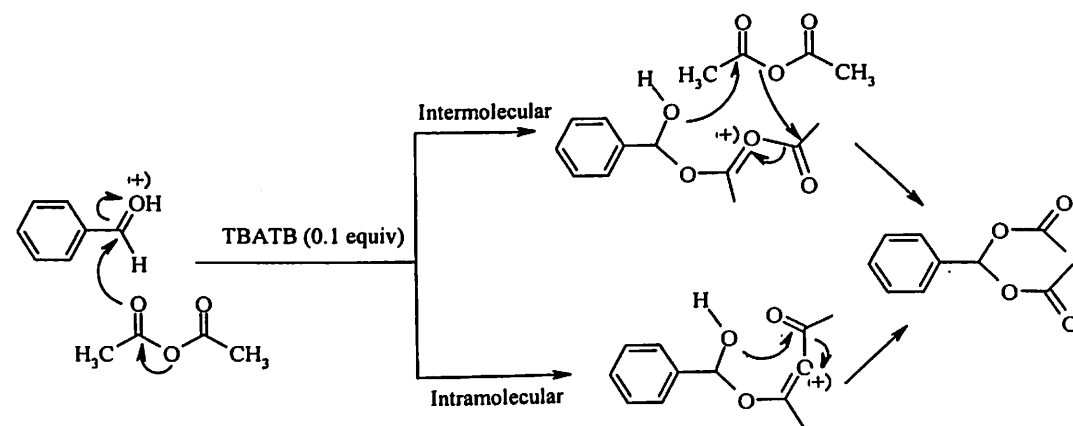
The failure to form the *gem*-diacetate as the sole product in the above reactions clearly rules out the possibility of an intramolecular mechanism (Scheme IIB.4.1). The formation of the mixed *gem*-diacylate **91r'** may be due to the attack of a second acylate group by an intermolecular path or by a transacylation of the symmetrical *gem*-diacylate (**91r** / **91s**) with an acylate (acetate or propionate). In order to ascertain the latter possibility, the *gem*-diacetate of benzaldehyde (**91r**; 1 equiv.) was treated with propionic acid (2 equiv.) in the presence of TBATB (0.1 equiv.) and the *gem*-dipropionate of benzaldehyde (**91s**; 1 equiv.) was treated with acetic acid (2 equiv.) in the presence of TBATB (0.1 equiv.). No mixed *gem*-diacylal **91r'** could be detected by GC at any stage of the reaction; rather, the *gem*-diacylates **91r** and **91s** were quantitatively deprotected to benzaldehyde after 10 h (Scheme IIB.4.3), thus ruling out the possibility of a transacylation process for the formation of mixed diacylates.



Scheme IIB.4.3. Deprotection of *gem*-diacylates with TBATB

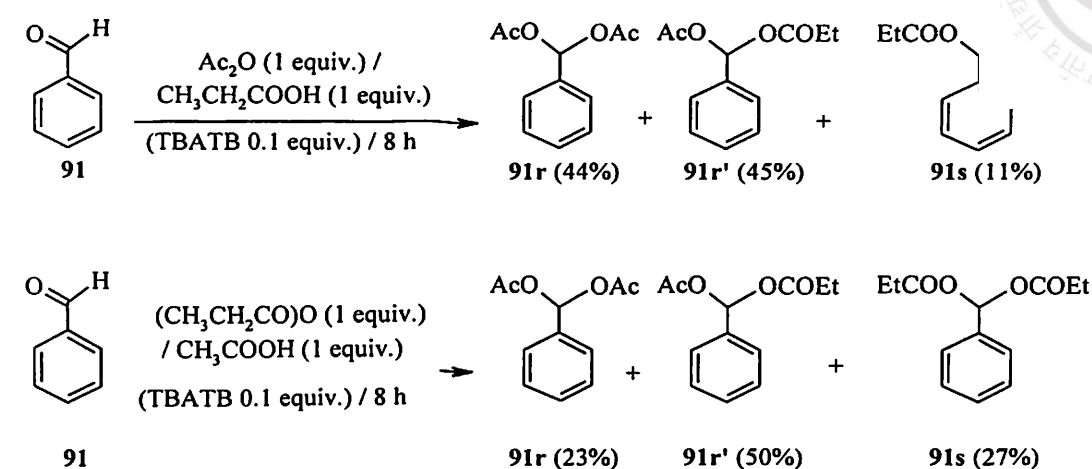
The *gem*-diacylate formation may be occurring by an intermolecular mechanism. To support this, benzaldehyde (**91**; 1 equiv.) was treated with an equimolar mixture of acetic anhydride (1 equiv.) and propionic anhydride (1 equiv.) in the presence of TBATB (0.1 equiv.). Analysis of the products

TBATB (0.5 mmol) for the time required for the completion of the reaction at room temperature. The exact role of the TBATB is not clear, but it is known to release anhydrous HBr in an alcoholic medium, and the medium becomes weakly acidic in a nonpolar aprotic solvent.^{40a–40c} The pH of neat acetic anhydride is 0.1, and this drops to a value of –0.7 on addition of 0.1 equivalents of TBATB. Similarly, the pH of various neat aldehydes drops to a more acidic pH on addition of TBATB. The mechanism of this reaction has been the subject of some controversy.^{19d,41} An intermolecular mechanism has been proposed involving an intermolecular transfer of a second acetate group after initial attack by acetic anhydride.^{1b} To get further insight into the mechanism we have carried out a series of experiments. Two plausible mechanisms could be thought of for *gem*-diacylation, one involving an intramolecular and other an intermolecular transfer of a second acylate group after the initial nucleophilic attack by an anhydride on an aldehydic group, as shown in Scheme IIB.4.1.



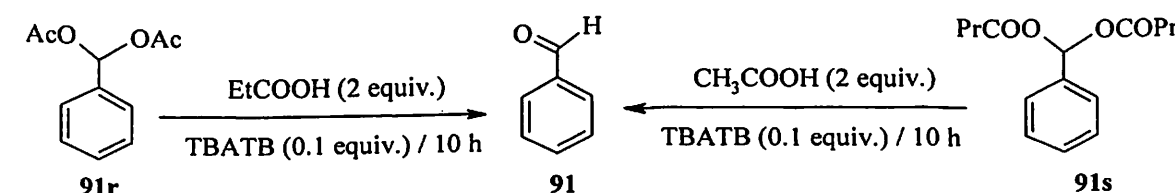
Scheme IIB.4.1. Plausible mechanisms formation of *gem*-diacylate

In order to test this, benzaldehyde (**91**; 1 equiv.) was treated with acetic anhydride (1 equiv.) in the presence of propionic acid (1 equiv.) and TBATB (0.1 equiv.). Analysis of the products by GC showed the formation of *gem*-diacetate **91r**, the mixed acetate-propionate **91r'** and the *gem*-dipropionate **91s**, in the ratio 44 : 45 : 11, respectively, after 8 h, as shown in Scheme IIB.4.2. In another experiment, benzaldehyde (**91**; 1 equiv.) was treated with propionic anhydride (1 equiv.) in the presence of acetic acid (1 equiv.) under identical conditions. The ratio of *gem* dipropionate **91s**, mixed acetatepropionate **91r'** and *gem*-diacetate **91r** obtained was 23 : 50 : 27, respectively, after 8 h, as shown in Scheme IIB.4.2.



Scheme IIB.4.2. Formation of mixed *gem*-diacylate

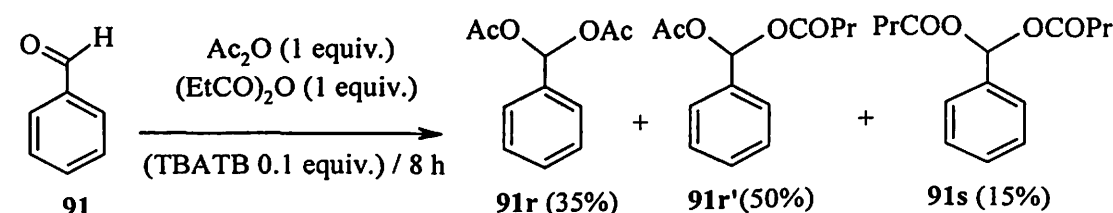
The failure to form the *gem*-diacetate as the sole product in the above reactions clearly rules out the possibility of an intramolecular mechanism (Scheme IIB.4.1). The formation of the mixed *gem*-diacylate **91r'** may be due to the attack of a second acylate group by an intermolecular path or by a transacylation of the symmetrical *gem*-diacylate (**91r** / **91s**) with an acylate (acetate or propionate). In order to ascertain the latter possibility, the *gem*-diacetate of benzaldehyde (**91r**; 1 equiv.) was treated with propionic acid (2 equiv.) in the presence of TBATB (0.1 equiv.) and the *gem*-dipropionate of benzaldehyde (**91s**; 1 equiv.) was treated with acetic acid (2 equiv.) in the presence of TBATB (0.1 equiv.). No mixed *gem*-diacylal **91r'** could be detected by GC at any stage of the reaction; rather, the *gem*-diacylates **91r** and **91s** were quantitatively deprotected to benzaldehyde after 10 h (Scheme IIB.4.3), thus ruling out the possibility of a transacylation process for the formation of mixed diacylates.



Scheme IIB.4.3. Deprotection of *gem*-diacylates with TBATB

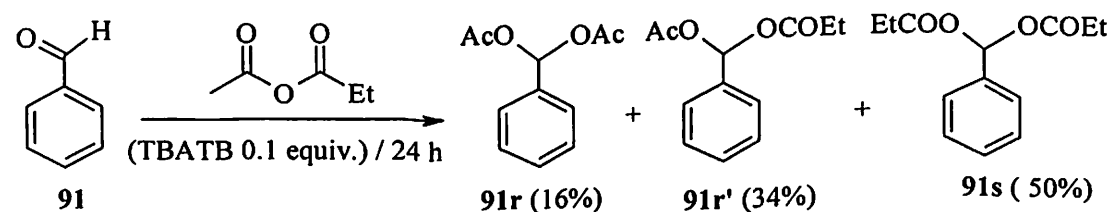
The *gem*-diacylate formation may be occurring by an intermolecular mechanism. To support this, benzaldehyde (**91**; 1 equiv.) was treated with an equimolar mixture of acetic anhydride (1 equiv.) and propionic anhydride (1 equiv.) in the presence of TBATB (0.1 equiv.). Analysis of the products

by GC showed the formation of *gem*-diacetate **91r** (35%), mixed acetate-propionate **91r'** (50%) and *gem*-dipropionate **91s** (14%) after 8 h (Scheme IIB.4.4.)



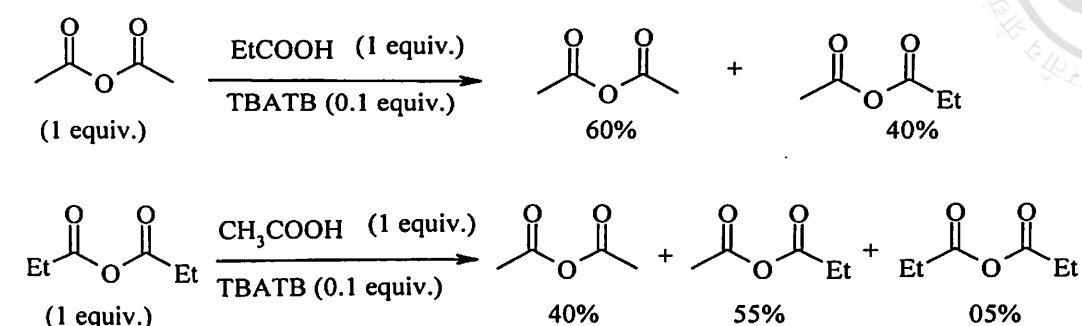
Scheme IIB.4.4. Formation of mixed *gem*-diacylates from two different anhydrides

In another experiment, benzaldehyde (**91**; 1 equiv.) was treated with a mixed anhydride, acetic-propionic anhydride (1 equiv.). Here again, *gem*-diacetate **91r**, mixed acetate-propionate **91r'** and *gem*-dipropionate **91s** were obtained in the ratio 16 : 34 : 50, respectively (Scheme IIB.4.5.), instead of the mixed diacylate, which would have been formed as the sole product if the mechanism followed an intramolecular path. This observation is consistent with the observation made by other groups, except for the distribution of the products.^{1b}



Scheme IIB.4.5. Formation of mixed *gem*-diacylate from a mixed anhydride

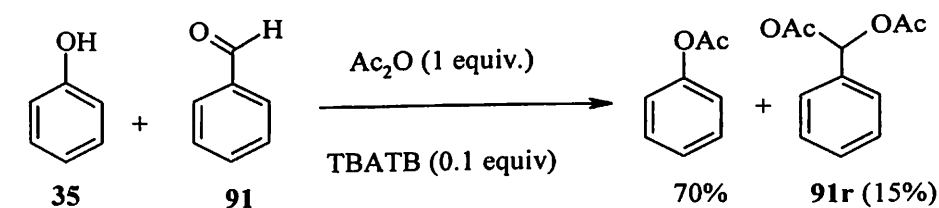
The formation of mixed diacylates **91r'** in Scheme IIB.4.2 can only be explained if there is formation of the mixed anhydride in the reaction medium itself. This was confirmed from the following experiments: Acetic anhydride (1 equiv.) was treated with propionic acid (1 equiv.) in the presence of a catalytic quantity of TBATB (0.1 equiv.), the percentage of acetic anhydride remaining and mixed anhydride formed after 0.5 h, as determined by GC, was 60% and 40%, respectively. Similarly, when propionic anhydride (1 equiv.) was treated with acetic acid (1 equiv.) under identical conditions the ratio of acetic anhydride, mixed anhydride and propionic anhydride formed after 0.5 h were 40%, 55% and 5%, respectively (Scheme IIB.4.6).



Scheme IIB.4.6. Formation of mixed anhydride

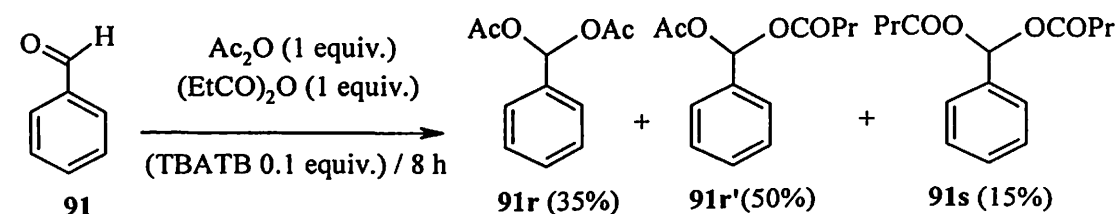
The formation of more than 90% of the *gem*-diacetate by the reaction of benzaldehyde with just one equivalent of acetic anhydride supports the regeneration of acetic anhydride and hence the intermolecular nature of the mechanism (Scheme IIB.4.1).

Aliphatic aldehydes **87–90** were converted into their corresponding *gem*-diacylates in excellent yields at room temperature by employing this reagent. A wide range of aldehydes containing activated, deactivated and hindered groups could all be diacylated in good to excellent yields, as shown in table IIB.4.1. Moreover, the protocol also worked equally well with α,β -unsaturated aldehydes **90** and **102** and with an aldehyde containing an allylic functionality **103**. Importantly, no other side-product, for example bromination, was observed, although this reagent is an excellent brominating agent for ethylenic substrates.^{40d,e} However, hindered aldehydes **100**, **109** and **110** required much longer reaction times, as did aromatic aldehydes containing an electron-withdrawing group, like a nitro group (**93**, **98** and **100**). This observation is not consistent with the observations by other groups that the presence of electron-donating and electron-withdrawing groups does not cause any difference in reactivity.^{1b,11,17,18,23,33} Moreover, acid-sensitive groups such as a methoxy group **97**, **99** and **101**, a TBS ether **105** and a furyl ring **106** are stable under the described reaction conditions. Hydroxy aldehydes (**92**, **96** and **99**) gave the corresponding triacetates. In fact, phenol could be chemoselectively acetylated over aldehyde **91**, thus demonstrating the higher reactivity of the phenolic functionality towards acetylation over an aldehydic group for diacylation. (Scheme IIB.4.7).



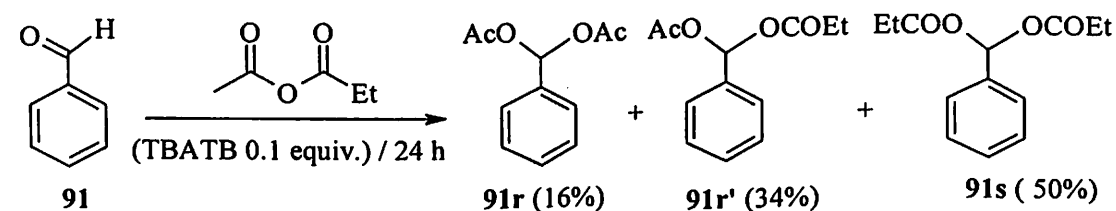
Scheme IIB.4.7. Chemoselective acetylation of phenol

by GC showed the formation of *gem*-diacetate **91r** (35%), mixed acetate-propionate **91r'** (50%) and *gem*-dipropionate **91s** (14%) after 8 h (Scheme IIB.4.4.)



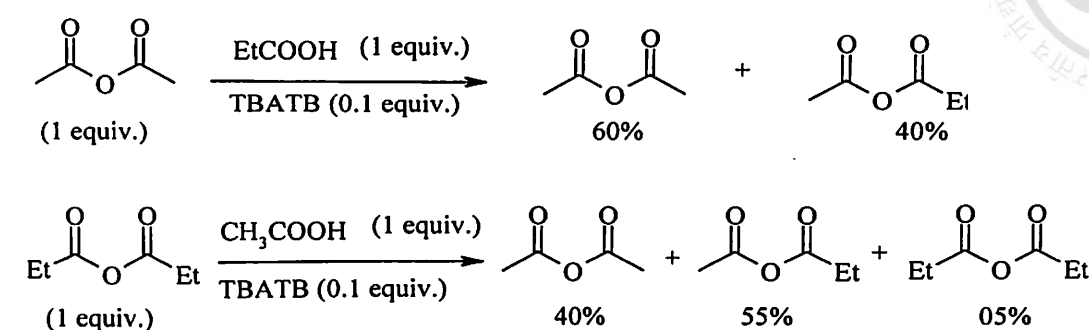
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Scheme IIB.4.5. Formation of mixed *gem*-diacylate from a mixed anhydride

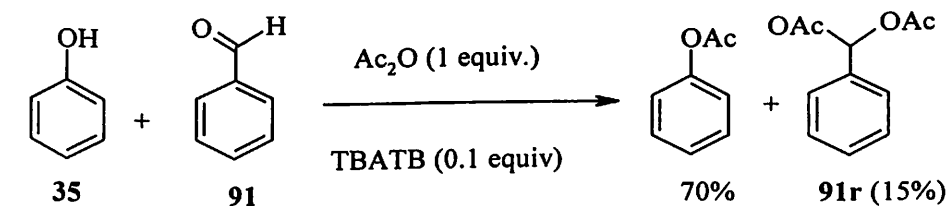
The formation of mixed diacylates **91r'** in Scheme IIB.4.2 can only be explained if there is formation of the mixed anhydride in the reaction medium itself. This was confirmed from the following experiments: Acetic anhydride (1 equiv.) was treated with propionic acid (1 equiv.) in the presence of a catalytic quantity of TBATB (0.1 equiv.), the percentage of acetic anhydride remaining and mixed anhydride formed after 0.5 h, as determined by GC, was 60% and 40%, respectively. Similarly, when propionic anhydride (1 equiv.) was treated with acetic acid (1 equiv.) under identical conditions the ratio of acetic anhydride, mixed anhydride and propionic anhydride formed after 0.5 h were 40%, 55% and 5%, respectively (Scheme IIB.4.6).



Scheme IIB.4.6. Formation of mixed anhydride

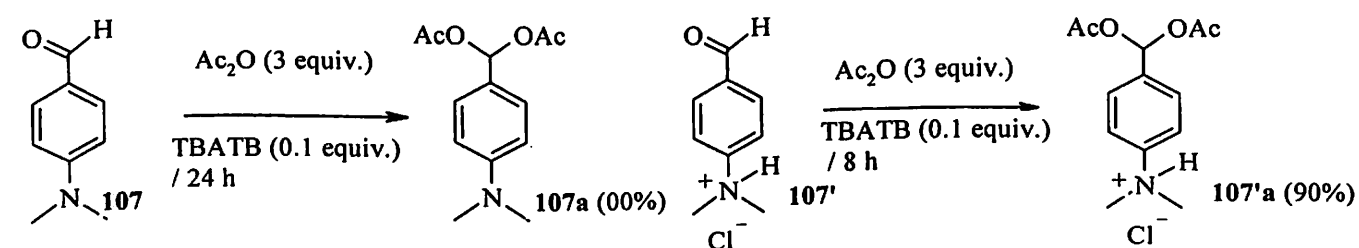
The formation of more than 90% of the *gem*-diacetate by the reaction of benzaldehyde with just one equivalent of acetic anhydride supports the regeneration of acetic anhydride and hence the intermolecular nature of the mechanism (Scheme IIB.4.1).

Aliphatic aldehydes **87–90** were converted into their corresponding *gem*-diacylates in excellent yields at room temperature by employing this reagent. A wide range of aldehydes containing activated, deactivated and hindered groups could all be diacylated in good to excellent yields, as shown in table IIB.4.1. Moreover, the protocol also worked equally well with α,β -unsaturated aldehydes **90** and **102** and with an aldehyde containing an allylic functionality **103**. Importantly, no other side-product, for example bromination, was observed, although this reagent is an excellent brominating agent for ethylenic substrates.^{40d,e} However, hindered aldehydes **100**, **109** and **110** required much longer reaction times, as did aromatic aldehydes containing an electron-withdrawing group, like a nitro group (**93**, **98** and **100**). This observation is not consistent with the observations by other groups that the presence of electron-donating and electron-withdrawing groups does not cause any difference in reactivity.^{1b,11,17,18,23,33} Moreover, acid-sensitive groups such as a methoxy group **97**, **99** and **101**, a TBS ether **105** and a furyl ring **106** are stable under the described reaction conditions. Hydroxy aldehydes (**92**, **96** and **99**) gave the corresponding triacetates. In fact, phenol could be chemoselectively acetylated over aldehyde **91**, thus demonstrating the higher reactivity of the phenolic functionality towards acetylation over an aldehydic group for diacylation. (Scheme IIB.4.7).



Scheme IIB.4.7. Chemoselective acetylation of phenol

2-Furaldehyde **106** gave a dark-colored polymeric compound when catalyzed by a heterogeneous inorganic acid³⁵ but gave an excellent yield of the product at 0 °C in the presence of TBATB as the catalyst. It has been reported that many catalysts are not suitable for the preparation of *gem*-diacylates from aldehydes carrying an amino functionality group, such as 4-(dimethylamino)benzaldehyde **107**,^{20,33,35,37} possibly due to the existence of the quinoid structure with an aldehyde which decreases the reactivity of the aldehyde group, as explained previously.^{20,35,37} However, it is worth noting that in the case of its protonated species, i.e. *N,N'*-dimethylammonium benzaldehyde **107'**, the reaction progressed smoothly at room temperature to afford excellent yields of the corresponding *gem*-diacylate **107'r**, which was isolated as its free amine **107r** after hydrogencarbonate work up (Scheme IIB.4.8). In spite of the strongly electron-withdrawing nature of the *N,N'*-dimethylammonium the reaction works well because the hydrochloride, being strongly acidic, activates the carbonyl towards nucleophilic attack by an anhydride. This was further confirmed by performing the diacylation of a substrate containing an electron-withdrawing group, such as a nitro group, in the presence of triethylamine hydrochloride. When *p*-nitrobenzaldehyde (**98**; 1 equiv.) was treated with acetic anhydride (3 equiv.) in the presence of TBATB (0.1 equiv.) and triethylamine hydrochloride (1 equiv.) the reaction went to completion, with an 85 % yield of isolated product, within 7 h, which is much faster than the formation in the absence of any hydrochloride (Table IIB.4.1).



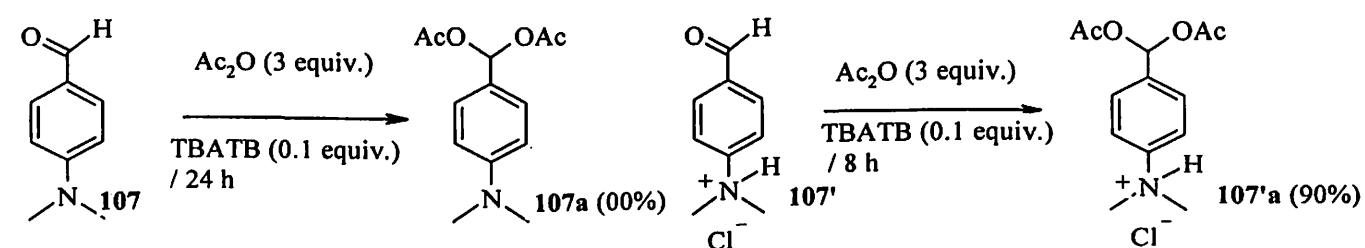
Scheme IIB.4.8. Diacylation of *N,N*-dimethyl benzaldehyde

Table IIB.4.1 Diacylation of Aldehydes Using Acetic Anhydride and TBATB^a

Substrate	Product ^b	Time (h)	Yield ^c (%)
87	87r	6	78
88	88r	6.2	82
89	89r	7	83
90	90r	5	84
91	91r	4	90
92	92r	5.3	93
93	93r	22	82
94	94r	2.5	94
95	95r	5	88
96	96r	6	93
97	97r	5.5	92
98	98r	22	78

Table Contd.

2-Furaldehyde **106** gave a dark-colored polymeric compound when catalyzed by a heterogeneous inorganic acid³⁵ but gave an excellent yield of the product at 0 °C in the presence of TBATB as the catalyst. It has been reported that many catalysts are not suitable for the preparation of *gem*-diacylates from aldehydes carrying an amino functionality group, such as 4-(dimethylamino)benzaldehyde **107**,^{20,33,35,37} possibly due to the existence of the quinoid structure with an aldehyde which decreases the reactivity of the aldehyde group, as explained previously.^{20,35,37} However, it is worth noting that in the case of its protonated species, i.e. *N,N'*-dimethylammonium benzaldehyde **107'**, the reaction progressed smoothly at room temperature to afford excellent yields of the corresponding *gem*-diacylate **107'r**, which was isolated as its free amine **107r** after hydrogencarbonate work up (Scheme IIB.4.8). In spite of the strongly electron-withdrawing nature of the *N,N'*-dimethylammoniumion the reaction works well because the hydrochloride, being strongly acidic, activates the carbonyl towards nucleophilic attack by an anhydride. This was further confirmed by performing the diacylation of a substrate containing an electron-withdrawing group, such as a nitro group, in the presence of triethylamine hydrochloride. When *p*-nitrobenzaldehyde (**98**; 1 equiv.) was treated with acetic anhydride (3 equiv.) in the presence of TBATB (0.1 equiv.) and triethylamine hydrochloride (1 equiv.) the reaction went to completion, with an 85 % yield of isolated product, within 7 h, which is much faster than the formation in the absence of any hydrochloride (Table IIB.4.1).



Scheme IIB.4.8. Diacylation of *N,N*-dimethyl benzaldehyde

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90	90r	5	84
91	91r	4	90
92	92r	5.3	93
93	93r	22	82
94	94r	2.5	94
95	95r	5	88
96	96r	6	93
97	97r	5.5	92
98	98r	22	78

Table Contd.

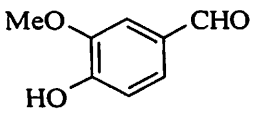
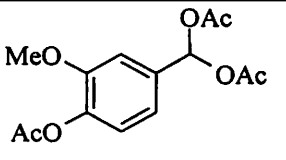
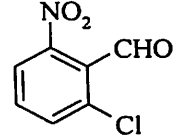
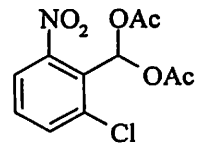
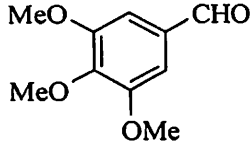
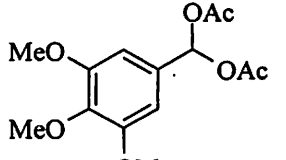
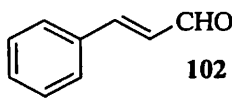
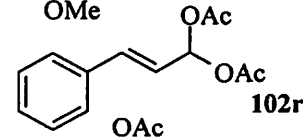
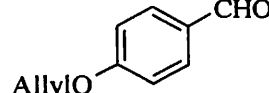
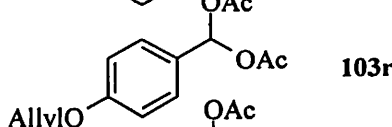
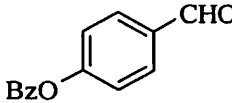
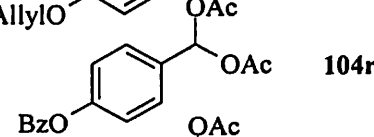
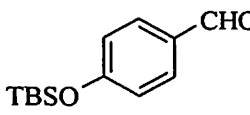
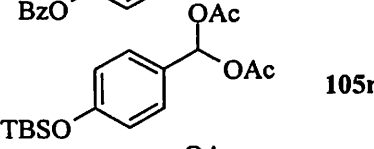
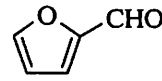
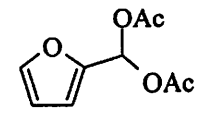
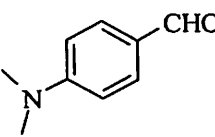
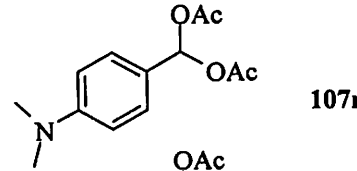
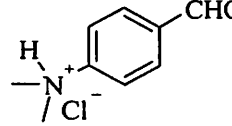
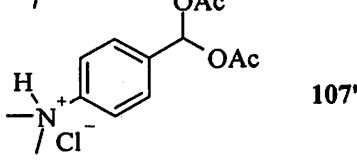
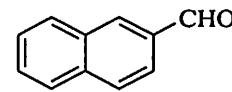
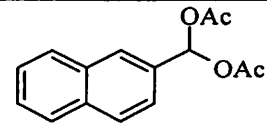
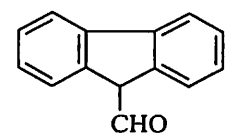
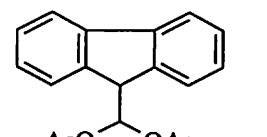
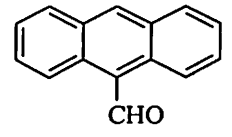
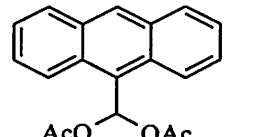
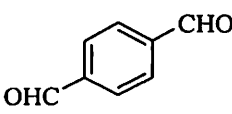
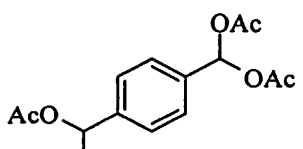
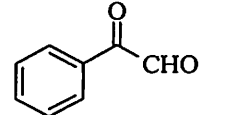
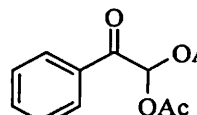
Substrate	Product ^b	Time (h)	Yield ^c (%)
 99	 99r	9	80
 100	 100r	22	78
 101	 101r	4	94
 102	 102r	5.2	87
 103	 103r	5.5	86
 104	 104r	6.5	87
 105	 105r	7	90
 106	 106r	7	80 ^d
 107	 107r	24	00
 107'	 107'r	7	90

Table Contd....

Substrate	Product ^b	Time (h)	Yield (%)
 108	 108r	8	91
 109	 109r	16	92
 110	 110r	24	61
 111	 111r	12	80
 112	 112r	25	89

^aReactions were monitored by TLC/GC. ^bProducts were characterized by IR, ¹H and ¹³CNMR spectroscopy. ^cYields of isolated product. ^dPerformed at 0 °C

Terephthalaldehyde **111** a substrate containing two aldehydic groups could be tetraacylated with six equivalents of acetic anhydride under the present conditions. Ketones such as cyclohexanone and acetophenone did not yield any diacylates in the presence of TBATB. Aldehydes having higher ground state and lower activation energy compared to ketones having lower ground state and higher activation energy are more reactive than ketones. Therefore it is not surprising to observe the chemoselective diacylation of aldehydes over ketones (Scheme IIB.4.9).^{40a,40f} Furthermore, the chemoselective diacylation of a aldehyde over a ketone was demonstrated in an intramolecular fashion with ketoaldehyde **112**. The nature of the substituents on the aromatic ring has a substantial effect on the reaction, as demonstrated in Scheme IIB.4.9. Selective *gem*-diacylation of benzaldehyde **91**, *p*-methylbenzaldehyde **94** and *p*-methoxybenzaldehyde **97** could be achieved in the presence of *p*-nitrobenzaldehyde **98** with TBATB as the catalyst at room temperature; this shows the influence of electronic effects on these reactions. Similar results have been obtained with AlPW₁₂O₄₀.³⁵ We have

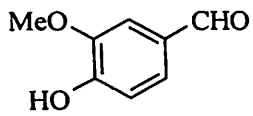
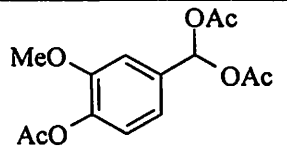
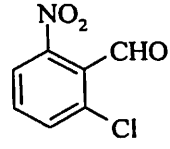
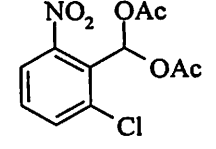
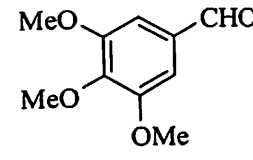
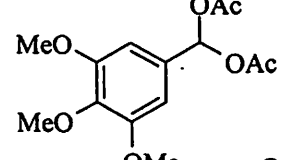
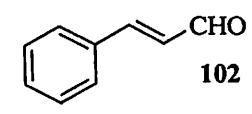
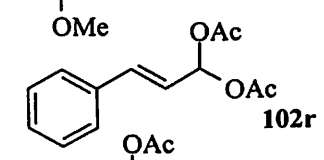
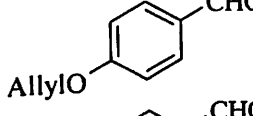
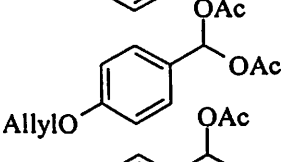
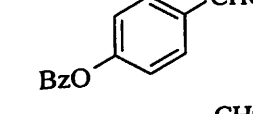
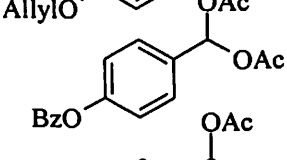
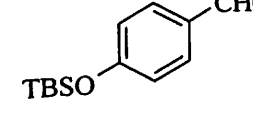
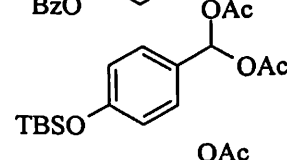
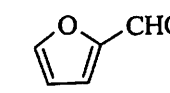
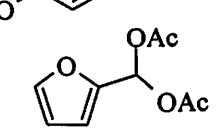
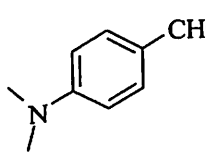
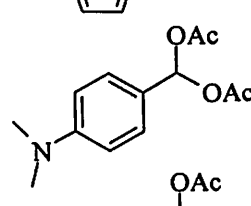
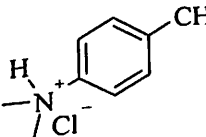
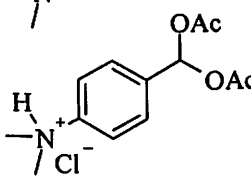
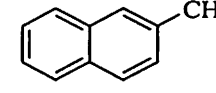
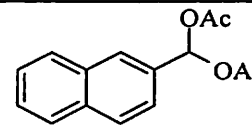
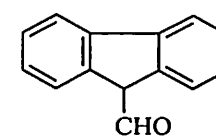
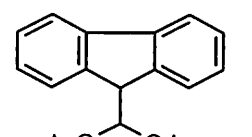
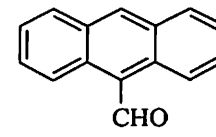
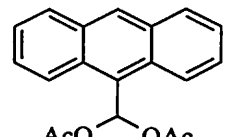
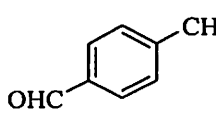
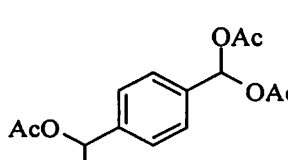
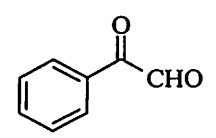
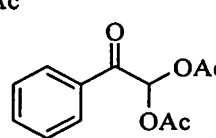
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 106	 106r	7	80 ^d
 107	 107r	24	00
 107'	 107'r	7	90

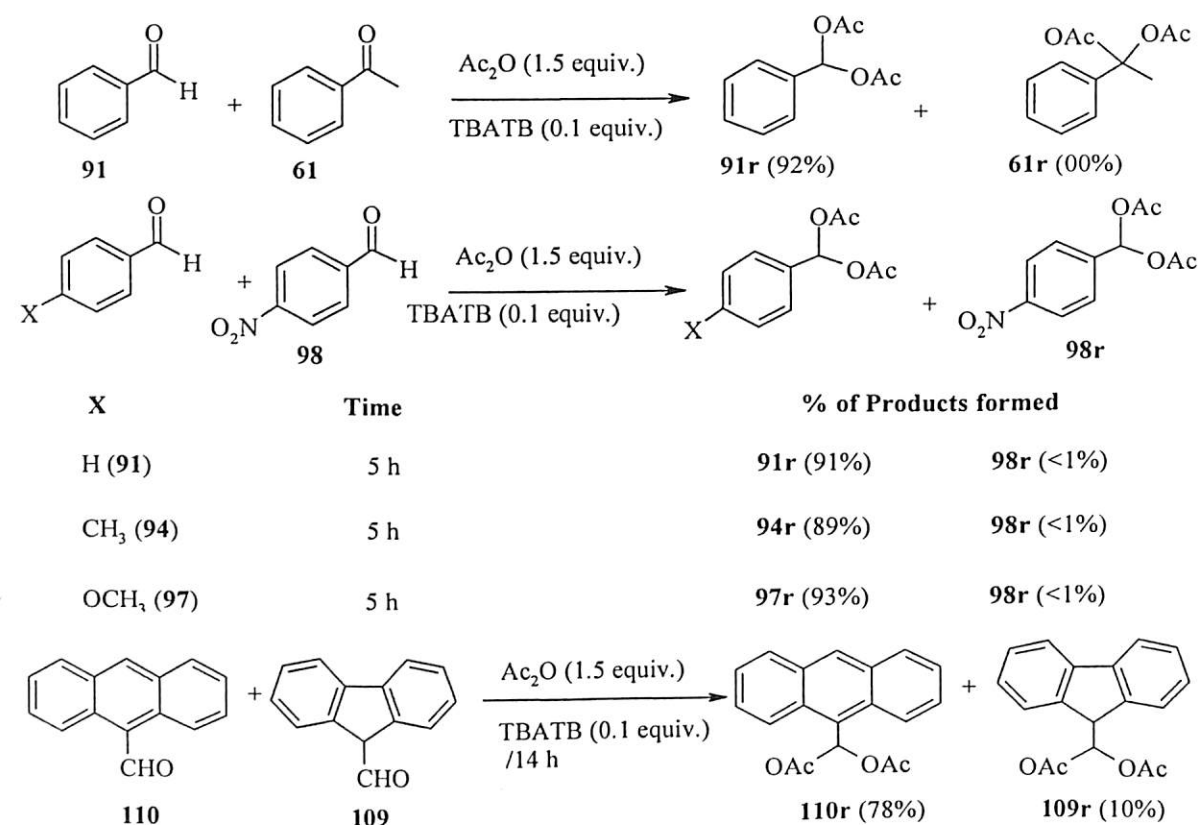
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 112	 112r	25	89

^aReactions were monitored by TLC/GC. ^bProducts were characterized by IR, ¹H and ¹³CNMR spectroscopy. ^cYields of isolated product. ^dPerformed at 0 °C

Terephthalaldehyde **111** a substrate containing two aldehydic groups could be tetraacylated with six equivalents of acetic anhydride under the present conditions. Ketones such as cyclohexanone and acetophenone did not yield any diacylates in the presence of TBATB. Aldehydes having higher ground state and lower activation energy compared to ketones having lower ground state and higher activation energy are more reactive than ketones. Therefore it is not surprising to observe the chemoselective diacylation of aldehydes over ketones (Scheme IIB.4.9).^{40a,40f} Furthermore, the chemoselective diacylation of a aldehyde over a ketone was demonstrated in an intramolecular fashion with ketoaldehyde **112**. The nature of the substituents on the aromatic ring has a substantial effect on the reaction, as demonstrated in Scheme IIB.4.9. Selective *gem*-diacylation of benzaldehyde **91**, *p*-methylbenzaldehyde **94** and *p*-methoxybenzaldehyde **97** could be achieved in the presence of *p*-nitrobenzaldehyde **98** with TBATB as the catalyst at room temperature; this shows the influence of electronic effects on these reactions. Similar results have been obtained with AlPW₁₂O₄₀.³⁵ We have

also studied the competitive *gem*-diacylation reaction between 9-anthraldehyde **110** and 9-fluorencarboxaldehyde **109**. The former was chemoselectively diacylated over the latter, which further shows the significance of steric effects on these reactions in the presence of this reagent



Scheme IIB.4.9. Chemoselective *gem*-diacylation of aldehydes

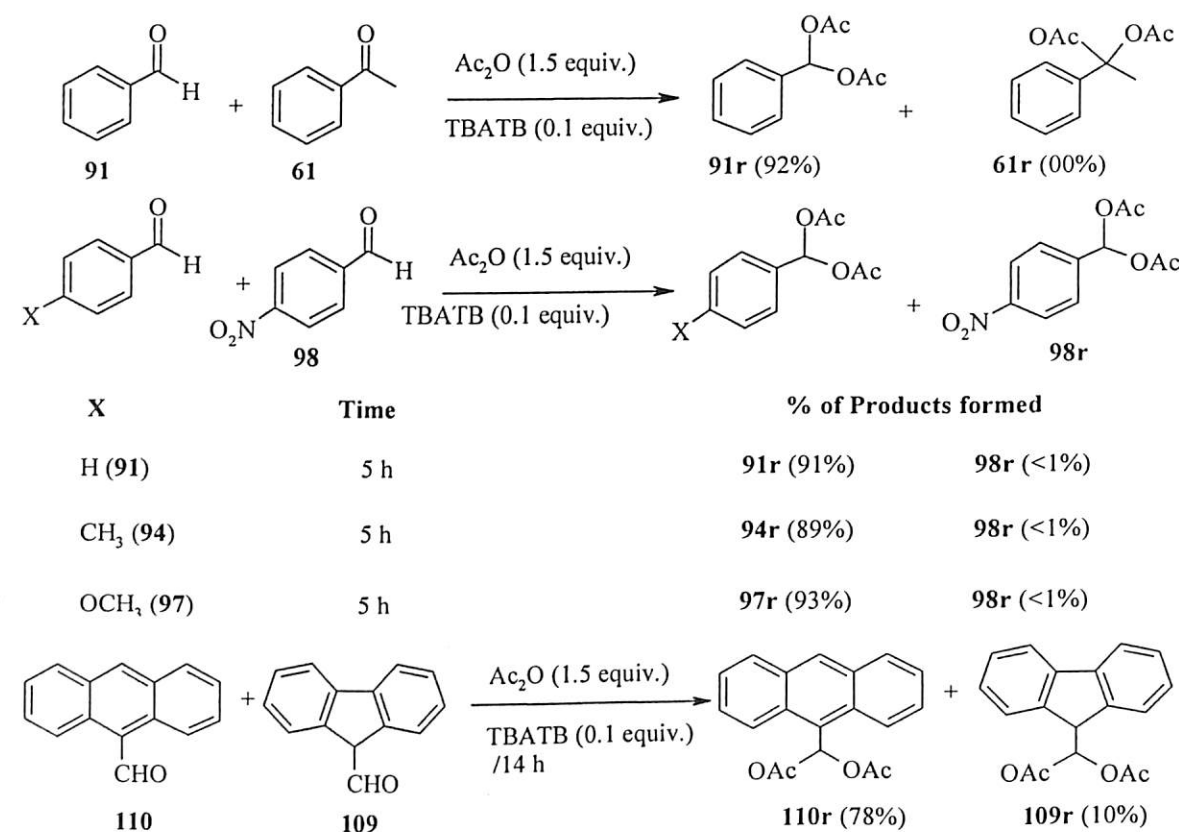
There are few reports of a geminal diester possessing a carboxyl moiety (butyryloxy, isobutyryloxy and pivaloxy) other than the acetoxy group,^{16a,18} and not a single report could be found of the reaction of aldehydes with benzoic anhydride. Employing propionic anhydride in the same manner as acetic anhydride furnished the corresponding *gem*-dipropionates (Table IIB.4.2) compounds **91s**, **97s**, **102s** and **110s**). Similarly, isobutyric, pivalic and benzoic anhydride gave the corresponding *gem*-diisobutyrate (Table IIB.4.2 compounds **91t**, **97t**, **102t** and **110t**), *gem*-dipivalates (Table IIB.4.2) compounds **91u**, **94u**, **97u** and **102u**) and *gem*-dibenzoates (Table IIB.4.2) compounds **102v** and **110v** respectively. Two equivalents of anhydrides were used for each equivalent of the aldehyde for propionic, isobutyric and pivalic anhydride, whereas the ratio was 1 : 1 in the case of benzoic anhydride

Table IIB.4.2. Diacylation^a of Aldehydes Using Propionic and Isobutyric Anhy

Substrate	Product ^b	1	
		4	90
		5.5	92
		5.2	87
		16	92
		4	90
		5.5	92
		5.2	87
		18	90
		19	85
		17	80

Table Contd....

also studied the competitive *gem*-diacylation reaction between 9-anthraldehyde **110** and 9-fluorene-9-carboxaldehyde **109**. The former was chemoselectively diacylated over the latter, which further shows the significance of steric effects on these reactions in the presence of this reagent



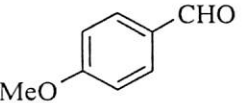
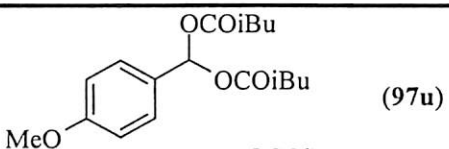
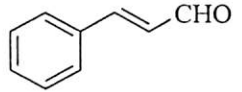
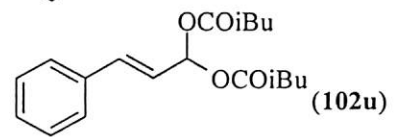
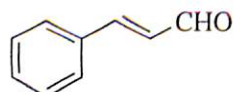
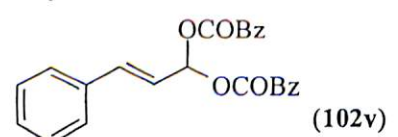
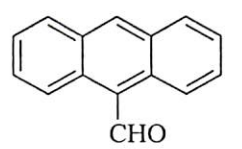
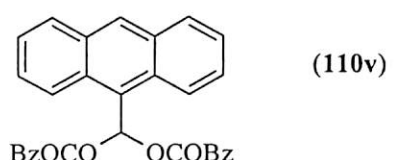
Scheme IIB.4.9. Chemoselective *gem*-diacylation of aldehydes

There are few reports of a geminal diester possessing a carboxyl moiety (butyryloxy, isobutyryloxy and pivaloxy) other than the acetoxy group,^{16a,18} and not a single report could be found of the reaction of aldehydes with benzoic anhydride. Employing propionic anhydride in the same manner as acetic anhydride furnished the corresponding *gem*-dipropionates (Table IIB.4.2) compounds **91s**, **97s**, **102s** and **110s**). Similarly, isobutyric, pivalic and benzoic anhydride gave the corresponding *gem*-diisobutyrate (Table IIB.4.2 compounds **91t**, **97t**, **102t** and **110t**), *gem*-dipivalates (Table IIB.4.2) compounds **91u**, **94u**, **97u** and **102u**) and *gem*-dibenzoates (Table IIB.4.2) compounds **102v** and **110v** respectively. Two equivalents of anhydrides were used for each equivalent of the aldehyde for propionic, isobutyric and pivalic anhydride, whereas the ratio was 1 : 1 in the case of benzoic anhydride

Table IIB.4.2. Diacylation^a of Aldehydes Using Propionic and Isobutyric Anh.

Substrate		Product ^b			
	(91)		(91s)	4	90
	(97)		(97s)	5.5	92
	(102)		(102s)	5.2	87
	(110)		(110s)	16	92
	(91)		(91t)	4	90
	(97)		(97t)	5.5	92
	(102)		(102t)	5.2	87
	(110)		(110t)	18	90
	(91)		(91u)	19	85
	(94)		(94u)	17	80

Table Contd....

Substrate	Product ^b	Time (h)	Yield ^c (%)
	 (97u)	10	92
	 (102u)	22	87
	 (102v)	10	90
	 (110v)	24	90

^aReactions were monitored by TLC/GC. ^bProducts were characterized by IR, ¹H NMR, ¹³C NMR spectroscopy. ^cYields of isolated products

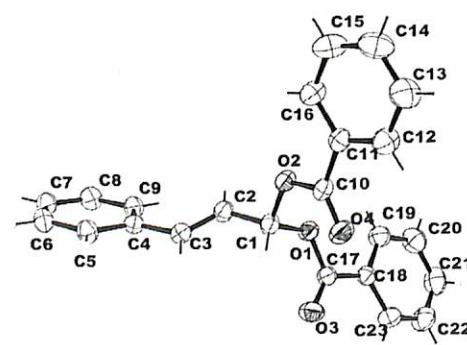
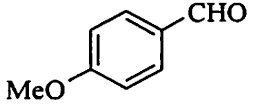
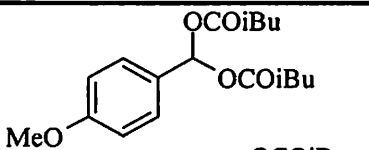
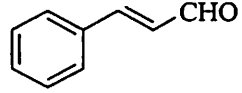
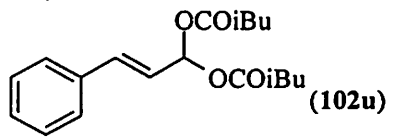
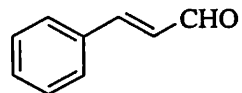
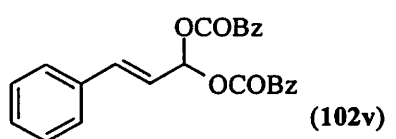
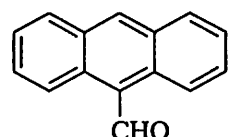
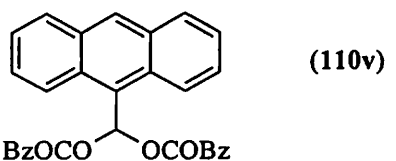


Figure IIB.4.1. Crystal structure of cinnamaldehyde dibenzoate (102v)

The product obtained from the dibenzoylation of cinnamaldehyde was further characterized X-ray crystallographic analysis. Crystal structure of the compound (102v) is shown in the (Figure IIB.4.1) the product was crystallized in the 1:1 mixture of ethyl acetate and hexane.

Only a few methods have been reported in the literature for the deprotection of diacylates to their corresponding aldehydes. The reagents used are H₂SO₄,^{6c} HCl,⁴² boron triiodide-*N,N*'dimethylaniline complex,^{2g} CAN on silicagel,⁴³ BiCl₃,⁴⁴ CBr₄,⁴⁵ CeCl₃·7H₂O/NaI,⁴⁶ KSF,⁴⁷

montmorillonite K-10,⁴⁸ neutral alumina under microwave irradiation,⁴⁹ hydroxide or aqueous K₂CO₃,^{1b} or envirocat EPZG.⁵¹ Some of the reagent promoting acylation can also cause cleavage to the parent aldehyde upon changing the reaction conditions. These reagents are zeolite,^{28b} graphite,³⁰ zirconium sulfenyl phosphonate³⁴ and ZrCl₄.¹⁸ We investigated the use of a catalytic quantity of TBATB (0.1 equiv.) for the deprotection of *gem*-diacetates to their corresponding aldehydes. When the *gem*-diacetate of benzaldehyde (91r, 1 mmol) was treated with a catalytic quantity of TBATB (0.1 equiv.) in methanol (1 mL) at room temperature the diacetate was cleanly deprotected to benzaldehyde. This protocol was applied to the diacetates of several aliphatic and aromatic aldehydes (Table IIB.4.3) to give excellent yields of the corresponding aldehydes. Zirconium sulfenyl phosphonate,³⁴ although capable of deprotecting the *gem*-diacetates of several aromatic aldehydes, was found to be unsuitable for the cleavage of aliphatic diacetates. However, we observed complete deprotection of aliphatic diacetates to their corresponding aldehydes at room temperature (87r, 88r) with our system. It is surprising to note that no additional water is necessary for the deprotection. The deprotection reaction is expected to proceed by an intramolecular path, as proposed previously.⁵¹ It is noteworthy that the phenolic acetate 96r is untouched during the reaction. Therefore, the present procedure is selective for deprotection of an aldehydic *gem*-diacetate to aldehyde in the presence of phenolic acetate (Scheme IIB.4.7), which suggests a faster rate of formation of phenolic acetate but slower rate of deprotection (Table IIB.4.3). Similar to their formation, substrates containing electron-withdrawing groups, such as nitro, react slowly and require longer reaction times for their deprotection, as shown in the case of 98r. This observation is consistent with the observation using zirconium sulfenyl phosphonate.³⁴ However; it is surprising to note that the catalyst ZrCl₄¹⁸ can deprotect *gem*-diacylates of substrates containing electron-withdrawing groups within five minutes at room temperature with only 5 mol % of the catalyst. Acid-sensitive substrates such as the phenolic OTBS ether 105r remained unaffected. Several *gem*-dipropionates (91s, 97s, 102s and 110s) and *gem*-diisobutyrate (91t, 97t and 102t) could also be smoothly deprotected under identical reaction conditions (Table IIB.4.3). It is pertinent to note that *gem*-dipivalates (91u, 97u and 102u) and the *gem*-dibenzoate 102v remained unchanged up to 4 h under these reaction conditions. However, they can be deprotected at reflux temperature (Table IIB.4.3).

Substrate	Product ^b	Time (h)	Yield ^c (%)
 (97)	 (97u)	10	92
 (102)	 (102u)	22	87
 (102)	 (102v)	10	90
 (110)	 (110v)	24	90

^aReactions were monitored by TLC/GC. ^bProducts were characterized by IR, ¹H NMR, ¹³C NMR spectroscopy. ^cYields of isolated products

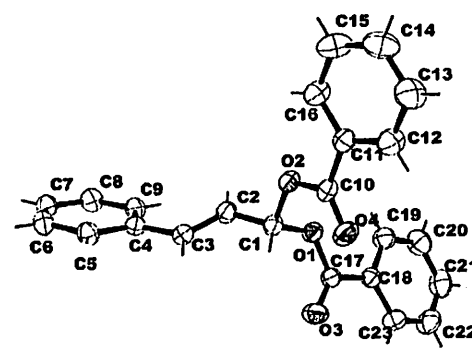


Figure IIB.4.1. Crystal structure of cinnamaldehyde dibenzoate (102v)

The product obtained from the dibenylation of cinnamaldehyde was further characterized X-ray crystallographic analysis. Crystal structure of the compound (102v) is shown in the (Figure IIB.4.1) the product was crystallized in the 1:1 mixture of ethyl acetate and hexane.

Only a few methods have been reported in the literature for the deprotection of diacylates to their corresponding aldehydes. The reagents used are H₂SO₄,^{6c} HCl,⁴² boron triiodide-*N,N'*-dimethylaniline complex,^{2g} CAN on silicagel,⁴³ BiCl₃,⁴⁴ CBr₄,⁴⁵ CeCl₃·7H₂O/NaI,⁴⁶ KSF,⁴⁷

montmorillonite K-10,⁴⁸ neutral alumina under microwave irradiation,⁴⁹ hydroxide or aqueous K₂CO₃,^{1b} or envirocat EPZG.⁵¹ Some of the reagent promoting acylation can also cause cleavage to the parent aldehyde upon changing the reaction conditions. These reagents are zeolite,^{28b} graphite,³⁰ zirconium sulfenyl phosphonate³⁴ and ZrCl₄.¹⁸ We investigated the use of a catalytic quantity of TBATB (0.1 equiv.) for the deprotection of *gem*-diacetates to their corresponding aldehydes. When the *gem*-diacetate of benzaldehyde (91r, 1 mmol) was treated with a catalytic quantity of TBATB (0.1 equiv.) in methanol (1 mL) at room temperature the diacetate was cleanly deprotected to benzaldehyde. This protocol was applied to the diacetates of several aliphatic and aromatic aldehydes (Table IIB.4.3) to give excellent yields of the corresponding aldehydes. Zirconium sulfenyl phosphonate,³⁴ although capable of deprotecting the *gem*-diacetates of several aromatic aldehydes, was found to be unsuitable for the cleavage of aliphatic diacetates. However, we observed complete deprotection of aliphatic diacetates to their corresponding aldehydes at room temperature (87r, 88r) with our system. It is surprising to note that no additional water is necessary for the deprotection. The deprotection reaction is expected to proceed by an intramolecular path, as proposed previously.⁵¹ It is noteworthy that the phenolic acetate 96r is untouched during the reaction. Therefore, the present procedure is selective for deprotection of an aldehydic *gem*-diacetate to aldehyde in the presence of phenolic acetate (Scheme IIB.4.7), which suggests a faster rate of formation of phenolic acetate but slower rate of deprotection (Table IIB.4.3). Similar to their formation, substrates containing electron-withdrawing groups, such as nitro, react slowly and require longer reaction times for their deprotection, as shown in the case of 98r. This observation is consistent with the observation using zirconium sulfenyl phosphonate.³⁴ However; it is surprising to note that the catalyst ZrCl₄¹⁸ can deprotect *gem*-diacylates of substrates containing electron-withdrawing groups within five minutes at room temperature with only 5 mol % of the catalyst. Acid-sensitive substrates such as the phenolic OTBS ether 105r remained unaffected. Several *gem*-dipropionates (91s, 97s, 102s and 110s) and *gem*-diisobutyrate (91t, 97t and 102t) could also be smoothly deprotected under identical reaction conditions (Table IIB.4.3). It is pertinent to note that *gem*-dipivalates (91u, 97u and 102u) and the *gem*-dibenzoate 102v remained unchanged up to 4 h under these reaction conditions. However, they can be deprotected at reflux temperature (Table IIB.4.3).

Table IIB.4.3. Deprotection of Acylals^a Using TBATB in Methanol.

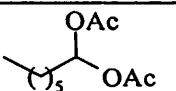
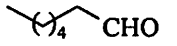
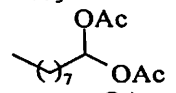
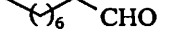
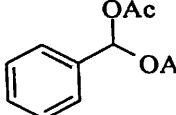
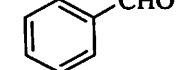
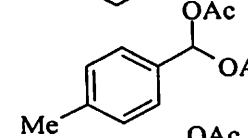
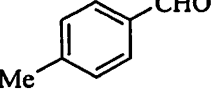
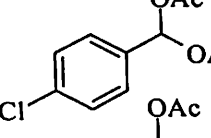
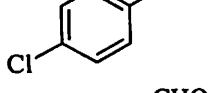
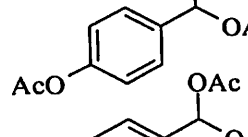
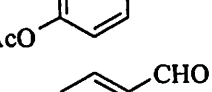
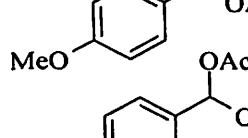
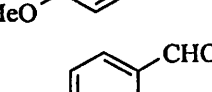
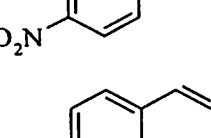
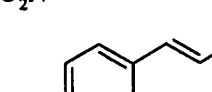
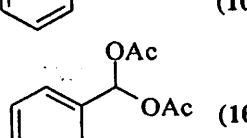
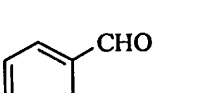
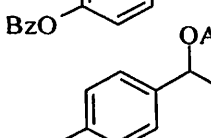
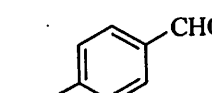
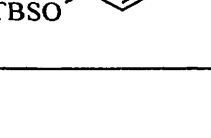
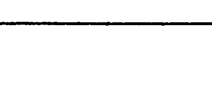
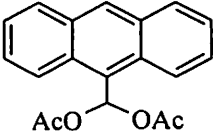
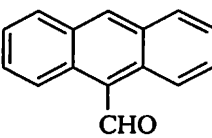
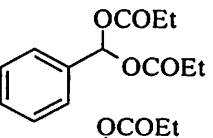
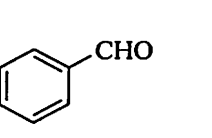
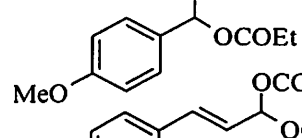
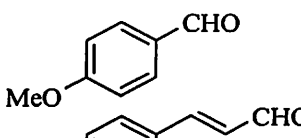
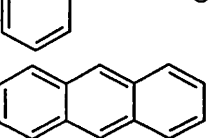
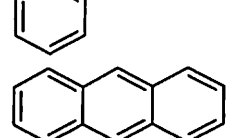
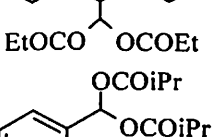
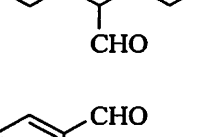
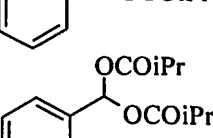
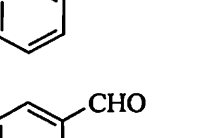
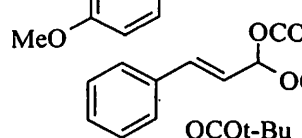
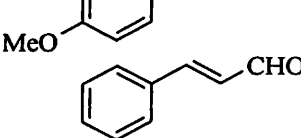
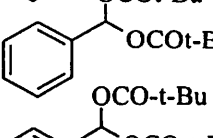
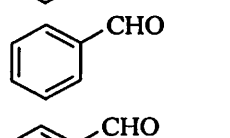
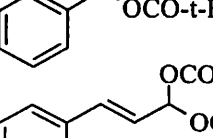
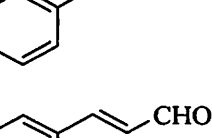
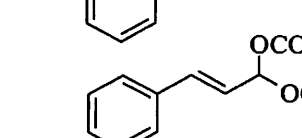
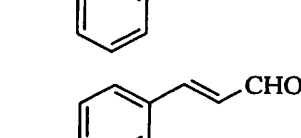
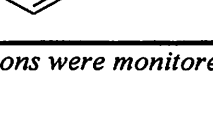
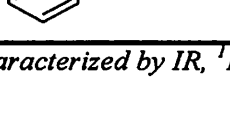
Substrate	Product ^b	Time(h)	Yield ^c (%)
 (87r)	 (87)	0.25	95
 (88r)	 (88)	0.25	97
 (91r)	 (91)	1.25	90
 (94r)	 (94)	1.5	94
 (95r)	 (95)	3	9
 (96r)	 (96')	0.80	93
 (97r)	 (97)	5.	9
 (98r)	 (98)	15	78
 (102r)	 (102)	0.75	98
 (104r)	 (104)	8.00	87
 (105r)	 (105)	4.00	90

Table Contd....

Substrate	Product ^b	Time(h)	Yield ^c (%)
 (110r)	 (110)	12	85
 (91s)	 (91)	4	90
 (97s)	 (97)	5.5	92
 (102s)	 (102)	5.2	87
 (110s)	 (110)	16	92
 (91t)	 (91)	4	90
 (97t)	 (97)	5.5	92
 (102t)	 (102)	5.2	87
 (91u)	 (91)	4	90
 (97u)	 (97)	5.5	92
 (102u)	 (102)	5.2	87
 (102v)	 (102)	5.2	87

^aReactions were monitored by TLC/GC. ^bProducts were characterized by IR, ¹H NMR, ¹³C NMR spectroscopy. ^cIsolated yields

Table IIB.4.3. Deprotection of Acylals^a Using TBATB in Methanol.

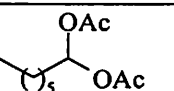
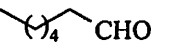
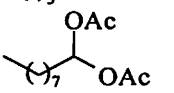
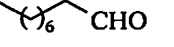
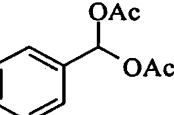
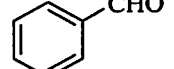
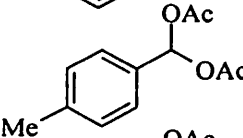
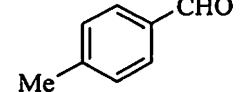
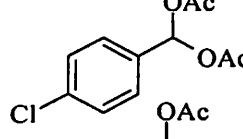
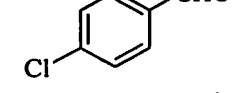
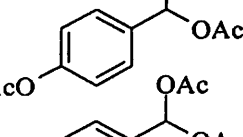
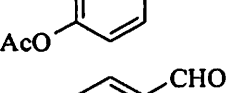
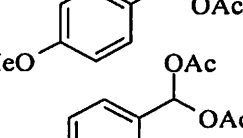
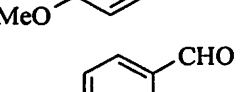
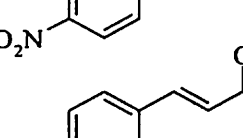
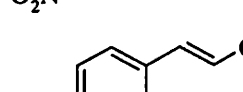
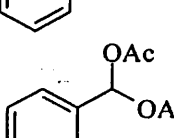
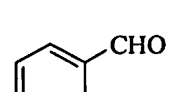
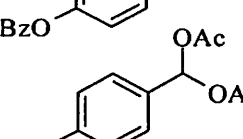
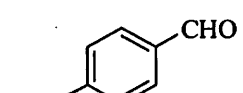
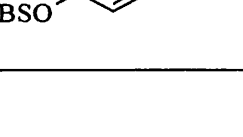
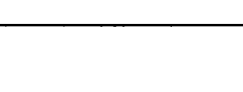
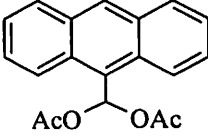
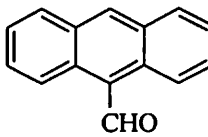
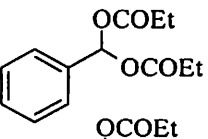
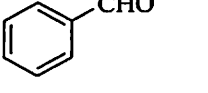
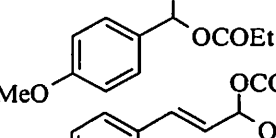
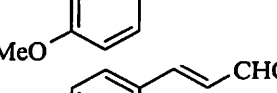
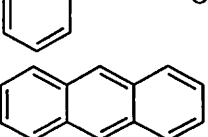
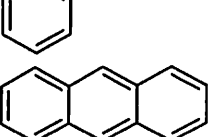
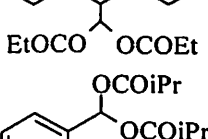
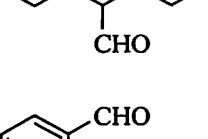
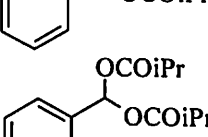
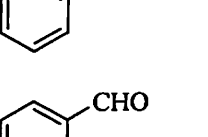
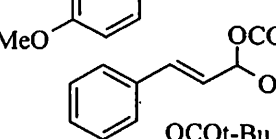
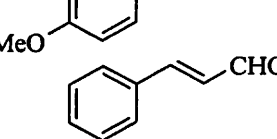
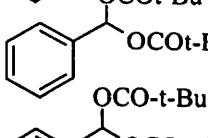
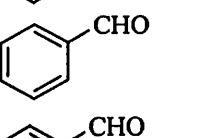
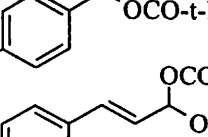
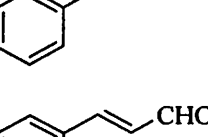
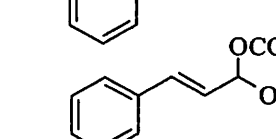
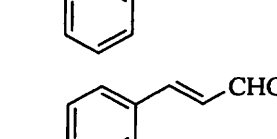
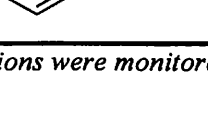
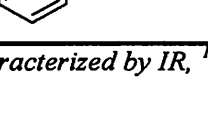
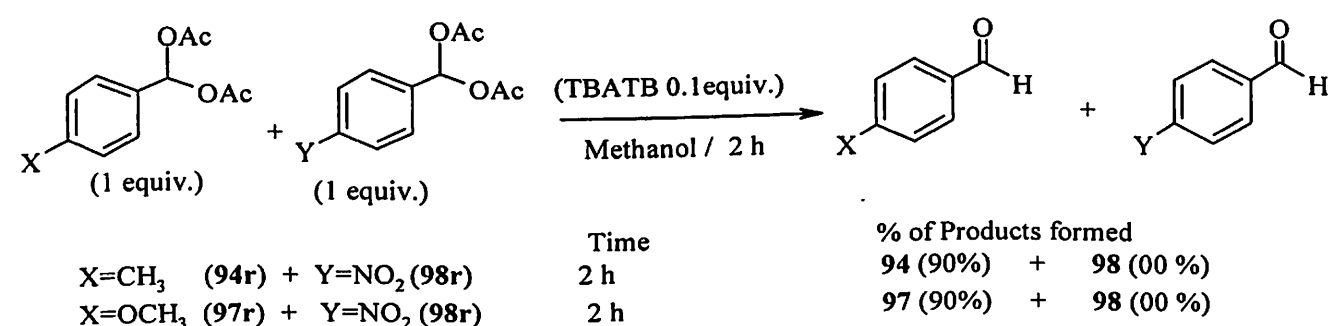
Substrate	Product ^b	Time(h)	Yield ^c (%)
 (87r)	 (87)	0.25	95
 (88r)	 (88)	0.25	97
 (91r)	 (91)	1.25	90
 (94r)	 (94)	1.5	94
 (95r)	 (95)	3	9
 (96r)	 (96')	0.80	93
 (97r)	 (97)	5.	9
 (98r)	 (98)	15	78
 (102r)	 (102)	0.75	98
 (104r)	 (104)	8.00	87
 (105r)	 (105)	4.00	90

Table Contd....

Substrate	Product ^b	Time(h)	Yield ^c (%)
 (110r)	 (110)	12	85
 (91s)	 (91)	4	90
 (97s)	 (97)	5.5	92
 (102s)	 (102)	5.2	87
 (110s)	 (110)	16	92
 (91t)	 (91)	4	90
 (97t)	 (97)	5.5	92
 (102t)	 (102)	5.2	87
 (91u)	 (91)	4	90
 (97u)	 (97)	5.5	92
 (102u)	 (102)	5.2	87
 (102v)	 (102)	5.2	87

^aReactions were monitored by TLC/GC. ^bProducts were characterized by IR, ¹H NMR, ¹³C NMR spectroscopy. ^cIsolated yields

The slower rate of deprotection of *p*-nitrobenzaldehyde diacetate (**98r**) prompted us to test the chemoselective deprotection with other *gem*-diacetates. Thus, when an equimolar mixture of *p*-methylbenzaldehyde diacetate (**94r**) and *p*-nitrobenzaldehyde diacetate (**98r**) was treated with TBATB (0.1 equiv.) in methanol, the former was completely deprotected and the latter unaffected after 1.5 h. Similarly, *p*-methoxybenzaldehyde diacetate (**97r**) could also be chemoselectively deprotected in the presence of *p*-nitrobenzaldehyde diacetate (**98r**), thereby showing the influence of electronic effects on these reactions in the presence of this reagent (Scheme IIB.4.10).



Scheme IIB.4.10. Chemoselective deprotection of *gem*-diacylates.

As can be seen from Table IIB.4.3, *gem*-diisobutyrate, *gem*-dipivalate and *gem*-dibenzoate are relatively stable compared to *gem*-diacetates and *gem*-dipropionate. Therefore, we investigated the possible chemoselective cleavage of different *gem*-diacylates in the presence of each other, as shown in Scheme IIB.4.11. We focused our attention on diacylates of α,β -unsaturated aldehydes since they serve as important building blocks for the synthesis of dienes to be used for Diels-Alder reactions. In a competitive intermolecular deprotection⁵² between cinnamaldehyde diacetate **102r** and cinnamaldehyde dipropionate **102s** in methanol at room temperature, we observed that both were deprotected with nearly equal ease. A better intermolecular chemoselectivity (80 %) was obtained for **102r** by performing the reaction in methanol/water (5:1), although a longer reaction time (2 h) was required for the process (Scheme IIB.4.11). A relatively poor chemoselectivity was observed for cinnamaldehyde diisobutyrate **102t** over **102s** (40 %) and over **102r** (60 %). Excellent intermolecular chemoselectivity was observed for cinnamaldehyde dipivalate **102u** in the presence of **102t** (100 %), and for cinnamaldehyde dibenzoate **102v** over **102u** (90 %). Thus, the relative stability order found from the present experimental study is *gem*-dibenzoate > *gem*-dipivalate > *gem*-diisobutyrate > *gem*-

diacetate > *gem*-dipropionate; the relative stability of different acylates will be of protection and deprotection chemistry.

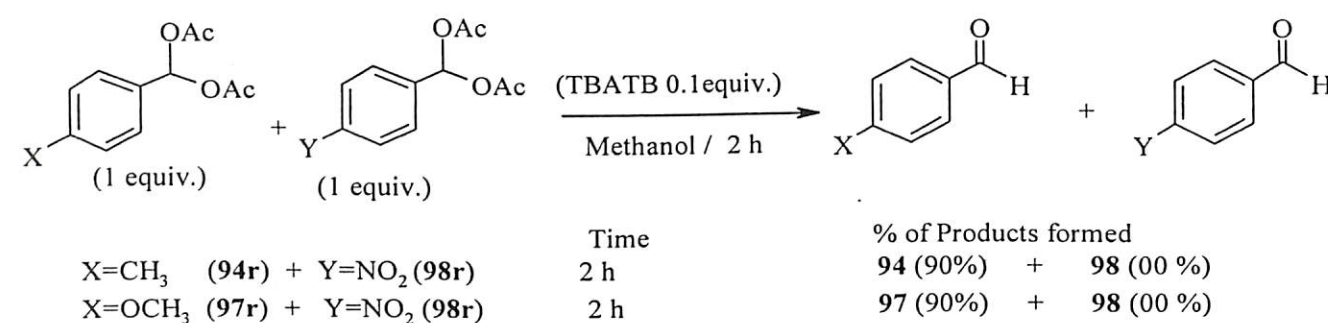
R	R'	Time	% Remaining	Selectivity
CH ₃ (102r)	Et (102s)	2 h	102r (90%) / 102s (10%)	80
Et (102s)	iPr (102t)	2 h	102s (30%) / 102t (70%)	40
CH ₃ (102r)	iPr (102t)	2 h	102r (20%) / 102t (80%)	60
iPr (102t)	tBu (102u)	8 h	102t (00%) / 102u (100%)	100
tBu (102u)	Ph (102v)	12 h	102u (10%) / 102v (100%)	90

Scheme IIB.4.11. Intermolecular chemoselectivity of different *gem*-diacylates of cinnamaldehyde.

We further investigated the stability of various acylates under basic conditions (10 % aq. sodium hydroxide) because acylates differ from acetals in this respect. Cinnamaldehyde *gem*-diacetate **102r**, *gem*-dipropionate **102s**, *gem*-diisobutyrate **102t**, *gem*-dipivalate **102u** and *gem*-dibenzoate **102v** were each stirred with 10 % aq. NaOH in dioxane and deprotection was monitored by GC. Complete deprotection of cinnamaldehyde *gem*-dipropionate, *gem*-diacetate and *gem*-diisobutyrate was observed after 9 h, 13 h and 17 h, respectively. The *gem*-dipivalate and *gem*-dibenzoate could be deprotected after 25 h and 56 h, respectively. Interestingly, we obtained a similar stability order as obtained in an acidic medium, although the compounds are more stable under basic conditions. The pK_a's of acetic acid (4.75), propionic acid (4.87), isobutyric acid (4.84), pivalic acid (4.76) and benzoic acid (4.19), are very similar; they differ by less than one pK_a unit. The stability orders of the different *gem*-diacylates determined above do not correlate with the pK_a's of the corresponding acid; rather, they are directly related to the steric crowding around the carbonyl carbon.

In conclusion, we have demonstrated that *gem*-diacylation of aldehyde is an acid-catalyzed process. The first step of the reaction is initiated by protonation of an aldehydic carbonyl group, followed by nucleophilic attack of an anhydride on an activated aldehydic carbonyl group, nucleophilic attack of the hemiacylate intermediate on a second molecule of anhydride and an intermolecular attack of the second acetate group. We have also demonstrated that *gem*-diacylates of

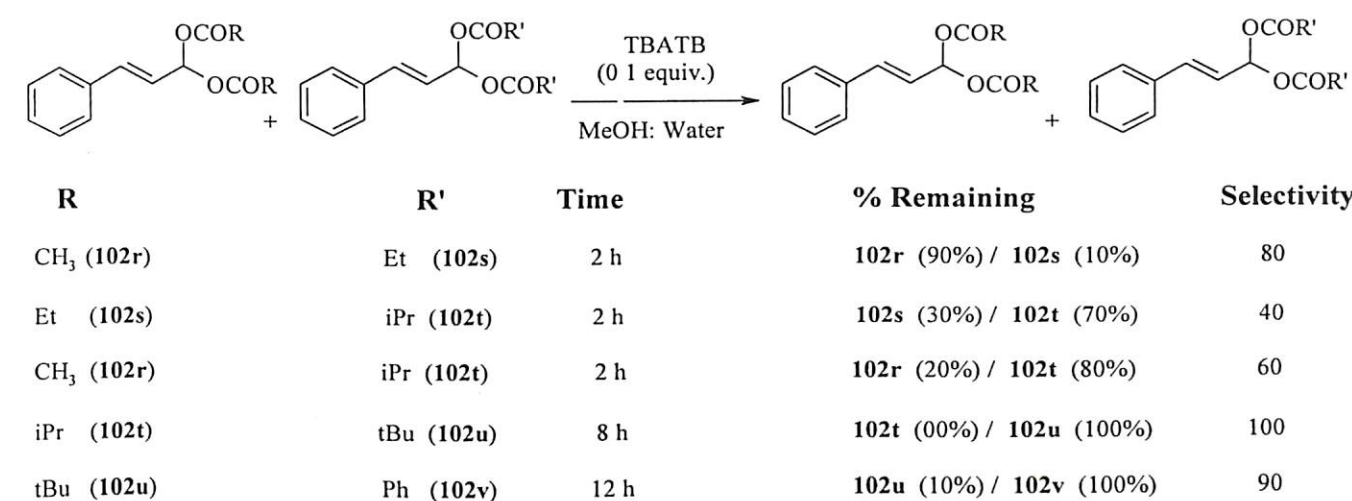
The slower rate of deprotection of *p*-nitrobenzaldehyde diacetate (**98r**) prompted us to test the chemoselective deprotection with other *gem*-diacetates. Thus, when an equimolar mixture of *p*-methylbenzaldehyde diacetate (**94r**) and *p*-nitrobenzaldehyde diacetate (**98r**) was treated with TBATB (0.1 equiv.) in methanol, the former was completely deprotected and the latter unaffected after 1.5 h. Similarly, *p*-methoxybenzaldehyde diacetate (**97r**) could also be chemoselectively deprotected in the presence of *p*-nitrobenzaldehyde diacetate (**98r**), thereby showing the influence of electronic effects on these reactions in the presence of this reagent (Scheme IIB.4.10).



Scheme IIB.4.10. Chemoselective deprotection of *gem*-diacylates.

As can be seen from Table IIB.4.3, *gem*-diisobutyrate, *gem*-dipivalate and *gem*-dibenzoate are relatively stable compared to *gem*-diacetates and *gem*-dipropionate. Therefore, we investigated the possible chemoselective cleavage of different *gem*-diacylates in the presence of each other, as shown in Scheme IIB.4.11. We focused our attention on diacylates of α,β -unsaturated aldehydes since they serve as important building blocks for the synthesis of dienes to be used for Diels-Alder reactions. In a competitive intermolecular deprotection⁵² between cinnamaldehyde diacetate **102r** and cinnamaldehyde dipropionate **102s** in methanol at room temperature, we observed that both were deprotected with nearly equal ease. A better intermolecular chemoselectivity (80 %) was obtained for **102r** by performing the reaction in methanol/water (5:1), although a longer reaction time (2 h) was required for the process (Scheme IIB.4.11). A relatively poor chemoselectivity was observed for cinnamaldehyde diisobutyrate **102t** over **102s** (40 %) and over **102r** (60 %). Excellent intermolecular chemoselectivity was observed for cinnamaldehyde dipivalate **102u** in the presence of **102t** (100 %), and for cinnamaldehyde dibenzoate **102v** over **102u** (90 %). Thus, the relative stability order found from the present experimental study is *gem*-dibenzoate > *gem*-dipivalate > *gem*-diisobutyrate > *gem*-

diacetate > *gem*-dipropionate; the relative stability of different acylates will be of protection and deprotection chemistry.



Scheme IIB.4.11. Intermolecular chemoselectivity of different *gem*-diacylates of cinnamaldehyde.

We further investigated the stability of various acylates under basic conditions (10 % aq. sodium hydroxide) because acylates differ from acetals in this respect. Cinnamaldehyde *gem*-diacetate **102r**, *gem*-dipropionate **102s**, *gem*-diisobutyrate **102t**, *gem*-dipivalate **102u** and *gem*-dibenzoate **102v** were each stirred with 10 % aq. NaOH in dioxane and deprotection was monitored by GC. Complete deprotection of cinnamaldehyde *gem*-dipropionate, *gem*-diacetate and *gem*-diisobutyrate was observed after 9 h, 13 h and 17 h, respectively. The *gem*-dipivalate and *gem*-dibenzoate could be deprotected after 25 h and 56 h, respectively. Interestingly, we obtained a similar stability order as obtained in an acidic medium, although the compounds are more stable under basic conditions. The pK_a's of acetic acid (4.75), propionic acid (4.87), isobutyric acid (4.84), pivalic acid (4.76) and benzoic acid (4.19), are very similar; they differ by less than one pK_a unit. The stability orders of the different *gem*-diacylates determined above do not correlate with the pK_a's of the corresponding acid; rather, they are directly related to the steric crowding around the carbonyl carbon.

In conclusion, we have demonstrated that *gem*-diacylation of aldehyde is an acid-catalyzed process. The first step of the reaction is initiated by protonation of an aldehydic carbonyl group, followed by nucleophilic attack of an anhydride on an activated aldehydic carbonyl group, nucleophilic attack of the hemiacylate intermediate on a second molecule of anhydride and an intermolecular attack of the second acetate group. We have also demonstrated that *gem*-diacylates of

various aliphatic and aromatic aldehydes can be prepared from a variety of aliphatic and aromatic anhydrides under solvent-free conditions in the presence of a catalytic quantity of tetrabutyl ammonium tribromide (TBATB). The faster rate of *gem*-diacylate formation for substrates containing electron-donating substituents as compared to substrates containing electron-withdrawing substituents, and chemoselective protection of the latter in the presence of the former, shows the significance of electronic effects during the formation. Deprotection of *gem*-diacylates to the corresponding parent carbonyl compounds has been accomplished by performing the reaction in methanol with the same catalyst. Chemoselective deprotection of the *gem*-diacylate of a substrate containing an electron-donating group has been achieved in the presence of a substrate containing an electron-withdrawing group, further showing the electronic effects during the deprotection. *gem*-Diacylates are more stable under basic conditions than acidic conditions. Interestingly, both the acid and base stability of various *gem*-diacylates follow the same order. The stability order obtained from a series of competitive experiments is: *gem*-dibenzoate > *gem* dipivalate > *gem*-diisobutyrate > *gem*-diacetate > *gem*-dipropionate, and is directly related to the steric crowding around the carbonyl carbon rather than to the pKa of the corresponding acid.

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various aliphatic and aromatic aldehydes can be prepared from a variety of aliphatic and aromatic anhydrides under solvent-free conditions in the presence of a catalytic quantity of tetrabutyl ammonium tribromide (TBATB). The faster rate of *gem*-diacylate formation for substrates containing electron-donating substituents as compared to substrates containing electron-withdrawing substituents, and chemoselective protection of the latter in the presence of the former, shows the significance of electronic effects during the formation. Deprotection of *gem*-diacylates to the corresponding parent carbonyl compounds has been accomplished by performing the reaction in methanol with the same catalyst. Chemoselective deprotection of the *gem*-diacylate of a substrate containing an electron-donating group has been achieved in the presence of a substrate containing an electron-withdrawing group, further showing the electronic effects during the deprotection. *gem*-Diacylates are more stable under basic conditions than acidic conditions. Interestingly, both the acid and base stability of various *gem*-diacylates follow the same order. The stability order obtained from a series of competitive experiments is: *gem*-dibenzoate > *gem* dipivalate > *gem*-diisobutyrate > *gem*-diacetate > *gem*-dipropionate, and is directly related to the steric crowding around the carbonyl carbon rather than to the pKa of the corresponding acid.

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IIC. Experimental Section

IIC.1. General Remarks

As described in Section 1C.1 Page no.46

IIC.2. Characterization of Organic Substrates

As described in Section 1C.2 Page no.46

IIC.3. General procedures

IIC.3.1. Preparation of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT)

Pyridine (8 mL, 100 mmol) and 1,2-dibromoethane (4.3 mL, 50 mmol) were refluxed for 0.5 h. The resultant solid, 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) was washed with ether (2 x 20 mL) and dissolved in water (50 mL). To this was added KBr (26.7 gm, 225 mmol) followed by an aqueous solution of Oxone® (122.8 gm, 100 mmol dissolved in 80 mL of water) over a period of 10 minutes. The orange precipitate was filtered, dried in a vacuum desiccators and recrystallized from acetonitrile to yield 29.3 gm (88 % yield) of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT)

IIC.3.2. General Experimental Procedure for Bromination of Phenol (35) to *p*-Bromophenol (35n)

A mixture of phenol **35** (440 µl, 5 mmol) and 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (1.66g, 2.5 mmol) was ground in a mortar by a pestle at room temperature. After disappearance of the starting material (monitored by TLC by taking a small amount of the mixture and dissolving it in ethyl acetate), the reaction mixture was transferred into a separatory funnel, admixed with ethyl acetate (20 mL) and washed with water (5 x 5 mL). Organic layer was dried over anhydrous Na₂SO₄, filtered and solvent was concentrated in a rotary evaporator. The compound was sufficiently pure but for analytical data it was purified by passing it over a short column of silica gel using a mixture of hexane and ethyl acetate as the eluent to yield 740 mg (85 %) of *p*-bromophenol (**35n**). This procedure is applicable to all substrates giving products as liquid. Alternatively 10 equivalents of NaHCO₃ can be mixed in the reaction mixture for aromatic phenols and amines to prevent liberation of acidic fumes.

IIC.3.3. Bromination of Acetanilide (37) to *p*-Bromoacetanilide (37n)

A mixture of acetanilide **37** (0.675g, 5 mmol) and 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (1.66g, 2.5 mmol) was ground in a mortar by a pestle at room temperature. After disappearance of the starting material (monitored by TLC by taking a small amount of the mixture and dissolving it in ethyl acetate), the reaction mixture was transferred into a G₃ sintered funnel, washed with water (5 x 5 mL), and the solid was dried to yield 1021 mg (95 %) of *p*-bromoacetanilide **37n**. This procedure is applicable to all substrates giving products as solid.

IIC.3.4. Regeneration of 1,1'-(Ethane-1,2-diyl)Dipyridinium Bistribromide (EDPBT)

(From the reaction of aromatic electrophilic substitution and α-bromination of ketones where mono bromo products were obtained)

To the aqueous layer originating from the above reaction containing 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) (1 equiv) and two equiv of bromide ion was concentrated to 5 mL, extracted with ethyl acetate (10 mL) to get rid of organic contaminants. To the aqueous layer was added KBr (354mg, 3 equiv) followed by pinch wise addition of Oxone® (1.228g, 2 equiv) under stirring. The precipitated orange solid was filtered to yield 1.17g (88 %) of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide. The recovered reagent is identical in all respect to the parent EDPBT reagent. In principle aqueous layers of several reactions were combined and kept for several days to allow the water to evaporate and proportionate amounts of KBr and Oxone® were added to regenerate the reagent.

IIC.3.5. Regeneration of 1,1'-(Ethane-1,2-diyl)Dipyridinium Bistribromide (EDPBT)

(From the reaction of addition to C-C multiple bond)

Identical to IIC.3.4, except two equivalents of additional KBr was added.

IIC.3.6. General Procedure for Syntheses of 2-Phenyl Benzothiazoles

Thiobenzanilide **62** (1 mmol) in chloroform (5 mL) was added EDPBT (0.6 equiv). The reaction mixture was left stirring at room temperature and the progress of the reaction was monitored by TLC. After completion of the reaction, chloroform (20 mL) was added. The chloroform layer was washed with water (2 x 10 mL) to get rid of the spent reagent (EDPBB) followed by washing with 5 % NaHCO₃ (2 x 5 mL). The organic layer was separated, dried over anhydrous sodium sulfate and

IIC. Experimental Section

IIC.1. General Remarks

As described in Section 1C.1 Page no.46

IIC.2. Characterization of Organic Substrates

As described in Section 1C.2 Page no.46

IIC.3. General procedures

IIC.3.1. Preparation of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT)

Pyridine (8 mL, 100 mmol) and 1,2-dibromoethane (4.3 mL, 50 mmol) were refluxed for 0.5 h. The resultant solid, 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) was washed with ether (2 x 20 mL) and dissolved in water (50 mL). To this was added KBr (26.7 gm, 225 mmol) followed by an aqueous solution of Oxone® (122.8 gm, 100 mmol dissolved in 80 mL of water) over a period of 10 minutes. The orange precipitate was filtered, dried in a vacuum desiccators and recrystallized from acetonitrile to yield 29.3 gm (88 % yield) of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT)

IIC.3.2. General Experimental Procedure for Bromination of Phenol (35) to *p*-Bromophenol (35n)

A mixture of phenol **35** (440 µl, 5 mmol) and 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (1.66g, 2.5 mmol) was ground in a mortar by a pestle at room temperature. After disappearance of the starting material (monitored by TLC by taking a small amount of the mixture and dissolving it in ethyl acetate), the reaction mixture was transferred into a separatory funnel, admixed with ethyl acetate (20 mL) and washed with water (5 x 5 mL). Organic layer was dried over anhydrous Na₂SO₄, filtered and solvent was concentrated in a rotary evaporator. The compound was sufficiently pure but for analytical data it was purified by passing it over a short column of silica gel using a mixture of hexane and ethyl acetate as the eluent to yield 740 mg (85 %) of *p*-bromophenol (**35n**). This procedure is applicable to all substrates giving products as liquid. Alternatively 10 equivalents of NaHCO₃ can be mixed in the reaction mixture for aromatic phenols and amines to prevent liberation of acidic fumes.

IIC.3.3. Bromination of Acetanilide (37) to *p*-Bromoacetanilide (37n)

A mixture of acetanilide **37** (0.675g, 5 mmol) and 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (1.66g, 2.5 mmol) was ground in a mortar by a pestle at room temperature. After disappearance of the starting material (monitored by TLC by taking a small amount of the mixture and dissolving it in ethyl acetate), the reaction mixture was transferred into a G₃ sintered funnel, washed with water (5 x 5 mL), and the solid was dried to yield 1021 mg (95 %) of *p*-bromoacetanilide **37n**. This procedure is applicable to all substrates giving products as solid.

IIC.3.4. Regeneration of 1,1'-(Ethane-1,2-diyl)Dipyridinium Bistribromide (EDPBT)

(From the reaction of aromatic electrophilic substitution and α-bromination of ketones where mono bromo products were obtained)

To the aqueous layer originating from the above reaction containing 1,1'-(ethane-1,2-diyl)dipyridinium bisbromide (EDPBB) (1 equiv) and two equiv of bromide ion was concentrated to 5 mL, extracted with ethyl acetate (10 mL) to get rid of organic contaminants. To the aqueous layer was added KBr (354mg, 3 equiv) followed by pinch wise addition of Oxone® (1.228g, 2 equiv) under stirring. The precipitated orange solid was filtered to yield 1.17g (88 %) of 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide. The recovered reagent is identical in all respect to the parent EDPBT reagent. In principle aqueous layers of several reactions were combined and kept for several days to allow the water to evaporate and proportionate amounts of KBr and Oxone® were added to regenerate the reagent.

IIC.3.5. Regeneration of 1,1'-(Ethane-1,2-diyl)Dipyridinium Bistribromide (EDPBT)

(From the reaction of addition to C-C multiple bond)

Identical to IIC.3.4, except two equivalents of additional KBr was added.

IIC.3.6. General Procedure for Syntheses of 2-Phenyl Benzothiazoles

Thiobenzanilide **62** (1 mmol) in chloroform (5 mL) was added EDPBT (0.6 equiv). The reaction mixture was left stirring at room temperature and the progress of the reaction was monitored by TLC. After completion of the reaction, chloroform (20 mL) was added. The chloroform layer was washed with water (2 x 10 mL) to get rid of the spent reagent (EDPBB) followed by washing with 5 % NaHCO₃ (2 x 5 mL). The organic layer was separated, dried over anhydrous sodium sulfate and

concentrated to yield the crude product which was further purified by column chromatography using hexane, ethyl acetate as the eluent over a neutral alumina column to yield the pure product **63o** in 70 % yield.

IIC.3.7. General Procedure for the Syntheses of 2-Amino Benzothiazoles

Diphenylthiourea **69** (1 mmol) in acetonitrile (5 mL) was added EDPBT (0.6 equiv). The reaction mixture was left stirring at 70 °C and the progress of the reaction was monitored by TLC. After completion of the reaction, chloroform (20 mL) was added. After completion of the reaction, the acetonitrile was evaporated on a rotary evaporator and residue was washed with water (2 x 5 mL) to get rid of the spent reagent (EDPBB) leaving behind the solid hydrobromide salt. The residual organic compound was treated with a saturated solution of NaHCO₃ (2 mL) and extracted with ethyl acetate (2 x 10 mL). The organic layer was separated, dried over anhydrous sodium sulfate and concentrated to yield the desired product **69p**. The product was further purified by crystallization using ethyl acetate hexane mixture (8 : 2).

IIC.3.8. General Procedure for Enol Addition to 9-Phenyl-9H-xanthen-9-ol

To 9-phenyl-9H-xanthen-9-ol **76** (1.37g, 5 mmol) in ketone (5 mL) was added (EDPBT) (166 mg, 0.25 mmol) and acetic anhydride (945 µL, 10 mmol). After the addition of the EDPBT the color of the reaction mixture turned to red, intensity of which increased after some time. Progress of the reaction was monitored by tlc. Towards the completion of the reaction the color intensity faded. The reaction mixture was concentrated, admixed with ethyl acetate [product **83q** was extracted with CH₂Cl₂ (2 x 25 mL)]. Organic layer was washed subsequently with saturated sodium bicarbonate solution (2 x 5 mL), water (2 x 5 mL). The product was dried and crystallized from a mixture of ethyl acetate: hexane (8 : 2) to yield the desired product. In the case of **84q** it was separated over neutral alumina column using ethyl acetate : hexane as the eluent.

IIC.3.9. Change of pH of Organic Solvent with TBATB

Acetic anhydride (2.5 mL, 27 mmol) was placed in a 10 mL beaker. The pH of the solution was measured by dipping the pH meter into it after calibrating with a pH 4 buffer. The pH of the solution was found to be 0.1. TBATB (1.3 g, 2.7 mmol) was added and the mixture stirred. The final pH was -0.7 after complete dissolution of TBATB, and it remained unchanged thereafter.

IIC.3.10. Formation of Mixed Acylates from an Acid Anhydride and Carboxyli

Benzaldehyde **91** (1 mmol) was added to a mixture of acetic anhydride (or propionic anhydride; 1 mmol), and propionic acid (or acetic acid; 1 mmol), and then TBATB (0.1 mmol) was also added. The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.11. Formation of Mixed Acylates from a Mixture of Anhydrides

Benzaldehyde **91** (1 mmol) was added to a mixture of acetic anhydride (1 mmol) and propionic anhydride (1 mmol), and then TBATB (0.1 mmol) was added. The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.12. Formation of Mixed Acylates from a Mixed Anhydride

Benzaldehyde **91** (1 mmol) was added to acetic-propionic anhydride (1 mmol), prepared by the reaction of acetyl chloride and propionic acid with pyridine, and then TBATB (0.1 mmol) was added. The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.13. Formation of the Mixed Anhydride

TBATB (0.1 mmol) was added to a mixture of acetic anhydride (or propionic anhydride; 1 mmol) and propionic acid (or acetic acid; 1 mmol). The homogeneous reaction was left at room temperature. The percentage of different anhydrides formed at different times was determined by gas liquid chromatography.

IIC.3.14. General Procedure for the Preparation of *gem*-Diacetates

TBATB (0.5 mmol) was added to a mixture of aldehyde (5 mmol) and acetic anhydride (15 mmol). The homogeneous reaction was left stirring at room temperature and the progress of the reaction was monitored by TLC. After completion of the reaction, the reaction mixture was poured into saturated NaHCO₃ solution (10 mL) and extracted with ethyl acetate (3 x 25 mL). The organic layer was separated, dried over anhydrous sodium sulfate and concentrated. Further purification was achieved by passing through a short column of silica gel, and the products were identified by

concentrated to yield the crude product which was further purified by column chromatography using hexane, ethyl acetate as the eluent over a neutral alumina column to yield the pure product **63o** in 70 % yield.

IIC.3.7. General Procedure for the Syntheses of 2-Amino Benzothiazoles

Diphenylthiourea **69** (1 mmol) in acetonitrile (5 mL) was added EDPBT (0.6 equiv). The reaction mixture was left stirring at 70 °C and the progress of the reaction was monitored by TLC. After completion of the reaction, chloroform (20 mL) was added. After completion of the reaction, the acetonitrile was evaporated on a rotary evaporator and residue was washed with water (2 x 5 mL) to get rid of the spent reagent (EDPBB) leaving behind the solid hydrobromide salt. The residual organic compound was treated with a saturated solution of NaHCO₃ (2 mL) and extracted with ethyl acetate (2 x 10 mL). The organic layer was separated, dried over anhydrous sodium sulfate and concentrated to yield the desired product **69p**. The product was further purified by crystallization using ethyl acetate hexane mixture (8 : 2).

IIC.3.8. General Procedure for Enol Addition to 9-Phenyl-9H-xanthen-9-ol

To 9-phenyl-9H-xanthen-9-ol **76** (1.37g, 5 mmol) in ketone (5 mL) was added (EDPBT) (166 mg, 0.25 mmol) and acetic anhydride (945 µL, 10 mmol). After the addition of the EDPBT the color of the reaction mixture turned to red, intensity of which increased after some time. Progress of the reaction was monitored by tlc. Towards the completion of the reaction the color intensity faded. The reaction mixture was concentrated, admixed with ethyl acetate [product **83q** was extracted with CH₂Cl₂ (2 x 25 mL)]. Organic layer was washed subsequently with saturated sodium bicarbonate solution (2 x 5 mL), water (2 x 5 mL). The product was dried and crystallized from a mixture of ethyl acetate: hexane (8 : 2) to yield the desired product. In the case of **84q** it was separated over neutral alumina column using ethyl acetate : hexane as the eluent.

IIC.3.9. Change of pH of Organic Solvent with TBATB

Acetic anhydride (2.5 mL, 27 mmol) was placed in a 10 mL beaker. The pH of the solution was measured by dipping the pH meter into it after calibrating with a pH 4 buffer. The pH of the solution was found to be 0.1. TBATB (1.3 g, 2.7 mmol) was added and the mixture stirred. The final pH was -0.7 after complete dissolution of TBATB, and it remained unchanged thereafter.



IIC.3.10. Formation of Mixed Acylates from an Acid Anhydride and Carboxyli

Benzaldehyde **91** (1 mmol) was added to a mixture of acetic anhydride (or propionic anhydride; 1 mmol), and propionic acid (or acetic acid; 1 mmol), and then TBATB (0.1 mmol) was also added. The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.11. Formation of Mixed Acylates from a Mixture of Anhydrides

Benzaldehyde **91** (1 mmol) was added to a mixture of acetic anhydride (1 mmol) and propionic anhydride (1 mmol), and then TBATB (0.1 mmol) was added. The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.12. Formation of Mixed Acylates from a Mixed Anhydride

Benzaldehyde **91** (1 mmol) was added to acetic-propionic anhydride (1 mmol), prepared by the reaction of acetyl chloride and propionic acid with pyridine, and then TBATB (0.1 mmol) was added. The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.13. Formation of the Mixed Anhydride

TBATB (0.1 mmol) was added to a mixture of acetic anhydride (or propionic anhydride; 1 mmol) and propionic acid (or acetic acid; 1 mmol). The homogeneous reaction was left at room temperature. The percentage of different anhydrides formed at different times was determined by gas liquid chromatography.

IIC.3.14. General Procedure for the Preparation of *gem*-Diacetates

TBATB (0.5 mmol) was added to a mixture of aldehyde (5 mmol) and acetic anhydride (15 mmol). The homogeneous reaction was left stirring at room temperature and the progress of the reaction was monitored by TLC. After completion of the reaction, the reaction mixture was poured into saturated NaHCO₃ solution (10 mL) and extracted with ethyl acetate (3 x 25 mL). The organic layer was separated, dried over anhydrous sodium sulfate and concentrated. Further purification was achieved by passing through a short column of silica gel, and the products were identified by

comparison of their NMR and IR spectra, GC profile, and GC co-injection, with authentic samples prepared by known methods.

IIC.3.15. General Procedure for the Preparation of *gem*-Dipropionate, *gem*-Diisobutyrate and *gem*-Dipivalate

Similar to the preparation of *gem*-diacetate (Section IIC.3.14), except 10 mmol of anhydride (propionic, isobutyric and pivalic) was used per 5 mmol of the aldehyde.

IIC.3.16. General Procedure for Preparation of *gem*-Dibenzoate

Similar to the preparation of *gem*-diacetate (Section IIC.3.14), except 5 mmol of benzoic anhydride was used per 5 mmol of the aldehyde in acetonitrile (0.5 mL).

IIC.3.17. Chemoselective Diacylation of Benzaldehyde in the Presence of Acetophenone

Acetic anhydride (1.5 mmol) and TBATB (0.1 mmol) were added to an equimolar mixture of acetophenone (**61**, 1 mmol) and benzaldehyde (**91**; 1 mmol) in acetonitrile (1 mL). The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.18. Chemoselective *gem*-Diacylation of *p*-Methylbenzaldehyde (**95**) or *p*-Methoxybenzaldehyde (**98**) in the Presence of *p*-Nitrobenzaldehyde (**99**)

Acetic anhydride (1.5 mmol) and TBATB (0.1 mmol) were added to an equimolar mixture of *p*-methylbenzaldehyde (**94**) or *p*-methoxybenzaldehyde (**97**; 1 mmol), and *p*-nitrobenzaldehyde (**98**; 1 mmol) in acetonitrile (1 mL). The homogeneous reaction was left stirring at room temperature and the percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.19. Chemoselective Diacylation of 9-Anthraldehyde (**110**) in the Presence of 9-Fluorencarboxaldehyde (**109**)

Acetic anhydride (1.5 mmol) and TBATB (0.1 mmol) were added to an equimolar mixture of 9-anthraldehyde (**110**; 1 mmol) and 9-fluorencarboxaldehyde (**109**; 1 mmol) in acetonitrile (1 mL). The homogeneous reaction was left stirring at room temperature and the percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.20. General Procedure for the Deprotection of *gem*-Diacylates

TBATB (0.1 mmol) was added to a mixture of diacylate (2 mmol) and homogeneous reaction was left stirring at room temperature and the progress of the reaction was monitored by TLC. After completion of the reaction, the methanol was evaporated on a rotary evaporator and ethyl acetate (20 mL) was added to the residue. The organic layer was washed with 10 % sodium hydrogen carbonate (10 mL). The organic layer was separated, dried over anhydrous sodium sulfate and concentrated. Further purification was achieved by passing through a short column of silica gel, and the products were identified by comparison of their NMR and IR spectra and GC profile, and GC co-injection, with authentic samples.

IIC.3.21. General Procedure for the Chemoselective Deprotection of Different *gem*-Diacylates of Cinnamaldehyde

TBATB (0.1 mmol) was added to an equimolar mixture of two different cinnamyl diacylate (say *X* and *Y*) in methanol / water (5:1; 1 mL). The homogeneous reaction was left stirring at room temperature and the progress of the reaction was monitored by gas-liquid chromatography. The percentage of products formed at different times was determined by gas-liquid chromatography using benzophenone as an internal standard. The percentage selectivity was calculated as follows: Selectivity = percentage of *Y* deprotected – percentage of *X* deprotected at time *t*.

comparison of their NMR and IR spectra, GC profile, and GC co-injection, with authentic samples prepared by known methods.

IIC.3.15. General Procedure for the Preparation of *gem*-Dipropionate, *gem*-Diisobutyrate and *gem*-Dipivalate

Similar to the preparation of *gem*-diacetate (Section IIC.3.14), except 10 mmol of anhydride (propionic, isobutyric and pivalic) was used per 5 mmol of the aldehyde.

IIC.3.16. General Procedure for Preparation of *gem*-Dibenzoate

Similar to the preparation of *gem*-diacetate (Section IIC.3.14), except 5 mmol of benzoic anhydride was used per 5 mmol of the aldehyde in acetonitrile (0.5 mL).

IIC.3.17. Chemoselective Diacylation of Benzaldehyde in the Presence of Acetophenone

Acetic anhydride (1.5 mmol) and TBATB (0.1 mmol) were added to an equimolar mixture of acetophenone (61, 1 mmol) and benzaldehyde (91; 1 mmol) in acetonitrile (1 mL). The homogeneous reaction was left at room temperature. The percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.18. Chemoselective *gem*-Diacylation of *p*-Methylbenzaldehyde (95) or *p*-Methoxybenzaldehyde (98) in the Presence of *p*-Nitrobenzaldehyde (99)

Acetic anhydride (1.5 mmol) and TBATB (0.1 mmol) were added to an equimolar mixture of *p*-methylbenzaldehyde (94) or *p*-methoxybenzaldehyde (97; 1 mmol), and *p*-nitrobenzaldehyde (98; 1 mmol) in acetonitrile (1 mL). The homogeneous reaction was left stirring at room temperature and the percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.19. Chemoselective Diacylation of 9-Anthraldehyde (110) in the Presence of 9-Fluorencarboxaldehyde (109)

Acetic anhydride (1.5 mmol) and TBATB (0.1 mmol) were added to an equimolar mixture of 9-anthraldehyde (110; 1 mmol) and 9-fluorencarboxaldehyde (109; 1 mmol) in acetonitrile (1 mL). The homogeneous reaction was left stirring at room temperature and the percentage of products formed at different times was determined by gas-liquid chromatography.

IIC.3.20. General Procedure for the Deprotection of *gem*-Diacylates

TBATB (0.1 mmol) was added to a mixture of diacylate (2 mmol) and homogeneous reaction was left stirring at room temperature and the progress of the reaction was monitored by TLC. After completion of the reaction, the methanol was evaporated on a rotary evaporator and ethyl acetate (20 mL) was added to the residue. The organic layer was washed with 10 % sodium hydrogen carbonate (10 mL). The organic layer was separated, dried over anhydrous sodium sulfate and concentrated. Further purification was achieved by passing through a short column of silica gel, and the products were identified by comparison of their NMR and IR spectra and GC profile, and GC co-injection, with authentic samples.

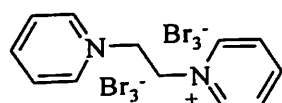
IIC.3.21. General Procedure for the Chemoselective Deprotection of Different *gem*-Diacylates of Cinnamaldehyde

TBATB (0.1 mmol) was added to an equimolar mixture of two different cinnamyl diacylate (say *X* and *Y*) in methanol / water (5:1; 1 mL). The homogeneous reaction was left stirring at room temperature and the progress of the reaction was monitored by gas-liquid chromatography. The percentage of products formed at different times was determined by gas-liquid chromatography using benzophenone as an internal standard. The percentage selectivity was calculated as follows: Selectivity = percentage of *Y* deprotected – percentage of *X* deprotected at time *t*.

IID. Spectral Data

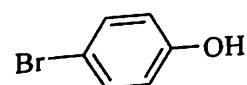
IID.1. Spectral Data of Brominated Products

1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT)



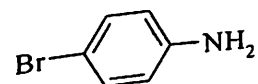
M.p. 136-138°C. ^1H NMR (400 MHz, CD_3CN): δ 5.20 (s, 4H), 8.15 (m, 4H), 8.65 (m, 2H), 8.81 (m, 4H). ^{13}C NMR (100 MHz, CD_3CN): δ = 59.6, 129.1, 145.1, 147.3. Elemental Analysis: Calcd for $\text{C}_{12}\text{H}_{14}\text{N}_2\text{Br}_6$: C, 21.6; H, 2.11; N, 4.20, Br, 72.02. Found: C, 20.8; H, 2.18; N, 3.98, Br, 71.06. UV (CH_3CN): 267 nm. IR (KBr): 3129, 3083, 3053, 3027, 2966, 2853, 1634, 1491, 1189, 958, 779 cm^{-1} .

4-Bromo-phenol (35n)



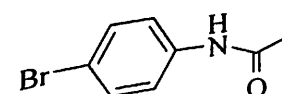
^1H NMR (400 MHz, CDCl_3): δ 5.03 (brs, 1H), 6.72 (d, J = 8.8 Hz, 2H), 7.32 (d, J = 8.8 Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 112.9, 117.4, 132.6, 154.8. IR (KBr): 3380, 1593, 1491, 1429, 1240, 1071, 1009, 825, 610, 508 cm^{-1} . Mass (CI): 172 / 174 (M^+).

4-Bromo-aniline (36n)



^1H NMR (400 MHz, CDCl_3): δ 3.65 (brs, 2H), 6.55 (d, J = 8.4 Hz, 2H), 7.22 (d, J = 8.4 Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 105.4, 116.9, 132.2, 142.9. IR (KBr): 3375, 3032, 2925, 1629, 1491, 1281, 1178, 1071, 810, 605, 502 cm^{-1} . Mass (CI): 171/173 (M^+).

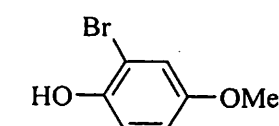
4-Bromo-acetanilide (37n)



^1H NMR (400 MHz, DMSO-d_6): δ 2.02 (s, 3H), 7.44 (d, J = 8.4 Hz, 2H), 7.

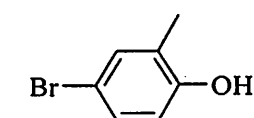
10.05 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ 24.9, 115.1, 121.5, 132.0, 3293, 3257, 3191, 3058, 1670, 1603, 1537, 1491, 1393, 1312, 1020, 820, 743 cm^{-1} .

2-Bromo-4-methoxy phenol (38n)



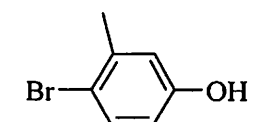
^1H NMR (400 MHz, CDCl_3): δ 3.74 (s, 3H), 5.32 (brs, 1H), 6.77 (m, 1H), 6.92 (m, 1H), 7.00 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 56.3, 110.1, 115.5, 116.6, 117.1, 146.6, 153.9. IR (KBr): 3431, 2950, 2842, 1588, 1495, 1208, 1039, 768 cm^{-1} .

4-Bromo-2-methyl-phenol (39n)



^1H NMR (400 MHz, CDCl_3): δ 2.21 (s, 3H), 5.01 (brs, 1H), 6.63 (d, J = 8.0 Hz, 1H), 7.14 (dd, J_1 = 8.0 Hz, J_2 = 2.4 Hz, 1H), 7.22 (d, J = 2.4 Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 16.1, 112.7, 116.7, 126.5, 129.9, 133.7, 153.0. IR (KBr): 3407, 2933, 1492, 1407, 1263, 1178, 1118, 814, 630 cm^{-1} . Mass (CI): 186 / 188 (M^+).

4-Bromo-3-methyl-phenol (40n)

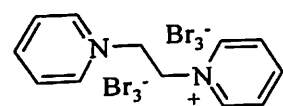


^1H NMR (400 MHz, CDCl_3): δ 2.29 (s, 3H), 5.86 (brs, 1H), 6.53 (dd, J_1 = 8.0 Hz, J_2 = 8.8 Hz, 1H), 6.79 (d, J = 3.2 Hz, 1H), 7.31 (d, J = 8.8 Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 23.4, 114.8, 115.8, 118.1, 133.3, 139.4, 154.5 cm^{-1} . IR (KBr): 3565, 3227, 2996, 2914, 1670, 1588, 1455, 1291, 1245, 1173, 1035, 871, 815, 605. MASS (CI): 186 / 188 (M^+).

IID. Spectral Data

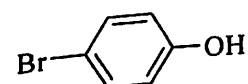
IID.1. Spectral Data of Brominated Products

1,1'-(ethane-1,2-diyl)dipyridinium bistr bromide (EDPBT)



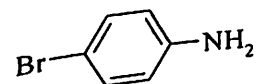
M.p. 136-138°C. ^1H NMR (400 MHz, CD_3CN): δ 5.20 (s, 4H), 8.15 (m, 4H), 8.65 (m, 2H), 8.81 (m, 4H). ^{13}C NMR (100 MHz, CD_3CN): δ = 59.6, 129.1, 145.1, 147.3. Elemental Analysis: Calcd for $\text{C}_{12}\text{H}_{14}\text{N}_2\text{Br}_6$, C: 21.6; H, 2.11; N, 4.20, Br, 72.02. Found, C: 20.8; H, 2.18; N, 3.98, Br, 71.06. UV (CH_3CN): 267 nm. IR (KBr): 3129, 3083, 3053, 3027, 2966, 2853, 1634, 1491, 1189, 958, 779 cm^{-1} .

4-Bromo-phenol (35n)



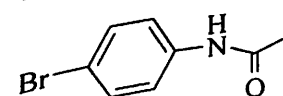
^1H NMR (400 MHz, CDCl_3): δ 5.03 (brs, 1H), 6.72 (d, J = 8.8 Hz, 2H), 7.32 (d, J = 8.8 Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 112.9, 117.4, 132.6, 154.8. IR (KBr): 3380, 1593, 1491, 1429, 1240, 1071, 1009, 825, 610, 508 cm^{-1} . Mass (CI): 172 / 174 (M^+).

4-Bromo-aniline (36n)



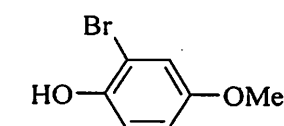
^1H NMR (400 MHz, CDCl_3): δ 3.65 (brs, 2H), 6.55 (d, J = 8.4 Hz, 2H), 7.22 (d, J = 8.4 Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 105.4, 116.9, 132.2, 142.9. IR (KBr): 3375, 3032, 2925, 1629, 1491, 1281, 1178, 1071, 810, 605, 502 cm^{-1} . Mass (CI): 171/173 (M^+).

4-Bromo-acetanilide (37n)



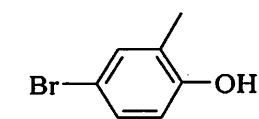
^1H NMR (400 MHz, DMSO-d_6): δ 2.02 (s, 3H), 7.44 (d, J = 8.4 Hz, 2H), 7.510.05 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ 24.9, 115.1, 121.5, 132.0, 132.9, 3293, 3257, 3191, 3058, 1670, 1603, 1537, 1491, 1393, 1312, 1020, 820, 743 cm^{-1} .

2-Bromo-4-methoxy phenol (38n)



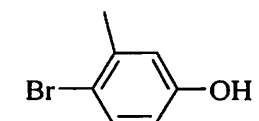
^1H NMR (400 MHz, CDCl_3): δ 3.74 (s, 3H), 5.32 (brs, 1H), 6.77 (m, 1H), 6.92 (m, 1H), 7.00 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 56.3, 110.1, 115.5, 116.6, 117.1, 146.6, 153.9. IR (KBr): 3431, 2950, 2842, 1588, 1495, 1208, 1039, 768 cm^{-1} .

4-Bromo-2-methyl-phenol (39n)

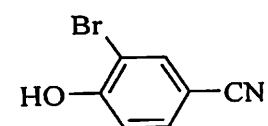


^1H NMR (400 MHz, CDCl_3): δ 2.21 (s, 3H), 5.01 (brs, 1H), 6.63 (d, J = 8.0 Hz, 1H), 7.14 (dd, J_1 = 8.0 Hz, J_2 = 2.4 Hz, 1H), 7.22 (d, J = 2.4 Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 16.1, 112.7, 116.7, 126.5, 129.9, 133.7, 153.0. IR (KBr): 3407, 2933, 1492, 1407, 1263, 1178, 1118, 814, 630 cm^{-1} . Mass (CI): 186 / 188 (M^+).

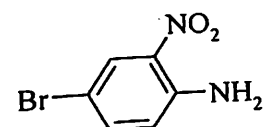
4-Bromo-3-methyl-phenol (40n)



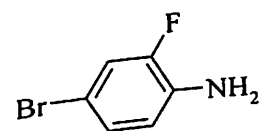
^1H NMR (400 MHz, CDCl_3): δ 2.29 (s, 3H), 5.86 (brs, 1H), 6.53 (dd, J_1 = 8.0 Hz, J_2 = 8.8 Hz, 1H), 6.79 (d, J = 3.2 Hz, 1H), 7.31 (d, J = 8.8 Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 23.4, 114.8, 115.8, 118.1, 133.3, 139.4, 154.5 cm^{-1} . IR (KBr): 3565, 3227, 2996, 2914, 1670, 1588, 1455, 1291, 1245, 1173, 1035, 871, 815, 605. MASS (CI): 186 / 188 (M^+).

3-Bromo-4-hydroxy-benzonitrile (41n)

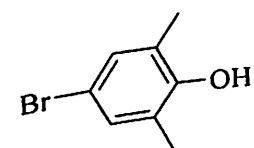
^1H NMR (400 MHz, CDCl_3): δ 6.43 (s, 1H), 7.77 (s, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 106.7, 110.6, 116.4, 135.8, 153.7. IR (KBr): 3411, 3073, 2233, 1593, 1470, 1158, 743, 615, 528 cm^{-1} .

4-Bromo-2-nitro-aniline (42n)

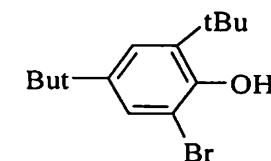
^1H NMR (400 MHz, CDCl_3): δ 6.14 (brs, 2H), 6.73 (d, $J = 9.2$ Hz, 1H), 7.42 (dd, $J_1 = 9.2$ Hz, $J_2 = 2.4$ Hz, 1H), 8.24 (d, $J = 2.4$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 108.0, 120.5, 128.5, 138.6, 143.7. IR (KBr): 3473, 3355, 2930, 1644, 1562, 1337, 1250, 1102, 815, 707, 630, 528 cm^{-1} . Mass (CI): 216 / 218 (M^+)

4-Bromo-2-fluoro-aniline (43n)

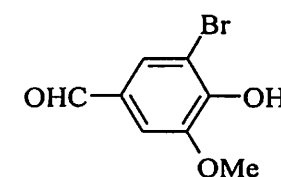
^1H NMR (400 MHz, CDCl_3): δ 3.72 (brs, 2H), 6.65 (m, 1H), 7.05 (m, 1H), 7.13 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 109.0, 117.9, 118.0, 118.7, 118.9, 127.5, 127.6, 134.0, 150.0, 152.6. IR (KBr): 3391, 3088, 2925, 1711, 1486, 1419, 1209, 1071, 892, 697, 564 cm^{-1} .

4-Bromo-2, 6-dimethyl-phenol (44n)

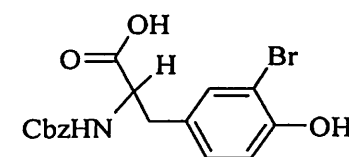
^1H NMR (400 MHz, CDCl_3): δ 2.21 (s, 6H), 4.62 (s, 1H), 7.09 (s, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 16.2, 112.2, 125.4, 131.2, 151.4. IR (KBr): 3406, 2919, 2848, 1460, 1399, 1317, 1219, 1137, 861, 682, 564 cm^{-1} .

2-Bromo-4,6-di-tert-butyl-phenol (45n)

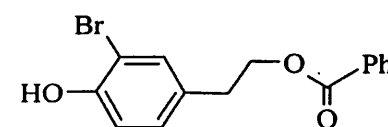
M.p. 58-60 $^{\circ}\text{C}$. ^1H NMR (400 MHz, CDCl_3): δ 1.27 (s, 9H), 1.40 (s, 9H), 5.63 (s, 1H), 7.23 (s, 1H), 7.30 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 26.8, 29.5, 29.9, 31.9, 34.8, 36.0, 112.1, 126.5, 136.9, 143.8, 148.1. IR (KBr): 3519, 2955, 2863, 1577, 1485, 1362, 1275, 1178, 870, 840, 742, 712 cm^{-1} . Mass (CI): 284 / 286 (M^+).

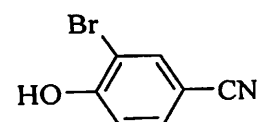
3-Bromo-4-hydroxy-5-methoxy-benzaldehyde (46n)

^1H NMR (400 MHz, CDCl_3): δ 3.98 (s, 3H), 6.55 (brs, 1H), 7.35 (d, $J = 1.4$ Hz, 1H), 7.63 (s, $J = 1.4$ Hz, 1H), 9.80 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 56.9, 108.3, 108.4, 130.2, 130.3, 147.8, 149.0, 189.6. IR (KBr): 3314, 2976, 2945, 2848, 1685, 1588, 1511, 1429, 1358, 1158, 1055, 682 cm^{-1} .

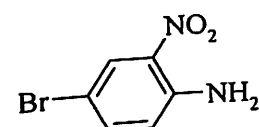
Bromo-N-carbobenzoxy-tyrosine (47n)

^1H NMR (400 MHz, CDCl_3): δ 2.69 (m, 2H), 2.98 (m, 2H), 4.14 (m, 1H), 4.96 (s, 2H), 7.20-7.44 (m, 7H), 7.66 (d, $J = 8.4$ Hz, 1H), 9.79 (brs, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 35.6, 56.1, 66.1, 112.2, 127.9, 128.3, 128.9, 132.9, 133.4, 137.6, 149.8, 156.5, 173.5. IR (KBr): 3407, 3317, 3033, 2943, 1712, 1517, 1258, 1058, 759, 704 cm^{-1} .

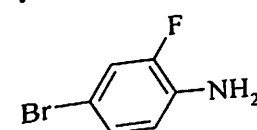
Benzoic acid 2-(3-bromo-4-hydroxy-phenyl)-ethyl ester (48n)

3-Bromo-4-hydroxy-benzonitrile (41n)

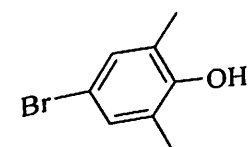
^1H NMR (400 MHz, CDCl_3): δ 6.43 (s, 1H), 7.77 (s, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 106.7, 110.6, 116.4, 135.8, 153.7. IR (KBr): 3411, 3073, 2233, 1593, 1470, 1158, 743, 615, 528 cm^{-1} .

4-Bromo-2-nitro-aniline (42n)

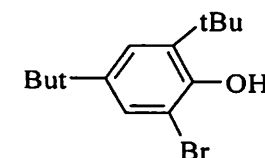
^1H NMR (400 MHz, CDCl_3): δ 6.14 (brs, 2H), 6.73 (d, $J = 9.2$ Hz, 1H), 7.42 (dd, $J_1 = 9.2$ Hz, $J_2 = 2.4$ Hz, 1H), 8.24 (d, $J = 2.4$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 108.0, 120.5, 128.5, 138.6, 143.7. IR (KBr): 3473, 3355, 2930, 1644, 1562, 1337, 1250, 1102, 815, 707, 630, 528 cm^{-1} . Mass (CI): 216 / 218 (M^+)

4-Bromo-2-fluoro-aniline (43n)

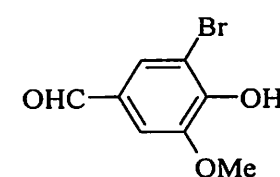
^1H NMR (400 MHz, CDCl_3): δ 3.72 (brs, 2H), 6.65 (m, 1H), 7.05 (m, 1H), 7.13 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 109.0, 117.9, 118.0, 118.7, 118.9, 127.5, 127.6, 134.0, 150.0, 152.6. IR (KBr): 3391, 3088, 2925, 1711, 1486, 1419, 1209, 1071, 892, 697, 564 cm^{-1} .

4-Bromo-2,6-dimethyl-phenol (44n)

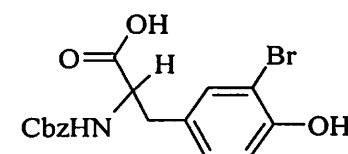
^1H NMR (400 MHz, CDCl_3): δ 2.21 (s, 6H), 4.62 (s, 1H), 7.09 (s, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 16.2, 112.2, 125.4, 131.2, 151.4. IR (KBr): 3406, 2919, 2848, 1460, 1399, 1317, 1219, 1137, 861, 682, 564 cm^{-1} .

2-Bromo-4,6-di-tert-butyl-phenol (45n)

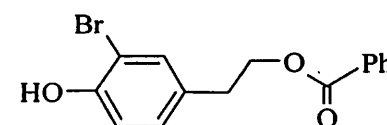
M.p. 58-60 $^{\circ}\text{C}$. ^1H NMR (400 MHz, CDCl_3): δ 1.27 (s, 9H), 1.40 (s, 9H), 5.63 (s, 1H), 7.23 (s, 1H), 7.30 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 26.8, 29.5, 29.9, 31.9, 34.8, 36.0, 112.1, 126.5, 136.9, 143.8, 148.1. IR (KBr): 3519, 2955, 2863, 1577, 1485, 1362, 1275, 1178, 870, 840, 742, 712 cm^{-1} . Mass (CI): 284 / 286 (M^+).

3-Bromo-4-hydroxy-5-methoxy-benzaldehyde (46n)

^1H NMR (400 MHz, CDCl_3): δ 3.98 (s, 3H), 6.55 (brs, 1H), 7.35 (d, $J = 1.4$ Hz, 1H), 7.63 (s, $J = 1.4$ Hz, 1H), 9.80 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 56.9, 108.3, 108.4, 130.2, 130.3, 147.8, 149.0, 189.6. IR (KBr): 3314, 2976, 2945, 2848, 1685, 1588, 1511, 1429, 1358, 1158, 1055, 682 cm^{-1} .

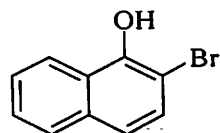
Bromo-N-carbobenzoxy-tyrosine (47n)

^1H NMR (400 MHz, CDCl_3): δ 2.69 (m, 2H), 2.98 (m, 2H), 4.14 (m, 1H), 4.96 (s, 2H), 7.20-7.44 (m, 7H), 7.66 (d, $J = 8.4$ Hz, 1H), 9.79 (brs, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 35.6, 56.1, 66.1, 112.2, 127.9, 128.3, 128.9, 132.9, 133.4, 137.6, 149.8, 156.5, 173.5. IR (KBr): 3407, 3317, 3033, 2943, 1712, 1517, 1258, 1058, 759, 704 cm^{-1} .

Benzoic acid 2-(3-bromo-4-hydroxy-phenyl)-ethyl ester (48n)

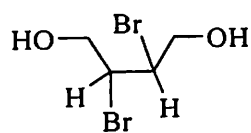
^1H NMR (400 MHz, CDCl_3): δ 2.98 (t, $J = 6.8$ Hz, 2H), 4.47 (t, $J = 6.8$ Hz, 2H), 5.73 (s, 1H), 6.96 (d, $J = 8.4$ Hz, 1H), 7.11 (m, 1H), 7.43 (m, 3H), 7.54 (m, 1H), 8.01 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 35.6, 56.1, 66.1, 112.2, 127.9, 128.3, 128.9, 132.9, 133.4, 137.6, 149.8, 156.5, 173.5. IR (KBr): 3355, 2996, 2955, 2530, 1716, 1516, 1465, 1424, 1388, 1281, 1030, 958, 830, 707, 630 cm^{-1} .

2-Bromo-1-naphthol (49n)



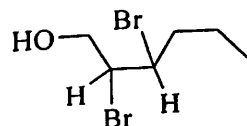
^1H NMR (400 MHz, CDCl_3): δ 5.96 (s, 1H), 7.60 (m, 3H), 7.79 (s, 1H), 8.13 (d, $J = 8.4$ Hz, 1H), 8.25 (d, $J = 8.4$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 103.4, 113.5, 122.9, 125.3, 127.1, 127.3, 128.3, 131.2, 132.0, 148.3. IR (KBr): 3411, 1583, 1378, 1332, 1230, 1209, 1061, 840, 758, 671 cm^{-1} .

2,3-Dibromo-butane-1,4-diol (50n)



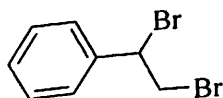
^1H NMR (400 MHz, CDCl_3): δ 3.41 (brs, 2H), 3.88 (m, 2H), 3.99 (m, 2H), 4.47 (t, $J = 4.8$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 55.6, 64.8. IR (KBr): 3273, 2950, 2868, 1450, 1368, 1230, 1081, 1030, 942, 742, 691, 640 cm^{-1} .

2,3-Dibromo-hexane-1-ol (51n)



^1H NMR (400 MHz, CDCl_3): δ 0.96 (t, 3H), 1.48 (m, 1H), 1.65 (m, 1H), 1.92 (m, 1H), 2.15 (m, 2H), 4.11 (m, 2H), 4.30 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 13.8, 20.4, 39.3, 55.2, 60.8, 66.3. IR (KBr): 3412, 2968, 2873, 1462, 1383, 1158, 1088, 1053, 749, 555 cm^{-1} .

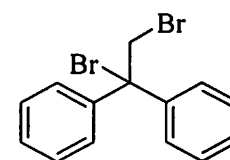
1,2-(Dibromo-ethyl)-benzene (52n)



^1H NMR (400 MHz, CDCl_3): δ 4.05 (m, 2H), 5.14 (dd, $J_1 = 5.2$ Hz, $J_2 = 5.6$ Hz, 1H).

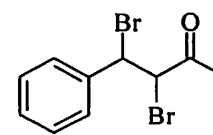
^{13}C NMR (100 MHz, CDCl_3): δ 35.6, 51.3, 127.9, 129.1, 129.4, 138.8. IR (KBr): 3088, 3022, 2981, 1496, 1460, 1429, 1199, 1132, 907, 774, 687, 589 cm^{-1} . Mass (CI): 263 / 265 (M^+).

1,2-Dibromo-1,1-diphenyl-ethane (53n)



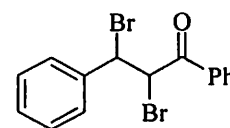
^1H NMR (400 MHz, CDCl_3): δ 4.11 (s, 2H), 7.34 (m, 6H), 7.43 (m, 4H). ^{13}C NMR (100 MHz, CDCl_3): δ 44.1, 126.2, 127.6, 128.2, 143.1. IR (KBr): 3063, 3022, 2976, 1598, 1496, 1460, 1230, 1163, 1066, 999, 764, 702, 610 cm^{-1} .

3,4-Dibromo-4-phenyl-butane-2-one (54n)



^1H NMR (400 MHz, CDCl_3): δ 2.48 (s, 3H), 4.93 (d, $J = 11.4$ Hz, 1H), 5.32 (d, $J = 11.4$ Hz, 1H), 7.38 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.4, 49.9, 53.1, 128.3, 129.1, 129.5, 137.9, 198.4. IR (KBr): 3058, 3032, 2996, 2925, 2899, 1731, 1460, 1363, 1209, 1143, 769, 692, 600, 559 cm^{-1} . Mass (CI): 305 / 307 (M^+).

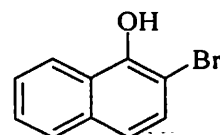
2,3-Dibromo-1,3-diphenyl-propane-1-one (55n)



^1H NMR (400 MHz, CDCl_3): δ 5.65 (d, $J = 11.4$ Hz, 1H), 5.83 (d, $J = 11.4$ Hz, 1H), 7.39 (m, 3H), 7.53 (m, 4H), 7.66 (m, 1H), 8.10 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 47.2, 50.2, 128.5, 128.7, 129.0, 129.1, 129.2, 129.5, 134.4, 134.6, 138.4, 191.2. IR (KBr): 3068, 3027, 1690, 1593, 1450, 1271, 1235, 984, 805, 779, 723, 692, 579, 564 cm^{-1} .

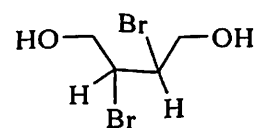
^1H NMR (400 MHz, CDCl_3): δ 2.98 (t, $J = 6.8$ Hz, 2H), 4.47 (t, $J = 6.8$ Hz, 2H), 5.73 (s, 1H), 6.96 (d, $J = 8.4$ Hz, 1H), 7.11 (m, 1H), 7.43 (m, 3H), 7.54 (m, 1H), 8.01 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 35.6, 56.1, 66.1, 112.2, 127.9, 128.3, 128.9, 132.9, 133.4, 137.6, 149.8, 156.5, 173.5. IR (KBr): 3355, 2996, 2955, 2530, 1716, 1516, 1465, 1424, 1388, 1281, 1030, 958, 830, 707, 630 cm^{-1} .

2-Bromo-1-naphthol (49n)



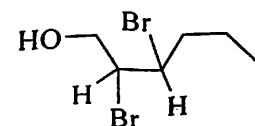
^1H NMR (400 MHz, CDCl_3): δ 5.96 (s, 1H), 7.60 (m, 3H), 7.79 (s, 1H), 8.13 (d, $J = 8.4$ Hz, 1H), 8.25 (d, $J = 8.4$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 103.4, 113.5, 122.9, 125.3, 127.1, 127.3, 128.3, 131.2, 132.0, 148.3. IR (KBr): 3411, 1583, 1378, 1332, 1230, 1209, 1061, 840, 758, 671 cm^{-1} .

2,3-Dibromo-butane-1,4-diol (50n)



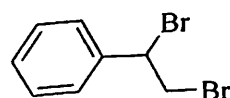
^1H NMR (400 MHz, CDCl_3): δ 3.41 (brs, 2H), 3.88 (m, 2H), 3.99 (m, 2H), 4.47 (t, $J = 4.8$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 55.6, 64.8. IR (KBr): 3273, 2950, 2868, 1450, 1368, 1230, 1081, 1030, 942, 742, 691, 640 cm^{-1} .

2,3-Dibromo-hexane-1-ol (51n)



^1H NMR (400 MHz, CDCl_3): δ 0.96 (t, 3H), 1.48 (m, 1H), 1.65 (m, 1H), 1.92 (m, 1H), 2.15 (m, 2H), 4.11 (m, 2H), 4.30 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 13.8, 20.4, 39.3, 55.2, 60.8, 66.3. IR (KBr): 3412, 2968, 2873, 1462, 1383, 1158, 1088, 1053, 749, 555 cm^{-1} .

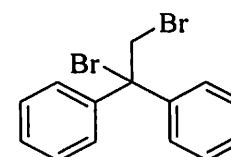
1,2-(Dibromo-ethyl)-benzene (52n)



^1H NMR (400 MHz, CDCl_3): δ 4.05 (m, 2H), 5.14 (dd, $J_1 = 5.2$ Hz, $J_2 = 5.6$ Hz, 1H).

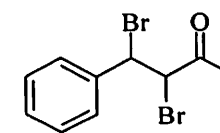
^{13}C NMR (100 MHz, CDCl_3): δ 35.6, 51.3, 127.9, 129.1, 129.4, 138.8. IR (KBr): 3000, 3022, 2901, 1496, 1460, 1429, 1199, 1132, 907, 774, 687, 589 cm^{-1} . Mass (CI): 263 / 265 (M^+).

1,2-Dibromo-1,1-diphenyl-ethane (53n)



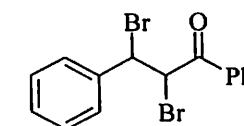
^1H NMR (400 MHz, CDCl_3): δ 4.11 (s, 2H), 7.34 (m, 6H), 7.43 (m, 4H). ^{13}C NMR (100 MHz, CDCl_3): δ 44.1, 126.2, 127.6, 128.2, 143.1. IR (KBr): 3063, 3022, 2976, 1598, 1496, 1460, 1230, 1163, 1066, 999, 764, 702, 610 cm^{-1} .

3,4-Dibromo-4-phenyl-butane-2-one (54n)

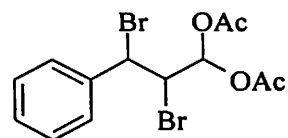


^1H NMR (400 MHz, CDCl_3): δ 2.48 (s, 3H), 4.93 (d, $J = 11.4$ Hz, 1H), 5.32 (d, $J = 11.4$ Hz, 1H), 7.38 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.4, 49.9, 53.1, 128.3, 129.1, 129.5, 137.9, 198.4. IR (KBr): 3058, 3032, 2996, 2925, 2899, 1731, 1460, 1363, 1209, 1143, 769, 692, 600, 559 cm^{-1} . Mass (CI): 305 / 307 (M^+).

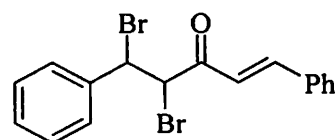
2,3-Dibromo-1,3-diphenyl-propane-1-one (55n)



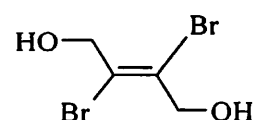
^1H NMR (400 MHz, CDCl_3): δ 5.65 (d, $J = 11.4$ Hz, 1H), 5.83 (d, $J = 11.4$ Hz, 1H), 7.39 (m, 3H), 7.53 (m, 4H), 7.66 (m, 1H), 8.10 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 47.2, 50.2, 128.5, 128.7, 129.0, 129.1, 129.2, 129.5, 134.4, 134.6, 138.4, 191.2. IR (KBr): 3068, 3027, 1690, 1593, 1450, 1271, 1235, 984, 805, 779, 723, 692, 579, 564 cm^{-1} .

1,1-Diacetoxy-2,3-dibromo-3-phenyl-propane (56n)

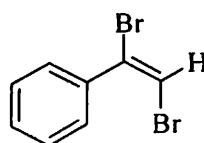
^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 3H), 2.23 (s, 3H), 4.79 (d, $J = 11.4$ Hz, 1H), 5.03 (d, $J = 11.4$ Hz, 1H), 7.35 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 21.2, 50.7, 54.7, 88.8, 128.0, 129.0, 129.3, 139.2, 168.4, 168.6. IR (KBr): 3094, 3037, 2991, 2966, 2940, 1762, 1373, 1235, 1194, 1117, 1004, 779, 707, 636, 605, 549 cm^{-1} .

4,5-Dibromo-1,5-diphenyl-pent-1-en-3-one (57n)

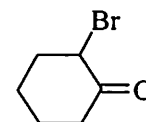
^1H NMR (400 MHz, CDCl_3): δ 5.22 (d, $J = 11.6$ Hz, 1H), 5.49 (d, $J = 11.6$ Hz, 1H), 6.97 (d, $J = 15.6$ Hz, 1H), 7.44 (m, 8H), 7.63 (m, 2H), 7.87 (d, $J = 15.6$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 49.9, 51.9, 114.8, 122.3, 128.4, 129.0, 129.1, 129.2, 129.4, 129.6, 131.4, 134.2, 138.3, 146.3, 189.9. IR (KBr): 3073, 3027, 2991, 1690, 1665, 1619, 1568, 1450, 1342, 1204, 1061, 989, 769, 697, 569 cm^{-1} . Mass (CI): 393 / 395 / 397 (M^+).

2,3-Dibromo-but-2-ene-1,4-diol (58n)

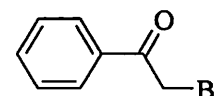
^1H NMR (400 MHz, CDCl_3): δ 1.62 (brs, 2H), 4.55 (s, 4H). ^{13}C NMR (100 MHz, CDCl_3): δ 66.9, 122.9. IR (KBr): 3227, 2925, 2853, 1450, 1071, 1015, 769, 564 cm^{-1} .

1,2-Dibromo-vinyl)-benzene (cis + trans) (59n)

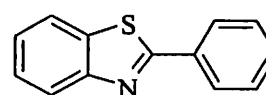
^1H NMR (400 MHz, CDCl_3): δ 7.04 (s, 1H), 7.35 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 109.1, 127.9, 128.4, 128.8, 129.3, 129.6, 131.3, 138.6. IR (KBr): 3063, 1588, 1478, 1415, 1211, 872, 738, 692, 605, 533 cm^{-1} . Mass (EI): 260 / 262 / 264 (M^+).

2-Bromo-cyclohexanone (60n)

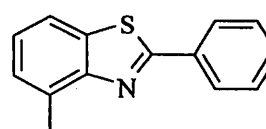
^1H NMR (400 MHz, CDCl_3): δ 1.73 (m, 1H), 1.81 (m, 1H), 1.95 (m, 1H), 2.02 (m, 1H), 2.24 (m, 1H), 2.34 (m, 2H), 2.99 (m, 1H), 4.45 (m, 1H).

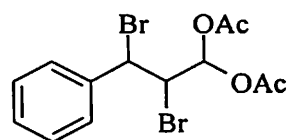
2-Bromo-1-phenyl-ethanone (61n)

^1H NMR (400 MHz, CDCl_3): δ 4.46 (s, 2H), 7.48 (m, 2H), 7.59 (m, 1H), 7.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 30.86, 128.79, 128.85, 133.84, 133.98, 191.14. IR (KBr): 3058, 2935, 1690, 1593, 1450, 1281, 1194, 1020, 764, 687, 615 cm^{-1} .

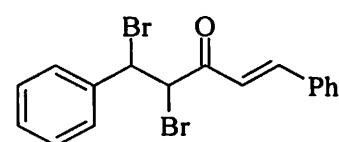
IID.2. Spectral Data of 2-Substituted Benzothiazoles**2-Phenyl-benzothiazole (62o)**

^1H NMR (400 MHz, CDCl_3): δ 7.13 (t, $J = 7.6$ Hz, 1H), 7.34 (t, $J = 7.2$ Hz, 2H), 7.47 (m, 3H), 7.61 (d, $J = 8.0$ Hz, 1H), 7.84 (d, $J = 8$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 119.5, 120.3, 120.9, 122.5, 124.4, 126.2, 129.6, 130.0, 139.9, 151.4, 164.5. IR (KBr): 3054, 2923, 1608, 1586, 1481, 1446, 1164, 1072, 918, 761, 694 cm^{-1} .

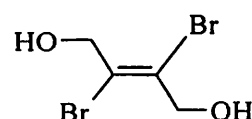
4-Methyl-2-phenyl-benzothiazole (63o)

1,1-Diacetoxy-2,3-dibromo-3-phenyl-propane (56n)

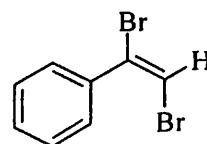
^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 3H), 2.23 (s, 3H), 4.79 (d, $J = 11.4$ Hz, 1H), 5.03 (d, $J = 11.4$ Hz, 1H), 7.35 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 21.2, 50.7, 54.7, 88.8, 128.0, 129.0, 129.3, 139.2, 168.4, 168.6. IR (KBr): 3094, 3037, 2991, 2966, 2940, 1762, 1373, 1235, 1194, 1117, 1004, 779, 707, 636, 605, 549 cm^{-1} .

4,5-Dibromo-1,5-diphenyl-pent-1-en-3-one (57n)

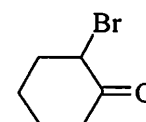
^1H NMR (400 MHz, CDCl_3): δ 5.22 (d, $J = 11.6$ Hz, 1H), 5.49 (d, $J = 11.6$ Hz, 1H), 6.97 (d, $J = 15.6$ Hz, 1H), 7.44 (m, 8H), 7.63 (m, 2H), 7.87 (d, $J = 15.6$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 49.9, 51.9, 114.8, 122.3, 128.4, 129.0, 129.1, 129.2, 129.4, 129.6, 131.4, 134.2, 138.3, 146.3, 189.9. IR (KBr): 3073, 3027, 2991, 1690, 1665, 1619, 1568, 1450, 1342, 1204, 1061, 989, 769, 697, 569 cm^{-1} . Mass (CI): 393 / 395 / 397 (M^+).

2,3-Dibromo-but-2-ene-1,4-diol (58n)

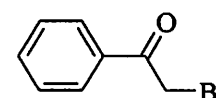
^1H NMR (400 MHz, CDCl_3): δ 1.62 (brs, 2H), 4.55 (s, 4H). ^{13}C NMR (100 MHz, CDCl_3): δ 66.9, 122.9. IR (KBr): 3227, 2925, 2853, 1450, 1071, 1015, 769, 564 cm^{-1} .

1,2-Dibromo-vinyl)-benzene (cis + trans) (59n)

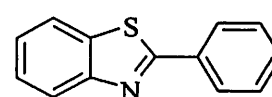
^1H NMR (400 MHz, CDCl_3): δ 7.04 (s, 1H), 7.35 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 109.1, 127.9, 128.4, 128.8, 129.3, 129.6, 131.3, 138.6. IR (KBr): 3063, 1588, 1498, 1478, 1451, 1372, 738, 692, 605, 533 cm^{-1} . Mass (EI): 260 / 262 / 264 (M^+).

2-Bromo-cyclohexanone (60n)

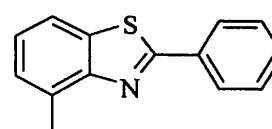
^1H NMR (400 MHz, CDCl_3): δ 1.73 (m, 1H), 1.81 (m, 1H), 1.95 (m, 1H), 2.02 (m, 1H), 2.24 (m, 1H), 2.34 (m, 2H), 2.99 (m, 1H), 4.45 (m, 1H).

2-Bromo-1-phenyl-ethanone (61n)

^1H NMR (400 MHz, CDCl_3): δ 4.46 (s, 2H), 7.48 (m, 2H), 7.59 (m, 1H), 7.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 30.86, 128.79, 128.85, 133.84, 133.98, 191.14. IR (KBr): 3058, 2935, 1690, 1593, 1450, 1281, 1194, 1020, 764, 687, 615 cm^{-1} .

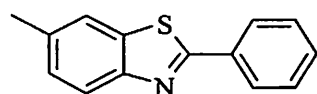
IID.2. Spectral Data of 2-Substituted Benzothiazoles**2-Phenyl-benzothiazole (62o)**

^1H NMR (400 MHz, CDCl_3): δ 7.13 (t, $J = 7.6$ Hz, 1H), 7.34 (t, $J = 7.2$ Hz, 2H), 7.47 (m, 3H), 7.61 (d, $J = 8.0$ Hz, 1H), 7.84 (d, $J = 8$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 119.5, 120.3, 120.9, 122.5, 124.4, 126.2, 129.6, 130.0, 139.9, 151.4, 164.5. IR (KBr): 3054, 2923, 1608, 1586, 1481, 1446, 1164, 1072, 918, 761, 694 cm^{-1} .

4-Methyl-2-phenyl-benzothiazole (63o)

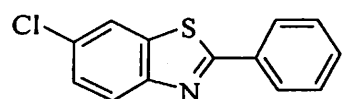
^1H NMR (400 MHz, CDCl_3): δ 2.48 (s, 3H), 7.02 (t, $J = 7.6$ Hz, 1H), 7.12 (m, 2H), 7.25 (d, $J = 7.6$ Hz, 2H), 7.39 (d, $J = 7.6$ Hz, 1H), 7.65 (d, $J = 8$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 18.3, 121.9, 123.3, 127.4, 128.7, 128.8, 129.3, 129.4, 129.7, 130.4, 152.3, 161.2. IR (KBr): 3043, 2922, 2846, 1629, 1603, 1481, 1446, 1341, 1234, 763, 691 cm^{-1} .

6-Methyl-2-phenyl-benzothiazole (64o)



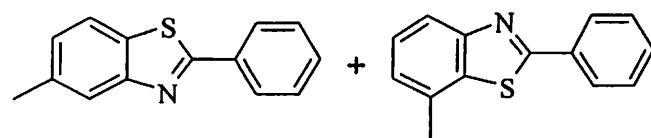
^1H NMR (400 MHz, CDCl_3): δ 2.39 (s, 3H), 7.18 (d, 1H, $J = 8$ Hz), 7.37 (m, 3H), 7.68 (d, 2H, $J = 8.2$ Hz), 7.93 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 120.9, 122.7, 127.3, 127.9, 128.9, 130.7, 134.3, 137.5, 151.4, 165.7. IR (KBr): 3028, 2962, 1608, 1557, 1429, 1306, 1239, 816, 753, 698 cm^{-1} .

6-Chloro-2-phenyl-benzothiazole (65o)



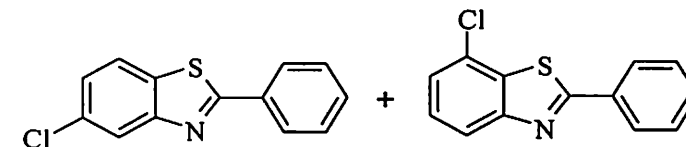
^1H NMR (400 MHz, CDCl_3): δ 7.15 (t, $J = 8$ Hz, 1H), 7.25 (m, 2H), 7.50 (m, 2H), 7.65 (m, 2H), 7.82 (m, 2H), 8.12 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 120.6, 122.2, 123.1, 125.1, 125.8, 129.3, 130.5, 132.2, 134.9, 137.6, 164.7. IR (KBr): 3046, 2917, 1596, 1563, 1467, 1344, 1273, 897 cm^{-1} .

5-Methyl-2-phenyl-benzothiazole and 7-Methyl-2-phenyl-benzothiazole (66o and 66o')



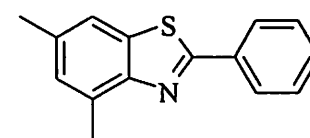
^1H NMR (400 MHz, CDCl_3): (mixture of two isomer) 1.96 (s, 3H), 2.12 (s, 3H), 6.24 (s, 1H), 6.31 (d, $J = 7.2$, 1H), 6.54 (s, 1H), 6.72 (m, 3H), 6.96 (t, $J = 7.6$ Hz, 1H), 7.13 (m, 2H), 7.24 (m, 2H), 7.45 (m, 4H), 8.15 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.0, 21.3, 118.7, 119.1, 119.8, 120.8, 121.1, 121.3, 122.0, 123.9, 125.9, 127.1, 127.3, 129.3, 129.9, 131.9, 132.2, 134.0, 137.2, 139.0, 139.8, 139.8, 149.1, 163.4, 164.4. IR (Neat): 3057, 3028, 2923, 2856, 1630, 1598, 1506, 1447, 1347, 1271, 1196, 999, 819, 755, 692 cm^{-1} .

5-Chloro-2-phenyl benzothiazole and 7-Chloro-2-phenyl benzothiazole (67)



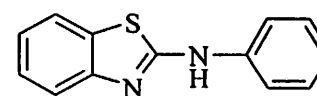
^1H NMR (400 MHz, CDCl_3): 6.34 (d, $J = 8$ Hz, 1H), 6.56 (s, 1H), 6.77 (m, 3H), 6.92 (d, $J = 8.4$ Hz, 2H), 7.01 (t, $J = 8$ Hz, 1H), 7.17 (t, $J = 7.6$ Hz, 1H), 7.27 (t, $J = 7.2$ Hz, 1H), 7.49 (m, 4H), 8.12 (d, $J = 6.8$ Hz, 2H). IR (Neat): 3062, 2925, 2858, 1652, 594, 1525, 1491, 1424, 1353, 1309, 1075, 1001, 876, 774, 691 cm^{-1} .

4,6-Dimethyl-2-phenyl-benzothiazole (68o)



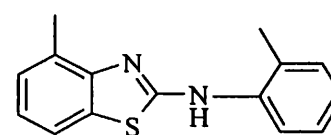
^1H NMR (400 MHz, CDCl_3): δ 2.24 (s, 3H), 2.29 (s, 3H), 6.99 (s, 1H), 7.42 (t, $J = 7.2$ Hz, 2H), 7.50 (d, $J = 8$ Hz, 1H), 7.63 (d, $J = 8$ Hz, 1H), 7.72 (s, 1H), 7.83 (d, $J = 7.2$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.9, 18.4, 118.2, 121.9, 123.2, 125.8, 126.7, 127.1, 128.8, 131.0, 138.2, 150.6, 165.2. IR (KBr): 3054, 3027, 2923, 2851, 1665, 1596, 1445, 1374, 1259, 1201, 1028, 932, 762, 688 cm^{-1} .

Benzothiazol-2-yl-phenyl-amine (69p)



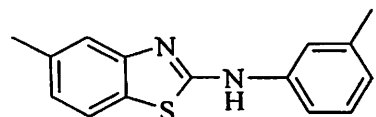
^1H NMR (400 MHz, CDCl_3): δ 7.14 (m, 2H), 7.29 (m, 1H), 7.38 (m, 2H), 7.48 (d, 2H, $J = 8.8$ Hz), 7.53 (d, 1H, $J = 8$ Hz), 7.60 (d, 1H, $J = 7.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 119.2, 120.3, 120.7, 122.2, 124.3, 126.0, 129.4, 139.7, 151.1, 165.3. IR (KBr): 3211, 3048, 3012, 2930, 2853, 1655, 1598, 1557, 1445, 1347, 1235, 712 cm^{-1} .

(4-Methyl-benzothiazol-2-yl)-o-tolyl-amine (70p)



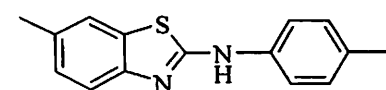
^1H NMR (400 MHz, CDCl_3): δ 2.31 (s, 3H), 2.52 (s, 3H), 7.00 (t, 1H, $J = 7.6$ Hz), 7.12 (m, 2H), 7.24 (d, 2H, $J = 7.6$ Hz), 7.39 (d, 1H, $J = 7.6$ Hz), 7.65 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 17.9, 18.4, 118.2, 121.9, 123.3, 125.8, 126.7, 127.1, 128.8, 131.0, 131.4, 138.2, 150.6, 165.3. IR (KBr): 3186, 3028, 2962, 1608, 1557, 1429, 1306, 1239, 753 cm^{-1} .

(5-Methyl-benzothiazol-2-yl)-m-tolyl-amine (71p)



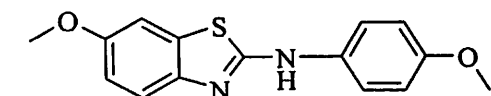
^1H NMR (400 MHz, CDCl_3): δ 2.37 (s, 3H), 2.40 (s, 3H), 6.95 (d, 2H, $J = 7.8$ Hz), 7.26 (d, 2H, $J = 7.6$ Hz), 7.37 (s, 1H), 7.47 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 17.9, 18.4, 118.2, 121.9, 123.3, 125.8, 126.7, 127.1, 128.8, 131.0, 131.4, 138.2, 150.6, 165.3. IR (KBr): 3186, 3028, 2962, 1608, 1557, 1429, 1306, 1239, 753 cm^{-1} .

(6-Methyl-benzothiazol-2-yl)-p-tolyl-amine (72p)



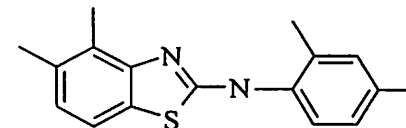
^1H NMR (400 MHz, CDCl_3): δ 2.29 (s, 3H), 2.34 (s, 3H), 7.10 (d, 1H, $J = 8$ Hz), 7.16 (d, 2H, $J = 8$ Hz), 7.37 (s, 1H), 7.32 (d, 2H, $J = 7.2$ Hz), 7.39 (m, 2H), 8.45 (brs, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 21.6, 118.9, 120.9, 127.3, 130.1, 132.0, 134.3, 137.5, 149.4, 164.7. IR (KBr): 3230, 30548, 2983, 1611, 1542, 1429, 1386, 1239, 923 cm^{-1} .

(6-Methoxy-benzothiazol-2-yl)-(4-methoxy-phenyl)-amine (73p)



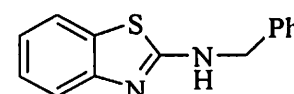
^1H NMR (400 MHz, CDCl_3): δ 3.78 (s, 3H), 3.78 (s, 3H), 6.84 (d, 1H, $J = 6.4$ Hz), 6.90 (d, 2H, $J = 8.8$ Hz), 7.07 (s, 1H), 7.34 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 55.7, 56.1, 104.5, 113.8, 114.9, 119.4, 123.9, 130.9, 133.3, 146.0, 155.6, 157.3, 165.5. IR (KBr): 3342, 3038, 2925, 1609, 1576, 1516, 1475, 1240, 1061, 1030, 820 cm^{-1} .

(4,5-Dimethyl-benzothiazol-2-yl)-(2,4-dimethyl-phenyl)-amine (74p)



^1H NMR (400 MHz, CDCl_3): δ 2.24 (s, 3H), 2.31 (s, 6H), 2.31 (s, 3H), 6.74 (s, 1H), 7.02 (m, 2H), 7.15 (s, 1H), 7.40 (s, 1H), 8.17 (brs, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.8, 18.3, 21.1, 21.3, 118.1, 124.6, 127.6, 127.9, 128.1, 129.9, 131.3, 131.7, 132.6, 135.8, 136.1, 148.6, 165.9. IR (KBr): 3124, 3048, 2925, 2868, 1588, 1552, 1440, 1260, 1045, 851, 799 cm^{-1} .

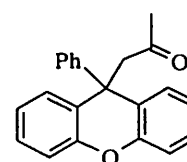
Benzothiazol-2-yl-benzyl-amine (75p)



^1H NMR (400 MHz, CDCl_3): δ 4.59 (s, 2H), 6.85 (brs, 1H), 7.03 (t, 2H, $J = 7.2$ Hz), 7.18-7.37 (m, 7H), 7.51 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 49.3, 118.6, 120.6, 121.3, 125.7, 127.5, 127.6, 128.6, 130.1, 137.2, 151.9, 167.6. IR (KBr): 3124, 3048, 2925, 2868, 1588, 1552, 1440, 1260, 1045, 851, 799 cm^{-1} .

IID.3. Spectral Data of Xanthene Derivatives

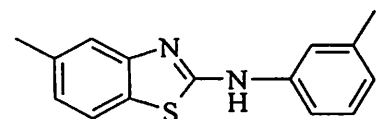
1-(9-Phenyl-9H-xanthen-9-yl)-propan-2-one (77q)



M.p. 139-140 $^{\circ}\text{C}$. ^1H NMR (400 MHz, CDCl_3): δ 1.72 (s, 3H), 3.51 (s, 2H), 6.81 (d, 2H, $J = 7.6$ Hz), 6.89 (t, 3H, $J = 7.6$ Hz), 7.07 (d, 2H, $J = 8$ Hz), 7.15 (t, 3H, $J = 7.6$ Hz), 7.25 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 31.3, 44.7, 55.8, 116.1, 122.9, 126.2, 126.5, 127.8, 128.0, 128.8, 148.9, 150.4, 205.3. IR (KBr): 3058, 3027, 2960, 2930, 1711, 1603, 1568, 1481, 1450, 1301, 1255, 1158, 1122, 1030, 892, 753, 702 cm^{-1} . Mass (m/z) 314.

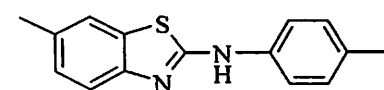
^1H NMR (400 MHz, CDCl_3): δ 2.31 (s, 3H), 2.52 (s, 3H), 7.00 (t, 1H, $J = 7.6$ Hz), 7.12 (m, 2H), 7.24 (d, 2H, $J = 7.6$ Hz), 7.39 (d, 1H, $J = 7.6$ Hz), 7.65 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 17.9, 18.4, 118.2, 121.9, 123.3, 125.8, 126.7, 127.1, 128.8, 131.0, 131.4, 138.2, 150.6, 165.3. IR (KBr): 3186, 3028, 2962, 1608, 1557, 1429, 1306, 1239, 753 cm^{-1} .

(5-Methyl-benzothiazol-2-yl)-m-tolyl-amine (71p)



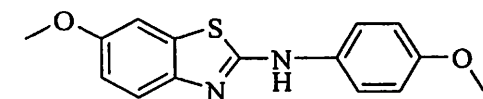
^1H NMR (400 MHz, CDCl_3): δ 2.37 (s, 3H), 2.40 (s, 3H), 6.95 (d, 2H, $J = 7.8$ Hz), 7.26 (d, 2H, $J = 7.6$ Hz), 7.37 (s, 1H), 7.47 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 17.9, 18.4, 118.2, 121.9, 123.3, 125.8, 126.7, 127.1, 128.8, 131.0, 131.4, 138.2, 150.6, 165.3. IR (KBr): 3186, 3028, 2962, 1608, 1557, 1429, 1306, 1239, 753 cm^{-1} .

(6-Methyl-benzothiazol-2-yl)-p-tolyl-amine (72p)



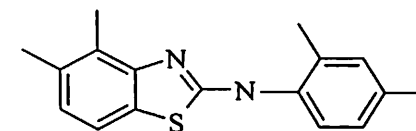
^1H NMR (400 MHz, CDCl_3): δ 2.29 (s, 3H), 2.34 (s, 3H), 7.10 (d, 1H, $J = 8$ Hz), 7.16 (d, 2H, $J = 8$ Hz), 7.37 (s, 1H), 7.32 (d, 2H, $J = 7.2$ Hz), 7.39 (m, 2H), 8.45 (brs, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 21.6, 118.9, 120.9, 127.3, 130.1, 132.0, 134.3, 137.5, 149.4, 164.7. IR (KBr): 3230, 30548, 2983, 1611, 1542, 1429, 1386, 1239, 923 cm^{-1} .

(6-Methoxy-benzothiazol-2-yl)-(4-methoxy-phenyl)-amine (73p)



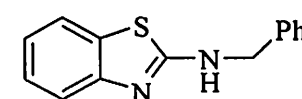
^1H NMR (400 MHz, CDCl_3): δ 3.78 (s, 3H), 3.78 (s, 3H), 6.84 (d, 1H, $J = 6.4$ Hz), 6.90 (d, 2H, $J = 8.8$ Hz), 7.07 (s, 1H), 7.34 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 55.7, 56.1, 104.5, 113.8, 114.9, 119.4, 123.9, 130.9, 133.3, 146.0, 155.6, 157.3, 165.5. IR (KBr): 3342, 3038, 2925, 1609, 1576, 1516, 1475, 1240, 1061, 1030, 820 cm^{-1} .

(4,5-Dimethyl-benzothiazol-2-yl)-(2,4-dimethyl-phenyl)-amine (74p)



^1H NMR (400 MHz, CDCl_3): δ 2.24 (s, 3H), 2.31 (s, 6H), 2.31 (s, 3H), 6.74 (s, 1H), 7.02 (m, 2H), 7.15 (s, 1H), 7.40 (s, 1H), 8.17 (brs, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.8, 18.3, 21.1, 21.3, 118.1, 124.6, 127.6, 127.9, 128.1, 129.9, 131.3, 131.7, 132.6, 135.8, 136.1, 148.6, 165.9. IR (KBr): 3124, 3048, 2925, 2868, 1588, 1552, 1440, 1260, 1045, 851, 799 cm^{-1} .

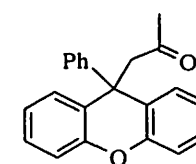
Benzothiazol-2-yl-benzyl-amine (75p)



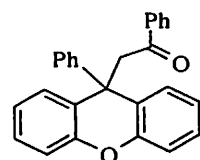
^1H NMR (400 MHz, CDCl_3): δ 4.59 (s, 2H), 6.85 (brs, 1H), 7.03 (t, 2H, $J = 7.2$ Hz), 7.18-7.37 (m, 7H), 7.51 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 49.3, 118.6, 120.6, 121.3, 125.7, 127.5, 127.6, 128.6, 130.1, 137.2, 151.9, 167.6. IR (KBr): 3124, 3048, 2925, 2868, 1588, 1552, 1440, 1260, 1045, 851, 799 cm^{-1} .

IID.3. Spectral Data of Xanthene Derivatives

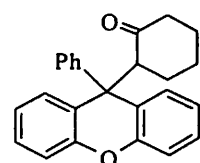
1-(9-Phenyl-9H-xanthen-9-yl)-propan-2-one (77q)



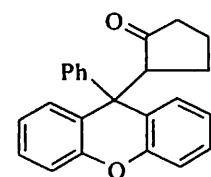
M.p. 139-140 $^{\circ}\text{C}$. ^1H NMR (400 MHz, CDCl_3): δ 1.72 (s, 3H), 3.51 (s, 2H), 6.81 (d, 2H, $J = 7.6$ Hz), 6.89 (t, 3H, $J = 7.6$ Hz), 7.07 (d, 2H, $J = 8$ Hz), 7.15 (t, 3H, $J = 7.6$ Hz), 7.25 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 31.3, 44.7, 55.8, 116.1, 122.9, 126.2, 126.5, 127.8, 128.0, 128.8, 148.9, 150.4, 205.3. IR (KBr): 3058, 3027, 2960, 2930, 1711, 1603, 1568, 1481, 1450, 1301, 1255, 1158, 1122, 1030, 892, 753, 702 cm^{-1} . Mass (m/z) 314.

1-Phenyl-2-(9-phenyl-9H-xanthen-9-yl)-ethanone (78q)

M.p. 186-188 °C. ^1H NMR (400 MHz, CDCl_3): δ 4.12 (s, 2H), 6.84 (m, 3H), 7.09 (m, 4H), 7.31 (m, 9H), 7.70 (d, 2H, $J = 7.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 45.3, 50.6, 116.4, 123.1, 126.6, 127.5, 127.9, 128.1, 128.4, 128.6, 129.0, 132.8, 137.6, 149.3, 151.2, 196.7. IR (KBr): 3065, 3038, 2951, 2891, 1685, 1598, 1571, 1484, 1451, 1352, 1310, 1257, 1222, 1181, 1126, 1098, 1040, 974, 889, 774, 698 cm^{-1} . Mass (m/z) 376.

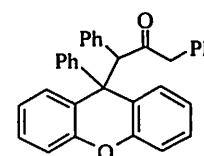
2-(9-Phenyl-9H-xanthen-9-yl)-cyclohexanone (79q)

M.p. 181-183 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.54 (m, 3H), 1.80 (m, 1H), 1.98 (m, 1H), 2.15 (m, 1H), 2.23 (m, 1H), 2.33 (m, 1H), 3.48 (dd, 1H, $J_1 = 5$ Hz, $J_2 = 12.8$ Hz), 6.68 (d, 1H, $J = 8$ Hz), 6.86 (m, 2H), 7.05 (m, 2H), 7.15 (m, 5H), 7.23 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 26.2, 28.4, 30.8, 44.3, 49.4, 61.4, 115.7, 116.0, 122.5, 126.0, 127.2, 127.7, 127.8, 127.9, 129.7, 130.1, 132.0, 147.1, 151.5, 151.8, 209.4. IR (KBr): 3066, 3031, 2930, 2857, 1711, 1596, 1571, 1475, 1440, 1308, 1276, 1240, 1124, 1095, 1035, 876, 758, 702 cm^{-1} .

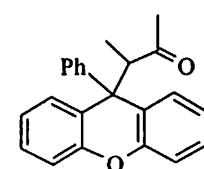
2-(9-Phenyl-9H-xanthen-9-yl)-cyclopentanone (80q)

M.p. 146-148 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.66 (m, 4H), 2.18 (brs, 2H), 3.36 (t, 1H, $J = 9.2$ Hz), 6.67 (d, 1H, $J = 8$ Hz), 6.87 (t, 2H, $J = 8$ Hz), 6.93 (d, 1H, $J = 8$ Hz), 7.09 (m, 3H), 7.20 (m, 2H), 7.27 (t, 2H, $J = 8$ Hz), 7.37 (d, 2H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.3, 27.6, 41.1, 49.9, 58.4, 115.8, 116.1, 123.0, 123.3, 126.3, 127.5, 127.7, 128.3, 129.6, 130.5, 131.8, 146.5, 150.1, 151.9,

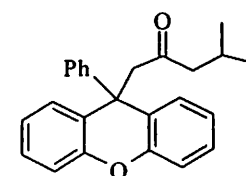
216.1. IR (KBr): 3056, 3031, 2964, 2878, 1736, 1598, 1572, 1477, 1444, 1097, 1039, 889, 754, 701 cm^{-1} .

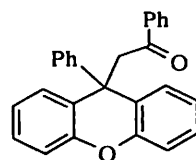
1,3-Diphenyl-1-(9-phenyl-9H-xanthen-9-yl)-propan-2-one (81q)

M.p. 141-143 °C. ^1H NMR (400 MHz, CDCl_3): δ 3.46 (d, 1H, $J = 14.8$ Hz), 3.59 (d, 1H, $J = 14.8$ Hz), 4.69 (s, 1H), 6.17 (d, 2H, $J = 7.2$ Hz), 6.57 (d, 1H, $J = 8$ Hz), 6.69 (dd, 3H, $J_1 = 8$ Hz, $J_2 = 15.6$ Hz), 6.86 (t, 2H, $J = 7.2$ Hz), 6.97 (t, 2H, $J = 8$ Hz), 7.02-7.39 (m, 12H), 7.62 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 50.5, 67.7, 115.3, 115.7, 121.8, 122.8, 126.3, 127.1, 127.6, 127.8, 128.0, 128.3, 128.5, 128.7, 129.4, 129.5, 129.7, 130.0, 131.1, 133.7, 134.4, 146.4, 151.2, 152.9, 204.8. IR (KBr): 3060, 3030, 2884, 1722, 1600, 1573, 1477, 1444, 1311, 1280, 1245, 1098, 1037, 753, 701 cm^{-1} .

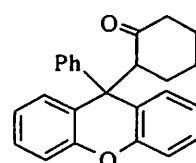
3-(9-Phenyl-9H-xanthen-9-yl)-butan-2-one (82q)

M.p. 133-134 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.14 (d, 3H, $J = 6.8$ Hz), 1.53 (s, 3H), 3.80 (q, 1H), 6.72 (dd, 1H, $J = 1.6$ Hz, $J = 7.6$ Hz), 6.78 (dd, 1H, $J = 1.6$ Hz, $J = 8$ Hz), 6.98 (m, 2H), 7.06 (m, 1H), 7.14 (m, 3H), 7.31 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.6, 31.5, 50.1, 55.2, 116.1, 116.4, 116.7, 122.1, 123.2, 123.3, 124.3, 126.5, 126.6, 127.6, 128.0, 128.2, 128.3, 128.5, 128.6, 129.2, 130.0, 130.2, 131.7, 147.0, 150.5, 152.3, 210.5. IR (KBr): 3071, 3033, 2929, 2870, 1701, 1603, 1571, 1484, 1441, 1363, 1305, 1278, 1245, 1183, 1045, 938, 902, 871, 761, 717 cm^{-1} . Mass (m/z) 328.

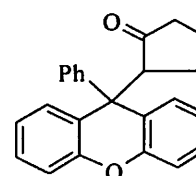
4-Methyl-1-(9-phenyl-9H-xanthen-9-yl)-penta-2-one (83q)

1-Phenyl-2-(9-phenyl-9H-xanthen-9-yl)-ethanone (78q)

M.p. 186-188 °C. ^1H NMR (400 MHz, CDCl_3): δ 4.12 (s, 2H), 6.84 (m, 3H), 7.09 (m, 4H), 7.31 (m, 9H), 7.70 (d, 2H, $J = 7.2$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 45.3, 50.6, 116.4, 123.1, 126.6, 127.5, 127.9, 128.1, 128.4, 128.6, 129.0, 132.8, 137.6, 149.3, 151.2, 196.7. IR (KBr): 3065, 3038, 2951, 2891, 1685, 1598, 1571, 1484, 1451, 1352, 1310, 1257, 1222, 1181, 1126, 1098, 1040, 974, 889, 774, 698 cm^{-1} . Mass (m/z) 376.

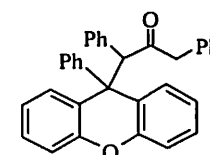
2-(9-Phenyl-9H-xanthen-9-yl)-cyclohexanone (79q)

M.p. 181-183 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.54 (m, 3H), 1.80 (m, 1H), 1.98 (m, 1H), 2.15 (m, 1H), 2.23 (m, 1H), 2.33 (m, 1H), 3.48 (dd, 1H, $J_1 = 5$ Hz, $J_2 = 12.8$ Hz), 6.68 (d, 1H, $J = 8$ Hz), 6.86 (m, 2H), 7.05 (m, 2H), 7.15 (m, 5H), 7.23 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 26.2, 28.4, 30.8, 44.3, 49.4, 61.4, 115.7, 116.0, 122.5, 126.0, 127.2, 127.7, 127.8, 127.9, 129.7, 130.1, 132.0, 147.1, 151.5, 151.8, 209.4. IR (KBr): 3066, 3031, 2930, 2857, 1711, 1596, 1571, 1475, 1440, 1308, 1276, 1240, 1124, 1095, 1035, 876, 758, 702 cm^{-1} .

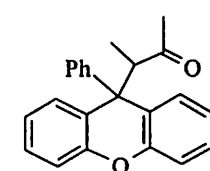
2-(9-Phenyl-9H-xanthen-9-yl)-cyclopentanone (80q)

M.p. 146-148 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.66 (m, 4H), 2.18 (brs, 2H), 3.36 (t, 1H, $J = 9.2$ Hz), 6.67 (d, 1H, $J = 8$ Hz), 6.87 (t, 2H, $J = 8$ Hz), 6.93 (d, 1H, $J = 8$ Hz), 7.09 (m, 3H), 7.20 (m, 2H), 7.27 (t, 2H, $J = 8$ Hz), 7.37 (d, 2H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.3, 27.6, 41.1, 49.9, 58.4, 115.8, 116.1, 123.0, 123.3, 126.3, 127.5, 127.7, 128.3, 129.6, 130.5, 131.8, 146.5, 150.1, 151.9,

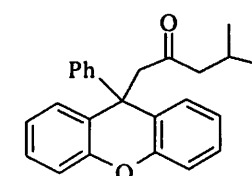
216.1. IR (KBr): 3056, 3031, 2964, 2878, 1736, 1598, 1572, 1477, 1444, 1409, 1097, 1039, 889, 754, 701 cm^{-1} .

1,3-Diphenyl-1-(9-phenyl-9H-xanthen-9-yl)-propan-2-one (81q)

M.p. 141-143 °C. ^1H NMR (400 MHz, CDCl_3): δ 3.46 (d, 1H, $J = 14.8$ Hz), 3.59 (d, 1H, $J = 14.8$ Hz), 4.69 (s, 1H), 6.17 (d, 2H, $J = 7.2$ Hz), 6.57 (d, 1H, $J = 8$ Hz), 6.69 (dd, 3H, $J_1 = 8$ Hz, $J_2 = 15.6$ Hz), 6.86 (t, 2H, $J = 7.2$ Hz), 6.97 (t, 2H, $J = 8$ Hz), 7.02-7.39 (m, 12H), 7.62 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 50.5, 67.7, 115.3, 115.7, 121.8, 122.8, 126.3, 127.1, 127.6, 127.8, 128.0, 128.3, 128.5, 128.7, 129.4, 129.5, 129.7, 130.0, 131.1, 133.7, 134.4, 146.4, 151.2, 152.9, 204.8. IR (KBr): 3060, 3030, 2884, 1722, 1600, 1573, 1477, 1444, 1311, 1280, 1245, 1098, 1037, 753, 701 cm^{-1} .

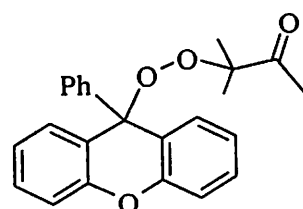
3-(9-Phenyl-9H-xanthen-9-yl)-butan-2-one (82q)

M.p. 133-134 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.14 (d, 3H, $J = 6.8$ Hz), 1.53 (s, 3H), 3.80 (q, 1H), 6.72 (dd, 1H, $J = 1.6$ Hz, $J = 7.6$ Hz), 6.78 (dd, 1H, $J = 1.6$ Hz, $J = 8$ Hz), 6.98 (m, 2H), 7.06 (m, 1H), 7.14 (m, 3H), 7.31 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.6, 31.5, 50.1, 55.2, 116.1, 116.4, 116.7, 122.1, 123.2, 123.3, 124.3, 126.5, 126.6, 127.6, 128.0, 128.2, 128.3, 128.5, 128.6, 129.2, 130.0, 130.2, 131.7, 147.0, 150.5, 152.3, 210.5. IR (KBr): 3071, 3033, 2929, 2870, 1701, 1603, 1571, 1484, 1441, 1363, 1305, 1278, 1245, 1183, 1045, 938, 902, 871, 761, 717 cm^{-1} . Mass (m/z) 328.

4-Methyl-1-(9-phenyl-9H-xanthen-9-yl)-penta-2-one (83q)

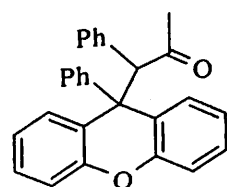
M.p. 133-134 °C. ^1H NMR (400 MHz, CDCl_3): δ 0.63 (d, 6H, $J = 5.2$ Hz), 1.56 (s, 1H), 1.85 (s, 2H), 3.46 (s, 2H), 6.78 (d, 2H, $J = 8$ Hz), 6.88 (t, 3H, $J = 7.6$ Hz), 7.06 (d, 2H, $J = 8$ Hz), 7.14 (m, 4H), 7.26 (d, 2H, $J = 4.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 22.4, 24.2, 44.8, 53.2, 55.1, 116.1, 122.8, 126.2, 126.6, 126.7, 127.7, 128.0, 128.2, 128.8, 134.6, 149.1, 150.5, 207.0. IR (KBr): 3050, 3037, 2966, 2879, 1711, 1603, 1578, 1486, 1450, 1404, 1368, 1312, 1260, 1235, 1126, 1062, 1040, 890, 750, 702 cm^{-1} . Mass (m/z) 356.

3-Methyl-3-(9-phenyl-9H-9-yl-peroxy)-butan-2-one (84q)



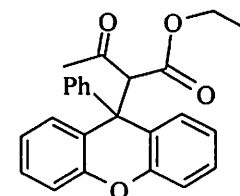
M.p. 125-128 °C. ^1H NMR (400 MHz, CDCl_3): δ 0.93 (s, 6H), 2.05 (s, 3H), 6.99 (t, 2H, $J = 6.8$ Hz), 7.07 (d, 2H, $J = 8$ Hz), 7.20 (t, 3H, $J = 8.4$ Hz), 7.31 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.5, 24.1, 86.9, 116.0, 122.4, 122.6, 127.1, 127.5, 127.6, 129.4, 130.8, 143.7, 151.7, 210.8. IR (KBr): 3054, 3036, 2996, 2983, 2927, 1710, 1601, 1573, 1476, 1449, 1352, 1319, 1293, 1251, 1219, 1164, 1156, 979, 935, 878, 765, 755, 702 cm^{-1} . HRMS: m/z (%) elemental composition) calcd for $\text{C}_{24}\text{H}_{22}\text{O}_4$ (M) $^+$ 374.4400; found (M+Na) $^+$ 397.1371.

1-Phenyl-1-(9-phenyl-9H-xanthene-9-yl)-propan-2-one (85q)



M.p. 185-188 °C. ^1H NMR (400 MHz, CDCl_3): δ 2.05 (s, 3H), 4.60 (s, 1H), 6.17 (d, 2H, $J = 7.2$ Hz), 6.67 (d, 2H, $J = 8$ Hz), 6.73 (d, 1H, $J = 8$ Hz), 6.88 (t, 1H, $J = 8$ Hz), 6.95 (t, 2H, $J = 7.6$ Hz), 7.05 (m, 2H), 7.18 (m, 2H), 7.28 (m, 5H), 7.64 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 30.9, 52.7, 68.8, 115.0, 115.5, 121.6, 122.6, 123.4, 126.2, 127.4, 127.5, 127.6, 127.8, 128.1, 129.1, 129.8, 130.5, 133.6, 134.2, 146.4, 150.9, 152.7, 205.4. IR (KBr): 3076, 3054, 3021, 2884, 1711, 1599, 1572, 1476, 1443, 1347, 1319, 1305, 1281, 1242, 1149, 1122, 1031, 880, 864, 770, 749, 702 cm^{-1} .

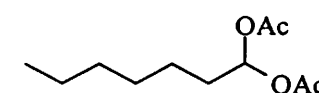
3-Oxo-2-(9-phenyl-9H-xanthene-9-yl)-butyric acid ethyl ester (86q)



M.p. 125-128 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.08 (t, 3H, $J = 7.8$ Hz), 1.80 (s, 3H), 3.97 (m, 2H), 4.61 (s, 1H), 6.86 (d, 1H, $J = 7.6$ Hz), 6.92 (q, 2H, $J = 8$ Hz), 7.01 (d, 1H, $J = 8$ Hz), 7.10 (d, 2H, $J = 8$ Hz), 7.21 (m, 3H), 7.28 (t, 2H, $J = 6.4$ Hz), 7.36 (d, 2H, $J = 6.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 13.8, 31.2, 61.4, 67.8, 115.8, 116.2, 122.4, 122.8, 125.7, 126.4, 127.6, 128.4, 129.6, 130.6, 131.8, 151.2, 151.3, 167.6, 201.2. IR (KBr): 3056, 3033, 2992, 2940, 1726, 1717, 1602, 1574, 1481, 1446, 1357, 1308, 1284, 1260, 1217, 1042, 1016, 906, 876, 763, 702 cm^{-1} .

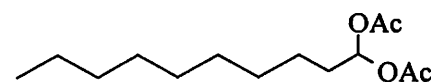
IID.4. Spectral Data of Diacylals

1,1-Diacetoxy-heptane (87r)



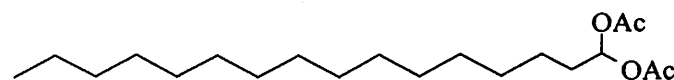
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, $J = 6.9$ Hz, 3H), 1.27 (m, 14H), 1.58 (m, 2H), 2.04 (s, 6H), 4.05 (t, $J = 6.9$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 21.3, 22.9, 23.8, 29.2, 32.0, 33.5, 90.8, 169.2. IR (KBr): 2995, 2925, 2858, 1767, 1470, 1373, 1250, 1219, 1127, 1020, 968, 773 cm^{-1} .

1,1-Diacetoxy-decane (88r)



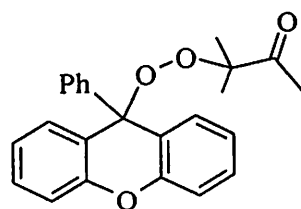
^1H NMR (300 MHz, CDCl_3): δ 0.88 (t, $J = 6.9$ Hz, 3H), 1.27 (m, 14H), 1.58 (m, 2H), 2.04 (s, 6H), 4.05 (t, $J = 6.9$ Hz, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 13.9, 20.8, 22.5, 25.8, 28.5, 29.1, 29.3, 29.4, 31.7, 33.8, 64.6, 171.2. IR (KBr): 2993, 2935, 2856, 1767, 1470, 1373, 1250, 1219, 1127, 1096, 1020, 968, 773, 610 cm^{-1} .

1,1-Diacetoxy-hexadecane (89r)



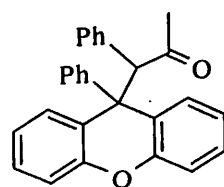
M.p. 133-134 °C. ^1H NMR (400 MHz, CDCl_3): δ 0.63 (d, 6H, $J = 5.2$ Hz), 1.56 (s, 1H), 1.85 (s, 2H), 3.46 (s, 2H), 6.78 (d, 2H, $J = 8$ Hz), 6.88 (t, 3H, $J = 7.6$ Hz), 7.06 (d, 2H, $J = 8$ Hz), 7.14 (m, 4H), 7.26 (d, 2H, $J = 4.4$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 22.4, 24.2, 44.8, 53.2, 55.1, 116.1, 122.8, 126.2, 126.6, 126.7, 127.7, 128.0, 128.2, 128.8, 134.6, 149.1, 150.5, 207.0. IR (KBr): 3050, 3037, 2966, 2879, 1711, 1603, 1578, 1486, 1450, 1404, 1368, 1312, 1260, 1235, 1126, 1062, 1040, 890, 750, 702 cm^{-1} . Mass (m/z) 356.

3-Methyl-3-(9-phenyl-9H-xanthene-9-yl-peroxy)-butan-2-one (84q)



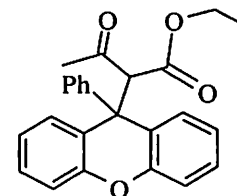
M.p. 125-128 °C. ^1H NMR (400 MHz, CDCl_3): δ 0.93 (s, 6H), 2.05 (s, 3H), 6.99 (t, 2H, $J = 6.8$ Hz), 7.07 (d, 2H, $J = 8$ Hz), 7.20 (t, 3H, $J = 8.4$ Hz), 7.31 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.5, 24.1, 86.9, 116.0, 122.4, 122.6, 127.1, 127.5, 127.6, 129.4, 130.8, 143.7, 151.7, 210.8. IR (KBr): 3054, 3036, 2996, 2983, 2927, 1710, 1601, 1573, 1476, 1449, 1352, 1319, 1293, 1251, 1219, 1164, 1156, 979, 935, 878, 765, 755, 702 cm^{-1} . HRMS: m/z (%) elemental composition) calcd for $\text{C}_{24}\text{H}_{22}\text{O}_4$ (M) $^+$ 374.4400; found ($\text{M}+\text{Na}$) $^+$ 397.1371.

1-Phenyl-1-(9-phenyl-9H-xanthene-9-yl)-propan-2-one (85q)



M.p. 185-188 °C. ^1H NMR (400 MHz, CDCl_3): δ 2.05 (s, 3H), 4.60 (s, 1H), 6.17 (d, 2H, $J = 7.2$ Hz), 6.67 (d, 2H, $J = 8$ Hz), 6.73 (d, 1H, $J = 8$ Hz), 6.88 (t, 1H, $J = 8$ Hz), 6.95 (t, 2H, $J = 7.6$ Hz), 7.05 (m, 2H), 7.18 (m, 2H), 7.28 (m, 5H), 7.64 (d, 1H, $J = 8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 30.9, 52.7, 68.8, 115.0, 115.5, 121.6, 122.6, 123.4, 126.2, 127.4, 127.5, 127.6, 127.8, 128.1, 129.1, 129.8, 130.5, 133.6, 134.2, 146.4, 150.9, 152.7, 205.4. IR (KBr): 3076, 3054, 3021, 2884, 1711, 1599, 1572, 1476, 1443, 1347, 1319, 1305, 1281, 1242, 1149, 1122, 1031, 880, 864, 770, 749, 702 cm^{-1} .

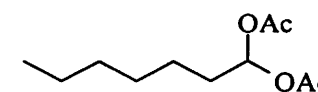
3-Oxo-2-(9-phenyl-9H-xanthene-9-yl)-butyric acid ethyl ester (86q)



M.p. 125-128 °C. ^1H NMR (400 MHz, CDCl_3): δ 1.08 (t, 3H, $J = 7.8$ Hz), 1.80 (s, 3H), 3.97 (m, 2H), 4.61 (s, 1H), 6.86 (d, 1H, $J = 7.6$ Hz), 6.92 (q, 2H, $J = 8$ Hz), 7.01 (d, 1H, $J = 8$ Hz), 7.10 (d, 2H, $J = 8$ Hz), 7.21 (m, 3H), 7.28 (t, 2H, $J = 6.4$ Hz), 7.36 (d, 2H, $J = 6.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 13.8, 31.2, 61.4, 67.8, 115.8, 116.2, 122.4, 122.8, 125.7, 126.4, 127.6, 128.4, 129.6, 130.6, 131.8, 151.2, 151.3, 167.6, 201.2. IR (KBr): 3056, 3033, 2992, 2940, 1726, 1717, 1602, 1574, 1481, 1446, 1357, 1308, 1284, 1260, 1217, 1042, 1016, 906, 876, 763, 702 cm^{-1} .

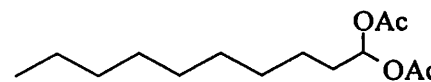
IID.4. Spectral Data of Diacylals

1,1-Diacetoxy-heptane (87r)



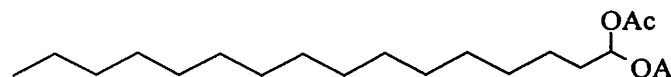
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, $J = 6.9$ Hz, 3H), 1.27 (m, 14H), 1.58 (m, 2H), 2.04 (s, 6H), 4.05 (t, $J = 6.9$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 21.3, 22.9, 23.8, 29.2, 32.0, 33.5, 90.8, 169.2. IR (KBr): 2995, 2925, 2858, 1767, 1470, 1373, 1250, 1219, 1127, 1020, 968, 773 cm^{-1} .

1,1-Diacetoxy-decane (88r)



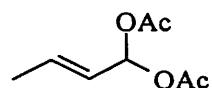
^1H NMR (300 MHz, CDCl_3): δ 0.88 (t, $J = 6.9$ Hz, 3H), 1.27 (m, 14H), 1.58 (m, 2H), 2.04 (s, 6H), 4.05 (t, $J = 6.9$ Hz, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 13.9, 20.8, 22.5, 25.8, 28.5, 29.1, 29.3, 29.4, 31.7, 33.8, 64.6, 171.2. IR (KBr): 2993, 2935, 2856, 1767, 1470, 1373, 1250, 1219, 1127, 1096, 1020, 968, 773, 610 cm^{-1} .

1,1-Diacetoxy-hexadecane (89r)



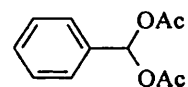
^1H NMR (400 MHz, CDCl_3): δ 0.88 (t, $J = 7.2$ Hz, 3H), 1.25 (m, 24H), 1.76 (m, 2H), 2.07 (s, 6H), 6.76 (t, $J = 5.2$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 14.5, 21.2, 23.1, 23.8, 29.5, 29.7, 29.8, 30.0, 30.1, 30.2, 32.3, 33.5, 90.8, 169.1. IR (KBr): 2919, 2842, 1757, 1470, 1338, 1255, 1203, 1050 cm^{-1} .

1,1-Diacetoxy-1-butene (90r)



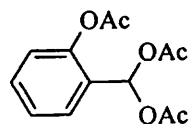
^1H NMR (400 MHz, CDCl_3): δ 1.76 (dd, $J_1 = 1.6$ Hz, $J_2 = 6.8$ Hz, 3H), 2.08 (s, 6H), 5.55 (m, 1H), 6.03 (m, 1H), 7.08 (d, $J = 6.8$, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 17.9, 21.1, 21.2, 89.9, 124.7, 133.2, 168.7. IR (KBr): 2976, 2945, 2919, 1762, 1675, 1445, 1380, 1250, 1214, 1112, 1015, 963 cm^{-1} .

1,1-Diacetoxy-1-phenyl methane (91r)



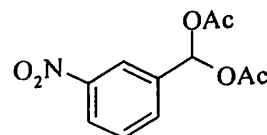
M.p. 43.7-45°C. ^1H NMR (400 MHz, CDCl_3): δ 2.11 (s, 6H), 7.39 (m, 3H), 7.51 (m, 2H), 7.67 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ 21.2, 89.9, 126.8, 128.7, 129.9, 135.6, 168.8. IR (KBr): 3068, 3037, 2930, 2863, 1762, 1378, 1250, 1204, 1071, 1015, 769, 702 cm^{-1} .

1,1-Diacetoxy-1-(2-acetoxy-phenyl) methane (92r)



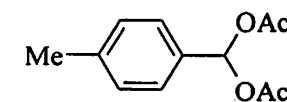
^1H NMR (400 MHz, CDCl_3): δ 2.13 (s, 6H), 2.36 (s, 3H), 7.11 (dd, $J_1 = 1.2$ Hz, $J_2 = 8.4$ Hz, 2H), 7.29 (m, 1H), 7.42 (m, 1H), 7.63 (dd, $J_1 = 2$ Hz, $J_2 = 7.6$ Hz, 1H), 7.89 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 21.2, 85.6, 123.4, 126.3, 127.9, 130.9, 148.4, 168.4, 169.4. IR (KBr): 3050, 2970, 1763, 1740, 1614, 1509, 1449, 1379, 1260, 1249, 1214, 1068, 881, 715, 602 cm^{-1} .

1,1-Diacetoxy-1-(3-Nitro-phenyl) methane (93r)



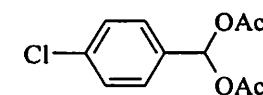
^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 6H), 7.60 (t, $J = 8.0$ Hz, 1H), 7.73 (t, $J = 8.0$ Hz, 1H), 8.25 (d, $J = 8.0$ Hz, 1H), 8.39 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 88.6, 122.0, 124.7, 129.9, 135.1, 137.7, 148.5, 168.4. IR (KBr): 3068, 3010, 2922, 2864, 1754, 1614, 1528, 1356, 1234, 1199, 1015, 984, 948, 720, 697 cm^{-1} .

1,1-Diacetoxy-1-(4-methyl-phenyl) methane (94r)



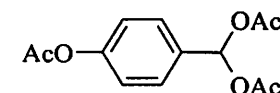
^1H NMR (400 MHz, CDCl_3): δ 2.11 (s, 6H), 2.36 (s, 3H), 7.20 (d, $J = 8$ Hz, 2H), 7.40 (d, $J = 8$ Hz, 2H), 7.64 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 21.7, 90.0, 126.8, 129.4, 132.8, 139.9, 168.6.

1,1-Diacetoxy-1-(4-chloro-phenyl) methane (95r)



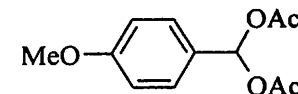
M.p. 77-79 °C. ^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 6H), 7.70 (d, $J = 8.8$ Hz, 2H), 7.72 (s, 1H), 8.24 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 88.6, 124.0, 128.0, 142.0, 142.8, 168.6.

1,1-Diacetoxy-1-(4-acetoxy-phenyl) methane (96r)



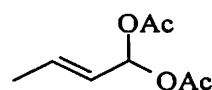
^1H NMR (300 MHz, CDCl_3): δ 2.11 (s, 6H), 2.29 (s, 3H), 7.12 (d, $J = 8.8$ Hz, 2H), 7.53 (d, $J = 8.8$ Hz, 2H), 7.67 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.7, 20.9, 89.0, 121.7, 127.9, 133, 151.5, 168.6, 169.0. IR (KBr): 3073, 2980, 1765, 1735, 1614, 1509, 1449, 1379, 1260, 1249, 1214, 1068, 998, 968, 881, 602 cm^{-1} .

1,1-Diacetoxy-1-(4-methoxy-phenyl) methane (97r)



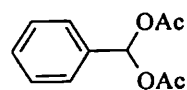
¹H NMR (400 MHz, CDCl₃): δ 0.88 (t, J = 7.2 Hz, 3H), 1.25 (m, 24H), 1.76 (m, 2H), 2.07 (s, 6H), 6.76 (t, J = 5.2 Hz, 1H). ¹³C NMR (100 MHz, CDCl₃): δ 14.5, 21.2, 23.1, 23.8, 29.5, 29.7, 29.8, 30.0, 30.1, 30.2, 32.3, 33.5, 90.8, 169.1. IR (KBr): 2919, 2842, 1757, 1470, 1338, 1255, 1203, 1050 cm⁻¹.

1,1-Diacetoxy-1-butene (90r)



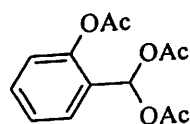
¹H NMR (400 MHz, CDCl₃): δ 1.76 (dd, J_1 = 1.6 Hz, J_2 = 6.8 Hz, 3H), 2.08 (s, 6H), 5.55 (m, 1H), 6.03 (m, 1H), 7.08 (d, J = 6.8, 1H). ¹³C NMR (100 MHz, CDCl₃): δ 17.9, 21.1, 21.2, 89.9, 124.7, 133.2, 168.7. IR (KBr): 2976, 2945, 2919, 1762, 1675, 1445, 1380, 1250, 1214, 1112, 1015, 963 cm⁻¹.

1,1-Diacetoxy-1-phenyl methane (91r)



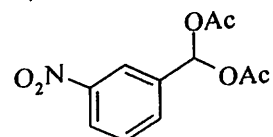
M.p. 43.7-45°C. ¹H NMR (400 MHz, CDCl₃): δ 2.11 (s, 6H), 7.39 (m, 3H), 7.51 (m, 2H), 7.67 (s, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 21.2, 89.9, 126.8, 128.7, 129.9, 135.6, 168.8. IR (KBr): 3068, 3037, 2930, 2863, 1762, 1378, 1250, 1204, 1071, 1015, 769, 702 cm⁻¹.

1,1-Diacetoxy-1-(2-acetoxy-phenyl) methane (92r)



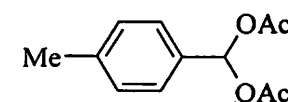
¹H NMR (400 MHz, CDCl₃): δ 2.13 (s, 6H), 2.36 (s, 3H), 7.11 (dd, J_1 = 1.2 Hz, J_2 = 8.4 Hz, 2H), 7.29 (m, 1H), 7.42 (m, 1H), 7.63 (dd, J_1 = 2 Hz, J_2 = 7.6 Hz, 1H), 7.89 (s, 1H). ¹³C NMR (100 MHz, CDCl₃): δ 21.1, 21.2, 85.6, 123.4, 126.3, 127.9, 130.9, 148.4, 168.4, 169.4. IR (KBr): 3050, 2970, 1763, 1740, 1614, 1509, 1449, 1379, 1260, 1249, 1214, 1068, 881, 715, 602 cm⁻¹.

1,1-Diacetoxy-1-(3-Nitro-phenyl) methane (93r)



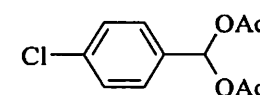
¹H NMR (400 MHz, CDCl₃): δ 2.15 (s, 6H), 7.60 (t, J = 8.0 Hz, 1H), 7.73 (t, J = 8.0 Hz, 1H), 8.25 (d, J = 8.0 Hz, 1H), 8.39 (s, 1H). ¹³C NMR (100 MHz, CDCl₃): δ 21.1, 21.2, 89.9, 124.7, 129.9, 135.1, 137.7, 148.5, 168.4. IR (KBr): 3068, 3010, 2922, 2864, 1754, 1614, 1528, 1356, 1234, 1199, 1015, 984, 948, 720, 697 cm⁻¹.

1,1-Diacetoxy-1-(4-methyl-phenyl) methane (94r)



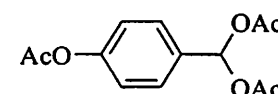
¹H NMR (400 MHz, CDCl₃): δ 2.11 (s, 6H), 2.36 (s, 3H), 7.20 (d, J = 8 Hz, 2H), 7.40 (d, J = 8 Hz, 2H), 7.64 (s, 1H). ¹³C NMR (100 MHz, CDCl₃): δ 21.3, 21.7, 90.0, 126.8, 129.4, 132.8, 139.9, 168.6.

1,1-Diacetoxy-1-(4-chloro-phenyl) methane (95r)



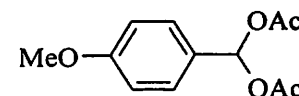
M.p. 77-79 °C. ¹H NMR (400 MHz, CDCl₃): δ 2.15 (s, 6H), 7.70 (d, J = 8.8 Hz, 2H), 7.72 (s, 1H), 8.24 (m, 2H). ¹³C NMR (100 MHz, CDCl₃): δ 21.1, 88.6, 124.0, 128.0, 142.0, 142.8, 168.6.

1,1-Diacetoxy-1-(4-acetoxy-phenyl) methane (96r)



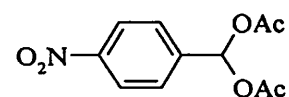
¹H NMR (300 MHz, CDCl₃): δ 2.11 (s, 6H), 2.29 (s, 3H), 7.12 (d, J = 8.8 Hz, 2H), 7.53 (d, J = 8.8 Hz, 2H), 7.67 (s, 1H). ¹³C NMR (75 MHz, CDCl₃): δ 20.7, 20.9, 89.0, 121.7, 127.9, 133, 151.5, 168.6, 169.0. IR (KBr): 3073, 2980, 1765, 1735, 1614, 1509, 1449, 1379, 1260, 1249, 1214, 1068, 998, 968, 881, 602 cm⁻¹.

1,1-Diacetoxy-1-(4-methoxy-phenyl) methane (97r)



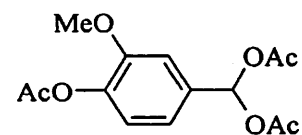
^1H NMR (400 MHz, CDCl_3): δ 2.10 (s, 6H), 3.81 (s, 3H), 6.91 (d, $J = 8.8$ Hz, 2H), 7.45 (d, $J = 8.8$ Hz, 2H), 7.64 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 55.6, 90.0, 114.1, 127.9, 128.3, 160.7, 168.9.

1,1-Diacetoxy-1-(4-nitro-phenyl) methane (98r)



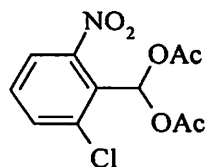
^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 6H), 7.69 (d, $J = 8.8$ Hz, 2H), 7.73 (s, 1H), 8.26 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 88.6, 124.0, 128.0, 142.0, 148.7, 168.6. IR (KBr): 3114, 3011, 2922, 2864, 1754, 1614, 1528, 1356, 1234, 1199, 1015, 984, 948, 861, 835, 697 cm^{-1} .

1,1-Diacetoxy-1-(4-acetoxy-3-methoxy-phenyl) methane (99r)



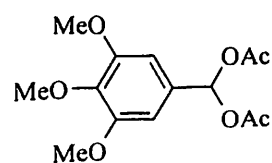
^1H NMR (400 MHz, CDCl_3): δ 2.12 (s, 6H), 2.31 (s, 3H), 3.85 (s, 3H), 7.11 (m, 3H), 7.64 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 55.6, 90.0, 114.1, 127.9, 128.3, 160.7, 168.9.

1,1-Diacetoxy-1-(2-chloro-5-nitrophenyl) methane (100r)



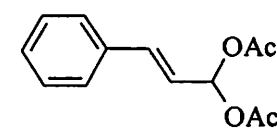
M.p. 66.8 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.21 (s, 6H), 5.27 (s, 1H), 7.58 (d, $J = 8.7$ Hz, 1H), 8.14 (dd, $J_1 = 2.7$ Hz, $J_2 = 8.7$ Hz, 1H), 8.31 (d, $J = 2.4$ Hz, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.7, 62.4, 123.8, 130.4, 135.7, 139.7, 146.6, 170.2. IR (KBr): 3100, 3073, 1742, 1537, 1352, 1261, 1244, 1071, 1040 cm^{-1} . $\text{C}_{11}\text{H}_9\text{ClNO}_6$ (287.66): calcd. C 45.93, H 3.50, N 4.87; found: C, 46.01, H, 3.41, N 4.78.

1,1-Diacetoxy-1-(3,4,5-trimethoxy-phenyl) methane (101r)



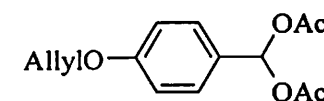
^1H NMR (400 MHz, CDCl_3): δ 2.13 (s, 6H), 3.84 (s, 3H), 3.88 (s, 6H), 6.74 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 56.5, 61.1, 90.0, 104.1, 131.1, 139.2, 153.5, 168.9.

1,1-Diacetoxy-3-phenyl-prop-2-ene(102r)



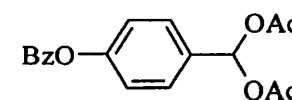
M.p. 85-88 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.09 (s, 6H), 6.18 (dd, $J_1 = 15$, $J_2 = 6$ Hz, 1H), 6.84 (d, $J = 15$ Hz, 1H), 7.29 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.7, 89.6, 121.6, 126.9, 128.7, 129.0, 135.0, 135.5, 168.6. IR (KBr): 3062, 3032, 1767, 1454, 1380, 1244, 1208, 1145, 1064, 1008, 963, 760, 699 cm^{-1} .

1,1-Diacetoxy-1-(4-allyloxy-phenyl) methane(103r)



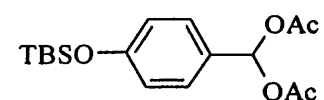
^1H NMR (400 MHz, CDCl_3): δ 2.11 (s, 6H), 4.54 (m, 2H), 5.28 (dd, $J_1 = 1.2$ Hz, $J_2 = 10.4$ Hz, 1H), 5.38 (dd, $J_1 = 1.6$ Hz, $J_2 = 17.2$ Hz, 1H), 6.03 (m, 1H), 6.93 (d, $J = 8.8$ Hz, 2H), 7.44 (d, $J = 8.8$ Hz, 2H), 7.61 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 69.1, 89.9, 114.9, 118.0, 128.0, 128.3, 128.5, 133.1, 159.7, 168.9.

1,1-Diacetoxy-1-(4-benzyloxy-phenyl) methane (104r)



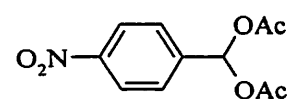
M.p. 102-104 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.12 (s, 6H), 7.27 (d, $J = 8.1$ Hz, 2H), 7.50 (t, $J = 7.5$ Hz, 2H), 7.61 (t, $J = 7.2$ Hz, 2H), 7.72 (s, 1H), 8.19 (d, $J = 7.5$ Hz, 2H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.7, 89.1, 121.9, 128.0, 128.5, 129.2, 130.1, 133.1, 133.7, 151.8, 164.8, 168.6. IR (KBr): 3073, 2980, 1765, 1735, 1620, 1514, 1449, 1379, 1290, 1249, 1214, 1068, 881, 800, 708, 602 cm^{-1} .

1,1-Diacetoxy-1-(4-tert-butyl dimethylsilyloxyphenyl) methane (105r)



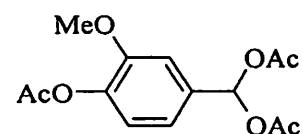
^1H NMR (400 MHz, CDCl_3): δ 2.10 (s, 6H), 3.81 (s, 3H), 6.91 (d, $J = 8.8$ Hz, 2H), 7.45 (d, $J = 8.8$ Hz, 2H), 7.64 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 55.6, 90.0, 114.1, 127.9, 128.3, 160.7, 168.9.

1,1-Diacetoxy-1-(4-nitro-phenyl) methane (98r)



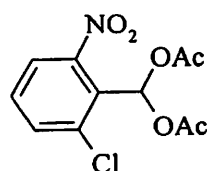
^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 6H), 7.69 (d, $J = 8.8$ Hz, 2H), 7.73 (s, 1H), 8.26 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 88.6, 124.0, 128.0, 142.0, 148.7, 168.6. IR (KBr): 3114, 3011, 2922, 2864, 1754, 1614, 1528, 1356, 1234, 1199, 1015, 984, 948, 861, 835, 697 cm^{-1} .

1,1-Diacetoxy-1-(4-acetoxy-3-methoxy-phenyl) methane (99r)



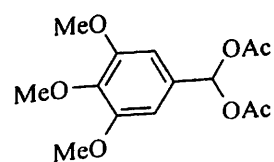
^1H NMR (400 MHz, CDCl_3): δ 2.12 (s, 6H), 2.31 (s, 3H), 3.85 (s, 3H), 7.11 (m, 3H), 7.64 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 55.6, 90.0, 114.1, 127.9, 128.3, 160.7, 168.9.

1,1-Diacetoxy-1-(2-chloro-5-nitrophenyl) methane (100r)



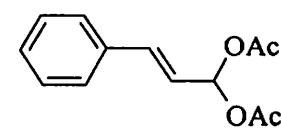
M.p. 66.8 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.21 (s, 6H), 5.27 (s, 1H), 7.58 (d, $J = 8.7$ Hz, 1H), 8.14 (dd, $J_1 = 2.7$ Hz, $J_2 = 8.7$ Hz, 1H), 8.31 (d, $J = 2.4$ Hz, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.7, 62.4, 123.8, 130.4, 135.7, 139.7, 146.6, 170.2. IR (KBr): 3100, 3073, 1742, 1537, 1352, 1261, 1244, 1071, 1040 cm^{-1} . $\text{C}_{11}\text{H}_9\text{ClNO}_6$ (287.66): calcd. C 45.93, H 3.50, N 4.87; found: C, 46.01, H, 3.41, N 4.78.

1,1-Diacetoxy-1-(3,4,5-trimethoxy-phenyl) methane (101r)



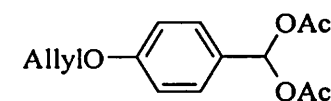
^1H NMR (400 MHz, CDCl_3): δ 2.13 (s, 6H), 3.84 (s, 3H), 3.88 (s, 6H), 6.74 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 56.5, 61.1, 90.0, 104.1, 131.1, 139.2, 153.5, 168.9.

1,1-Diacetoxy-3-phenyl-prop-2-ene(102r)



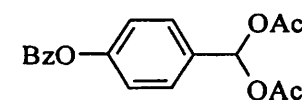
M.p. 85-88 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.09 (s, 6H), 6.18 (dd, $J_1 = 15$, $J_2 = 6$ Hz, 1H), 6.84 (d, $J = 15$ Hz, 1H), 7.29 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.7, 89.6, 121.6, 126.9, 128.7, 129.0, 135.0, 135.5, 168.6. IR (KBr): 3062, 3032, 1767, 1454, 1380, 1244, 1208, 1145, 1064, 1008, 963, 760, 699 cm^{-1} .

1,1-Diacetoxy-1-(4-allyloxy-phenyl) methane(103r)



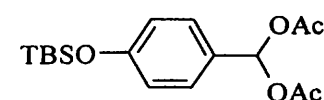
^1H NMR (400 MHz, CDCl_3): δ 2.11 (s, 6H), 4.54 (m, 2H), 5.28 (dd, $J_1 = 1.2$ Hz, $J_2 = 10.4$ Hz, 1H), 5.38 (dd, $J_1 = 1.6$ Hz, $J_2 = 17.2$ Hz, 1H), 6.03 (m, 1H), 6.93 (d, $J = 8.8$ Hz, 2H), 7.44 (d, $J = 8.8$ Hz, 2H), 7.61 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 69.1, 89.9, 114.9, 118.0, 128.0, 128.3, 128.5, 133.1, 159.7, 168.9.

1,1-Diacetoxy-1-(4-benzyloxy-phenyl) methane (104r)



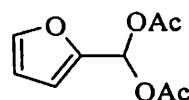
M.p. 102-104 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.12 (s, 6H), 7.27 (d, $J = 8.1$ Hz, 2H), 7.50 (t, $J = 7.5$ Hz, 2H), 7.61 (t, $J = 7.2$ Hz, 2H), 7.72 (s, 1H), 8.19 (d, $J = 7.5$ Hz, 2H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.7, 89.1, 121.9, 128.0, 128.5, 129.2, 130.1, 133.1, 133.7, 151.8, 164.8, 168.6. IR (KBr): 3073, 2980, 1765, 1735, 1620, 1514, 1449, 1379, 1290, 1249, 1214, 1068, 881, 800, 708, 602 cm^{-1} .

1,1-Diacetoxy-1-(4-tert-butyl dimethylsilyloxyphenyl) methane (105r)



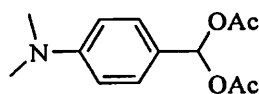
^1H NMR (400 MHz, CDCl_3): δ 0.20 (s, 6H), 0.98 (s, 9H), 2.11 (s, 6H), 6.83 (d, $J = 8.4$ Hz, 2H), 7.37 (d, $J = 8.0$ Hz, 2H), 7.61 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ -3.91, 18.6, 21.3, 26.0, 89.9, 120.2, 128.2, 128.4, 133.8, 157.0, 168.9. IR (KBr): 2960, 2935, 2863, 1767, 1618, 1520, 1378, 1249, 1203, 1064, 1010, 917, 841, 790 cm^{-1} .

1,1-Diacetoxy-2-furfuryl methane (106r)



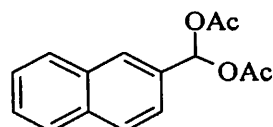
^1H NMR (400 MHz, CDCl_3): δ 2.13 (s, 6H), 6.38 (m, 1H), 6.53 (m, 1H), 7.43 (m, 1H), 7.71 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 21.2, 83.7, 89.9, 109.9, 110.6, 126.8, 128.7, 129.9, 135.6, 143.8, 148.0, 168.5, 168.8. IR (KBr): 3150, 3135, 3001, 2950, 1767, 1603, 1500, 1440, 1373, 1245, 1209, 1158, 1066, 1020, 758, 620, 600 cm^{-1} .

1,1-Diacetoxy-1-(4-N,N-dimethyl-phenyl) methane (107r)



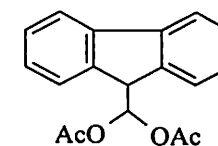
M.p. 66-68 $^{\circ}\text{C}$. ^1H NMR (400 MHz, CDCl_3): δ 2.10 (s, 6H), 2.96 (s, 6H), 6.70 (d, $J = 9.2$ Hz, 2H), 7.39 (d, $J = 8.4$ Hz, 2H), 7.59 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.4, 40.7, 90.6, 112.0, 123.0, 127.9, 151.5, 168.9. IR (KBr): 2998, 2909, 2838, 1762, 1624, 1520, 1378, 1250, 1214, 1076 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{13}\text{H}_{17}\text{NO}_4$, 251.28, found 251.0. $\text{C}_{13}\text{H}_{17}\text{NO}_4$ (251.28): calcd. C 62.14, H 6.82, N 5.57; found: C, 62.38, H, 6.70, N, 5.50.

1,1-Diacetoxy-1-methylnaphthlene (108r)



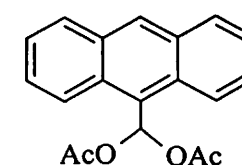
^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 6H), 7.51 (m, 2H), 7.61 (dd, $J_1 = 1.6$ Hz, $J_2 = 8.4$ Hz, 1H), 7.86 (m, 4H), 7.99 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 90.2, 123.7, 126.7, 126.8, 127.1, 127.9, 128.6, 128.8, 132.9, 133.0, 134.0, 168.8. IR (KBr): 3057, 2971, 2940, 2874, 1769, 1475, 1434, 1383, 1252, 1206, 1069, 1008, 973, 947, 826, 760 cm^{-1} .

1,1-Diacetoxy-9-methylantracene (109r)



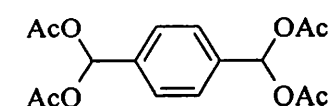
M.p. 197-199 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.10 (s, 6H), 7.47 (t, $J = 6.9$ Hz, 2H), 7.58 (t, $J = 6.6$ Hz, 2H), 7.98 (d, $J = 8.4$ Hz, 2H), 8.5 (s, 1H), 8.70 (d, $J = 9$ Hz, 1H), 9.24 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.8, 87.4, 124.7, 125.1, 126.7, 129, 130.5, 131.3, 168.9. IR (KBr): 3052, 3020, 2924, 2858, 1756, 1623, 1234, 1085, 962 cm^{-1} .

9-(Diacetoxy methyl)-9-H-fluorene (110r)



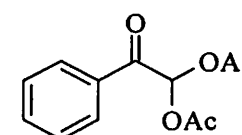
M.p. 95-97 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.01 (s, 6H), 7.23-7.51 (m, 9H). ^{13}C NMR (75 MHz, CDCl_3): δ 21.1, 99.6, 119.3, 119.4, 119.6, 124.9, 125.5, 125.6, 125.9, 126.2, 126.5, 127.7, 128.2, 128.5, 140.8, 141.0, 114.3, 141.5, 141.8, 143.1, 143.4, 169.2. IR (KBr): 2924, 2856, 1755, 1447, 1369, 1222, 1002, 743 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{18}\text{H}_{16}\text{O}_4$, 296.33, found 296.0. $\text{C}_{18}\text{H}_{16}\text{O}_4$ (296.33): calcd. C 72.96, H 5.44; found: C, 73.18, H, 5.54.

Teripthaldehyde tetra acetate (111r)



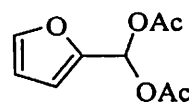
^1H NMR (300 MHz, CDCl_3): δ 2.13 (s, 12H), 7.57 (s, 4H), 7.68 (s, 2H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.8, 89.3, 127.0, 137.0, 168.7.

1,1-Diacetoxy-2-benzoyl-methane(112r)



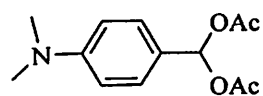
^1H NMR (400 MHz, CDCl_3): δ 0.20 (s, 6H), 0.98 (s, 9H), 2.11 (s, 6H), 6.83 (d, $J = 8.4$ Hz, 2H), 7.37 (d, $J = 8.0$ Hz, 2H), 7.61 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ -3.91, 18.6, 21.3, 26.0, 89.9, 120.2, 128.2, 128.4, 133.8, 157.0, 168.9. IR (KBr): 2960, 2935, 2863, 1767, 1618, 1520, 1378, 1249, 1203, 1064, 1010, 917, 841, 790 cm^{-1} .

1,1-Diacetoxy-2-furfuryl methane (106r)



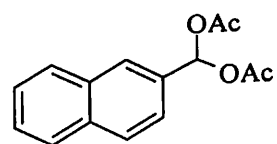
^1H NMR (400 MHz, CDCl_3): δ 2.13 (s, 6H), 6.38 (m, 1H), 6.53 (m, 1H), 7.43 (m, 1H), 7.71 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ 21.1, 21.2, 83.7, 89.9, 109.9, 110.6, 126.8, 128.7, 129.9, 135.6, 143.8, 148.0, 168.5, 168.8. IR (KBr): 3150, 3135, 3001, 2950, 1767, 1603, 1500, 1440, 1373, 1245, 1209, 1158, 1066, 1020, 758, 620, 600 cm^{-1} .

1,1-Diacetoxy-1-(4-N,N-dimethyl-phenyl) methane (107r)



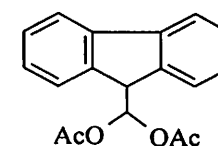
M.p. 66-68 $^{\circ}\text{C}$. ^1H NMR (400 MHz, CDCl_3): δ 2.10 (s, 6H), 2.96 (s, 6H), 6.70 (d, $J = 9.2$ Hz, 2H), 7.39 (d, $J = 8.4$ Hz, 2H), 7.59 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.4, 40.7, 90.6, 112.0, 123.0, 127.9, 151.5, 168.9. IR (KBr): 2998, 2909, 2838, 1762, 1624, 1520, 1378, 1250, 1214, 1076 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{13}\text{H}_{17}\text{NO}_4$, 251.28, found 251.0. $\text{C}_{13}\text{H}_{17}\text{NO}_4$ (251.28): calcd. C 62.14, H 6.82, N 5.57; found: C, 62.38, H, 6.70, N, 5.50.

1,1-Diacetoxy-1-methylnaphthlene (108r)



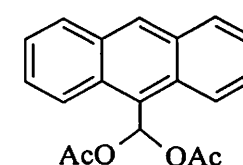
^1H NMR (400 MHz, CDCl_3): δ 2.15 (s, 6H), 7.51 (m, 2H), 7.61 (dd, $J_1 = 1.6$ Hz, $J_2 = 8.4$ Hz, 1H), 7.86 (m, 4H), 7.99 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.3, 90.2, 123.7, 126.7, 126.8, 127.1, 127.9, 128.6, 128.8, 132.9, 133.0, 134.0, 168.8. IR (KBr): 3057, 2971, 2940, 2874, 1769, 1475, 1434, 1383, 1252, 1206, 1069, 1008, 973, 973, 947, 826, 760 cm^{-1} .

1,1-Diacetoxy-9-methylanthracene (109r)



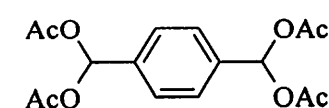
M.p. 197-199 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.10 (s, 6H), 7.47 (t, $J = 6.9$ Hz, 2H), 7.58 (t, $J = 6.6$ Hz, 2H), 7.98 (d, $J = 8.4$ Hz, 2H), 8.5 (s, 1H), 8.70 (d, $J = 9$ Hz, 1H), 9.24 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.8, 87.4, 124.7, 125.1, 126.7, 129, 130.5, 131.3, 168.9. IR (KBr): 3052, 3020, 2924, 2858, 1756, 1623, 1234, 1085, 962 cm^{-1} .

9-(Diacetoxy methyl)-9-H-fluorene (110r)



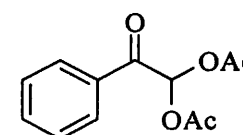
M.p. 95-97 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 2.01 (s, 6H), 7.23-7.51 (m, 9H). ^{13}C NMR (75 MHz, CDCl_3): δ 21.1, 99.6, 119.3, 119.4, 119.6, 124.9, 125.5, 125.6, 125.9, 126.2, 126.5, 127.7, 128.2, 128.5, 140.8, 141.0, 114.3, 141.5, 141.8, 143.1, 143.4, 169.2. IR (KBr): 2924, 2856, 1755, 1447, 1369, 1222, 1002, 743 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{18}\text{H}_{16}\text{O}_4$, 296.33, found 296.0. $\text{C}_{18}\text{H}_{16}\text{O}_4$ (296.33): calcd. C 72.96, H 5.44; found: C, 73.18, H, 5.54.

Teripthaldehyde tetra acetate (111r)



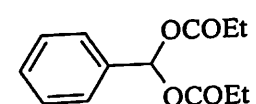
^1H NMR (300 MHz, CDCl_3): δ 2.13 (s, 12H), 7.57 (s, 4H), 7.68 (s, 2H). ^{13}C NMR (75 MHz, CDCl_3): δ 20.8, 89.3, 127.0, 137.0, 168.7.

1,1-Diacetoxy-2-benzoyl-methane(112r)



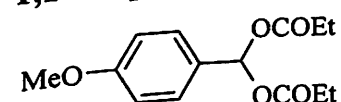
^1H NMR (300 MHz, CDCl_3): δ 2.20 (s, 6H), 7.80 (t, $J = 8.2$ Hz), 7.60 (s, 1H), 7.65 (m, 1H), 7.95 (d, $J = 8.2$ Hz). ^{13}C NMR (75 MHz, CDCl_3): δ 20.4, 113.8, 128.6, 128.8, 133.4, 136.8, 170.3, 192.5
IR (KBr): 3055, 2970, 1760, 1720, 1465, 1343, 1245, 1020, 972, 756 cm^{-1} .

1,1-Dipropionyloxy-1-phenyl methane (91s)



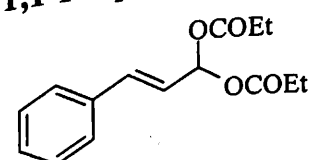
^1H NMR (400 MHz, CDCl_3): δ 1.15 (t, $J = 7.6$ Hz, 6H), 2.40 (m, 4H), 7.39 (m, 3H), 7.50 (m, 2H), 7.71 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 9.2, 27.8, 89.8, 126.8, 128.7, 129.8, 135.9, 172.3. IR (KBr): 3070, 3047, 2991, 2950, 284, 1762, 1459, 1353, 1280, 1194, 1143, 1079, 1044, 963, 704 cm^{-1} .

1,1-Propionyloxy-1-(4-methoxyphenyl)methane (97s)



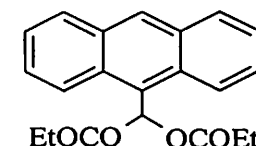
^1H NMR (400 MHz, CDCl_3): δ 1.14 (t, $J = 7.6$ Hz, 6H), 2.38 (m, 4H), 3.81 (s, 3H), 6.91 (d, $J = 8.8$ Hz, 2H), 7.45 (d, $J = 8.8$ Hz, 2H), 7.65 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 9.2, 27.8, 55.6, 89.8, 114.1, 128.1, 128.2, 160.6, 172.3. IR(KBr): 2986, 2950, 2843, 1762, 1614, 1516, 1470, 1363, 1260, 1220, 1168, 840 cm^{-1} . $\text{C}_{14}\text{H}_{18}\text{O}_6$ (266.30): calcd. C 63.15, H 6.81; found: C, 63.21, H, 6.93.

1,1-Propionyloxy-3-phenylprop-2-ene (102s)



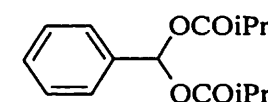
^1H NMR (300 MHz, CDCl_3): δ 1.18 (t, 6H), 2.41 (q, 4H), 6.23 (dd, $J_1 = 15.9$, $J_2 = 6.6$ Hz, 1H), 6.87 (d, $J = 16.2$ Hz, 1H), 7.30 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 8.7, 27.3, 89.6, 121.8, 126.9, 128.6, 128.7, 135.4, 172.1. IR (KBr): 2991, 2940, 1762, 1460, 1363, 1281, 1194, 1143, 958, 753, 697 cm^{-1} . $\text{C}_{15}\text{H}_{18}\text{O}_4$ (262.31): calcd. C 68.69, H 6.92; found: C, 68.54, H, 7.04.

9-(Dipropionyloxymethyl)anthracene (110s)



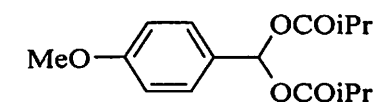
M.p. 141-142 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 1.10 (t, $J = 7.2$ Hz, 6H), 2.38 (m, 4H), 7.45 (t, $J = 7.2$ Hz, 2H), 7.58 (t, $J = 6.9$ Hz, 2H), 7.96 (d, $J = 8.4$ Hz, 2H), 8.47 (s, 1H), 8.72 (d, $J = 9.3$ Hz, 2H), 9.27 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 8.6, 27.3, 87.4, 124.7, 125.0, 125.5, 126.6, 128.9, 129.8, 130.4, 131.3, 172.4. IR(KBr): 3058, 2983, 2943, 1755, 1625, 1449, 1189, 1144, 978, 903, 738 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{21}\text{H}_{20}\text{O}_4$, 336.39, found 336. $\text{C}_{21}\text{H}_{20}\text{O}_4$ (336.39): calcd. C 74.98, H 5.99; found: C, 74.76, H, 6.13.

1,1-Diisobuteroxy-1-phenyl methane(91t)



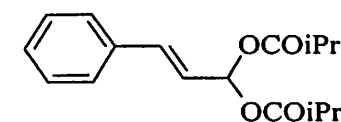
^1H NMR (400 MHz, CDCl_3): δ 1.18 (m, 12H), 2.60 (m, 2H), 7.39 (m, 3H), 7.49 (m, 2H), 7.68 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.0, 19.2, 34.3, 89.7, 126.8, 128.7, 129.7, 135.9, 174.9. IR (KBr): 3073, 3042, 2981, 2940, 2879, 1757, 1470, 1390, 1347, 1250, 1200, 1163, 1102, 963, 769 cm^{-1} .

1,1-Diisobutyryloxy-1-(4-methoxyphenyl)methane (97t)



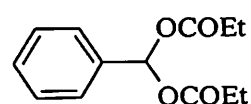
^1H NMR (300 MHz, CDCl_3): δ 1.19 (m, 12H), 2.58 (m, 2H), 3.80 (s, 3H), 6.91 (d, $J = 8.7$ Hz, 2H), 7.45 (d, $J = 8.4$, 2H), 7.64 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.4, 18.6, 33.8, 55.1, 89.5, 113.8, 127.9, 131.9, 160.4, 174.8. IR(KBr): 2981, 2940, 2884, 1762, 1624, 1516, 1470, 1255, 1158, 1035, 963, 834 cm^{-1} . $\text{C}_{16}\text{H}_{22}\text{O}_5$ (294.35): calcd. C 65.29, H 7.53; found: C, 65.39, H, 7.69.

1,1-Diisobutyryloxy-3-phenylprop-2-ene (102t)



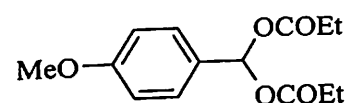
^1H NMR (300 MHz, CDCl_3): δ 2.20 (s, 6H), 7.80 (t, $J = 8.2$ Hz), 7.60 (s, 1H), 7.65 (m, 1H), 7.95 (d, $J = 8.2$ Hz). ^{13}C NMR (75 MHz, CDCl_3): δ 20.4, 113.8, 128.6, 128.8, 133.4, 136.8, 170.3, 192.5. IR (KBr): 3055, 2970, 1760, 1720, 1465, 1343, 1245, 1020, 972, 756 cm^{-1} .

1,1-Dipropionyloxy-1-phenyl methane (91s)



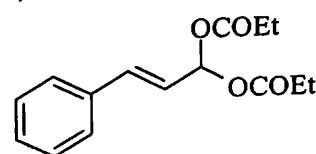
^1H NMR (400 MHz, CDCl_3): δ 1.15 (t, $J = 7.6$ Hz, 6H), 2.40 (m, 4H), 7.39 (m, 3H), 7.50 (m, 2H), 7.71 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 9.2, 27.8, 89.8, 126.8, 128.7, 129.8, 135.9, 172.3. IR (KBr): 3070, 3047, 2991, 2950, 284, 1762, 1459, 1353, 1280, 1194, 1143, 1079, 1044, 963, 704 cm^{-1} .

1,1-Propionyloxy-1-(4-methoxyphenyl)methane (97s)



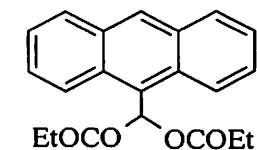
^1H NMR (400 MHz, CDCl_3): δ 1.14 (t, $J = 7.6$ Hz, 6H), 2.38 (m, 4H), 3.81 (s, 3H), 6.91 (d, $J = 8.8$ Hz, 2H), 7.45 (d, $J = 8.8$ Hz, 2H), 7.65 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 9.2, 27.8, 55.6, 89.8, 114.1, 128.1, 128.2, 160.6, 172.3. IR(KBr): 2986, 2950, 2843, 1762, 1614, 1516, 1470, 1363, 1260, 1220, 1168 cm^{-1} . $\text{C}_{14}\text{H}_{18}\text{O}_6$ (266.30): calcd. C 63.15, H 6.81; found: C, 63.21, H, 6.93.

1,1-Propionyloxy-3-phenylprop-2-ene (102s)



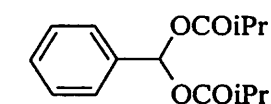
^1H NMR (300 MHz, CDCl_3): δ 1.18 (t, 6H), 2.41 (q, 4H), 6.23 (dd, $J_1 = 15.9$, $J_2 = 6.6$ Hz, 1H), 6.87 (d, $J = 16.2$ Hz, 1H), 7.30 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 8.7, 27.3, 89.6, 121.8, 126.9, 128.6, 128.7, 135.4, 172.1. IR (KBr): 2991, 2940, 1762, 1460, 1363, 1281, 1194, 1143, 958, 753 cm^{-1} . $\text{C}_{15}\text{H}_{18}\text{O}_4$ (262.31): calcd. C 68.69, H 6.92; found: C, 68.54, H, 7.04.

9-(Dipropionyloxymethyl)anthracene (110s)



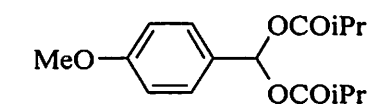
M.p. $141-142\text{ }^\circ\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 1.10 (t, $J = 7.2$ Hz, 6H), 2.38 (m, 4H), 7.45 (t, $J = 7.2$ Hz, 2H), 7.58 (t, $J = 6.9$ Hz, 2H), 7.96 (d, $J = 8.4$ Hz, 2H), 8.47 (s, 1H), 8.72 (d, $J = 9.3$ Hz, 2H), 9.27 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 8.6, 27.3, 87.4, 124.7, 125.0, 125.5, 126.6, 128.9, 129.8, 130.4, 131.3, 172.4. IR(KBr): 3058, 2983, 2943, 1755, 1625, 1449, 1189, 1144, 978, 903, 738 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{21}\text{H}_{20}\text{O}_4$, 336.39, found 336. $\text{C}_{21}\text{H}_{20}\text{O}_4$ (336.39): calcd. C 74.98, H 5.99; found: C, 74.76, H, 6.13.

1,1-Diisobuteroxy-1-phenyl methane(91t)



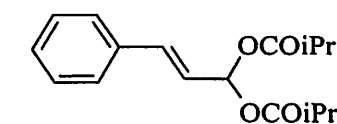
^1H NMR (400 MHz, CDCl_3): δ 1.18 (m, 12H), 2.60 (m, 2H), 7.39 (m, 3H), 7.49 (m, 2H), 7.68 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 19.0, 19.2, 34.3, 89.7, 126.8, 128.7, 129.7, 135.9, 174.9. IR (KBr): 3073, 3042, 2981, 2940, 2879, 1757, 1470, 1390, 1347, 1250, 1200, 1163, 1102, 963, 769 cm^{-1} .

1,1-Diisobutyryloxy-1-(4-methoxyphenyl)methane (97t)



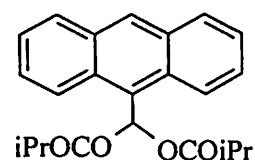
^1H NMR (300 MHz, CDCl_3): δ 1.19 (m, 12H), 2.58 (m, 2H), 3.80 (s, 3H), 6.91 (d, $J = 8.7$ Hz, 2H), 7.45 (d, $J = 8.4$, 2H), 7.64 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.4, 18.6, 33.8, 55.1, 89.5, 113.8, 127.9, 131.9, 160.4, 174.8. IR(KBr): 2981, 2940, 2884, 1762, 1624, 1516, 1470, 1255, 1158, 1035, 963, 834 cm^{-1} . $\text{C}_{16}\text{H}_{22}\text{O}_5$ (294.35): calcd. C 65.29, H 7.53; found: C, 65.39, H, 7.69.

1,1-Diisobutyryloxy-3-phenylprop-2-ene (102t)



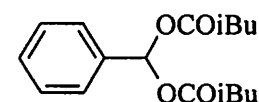
^1H NMR (300 MHz, CDCl_3): δ 1.21 (m, 12H), 2.56 (m, 2H), 6.22 (dd, $J = 6.3$ and 15.9 Hz, 1H), 6.83 (d, $J = 15.9$ Hz, 1H), 7.29 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.2, 18.5, 18.6, 18.7, 33.7, 33.8, 35.0, 50.4, 89.5, 121.9, 127.0, 128.6, 128.7, 129.1, 135.2, 174.8. IR (KBr): 3032, 2976, 2935, 2879, 1757, 1470, 1245, 1205, 1158, 1096, 958 cm^{-1} . $\text{C}_{17}\text{H}_{22}\text{O}_4$ (290.36): calcd. C 70.32, H 7.64; found: C, 69.99, H, 7.79.

1,1-Diisobutyryloxy-9-methylantracene (110t)



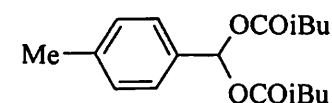
M.p. 132-134 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 1.09 (d, $J = 6.9$ Hz, 6H), 1.21 (d, $J = 6.9$, 6H), 2.61 (m, 2H), 7.47 (t, $J = 7.2$ Hz, 2H), 7.58 (t, $J = 8.4$ Hz, 2H), 8.0 (d, $J = 8.4$ Hz, 2H), 8.51 (s, 1H), 8.72 (d, $J = 9$ Hz, 2H), 9.20 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.4, 18.7, 33.9, 49.9, 87.6, 124.7, 125.0, 125.6, 126.5, 128.9, 129.9, 130.4, 131.4, 175.0. IR (KBr): 2976, 2930, 2879, 1757, 1470, 1388, 1250, 1194, 1158, 1050, 974, 738 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{23}\text{H}_{24}\text{O}_4$, 364.45, found 364. $\text{C}_{23}\text{H}_{24}\text{O}_4$ (364.45): calcd. C 75.80, H 6.64; found: C, 76.01, H, 6.71.

1,1-Dipivaloyloxy-1-(phenyl)methane (91u)



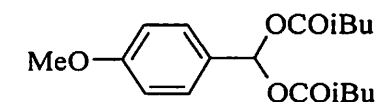
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 6.95-7.60 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.0, 38.5, 89.5, 113.7, 122, 127.7, 128.0, 176.0. IR (KBr): 2981, 2935, 2873, 1757, 1481, 1281, 1168, 1112, 968 cm^{-1} .

1,1-Dipivaloyloxy-1-(4-methyl-phenyl) methane (94u)



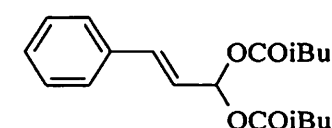
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 2.36 (s, 3H), 7.19 (d, $J = 8$ Hz, 2H), 7.40 (d, $J = 8$ Hz, 2H), 7.62 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.7, 27.3, 89.8, 126.5, 129.3, 133.8, 139.5, 176.3. IR (KBr): 2976, 2935, 2874, 1754, 1485, 1399, 1368, 1282, 1165, 1115, 1028, 968, 821, cm^{-1} .

1,1-Dipivaloyloxy-1-(4-methoxyphenyl)methane (97u)



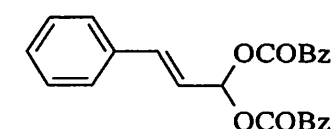
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 3.81 (s, 3H), 6.90 (d, $J = 8.8$ Hz, 2H), 7.41 (d, $J = 8.8$ Hz, 2H), 7.60 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.0, 38.9, 55.3, 89.5, 113.7, 127.7, 128.0, 160.1, 176.0. IR (KBr): 2981, 2935, 2873, 1757, 1481, 1281, 1168, 1112, 968 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{18}\text{H}_{26}\text{O}_5$, 322.40, found 322. $\text{C}_{18}\text{H}_{26}\text{O}_5$ (322.40): calcd. C 67.06, H 8.13; found: C, 66.88, H, 8.28.

1,1-Dipivaloyloxy-3-(phenyl)prop-2-ene (102u)



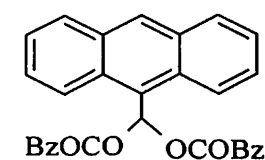
^1H NMR (300 MHz, CDCl_3): δ 1.21 (s, 18H), 6.22 (dd, $J_1 = 16$, $J_2 = 6.0$ Hz, 1H), 6.84 (d, $J = 15.6$ Hz, 1H), 7.30 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 27.3, 39.2, 89.6, 122.3, 127.2, 128.8, 128.9, 135.2, 135.5, 176.2.

1,1-Dibenzoyloxy-3-phenylprop-2-ene (102v)



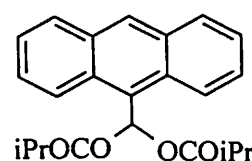
M.p. 145-147 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 6.49 (dd, $J_1 = 6.3$, $J_2 = 16.2$ Hz, 1H), 7.05 (d, $J = 16.2$, 1H), 7.32-7.55 (m, 11H), 7.85 (d, $J = 6.3$ Hz, 1H), 8.11 (d, $J = 7.5$ Hz, 4H). ^{13}C NMR (75 MHz, CDCl_3): δ 90.7, 121.9, 127.1, 128.4, 128.7, 128.8, 129.2, 130.0, 133.5, 135.8, 164.4. IR (KBr): 3073, 3027, 2981, 1737, 1603, 1455, 1281, 1250, 1148, 1061, 958, 702 cm^{-1} . Mass (FAB) (M^+) calcd. for $\text{C}_{23}\text{H}_{18}\text{O}_4$ 358.40, found 358.0. $\text{C}_{23}\text{H}_{18}\text{O}_4$ (358.40): calcd. C 77.08, H 5.06; found: C, 76.88, H, 5.28.

1,1-Dibenzoyloxy-9-methylantracene (110v)



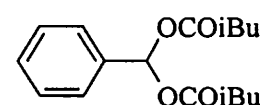
^1H NMR (300 MHz, CDCl_3): δ 1.21 (m, 12H), 2.56 (m, 2H), 6.22 (dd, $J = 6.3$ and 15.9 Hz, 1H), 6.83 (d, $J = 15.9$ Hz, 1H), 7.29 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.2, 18.5, 18.6, 18.7, 33.7, 33.8, 35.0, 50.4, 89.5, 121.9, 127.0, 128.6, 128.7, 129.1, 135.2, 174.8. IR (KBr): 3032, 2976, 2935, 2879, 1757, 1470, 1245, 1205, 1158, 1096, 958 cm^{-1} . $\text{C}_{17}\text{H}_{22}\text{O}_4$ (290.36): calcd. C 70.32, H 7.64; found: C, 69.99, H, 7.79.

1,1-Diisobutyryloxy-9-methylanthracene (110t)



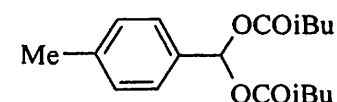
M.p. $132\text{--}134\text{ }^\circ\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 1.09 (d, $J = 6.9$ Hz, 6H), 1.21 (d, $J = 6.9$ Hz, 6H), 2.61 (m, 2H), 7.47 (t, $J = 7.2$ Hz, 2H), 7.58 (t, $J = 8.4$ Hz, 2H), 8.0 (d, $J = 8.4$ Hz, 2H), 8.51 (s, 1H), 8.72 (d, $J = 9$ Hz, 2H), 9.20 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.4, 18.7, 33.9, 49.9, 87.6, 124.7, 125.0, 125.6, 126.5, 128.9, 129.9, 130.4, 131.4, 175.0. IR (KBr): 2976, 2930, 2879, 1757, 1470, 1388, 1250, 1194, 1158, 1050, 974, 738 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{23}\text{H}_{24}\text{O}_4$, 364.45, found 364. $\text{C}_{23}\text{H}_{24}\text{O}_4$ (364.45): calcd. C 75.80, H 6.64; found: C, 76.01, H, 6.71.

1,1-Dipivaloyloxy-1-(phenyl)methane (91u)



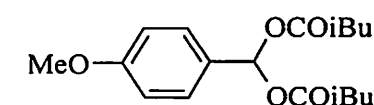
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 6.95–7.60 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.0, 38.5, 89.5, 113.7, 122, 127.7, 128.0, 176.0. IR (KBr): 2981, 2935, 2873, 1757, 1481, 1281, 1168, 1112, 968 cm^{-1} .

1,1-Dipivaloyloxy-1-(4-methyl-phenyl) methane (94u)



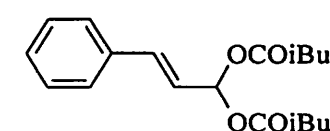
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 2.36 (s, 3H), 7.19 (d, $J = 8$ Hz, 2H), 7.40 (d, $J = 8$ Hz, 2H), 7.62 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.7, 27.3, 89.8, 126.5, 129.3, 133.8, 139.5, 176.3. IR (KBr): 2976, 2935, 2874, 1754, 1485, 1399, 1368, 1282, 1165, 1115, 1028, 968, 821 cm^{-1} .

1,1-Dipivaloyloxy-1-(4-methoxyphenyl)methane (97u)



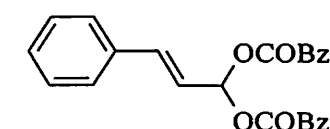
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 3.81 (s, 3H), 6.90 (d, $J = 8.8$ Hz, 2H), 7.41 (d, $J = 8.8$ Hz, 2H), 7.60 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.0, 38.9, 55.3, 89.5, 113.7, 127.7, 128.0, 160.1, 176.0. IR (KBr): 2981, 2935, 2873, 1757, 1481, 1281, 1168, 1112, 968 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{18}\text{H}_{26}\text{O}_5$, 322.40, found 322. $\text{C}_{18}\text{H}_{26}\text{O}_5$ (322.40): calcd. C 67.06, H 8.13; found: C, 66.88, H, 8.28.

1,1-Dipivaloyloxy-3-(phenyl)prop-2-ene (102u)



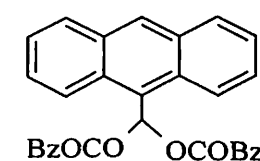
^1H NMR (300 MHz, CDCl_3): δ 1.21 (s, 18H), 6.22 (dd, $J_1 = 16$, $J_2 = 6.0$ Hz, 1H), 6.84 (d, $J = 15.6$ Hz, 1H), 7.30 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 27.3, 39.2, 89.6, 122.3, 127.2, 128.8, 128.9, 135.2, 135.5, 176.2.

1,1-Dibenzoyloxy-3-phenylprop-2-ene (102v)



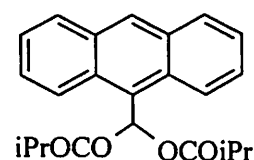
M.p. $145\text{--}147\text{ }^\circ\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 6.49 (dd, $J_1 = 6.3$, $J_2 = 16.2$ Hz, 1H), 7.05 (d, $J = 16.2$, 1H), 7.32–7.55 (m, 11H), 7.85 (d, $J = 6.3$ Hz, 1H), 8.11 (d, $J = 7.5$ Hz, 4H). ^{13}C NMR (75 MHz, CDCl_3): δ 90.7, 121.9, 127.1, 128.4, 128.7, 128.8, 129.2, 130.0, 133.5, 135.8, 164.4. IR (KBr): 3073, 3027, 2981, 1737, 1603, 1455, 1281, 1250, 1148, 1061, 958, 702 cm^{-1} . Mass (FAB) (M^+) calcd. for $\text{C}_{23}\text{H}_{18}\text{O}_4$ 358.40, found 358.0. $\text{C}_{23}\text{H}_{18}\text{O}_4$ (358.40): calcd. C 77.08, H 5.06; found: C, 76.88, H, 5.28.

1,1-Dibenzoyloxy-9-methylanthracene (110v)



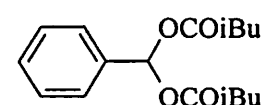
^1H NMR (300 MHz, CDCl_3): δ 1.21 (m, 12H), 2.56 (m, 2H), 6.22 (dd, $J = 6.3$ and 15.9 Hz, 1H), 6.83 (d, $J = 15.9$ Hz, 1H), 7.29 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.2, 18.5, 18.6, 18.7, 33.7, 33.8, 35.0, 50.4, 89.5, 121.9, 127.0, 128.6, 128.7, 129.1, 135.2, 174.8. IR (KBr): 3032, 2976, 2935, 2879, 1757, 1470, 1245, 1205, 1158, 1096, 958 cm^{-1} . $\text{C}_{17}\text{H}_{22}\text{O}_4$ (290.36): calcd. C 70.32, H 7.64; found: C, 69.99, H, 7.79.

1,1-Diisobutyryloxy-9-methylanthracene (110t)



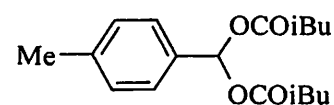
M.p. 132-134 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 1.09 (d, $J = 6.9$ Hz, 6H), 1.21 (d, $J = 6.9$, 6H), 2.61 (m, 2H), 7.47 (t, $J = 7.2$ Hz, 2H), 7.58 (t, $J = 8.4$ Hz, 2H), 8.0 (d, $J = 8.4$ Hz, 2H), 8.51 (s, 1H), 8.72 (d, $J = 9$ Hz, 2H), 9.20 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 18.4, 18.7, 33.9, 49.9, 87.6, 124.7, 125.0, 125.6, 126.5, 128.9, 129.9, 130.4, 131.4, 175.0. IR (KBr): 2976, 2930, 2879, 1757, 1470, 1388, 1250, 1194, 1158, 1050, 974, 738 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{23}\text{H}_{24}\text{O}_4$, 364.45, found 364. $\text{C}_{23}\text{H}_{24}\text{O}_4$ (364.45): calcd. C 75.80, H 6.64; found: C, 76.01, H, 6.71.

1,1-Dipivaloyloxy-1-(phenyl)methane (91u)



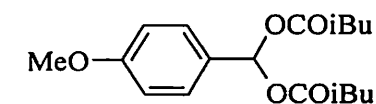
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 6.95-7.60 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.0, 38.5, 89.5, 113.7, 122, 127.7, 128.0, 176.0. IR (KBr): 2981, 2935, 2873, 1757, 1481, 1281, 1168, 1112, 968 cm^{-1} .

1,1-Dipivaloyloxy-1-(4-methyl-phenyl) methane (94u)



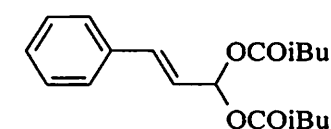
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 2.36 (s, 3H), 7.19 (d, $J = 8$ Hz, 2H), 7.40 (d, $J = 8$ Hz, 2H), 7.62 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.7, 27.3, 89.8, 126.5, 129.3, 133.8, 139.5, 176.3. IR (KBr): 2976, 2935, 2874, 1754, 1485, 1399, 1368, 1282, 1165, 1115, 1028, 968, 821, cm^{-1} .

1,1-Dipivaloyloxy-1-(4-methoxyphenyl)methane (97u)



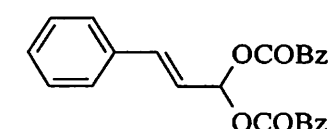
^1H NMR (400 MHz, CDCl_3): δ 1.21 (s, 18H), 3.81 (s, 3H), 6.90 (d, $J = 8.8$ Hz, 2H), 7.41 (d, $J = 8.8$ Hz, 2H), 7.60 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 27.0, 38.9, 55.3, 89.5, 113.7, 127.7, 128.0, 160.1, 176.0. IR (KBr): 2981, 2935, 2873, 1757, 1481, 1281, 1168, 1112, 968 cm^{-1} . Mass (FAB): (M^+) calcd. for $\text{C}_{18}\text{H}_{26}\text{O}_5$, 322.40, found 322. $\text{C}_{18}\text{H}_{26}\text{O}_5$ (322.40): calcd. C 67.06, H 8.13; found: C, 66.88, H, 8.28.

1,1-Dipivaloyloxy-3-(phenyl)prop-2-ene (102u)



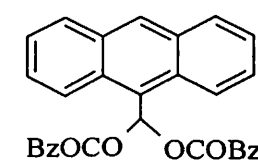
^1H NMR (300 MHz, CDCl_3): δ 1.21 (s, 18H), 6.22 (dd, $J_1 = 16$, $J_2 = 6.0$ Hz, 1H), 6.84 (d, $J = 15.6$ Hz, 1H), 7.30 (m, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 27.3, 39.2, 89.6, 122.3, 127.2, 128.8, 128.9, 135.2, 135.5, 176.2.

1,1-Dibenzoyloxy-3-phenylprop-2-ene (102v)



M.p. 145-147 $^{\circ}\text{C}$. ^1H NMR (300 MHz, CDCl_3): δ 6.49 (dd, $J_1 = 6.3$, $J_2 = 16.2$ Hz, 1H), 7.05 (d, $J = 16.2$, 1H), 7.32-7.55 (m, 11H), 7.85 (d, $J = 6.3$ Hz, 1H), 8.11 (d, $J = 7.5$ Hz, 4H). ^{13}C NMR (75 MHz, CDCl_3): δ 90.7, 121.9, 127.1, 128.4, 128.7, 128.8, 129.2, 130.0, 133.5, 135.8, 164.4. IR (KBr): 3073, 3027, 2981, 1737, 1603, 1455, 1281, 1250, 1148, 1061, 958, 702 cm^{-1} . Mass (FAB) (M^+) calcd. for $\text{C}_{23}\text{H}_{18}\text{O}_4$, 358.40, found 358.0. $\text{C}_{23}\text{H}_{18}\text{O}_4$ (358.40): calcd. C 77.08, H 5.06; found: C, 76.88, H, 5.28.

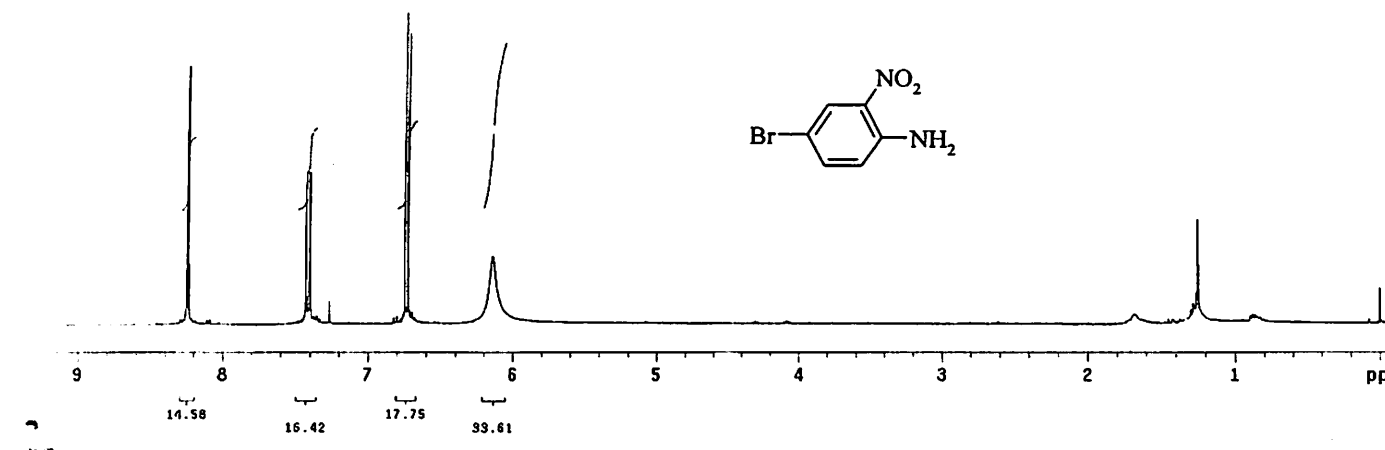
1,1-Dibenzoyloxy-9-methylanthracene (110v)



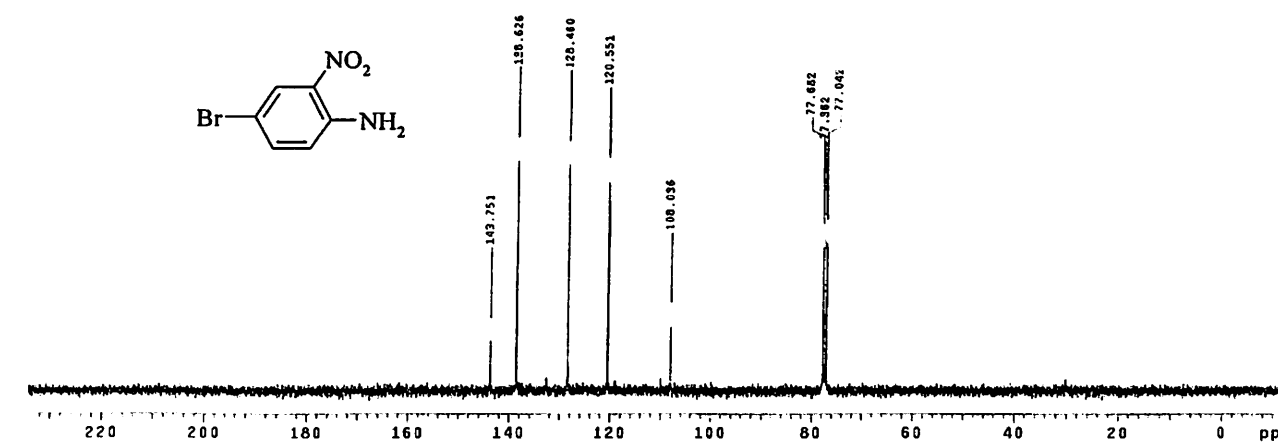
M.p. 171.5-173 °C. ^1H NMR (300 MHz, CDCl_3): δ 7.32 (m, 4H), 7.46 (m, 4H), 7.67 (t, $J = 8.4$ Hz, 2H), 7.98 (d, $J = 8.7$ Hz, 2H), 8.06 (d, $J = 7.8$ Hz, 3H), 8.48 (s, 1H), 9.02 (d, 2H), 9.82 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 88.3, 124.6, 125.1, 125.4, 126.9, 128.4, 129.1, 130.0, 130.6, 131.4, 133.5, 164.5. IR (KBr): 3063, 3007, 1747, 1726, 1286, 1250, 1081, 1061, 963 cm^{-1} . Mass (FAB) (M^+) calculated for $\text{C}_{29}\text{H}_{20}\text{O}_4$, 432.48, found 432.0 $\text{C}_{29}\text{H}_{20}\text{O}_4$ (432.48): calcd. C 80.54, H 4.66; found: C, 80.42, H, 4.78.

IID.5. Spectra of Selected Compounds

4-Bromo-2-nitro-aniline (42n) ^1H NMR (400 MHz, CDCl_3):



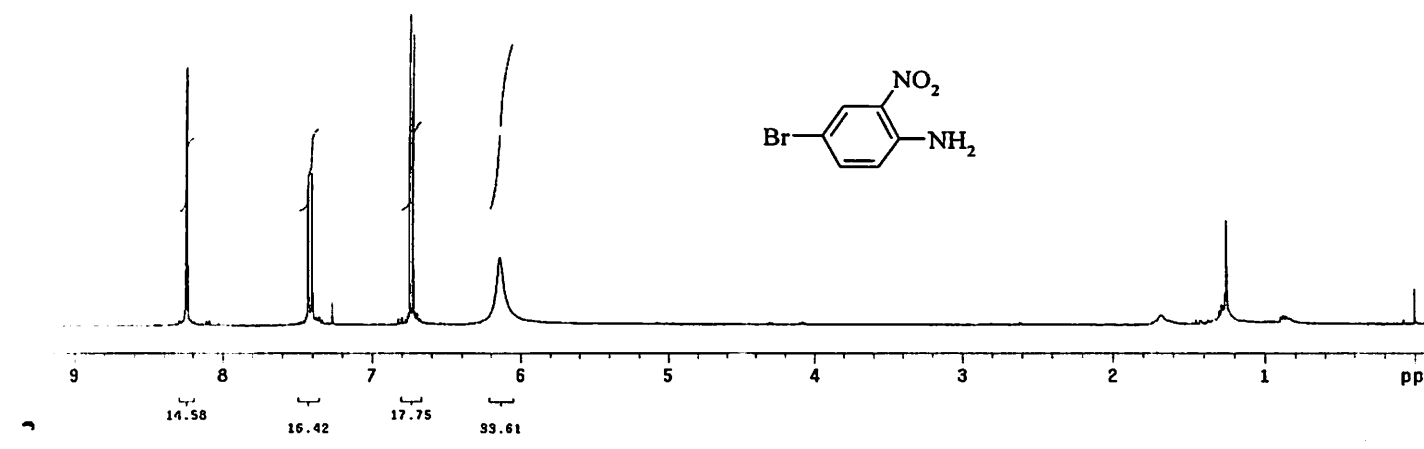
4-Bromo-2-nitro-aniline (42n) ^{13}C NMR (100 MHz, CDCl_3):



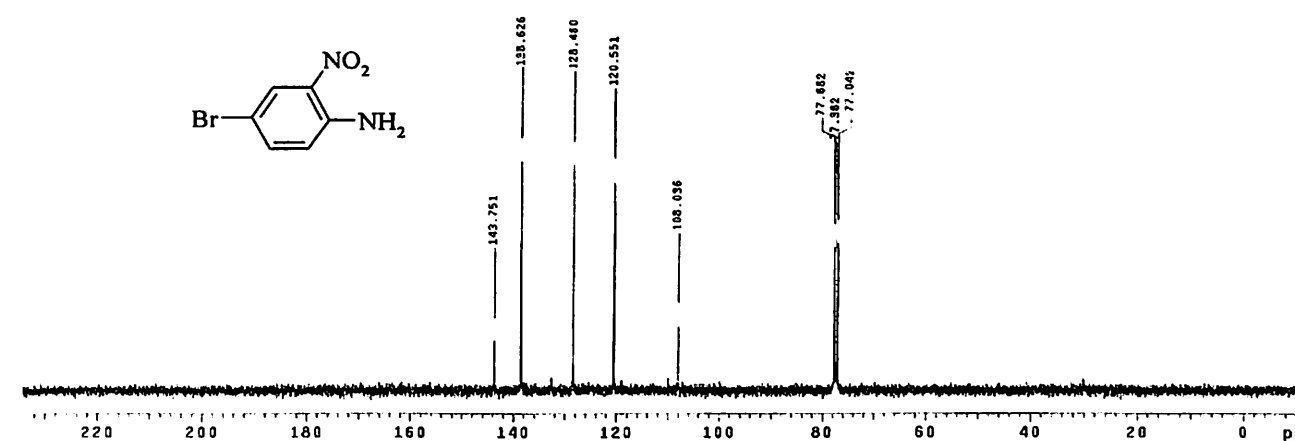
M.p. 171.5-173 °C. ^1H NMR (300 MHz, CDCl_3): δ 7.32 (m, 4H), 7.46 (m, 4H), 7.67 (t, $J = 8.4$ Hz, 2H), 7.98 (d, $J = 8.7$ Hz, 2H), 8.06 (d, $J = 7.8$ Hz, 3H), 8.48 (s, 1H), 9.02 (d, 2H), 9.82 (s, 1H). ^{13}C NMR (75 MHz, CDCl_3): δ 88.3, 124.6, 125.1, 125.4, 126.9, 128.4, 129.1, 130.0, 130.6, 131.4, 133.5, 164.5. IR (KBr): 3063, 3007, 1747, 1726, 1286, 1250, 1081, 1061, 963 cm^{-1} . Mass (FAB) (M^+) calculated for $\text{C}_{29}\text{H}_{20}\text{O}_4$, 432.48, found 432.0 $\text{C}_{29}\text{H}_{20}\text{O}_4$ (432.48): calcd. C 80.54, H 4.66; found: C, 80.42, H, 4.78.

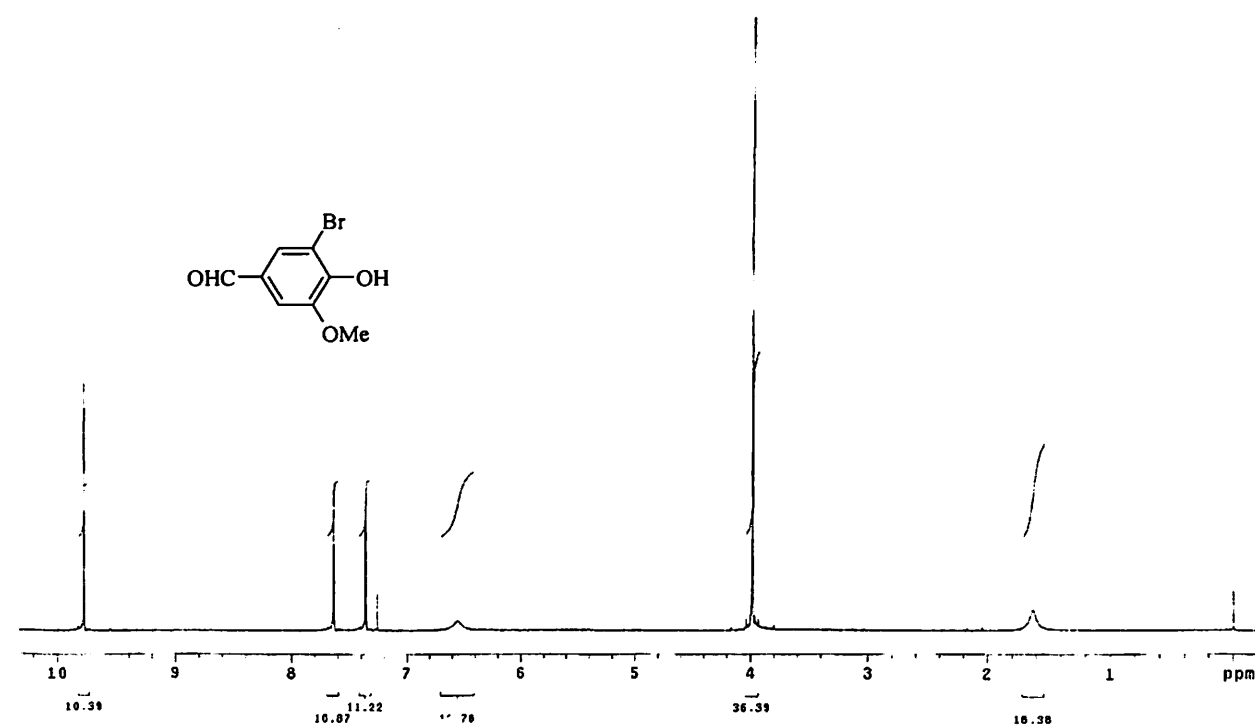
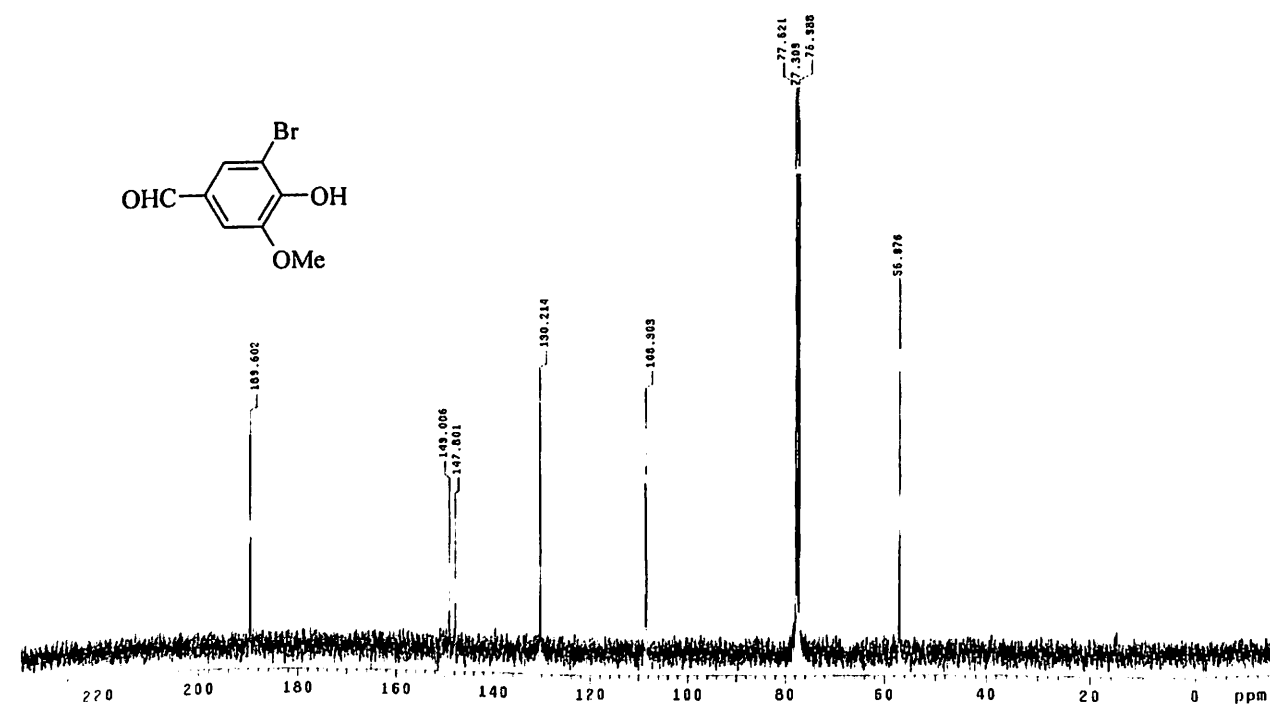
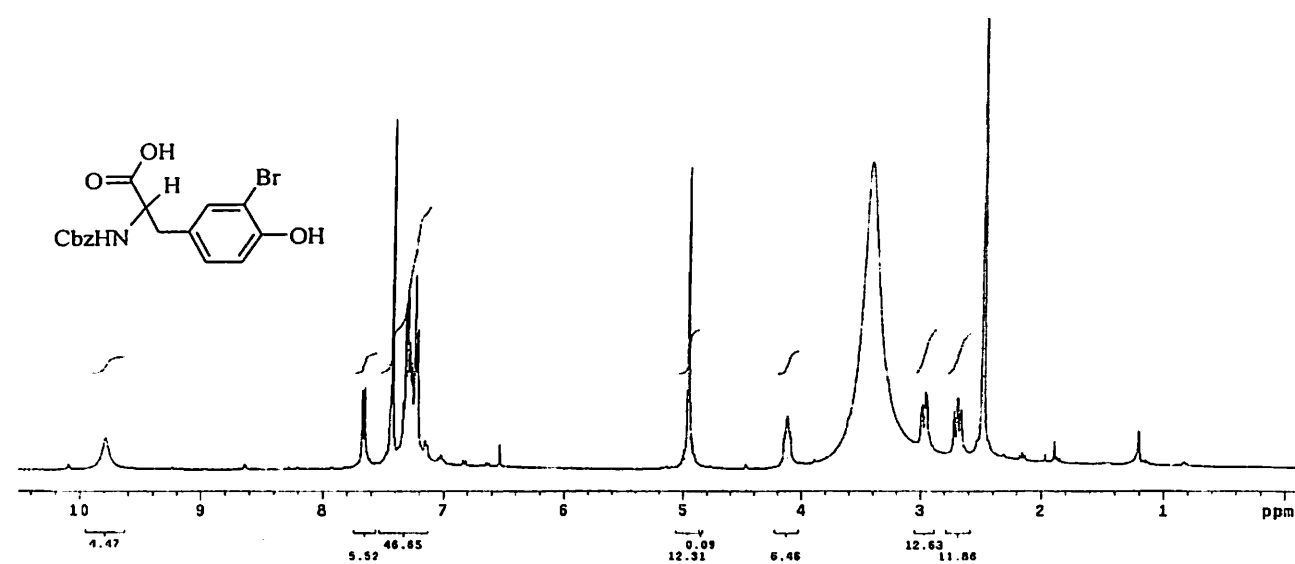
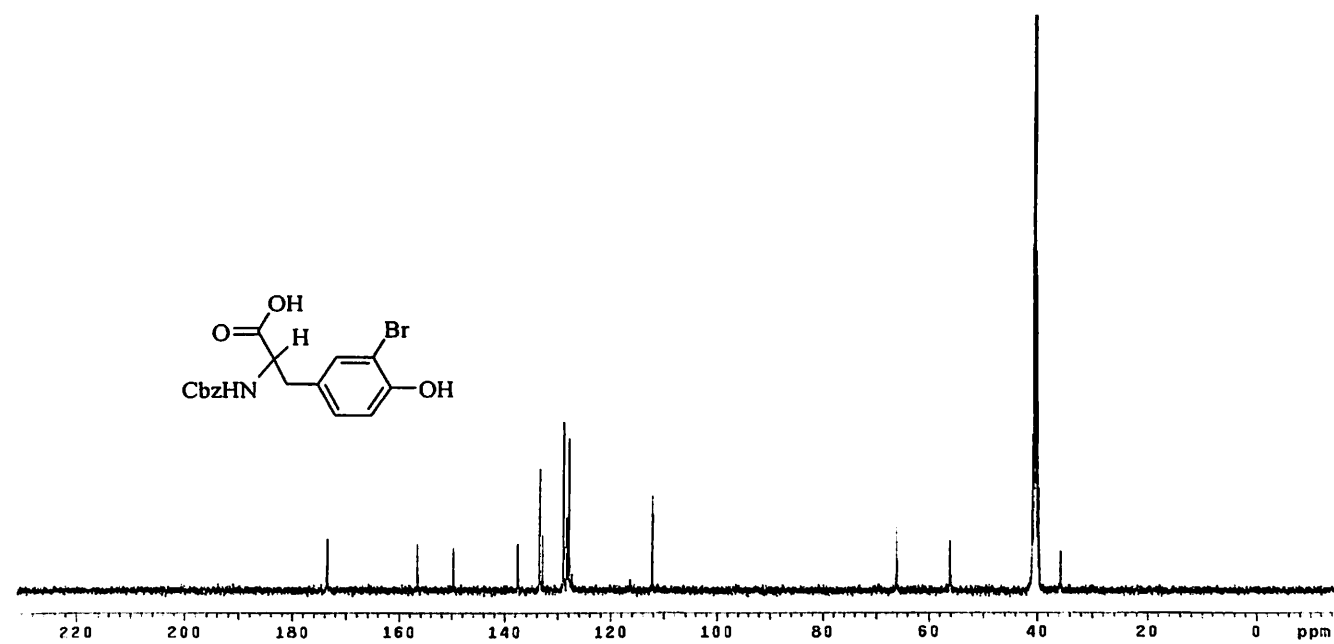
IID.5. Spectra of Selected Compounds

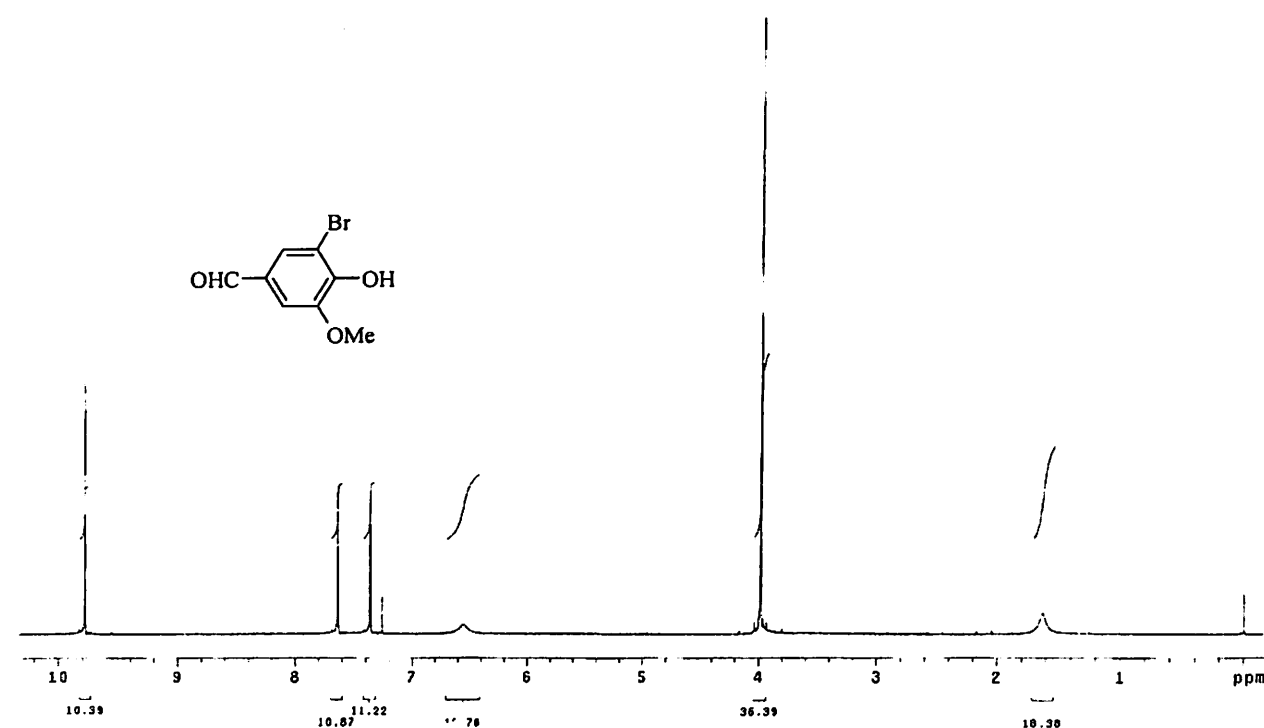
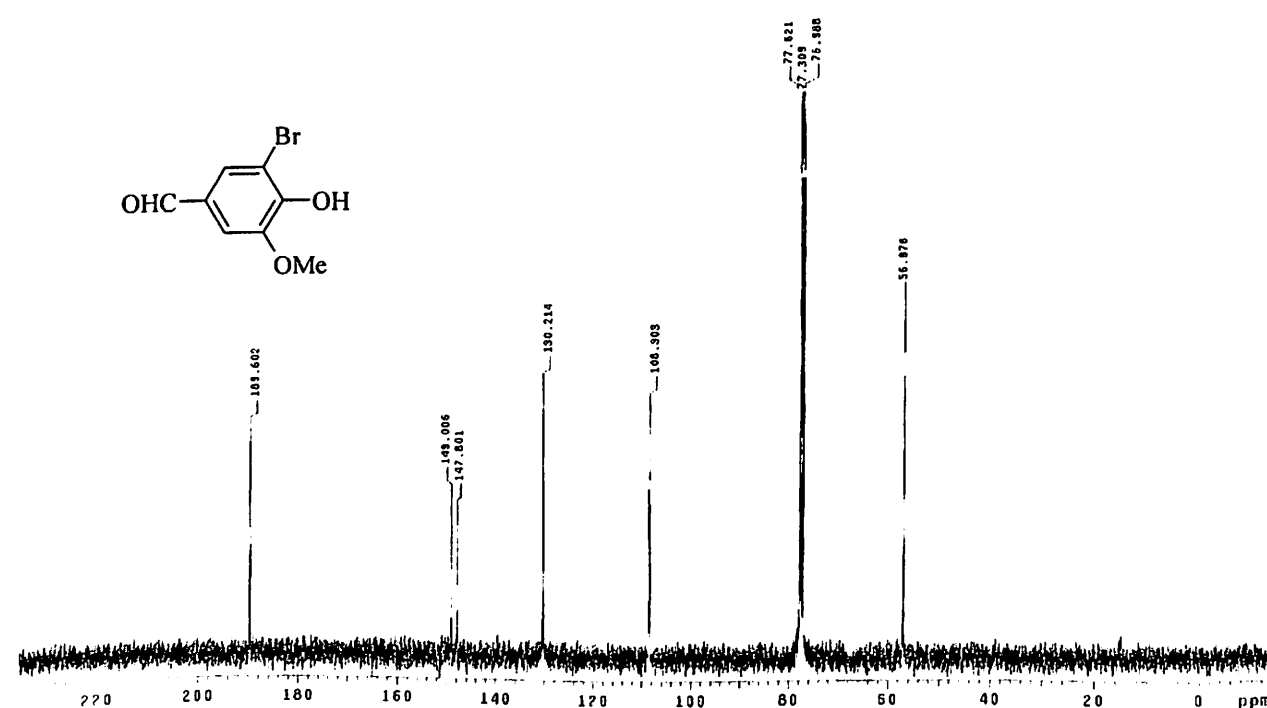
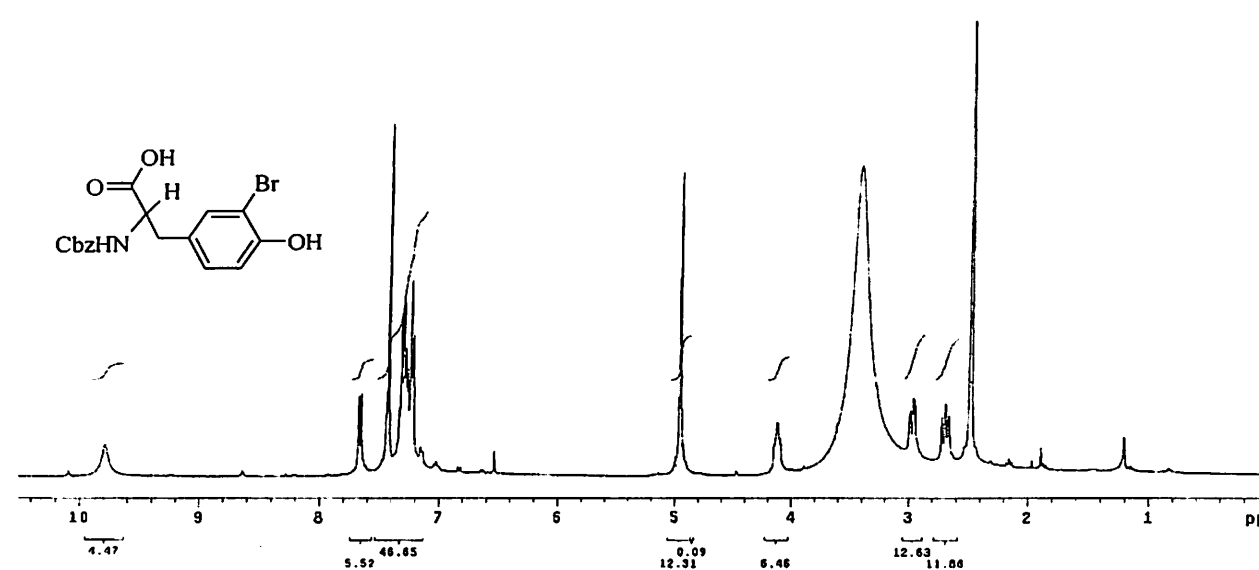
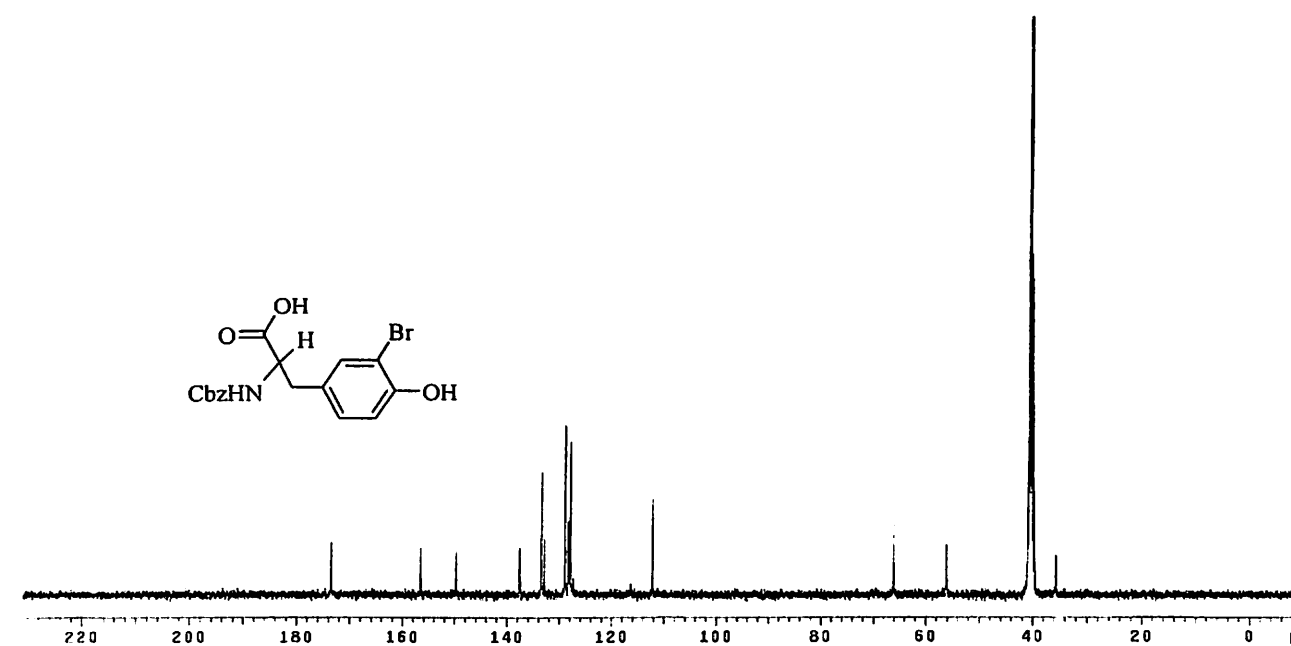
4-Bromo-2-nitro-aniline (42n) ^1H NMR (400 MHz, CDCl_3):

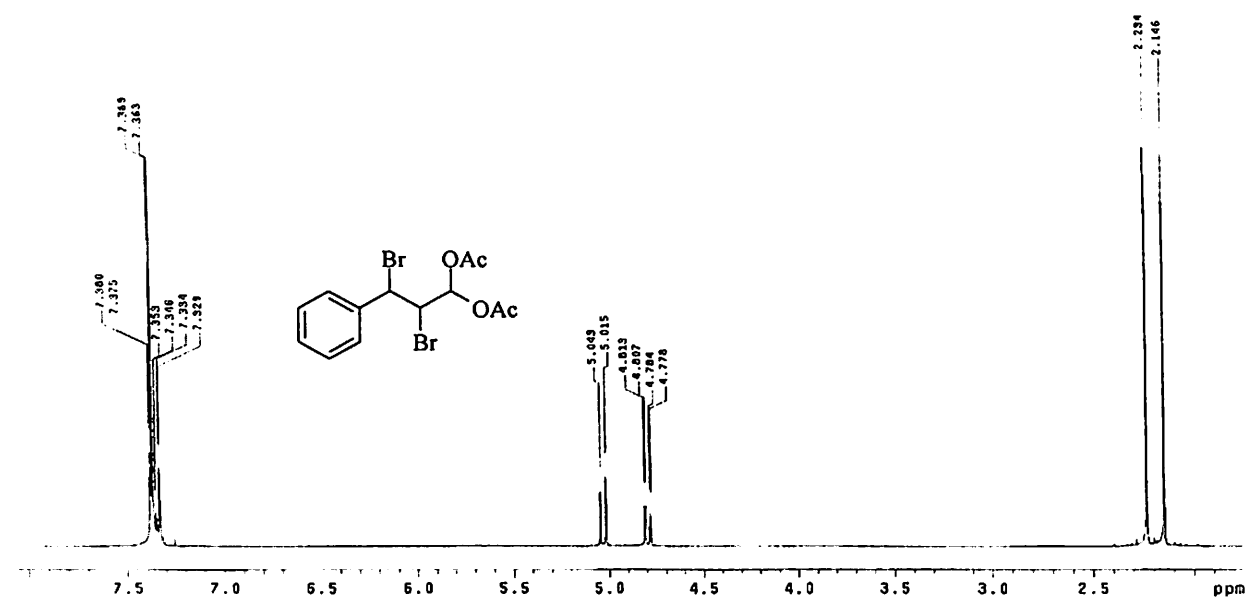
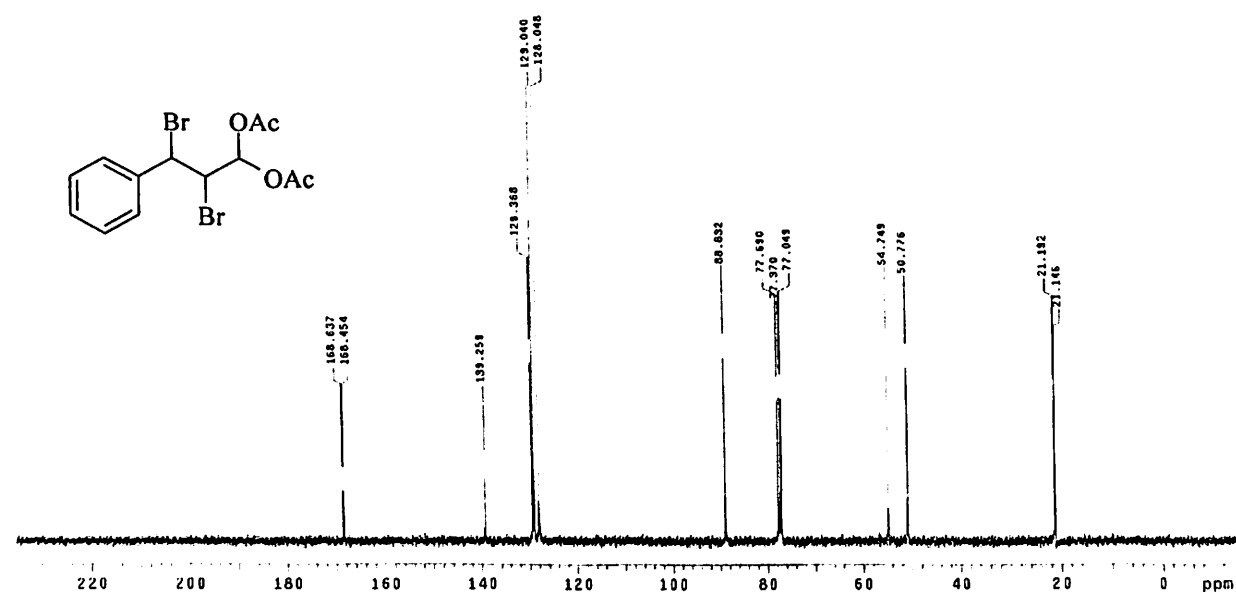
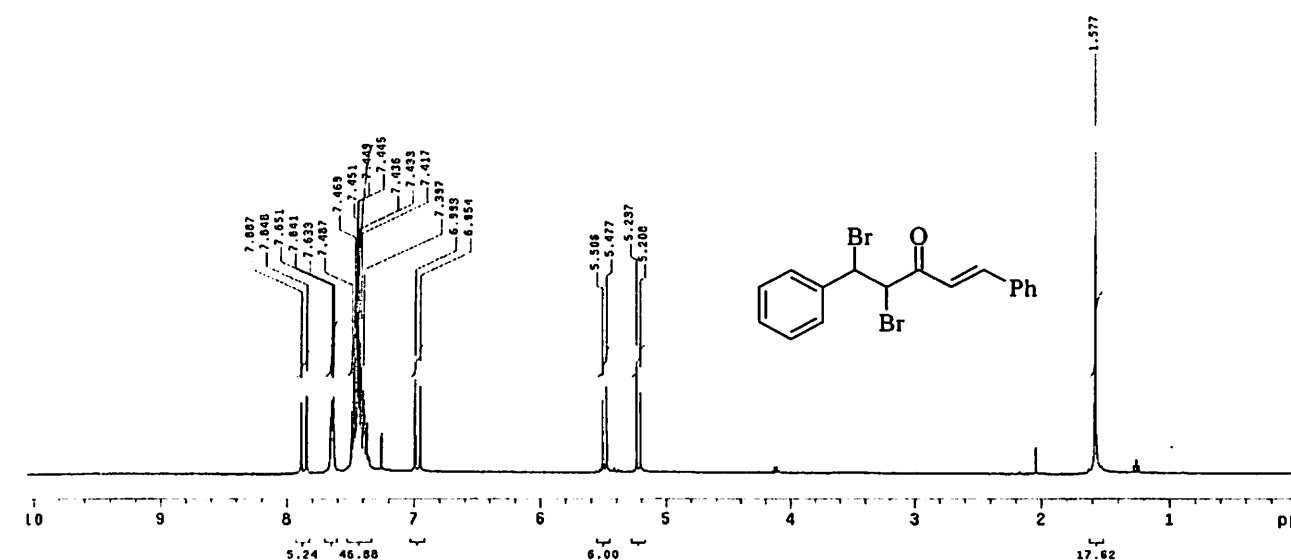
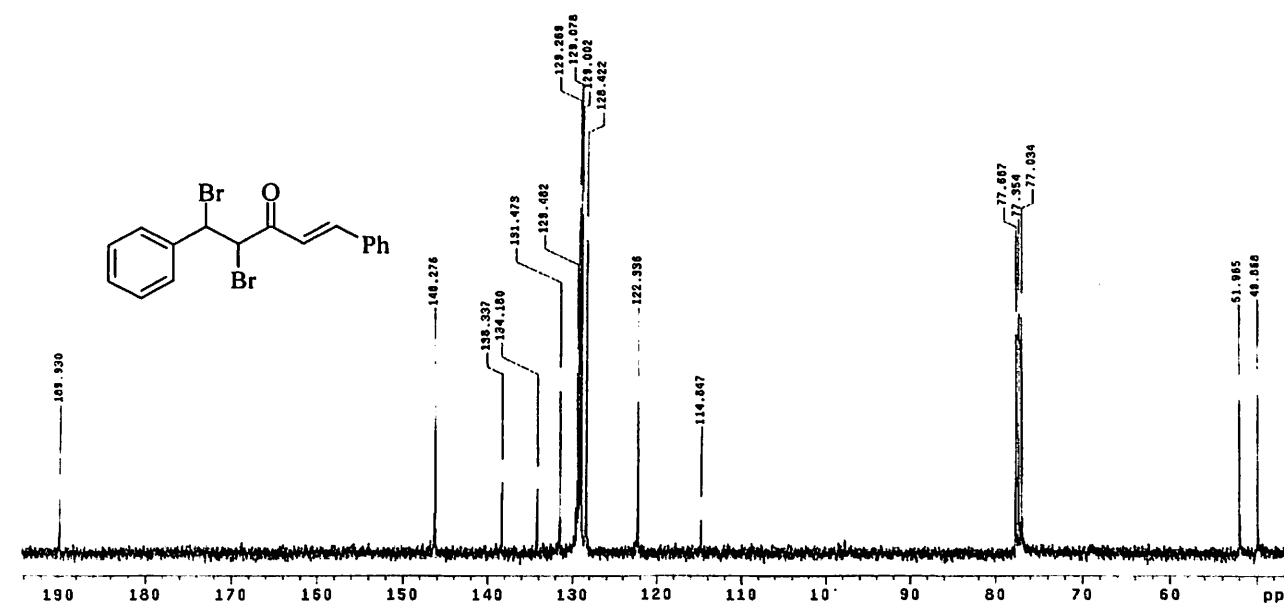


4-Bromo-2-nitro-aniline (42n) ^{13}C NMR (100 MHz, CDCl_3):



3-Bromo-4-hydroxy-5-methoxy-benzaldehyde (46n) ^1H NMR (400 MHz, CDCl_3):3-Bromo-4-hydroxy-5-methoxy-benzaldehyde (46n) ^{13}C NMR (100 MHz, CDCl_3):Bromo-N-carbobenzoxy-tyrosine (47n) ^1H NMR (400 MHz, CDCl_3):Bromo-N-carbobenzoxy-tyrosine (47n) ^{13}C NMR (100 MHz, CDCl_3):

3-Bromo-4-hydroxy-5-methoxy-benzaldehyde(46n) ^1H NMR (400 MHz, CDCl_3):3-Bromo-4-hydroxy-5-methoxy-benzaldehyde (46n) ^{13}C NMR (100 MHz, CDCl_3):Bromo-N-carbobenzoxy-tyrosine (47n) ^1H NMR (400 MHz, CDCl_3):Bromo-N-carbobenzoxy-tyrosine (47n) ^{13}C NMR (100 MHz, CDCl_3):

1,1-Diacetoxy-2,3-dibromo-3-phenyl-propane (56n) ^1H NMR (400 MHz, CDCl_3):1,1-Diacetoxy-2,3-dibromo-3-phenyl-propane (56n) ^{13}C NMR (100 MHz, CDCl_3):4,5-Dibromo-1,5-diphenyl-pent-1-en-3-one (57n) ^1H NMR (400 MHz, CDCl_3):4,5-Dibromo-1,5-diphenyl-pent-1-en-3-one (57n) ^{13}C NMR (100 MHz, CDCl_3):

Chemical structure: CC(=O)OC(Br)C(Br)Cc1ccccc1

¹H NMR spectrum (CDCl₃) data:

Chemical Shift (ppm)	Integration
7.365, 7.345, 7.325, 7.305, 7.285, 7.265	1.000
4.776, 4.764, 4.807, 4.815, 4.843	5.043
2.334, 2.346	2.000

Chemical structure: CC(=O)OC(Br)C(Br)Cc1ccccc1

¹³C NMR spectrum (ppm):

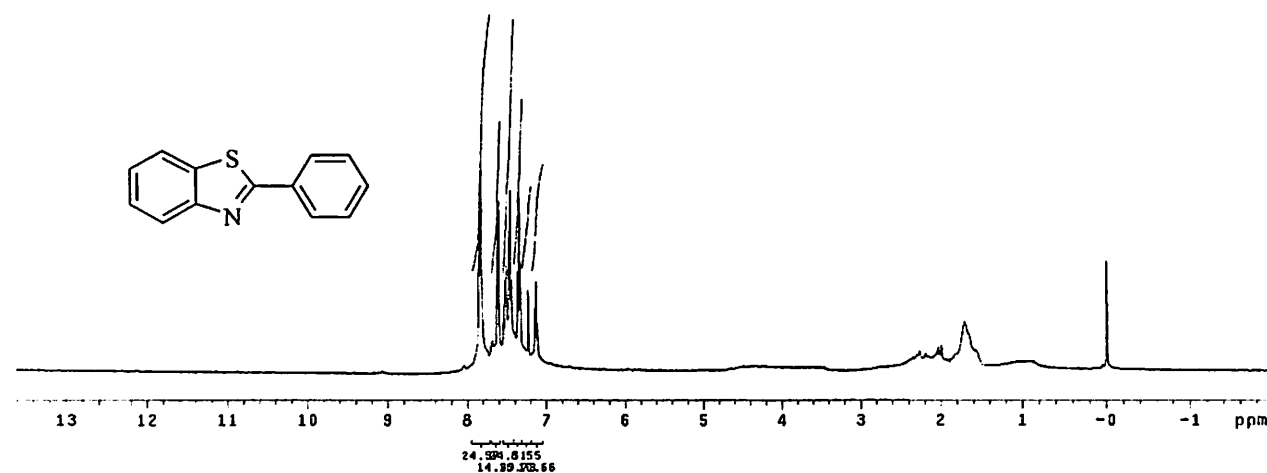
- 188.637
- 186.654
- 133.259
- 129.368
- 129.046
- 128.046
- 80.832
- 77.690
- 77.370
- 77.049
- 54.749
- 50.776
- 21.192
- 21.146

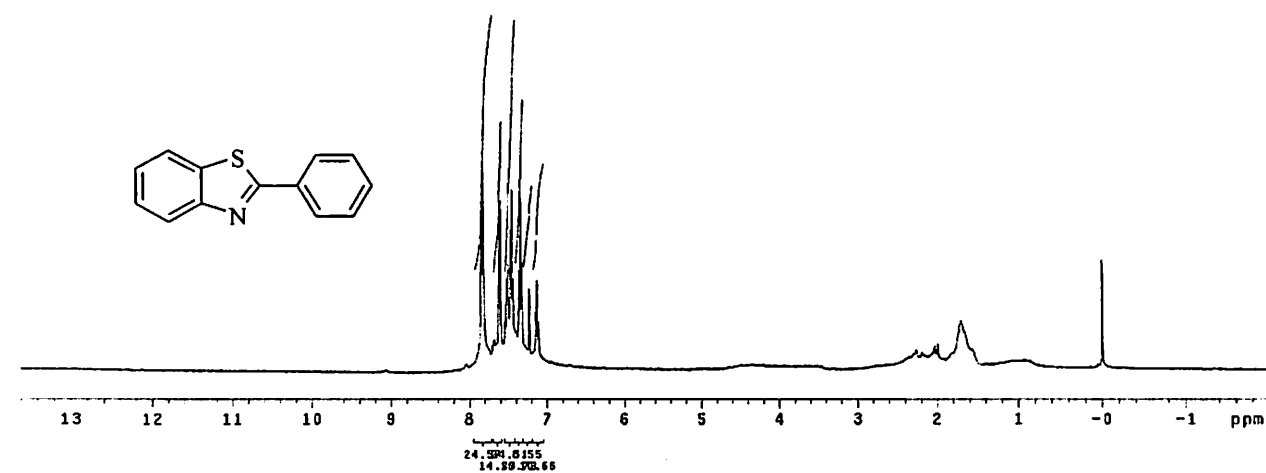
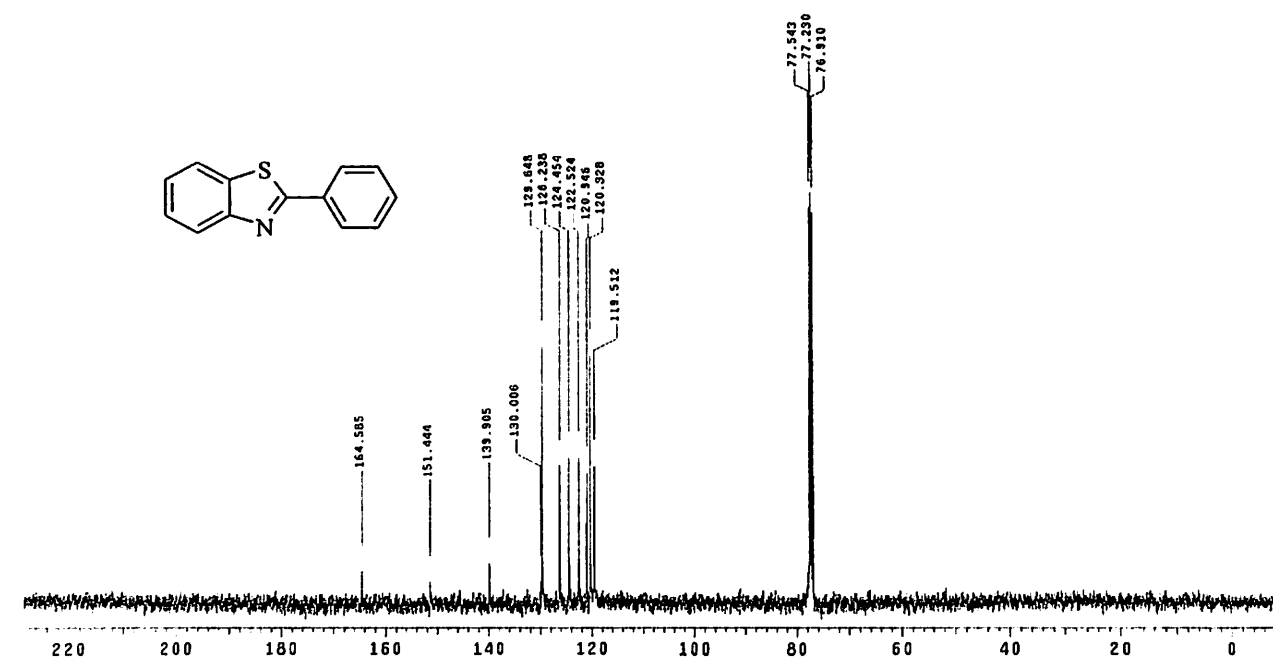
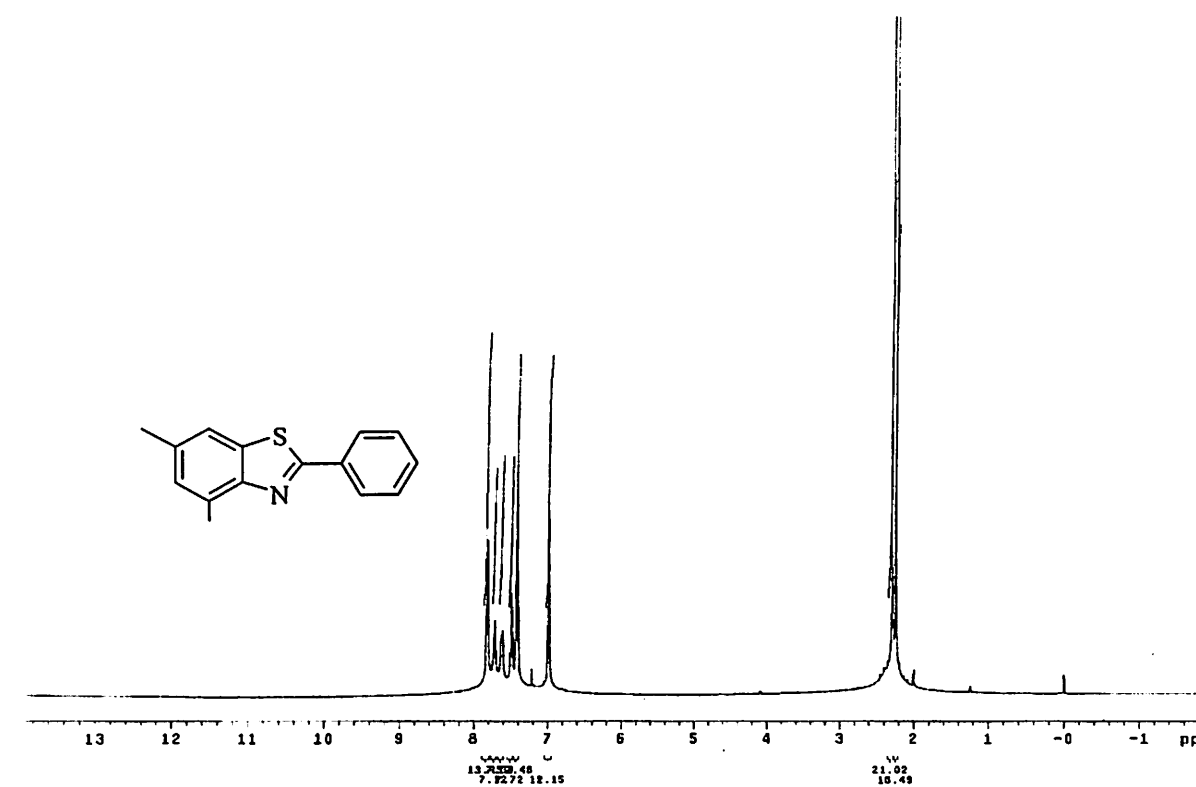
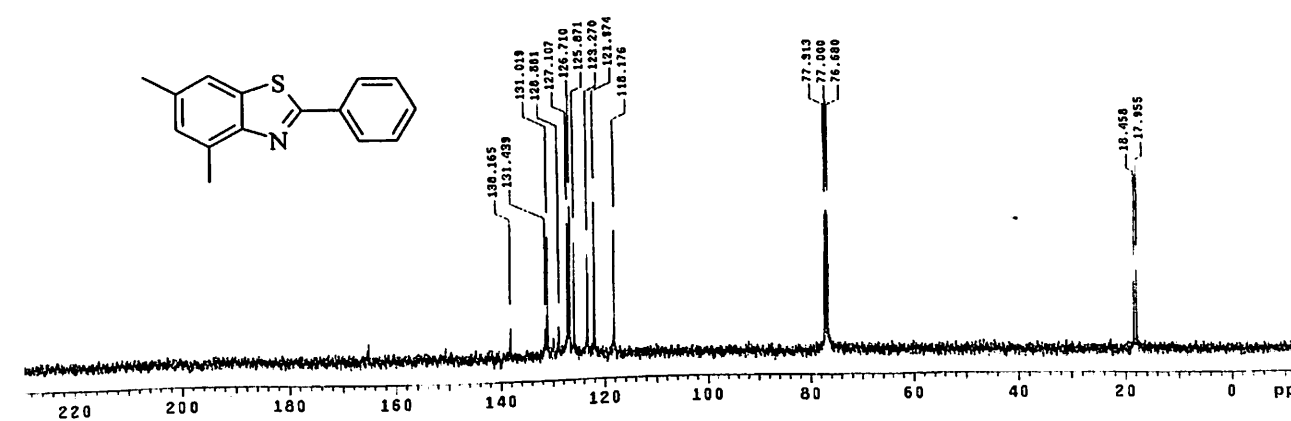
Chemical structure: O=C(C(=Cc1ccccc1)C(Br)Cc2ccccc2)Br

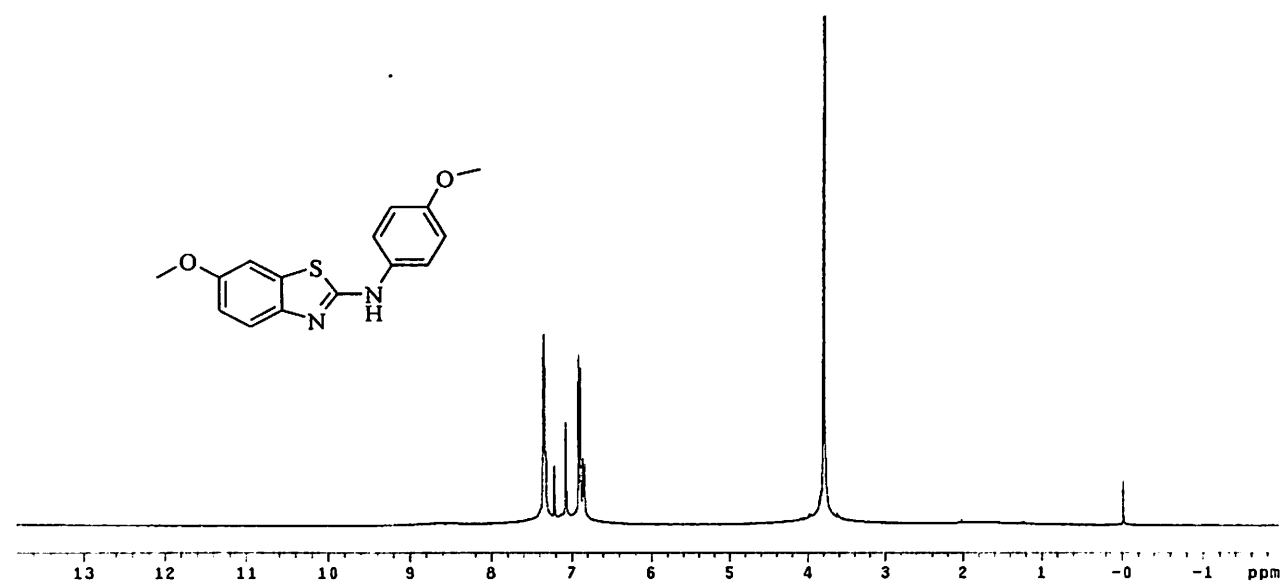
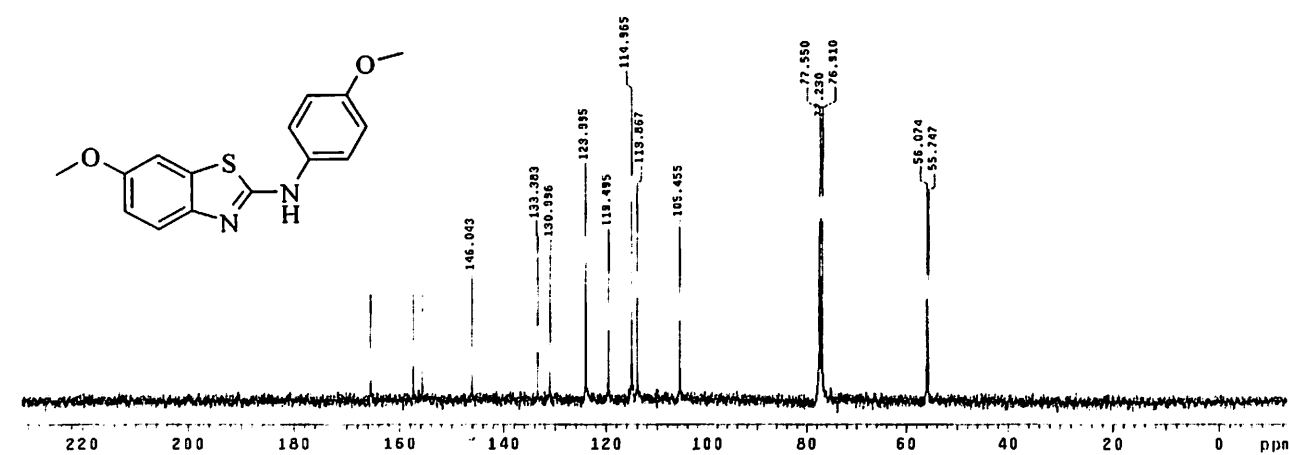
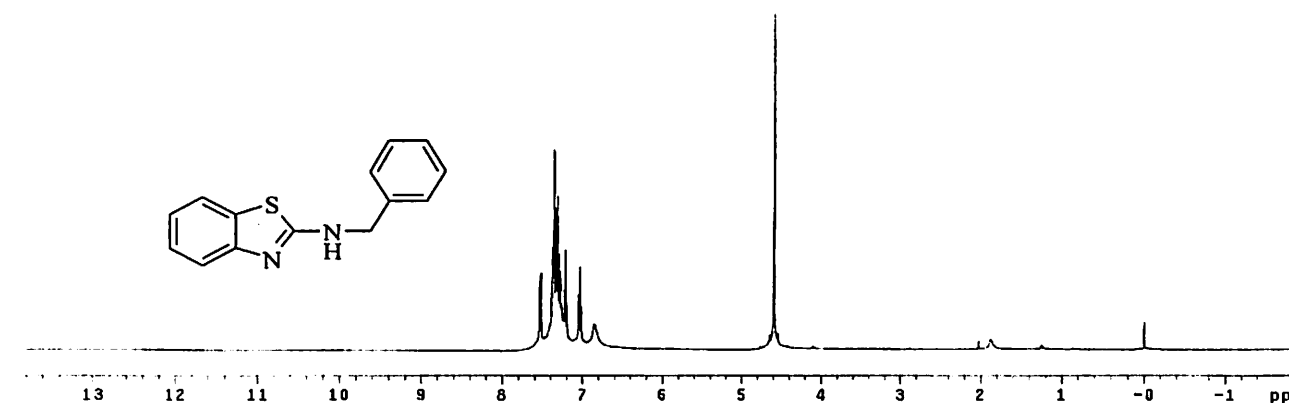
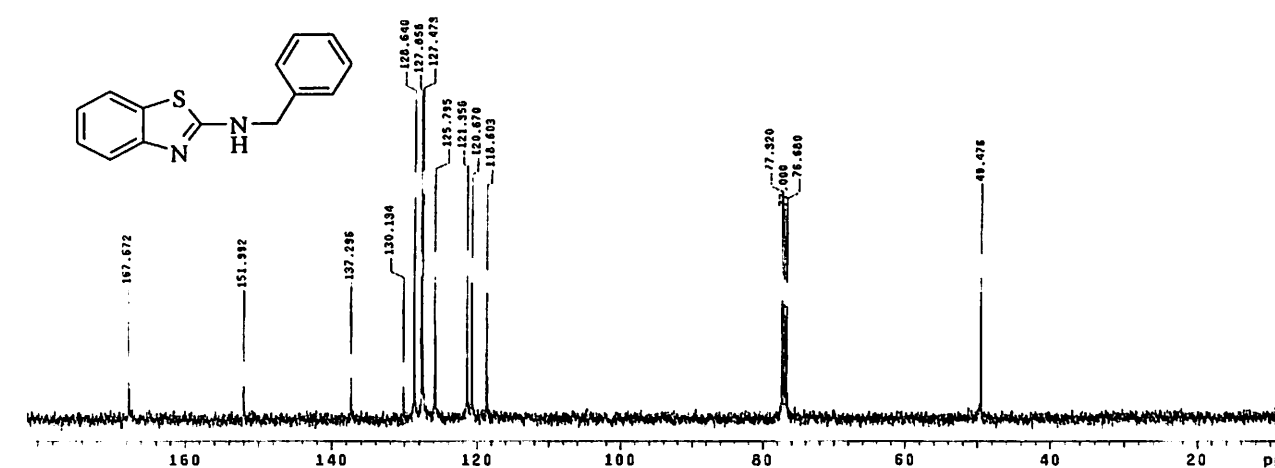
¹H NMR spectrum (CDCl₃) showing peaks at 7.867, 7.868, 7.851, 7.841, 7.831, 7.427, 7.469, 7.451, 7.443, 7.436, 7.415, 7.453, 7.417, 6.937, 6.922, 6.934, 5.508, 5.477, 5.237, 5.206, and 1.577 ppm. Integration values are shown below the baseline: 5.24, 46.88, 6.00, 17.62.

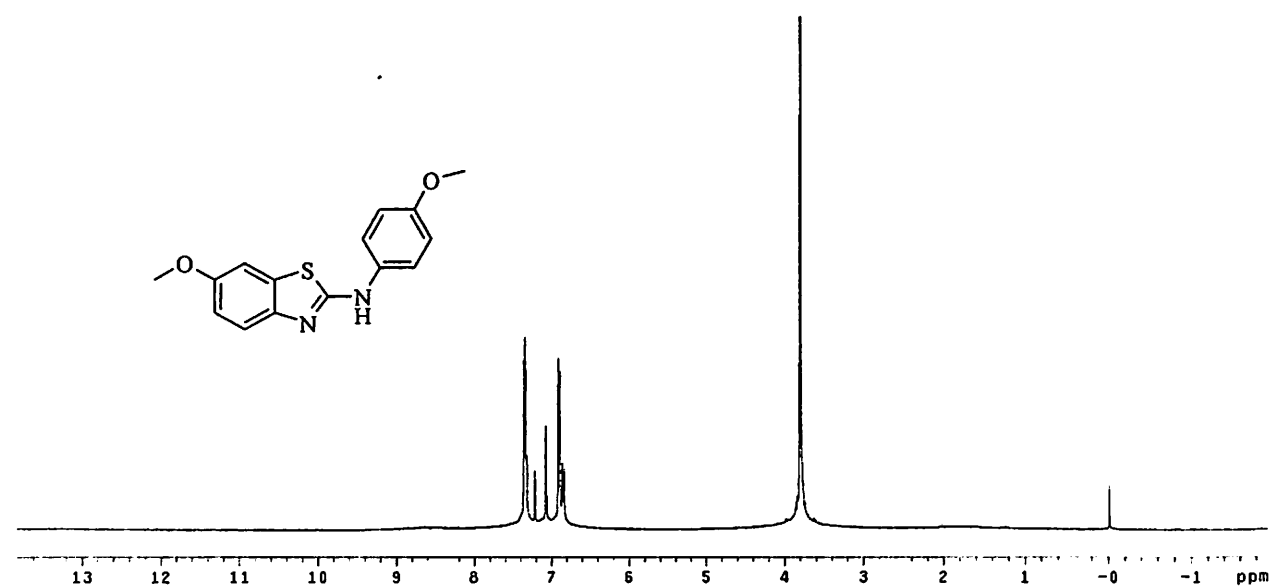
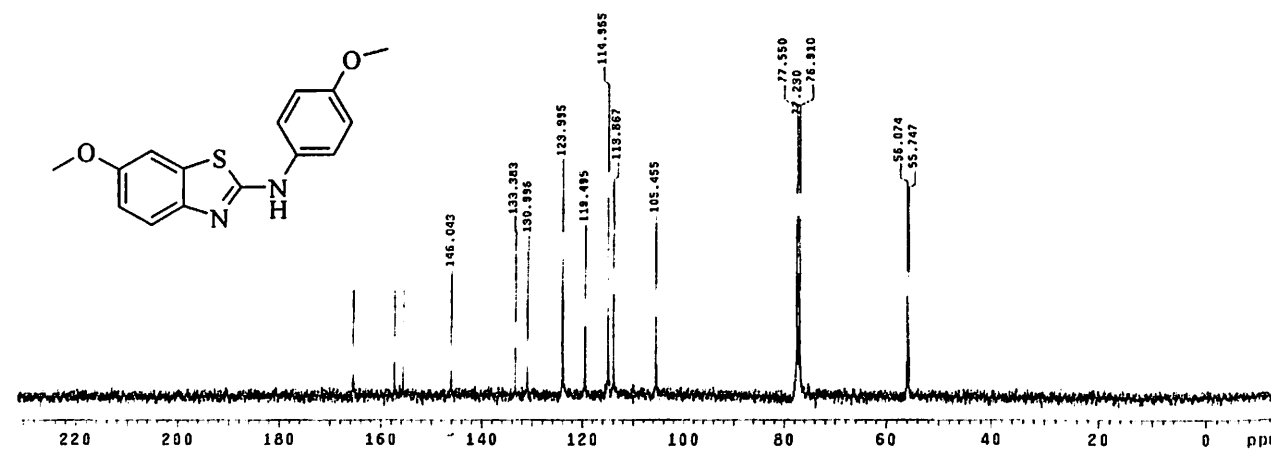
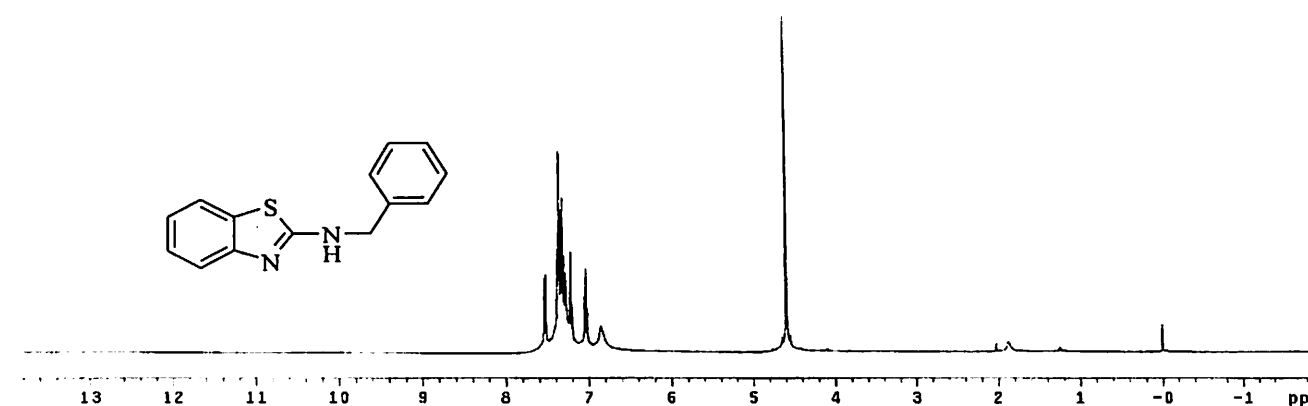
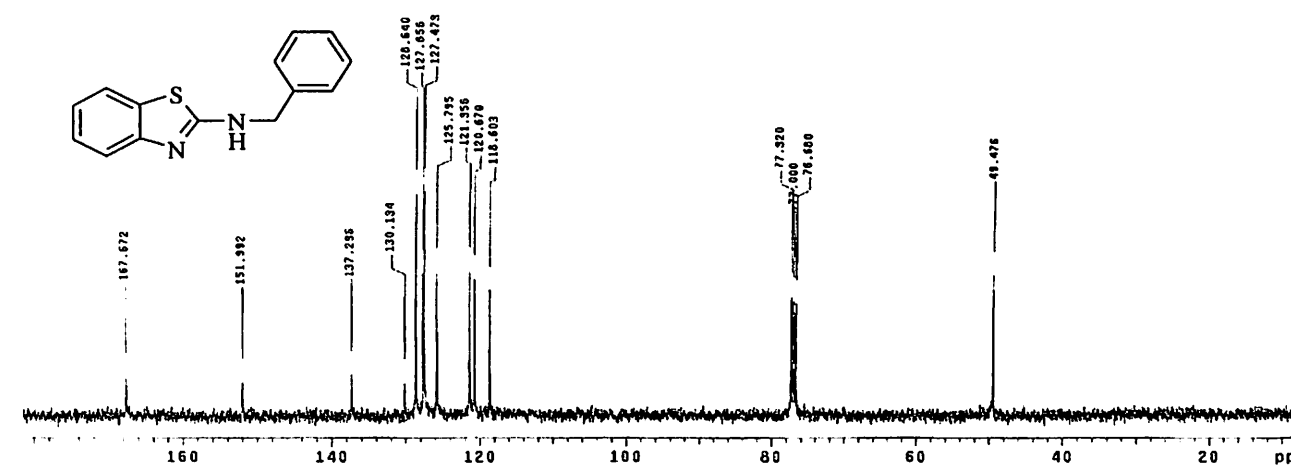
Chemical structure: O=C(C(Br)C1=CC=CC=C1)/C=C/C2=CC=CC=C2

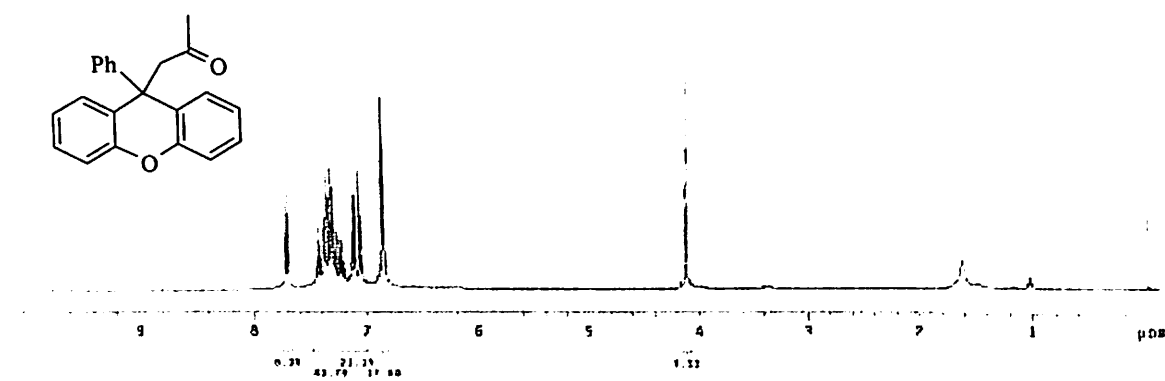
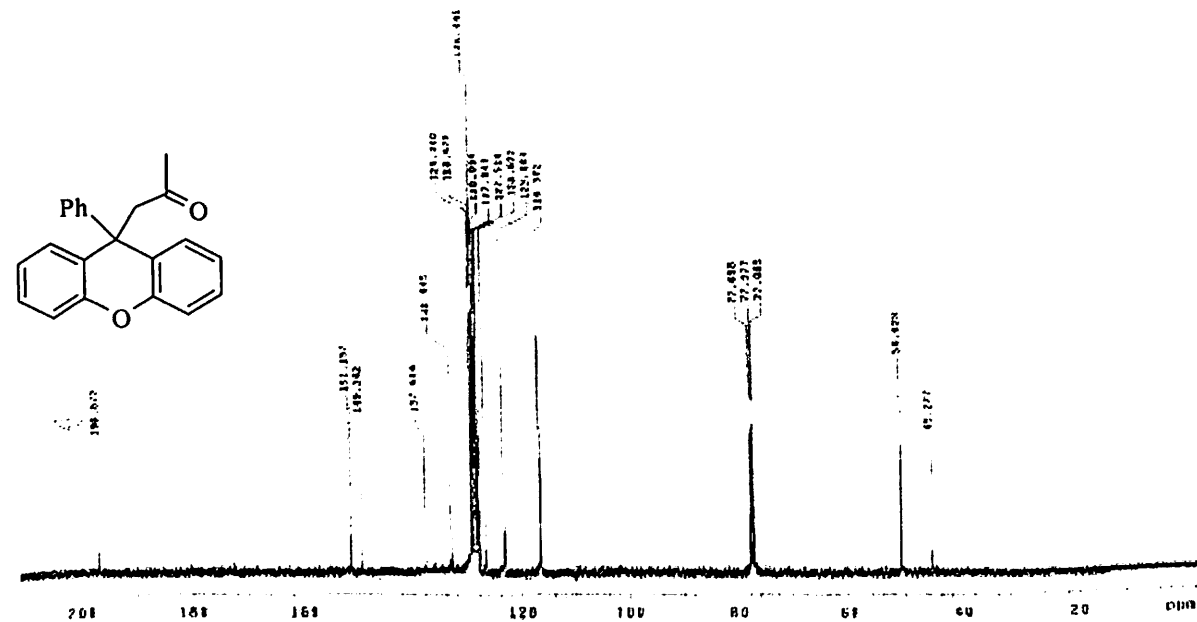
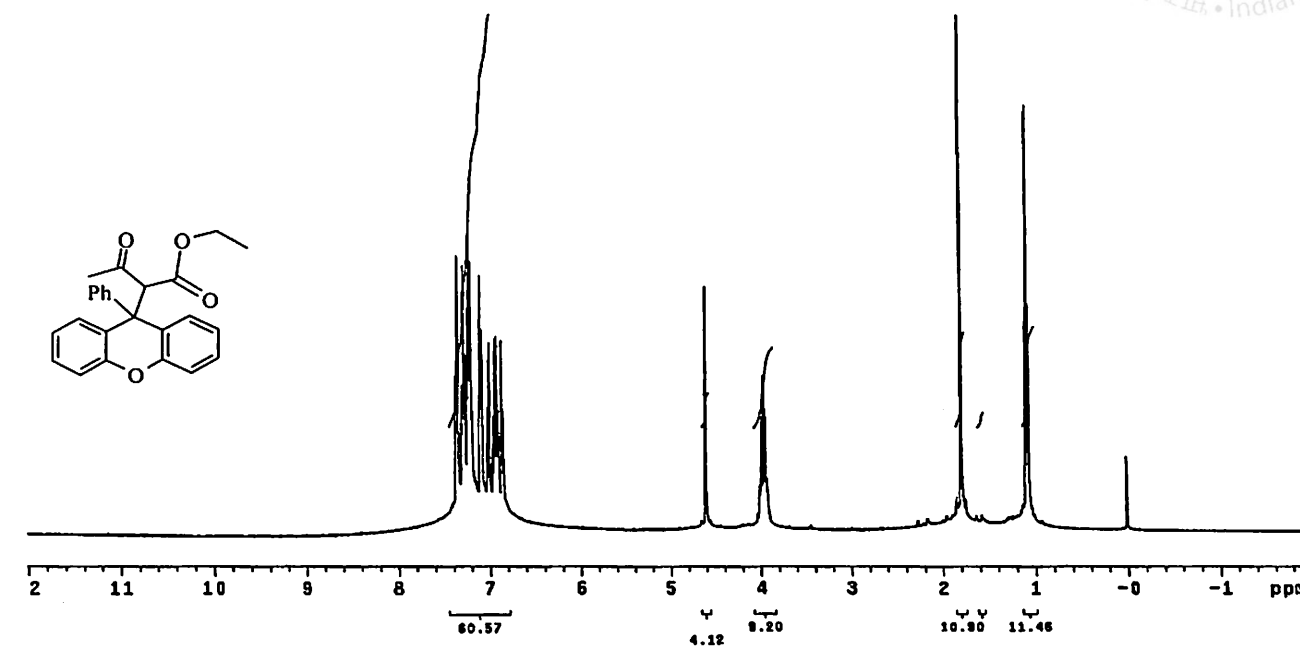
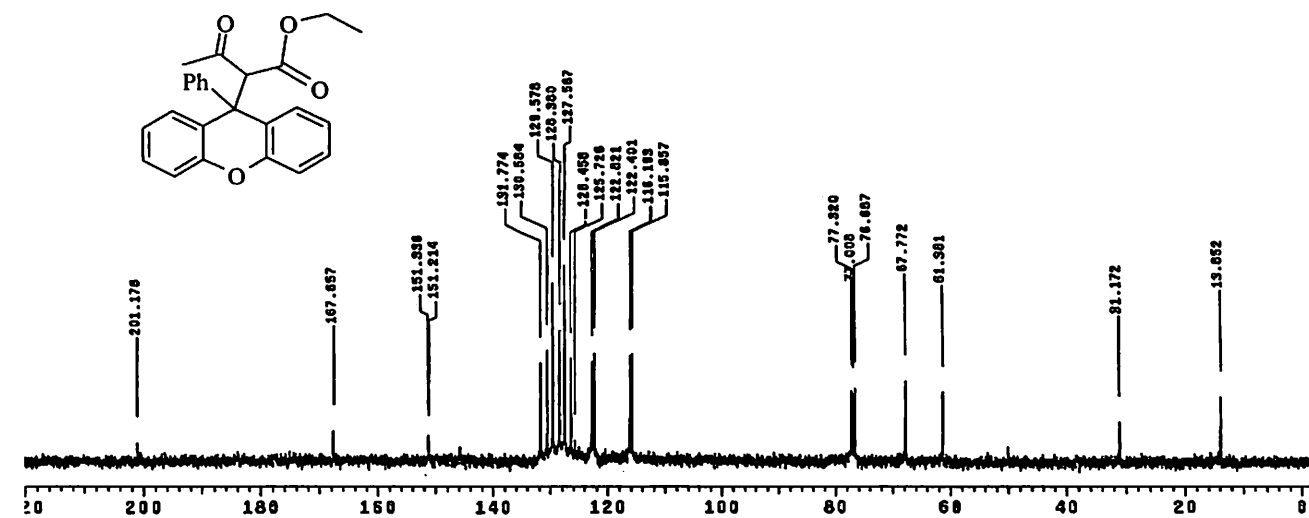
¹³C NMR peaks (ppm): 169.330, 146.276, 136.337, 134.160, 131.475, 129.482, 129.289, 129.070, 128.602, 128.482, 122.358, 114.447, 77.447, 77.354, 77.304, 51.885, 49.665.

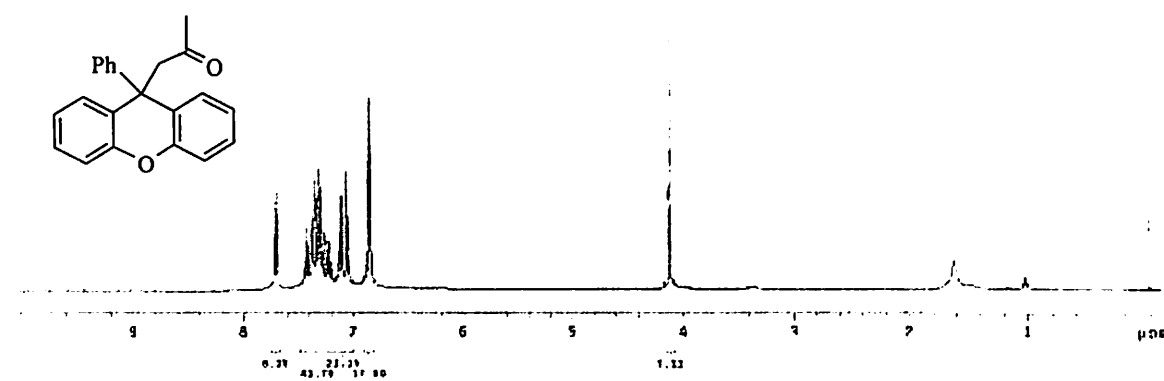
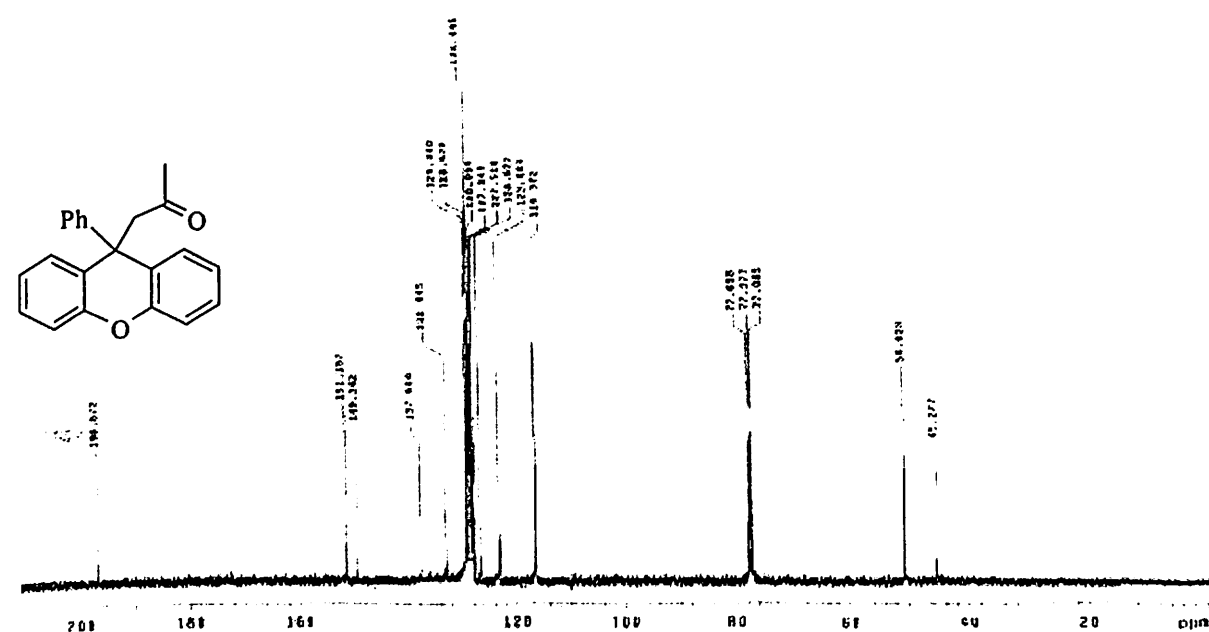
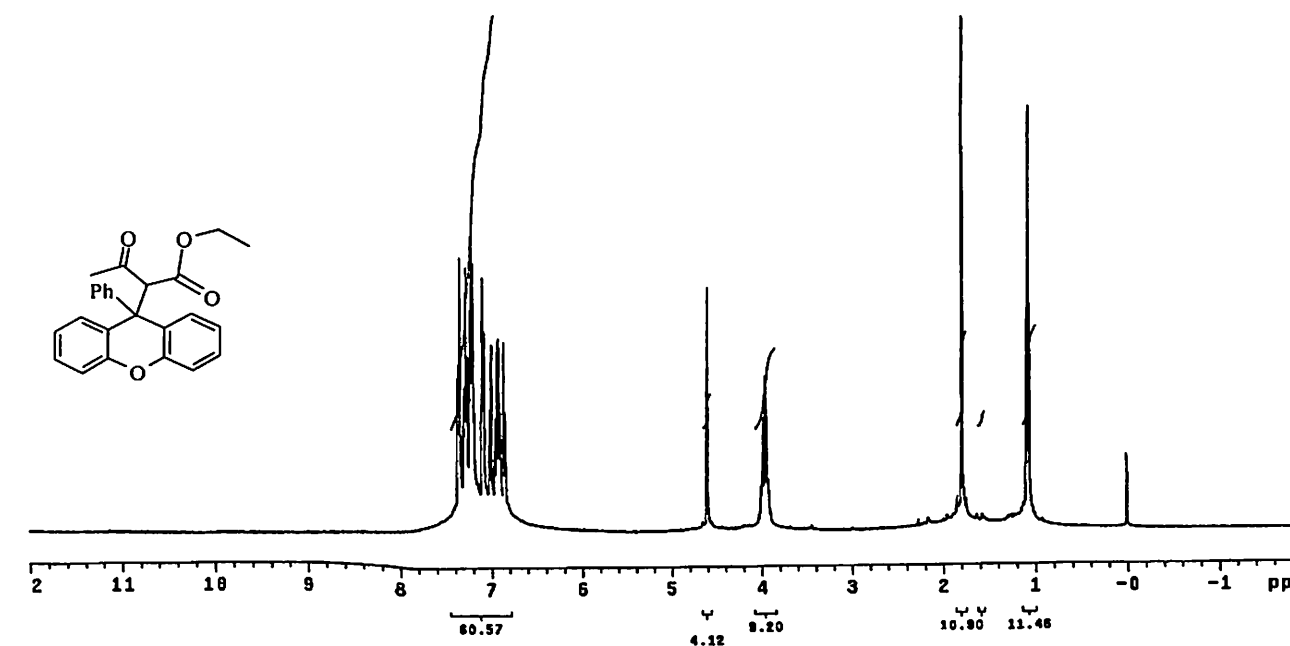
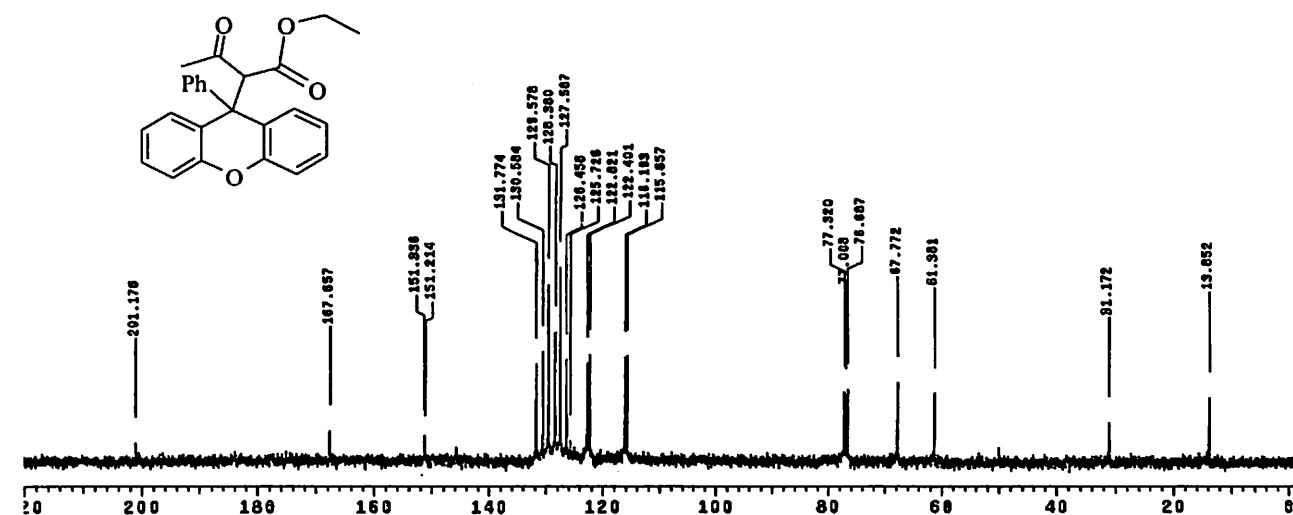
2-Phenyl-benzothiazole ¹H NMR (62o) (400 MHz, CDCl₃):

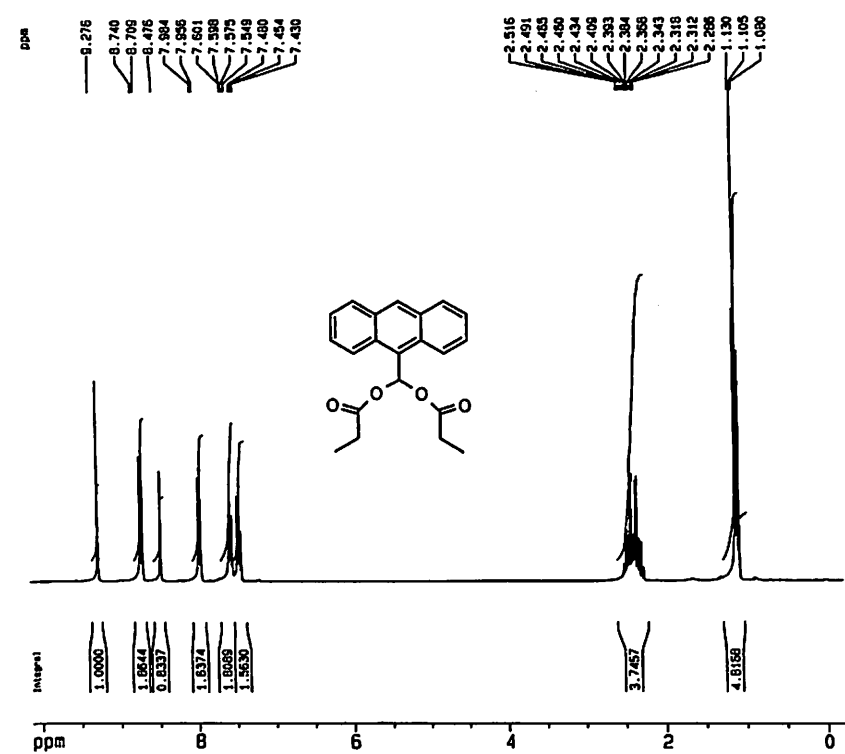
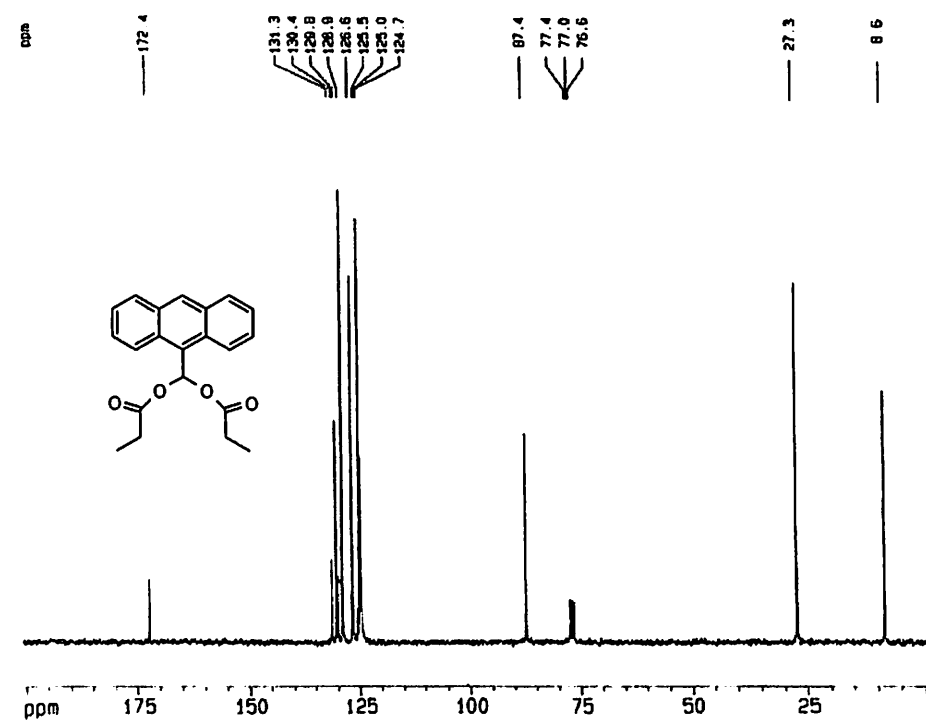
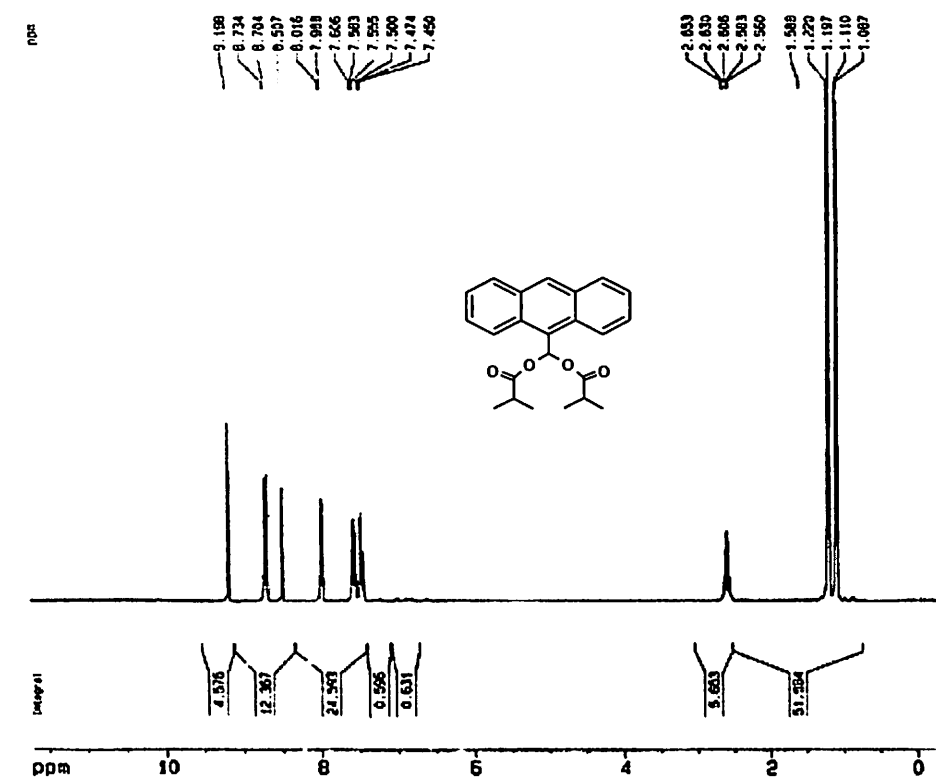
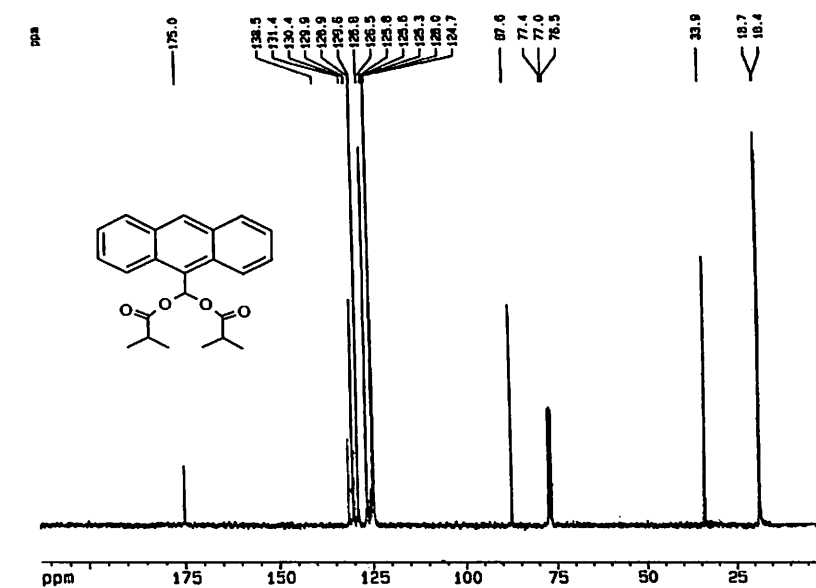
2-Phenyl-benzothiazole ¹H NMR (62o) (400 MHz, CDCl₃):2-Phenyl-benzothiazole ¹³C NMR (62o) (100 MHz, CDCl₃):4,6-Dimethyl-2-phenyl-benzothiazole (68o) ¹H NMR (400 MHz, CDCl₃):4,6-Dimethyl-2-phenyl-benzothiazole (68o) ¹³C NMR (100 MHz, CDCl₃):

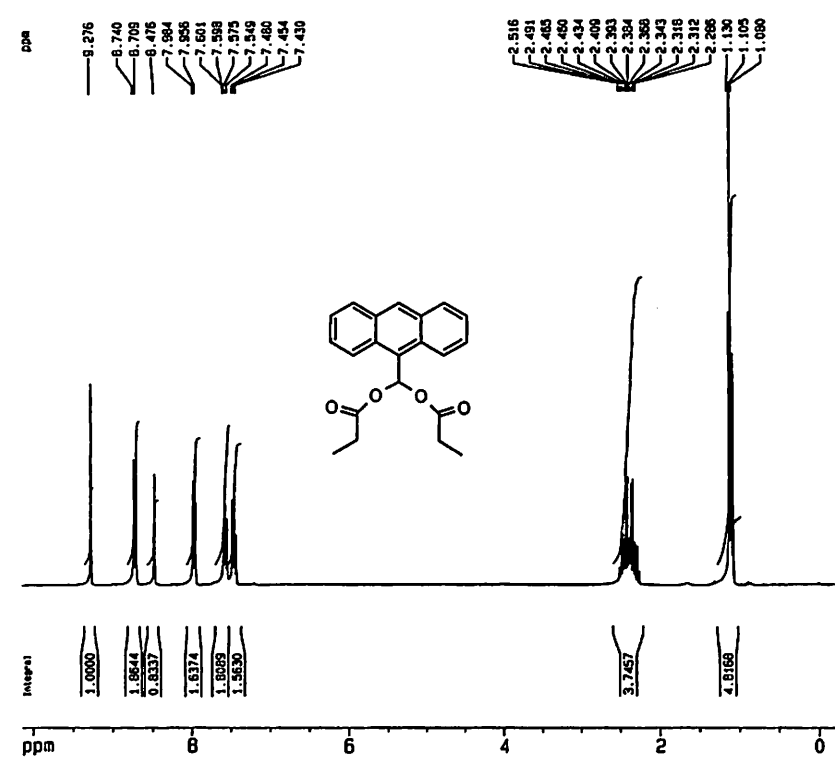
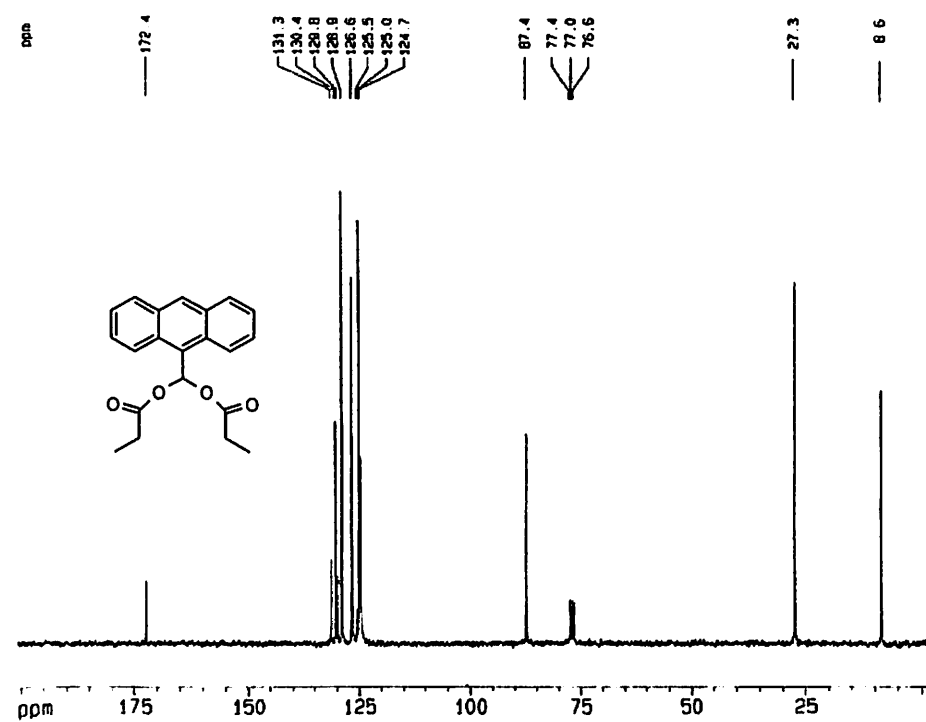
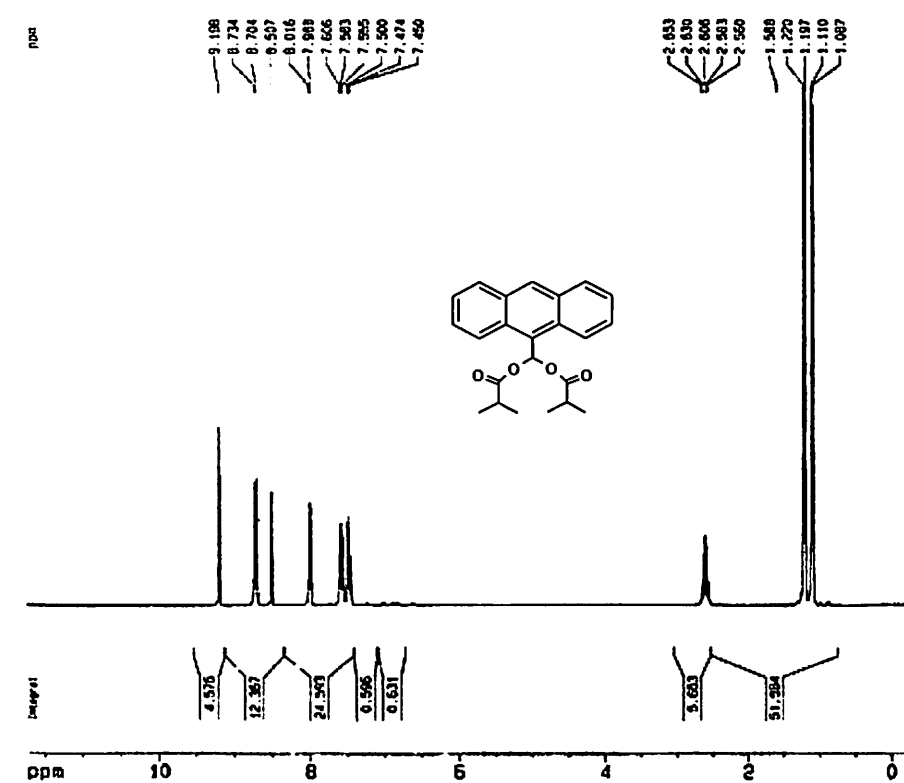
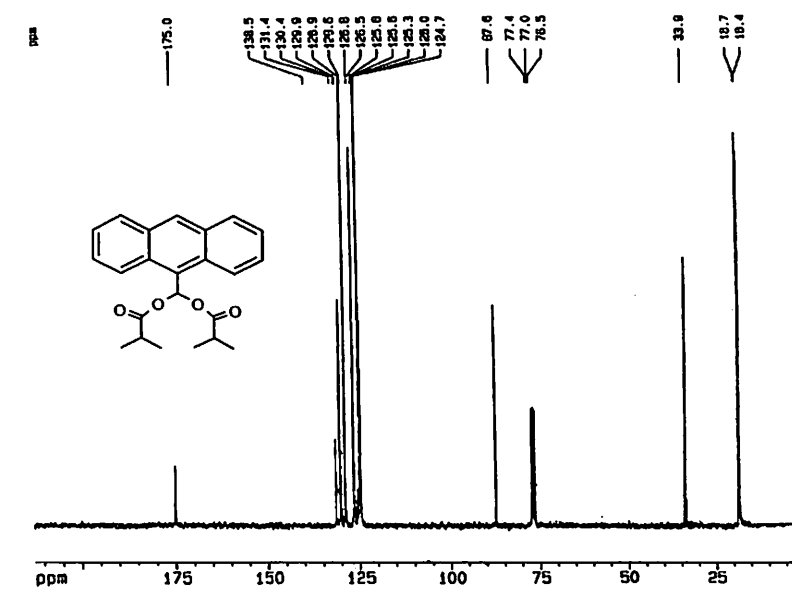
(6-Methoxy-benzothiazol-2-yl)-(4-methoxy-phenyl)-amine (73p) ^1H NMR (400 MHz, CDCl_3):(6-Methoxy-benzothiazol-2-yl)-(4-methoxy-phenyl)-amine (73p) ^{13}C NMR (100 MHz, CDCl_3):Benzothiazol-2-yl-benzyl-amine (75p) ^1H NMR (400 MHz, CDCl_3):Benzothiazol-2-yl-benzyl-amine (75p) ^{13}C NMR (100 MHz, CDCl_3):

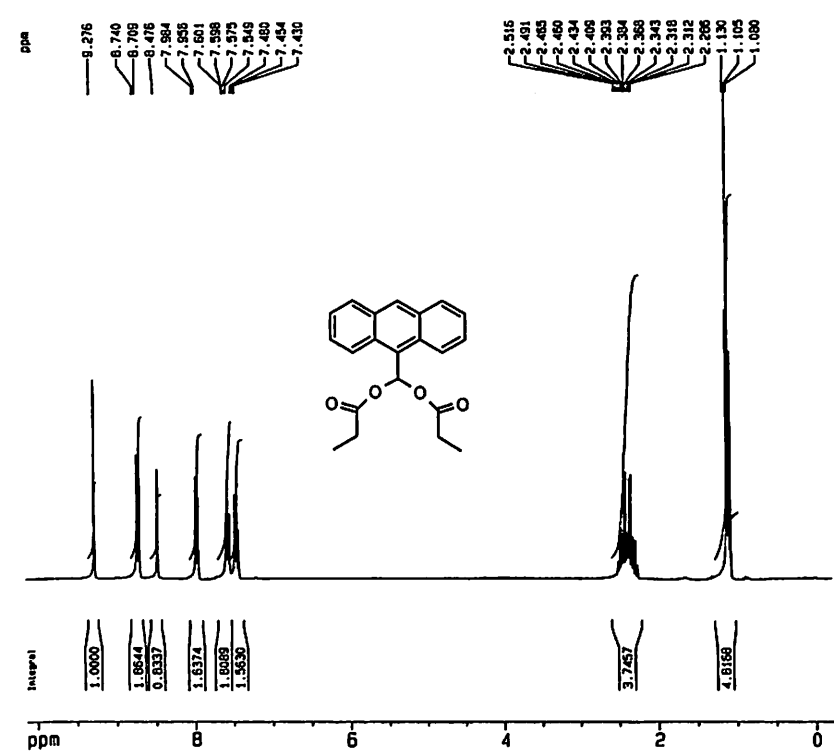
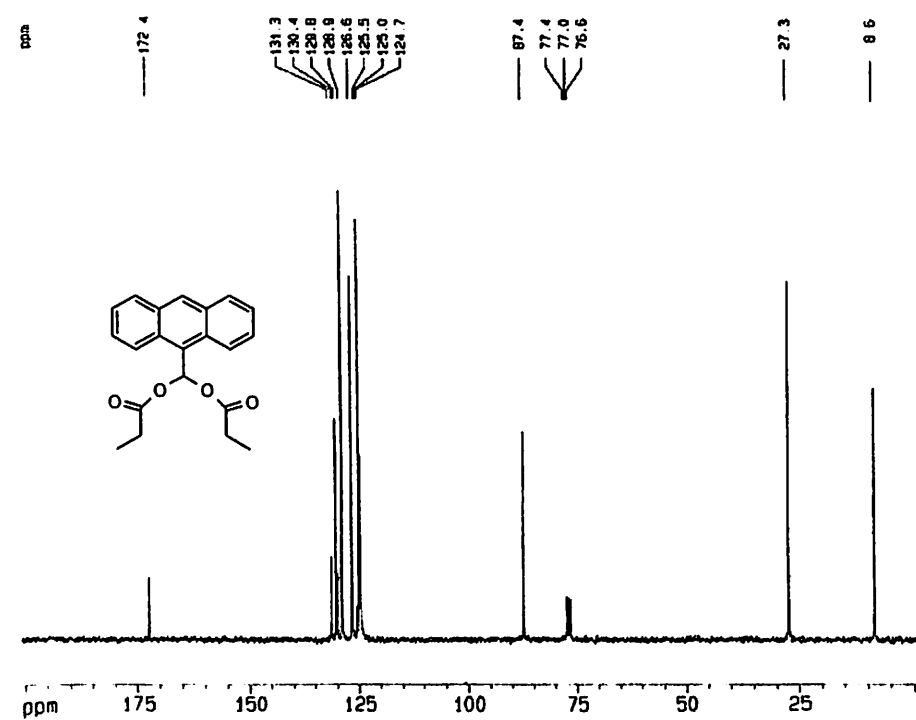
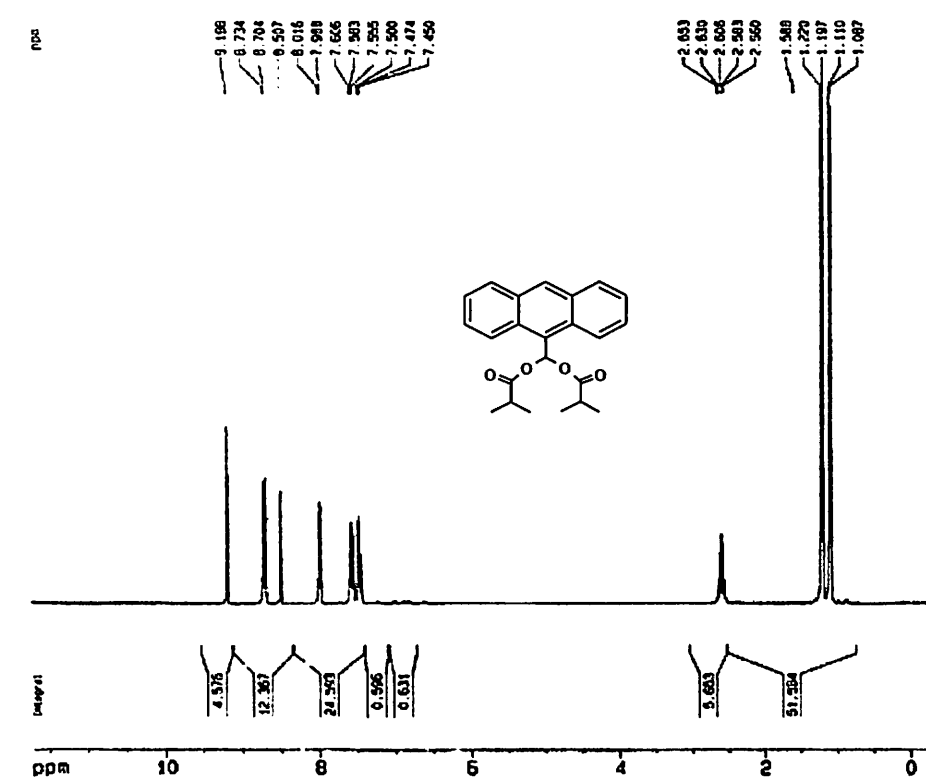
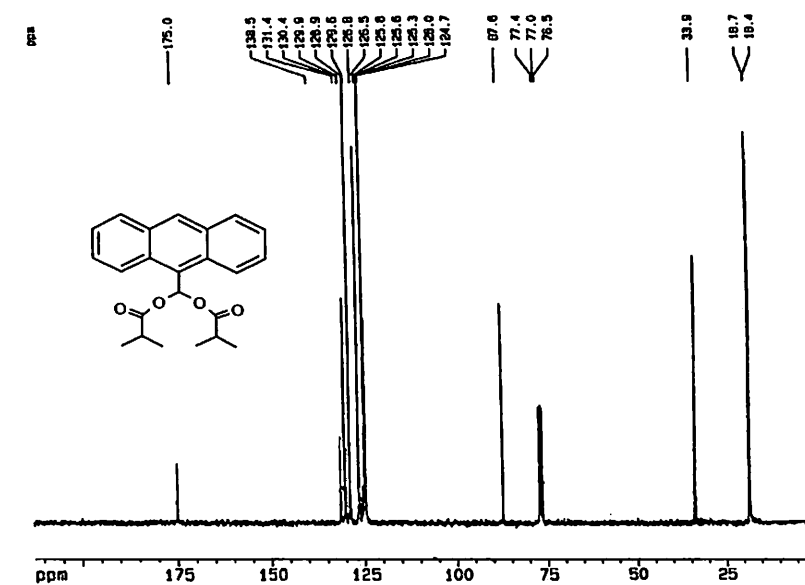
(6-Methoxy-benzothiazol-2-yl)-(4-methoxy-phenyl)-amine (73p) ^1H NMR (400 MHz, CDCl_3):(6-Methoxy-benzothiazol-2-yl)-(4-methoxy-phenyl)-amine (73p) ^{13}C NMR (100 MHz, CDCl_3):Benzothiazol-2-yl-benzyl-amine (75p) ^1H NMR (400 MHz, CDCl_3):Benzothiazol-2-yl-benzyl-amine (75p) ^{13}C NMR (100 MHz, CDCl_3):

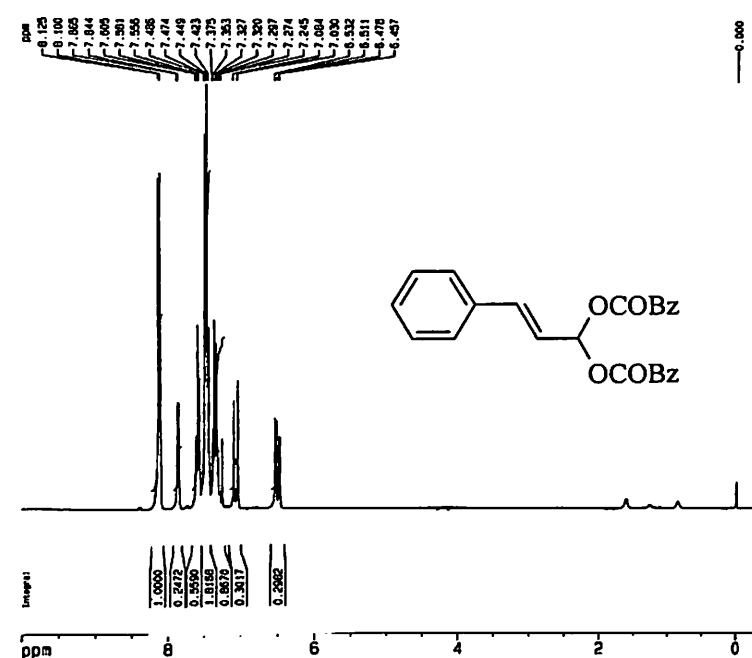
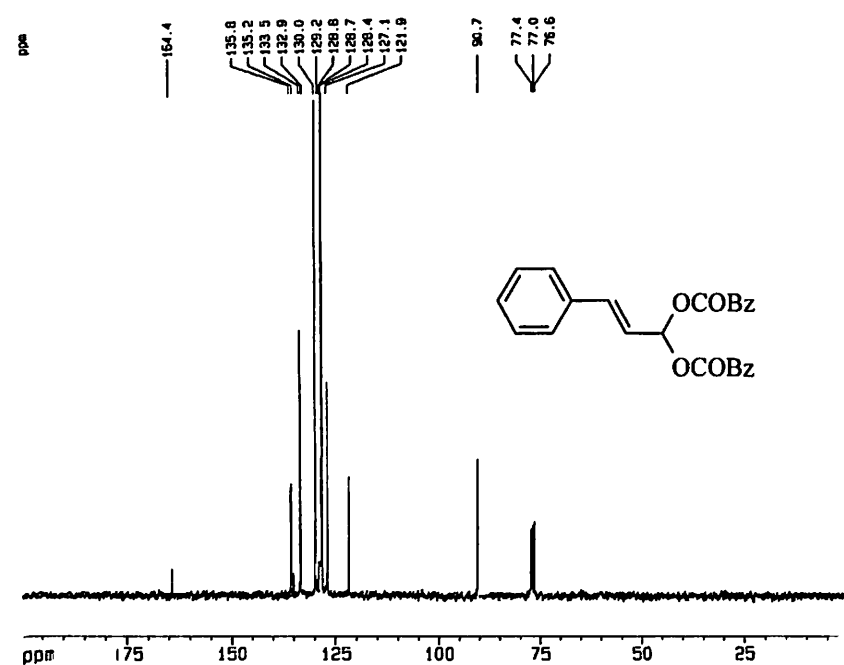
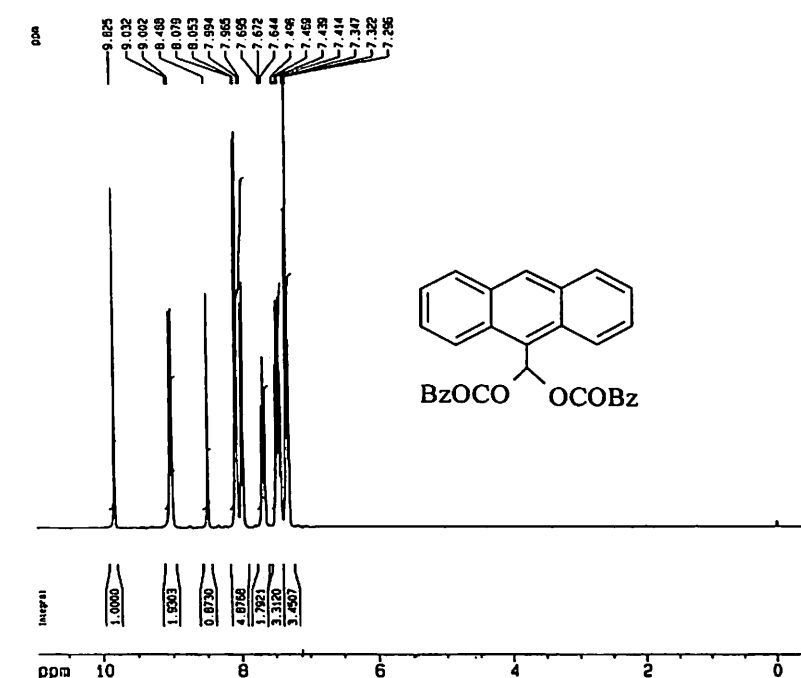
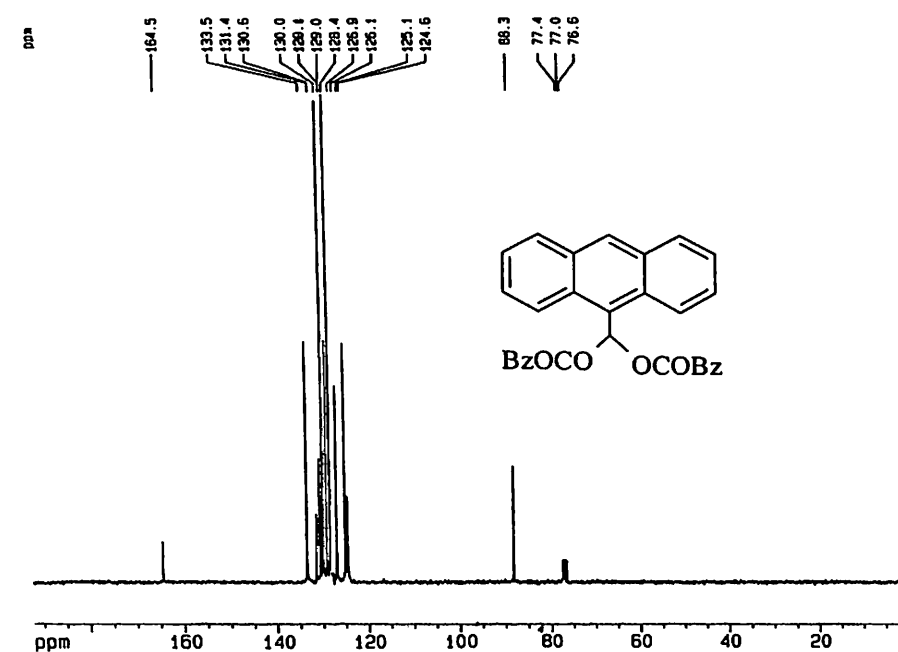
1-Phenyl-2-(9-phenyl-9H-xanthen-9-yl)-ethanone (77q) ^1H NMR (400 MHz, CDCl_3):1-Phenyl-2-(9-phenyl-9H-xanthen-9-yl)-ethanone (77q) ^{13}C NMR (100 MHz, CDCl_3):3-Oxo-2-(9-phenyl-9H-xanthen-9-yl)-butyric acid ethyl ester (86q): ^1H NMR3-Oxo-2-(9-phenyl-9H-xanthen-9-yl)-butyric acid ethyl ester (86q) ^{13}C NMR (100 MHz, CDCl_3):

1-Phenyl-2-(9-phenyl-9H-xanthen-9-yl)-ethanone (77q) ^1H NMR (400 MHz, CDCl_3):1-Phenyl-2-(9-phenyl-9H-xanthen-9-yl)-ethanone (77q) ^{13}C NMR (100 MHz, CDCl_3):3-Oxo-2-(9-phenyl-9H-xanthen-9-yl)-butyric acid ethyl ester (86q): ^1H NMR3-Oxo-2-(9-phenyl-9H-xanthen-9-yl)-butyric acid ethyl ester (86q) ^{13}C NMR (100 MHz, CDCl_3):

9-(Dipropionyloxymethyl)anthracene (110s) ^1H NMR (300 MHz, CDCl_3):9-(Dipropionyloxymethyl)anthracene (110s) ^{13}C NMR (75 MHz, CDCl_3):1,1-Diisobutyryloxy-9-methylantracene (110t) ^1H NMR (300 MHz, CDCl_3):1,1-Diisobutyryloxy-9-methylantracene (110t) ^{13}C NMR (75 MHz, CDCl_3):

9-(Dipropionyloxymethyl)anthracene (110s) ^1H NMR (300 MHz, CDCl_3):9-(Dipropionyloxymethyl)anthracene (110s) ^{13}C NMR (75 MHz, CDCl_3):1,1-Diisobutyryloxy-9-methylantracene (110t) ^1H NMR (300 MHz, CDCl_3):1,1-Diisobutyryloxy-9-methylantracene (110t) ^{13}C NMR (75 MHz, CDCl_3):

9-(Dipropionyloxymethyl)anthracene (110s) ^1H NMR (300 MHz, CDCl_3):9-(Dipropionyloxymethyl)anthracene (110s) ^{13}C NMR (75 MHz, CDCl_3):1,1-Diisobutyryloxy-9-methylantracene (110t) ^1H NMR (300 MHz, CDCl_3):1,1-Diisobutyryloxy-9-methylantracene (110t) ^{13}C NMR (75 MHz, CDCl_3):

1,1-Dibenzoyloxy-3-phenylprop-2-ene (102v) ^1H NMR (300 MHz, CDCl_3):1,1-Dibenzoyloxy-3-phenylprop-2-ene (102v) ^{13}C NMR (75 MHz, CDCl_3):1,1-Dibenzoyloxy-9-methylantracene (110v) ^1H NMR (300 MHz, CDCl_3):1,1-Dibenzoyloxy-9-methylantracene (110v) ^{13}C NMR (75 MHz, CDCl_3):

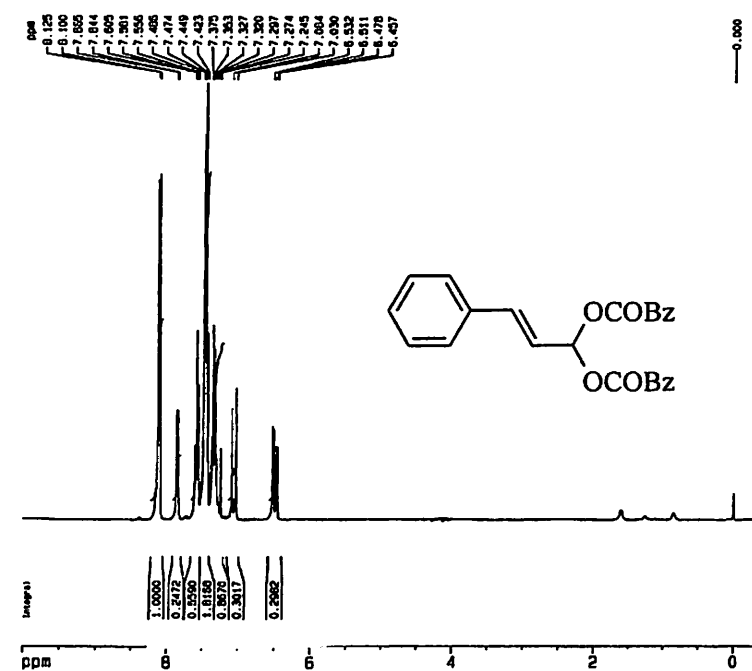
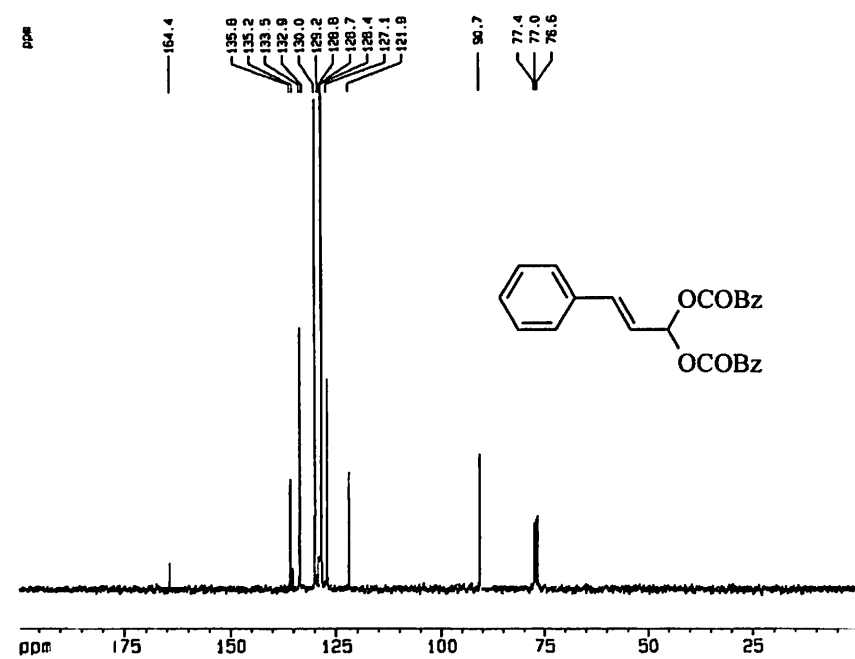
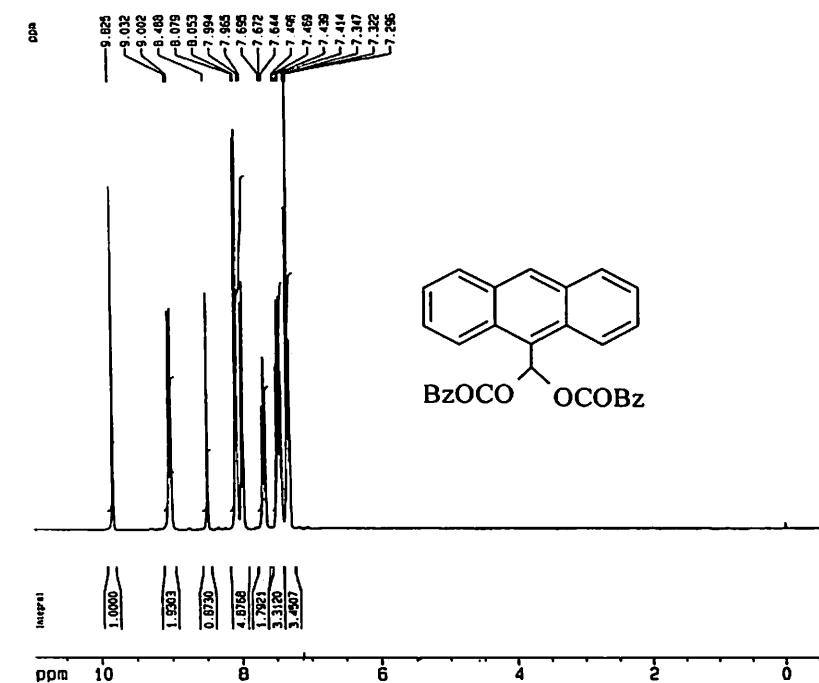
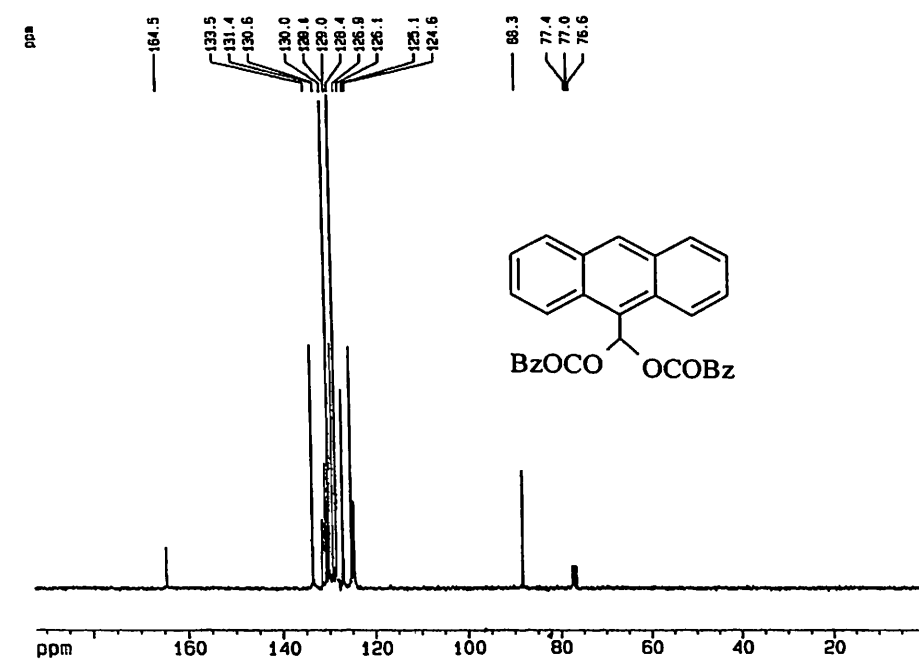
1,1-Dibenzoyloxy-3-phenylprop-2-ene (102v) ^1H NMR (300 MHz, CDCl_3):1,1-Dibenzoyloxy-3-phenylprop-2-ene (102v) ^{13}C NMR (75 MHz, CDCl_3):1,1-Dibenzoyloxy-9-methylantracene (110v) ^1H NMR (300 MHz, CDCl_3):1,1-Dibenzoyloxy-9-methylantracene (110v) ^{13}C NMR (75 MHz, CDCl_3):

Table 1. Crystallographic Data for the Compounds 76, 77q and 78q

Crystal parameters	Compound (76)	Compound (77q)	Compound (78q)
Crystal dimension (mm)	0.26 x 0.21 x 0.17	0.29 x 0.22 x 0.15	0.27 x 0.23 x 0.18
Formula	C ₁₉ H ₁₄ O ₂	C ₂₂ H ₁₈ O ₂	C ₂₇ H ₂₀ O ₂
Formula weight	274.30	314.36	376.43
Crystal system	triclinic	orthorhombic	monoclinic
Space group	P ₁	P2 ₁ 2 ₁ 2 ₁	P 21/n
Unit Cell dimentions	a = 8.7116 (3) Å, α = 81.577 ° (3) b = 8.9282 (4) Å, β = 71.429° (3) c = 10.3514 (4) Å, γ = 66.610° (2)	a = 9.9339 (14) Å b = 14.1874 (19) Å c = 23.786 (3) Å	a = 8.9261(11) Å b = 21.850 (3) Å c = 10.8533 (14) Å
Volume (Å ³)	700	3352.4 (8)	1966.2 (4)
Z	2	8	4
Density (ρ _{cal})	1.301 mg/m ³	1.246 mg/m ³	1.272mg/m ³
Absorption μ (mm ⁻¹)	0.083	0.079	0.079
F (000)	288	1328	792
Reflection collected /unique	7386/2962	11,407 / 6753	6996 /3061
Refinement method	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²
Final R indices [I>2σ _I]	R1 = 0.0383 wR2 = 0.0948	R1 = 0.0386 wR2 = 0.0852	R1 = 0.0559 wR2 = 0.0651
R indices (all data)	R1 = 0.0525 wR2 = 0.1068	R1 = 0.0502 wR2 = 0.0921	R1 = 0.0559 wR2 = 0.0665
Goodness of fit	1.066	1.061	3.052

Table 2. Crystallographic data for the compounds 79q-82q

Crystal parameters	Compound (79q)	Compound (80q)	Compound (81q)
Crystal dimension (mm)	0.40 x 0.16 x 0.15	0.41 x 0.27 x 0.22	0.35 x 0.18 x 0.08
Formula	C ₂₅ H ₂₂ O ₂	C ₂₄ H ₂₀ O ₂	C ₂₈ H ₂₂ O ₂
Formula weight	354.43	340.40	390.46
Crystal system	orthorhombic	monoclinic	orthorhombic,
Space group	P2(1)2(1)2(1)	P2(1)/c	Pbca

Unit Cell dimentions	a = 8.7476(19) Å b = 9.924(2) Å c = 21.511(5) Å	a = 13.6932(10) Å b = 10.0550(7) Å c = 12.8131(10) Å γ = 100.296 (4)°	a = 23.1193(6) Å b = 10.0550(7) Å c = 12.8131(10) Å γ = 100.296 (4)°
Volume (Å ³)	1867.4(7)	1735.8(2)	5045.5 (2)
Z	4	4	10
Density (ρ _{cal})	1.261 mg/m ³	1.303 Mg/m ³	1.285 mg/m ³
Absorption μ (mm ⁻¹)	0.078	0.081	0.079
F (000)	752	720	2060
Reflection collected /unique	16665 / 4412	18230 / 4280	31248 / 5895
Refinement method	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²
Final R indices [I>2σ _I]	R1 = 0.0481 wR2 = 0.0829	R1 = 0.0424 wR2 = 0.1022	R1 = 0.0758 wR2 = 0.1448
R indices (all data)	R1 = 0.0865 wR2 = 0.0952	R1 = 0.0558 wR2 = 0.1108	R1 = 0.2498 wR2 = 0.2109
Goodness of fit	0.991	1.029	0.963

Table 3. Crystallographic Data for the Compounds 82q-84q

Crystal parameters	Compound (82q)	Compound (83q)	Compound (84q)
Crystal dimension (mm)	0.23 x 0.19 x 0.17	0.19 x 0.16 x 0.12	0.26 x 0.14 x 0.12
Formula	C ₂₃ H ₂₀ O ₂	C ₂₅ H ₂₄ O ₂	C ₂₄ H ₂₂ O ₄
Formula weight	328.39	356.44	374.42
Crystal system	orthorhombic	orthorhombic	orthorhombic,
Space group	P2(1)2(1)2(1)	Pbca	P2(1)2(1)2(1)
Unit Cell dimentions	a = 9.4523 (2) Å b = 11.6668 (3) Å c = 16.0143 (4) Å	a = 10.5359 (3) Å b = 18.7269 (6) Å c = 19.5093 (7) Å	a = 9.7748(2) Å b = 10.7497(2) Å c = 19.0446(3) Å
Volume (Å ³)	1766(7)	3849 (2)	2001.13(6)
Z	4	8	4
Density (ρ _{cal})	1.235mg/m ³	1.230 mg/m ³	1.137 mg/m ³
Absorption μ (mm ⁻¹)	0.077	0.076	0.071

Table 1. Crystallographic Data for the Compounds 76, 77q and 78q

Crystal parameters	Compound (76)	Compound (77q)	Compound (78q)
Crystal dimension (mm)	0.26 x 0.21 x 0.17	0.29 x 0.22 x 0.15	0.27 x 0.23 x 0.18
Formula	C ₁₉ H ₁₄ O ₂	C ₂₂ H ₁₈ O ₂	C ₂₇ H ₂₀ O ₂
Formula weight	274.30	314.36	376.43
Crystal system	triclinic	orthorhombic	monoclinic
Space group	P ₁	P2 ₁ 2 ₁ 2 ₁	P 21/n
Unit Cell dimensions	a = 8.7116 (3) Å, α = 81.577° (3) b = 8.9282 (4) Å, β = 71.429° (3) c = 10.3514 (4) Å, γ = 66.610° (2)	a = 9.9339 (14) Å b = 14.1874 (19) Å c = 23.786 (3) Å	a = 8.9261 (11) Å b = 21.850 (3) Å c = 10.8533 (14) Å
Volume (Å ³)	700	3352.4 (8)	1966.2 (4)
Z	2	8	4
Density (ρ _{cal})	1.301 mg/m ³	1.246 mg/m ³	1.272 mg/m ³
Absorption μ (mm ⁻¹)	0.083	0.079	0.079
F (000)	288	1328	792
Reflection collected /unique	7386/2962	11,407 / 6753	6996 / 3061
Refinement method	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²
Final R indices [I > 2σ _I]	R1 = 0.0383 wR2 = 0.0948	R1 = 0.0386 wR2 = 0.0852	R1 = 0.0559 wR2 = 0.0651
R indices (all data)	R1 = 0.0525 wR2 = 0.1068	R1 = 0.0502 wR2 = 0.0921	R1 = 0.0559 wR2 = 0.0665
Goodness of fit	1.066	1.061	3.052

Table 2. Crystallographic data for the compounds 79q-82q

Crystal parameters	Compound (79q)	Compound (80q)	Compound (81q)
Crystal dimension (mm)	0.40 x 0.16 x 0.15	0.41 x 0.27 x 0.22	0.35 x 0.18 x 0.08
Formula	C ₂₅ H ₂₂ O ₂	C ₂₄ H ₂₀ O ₂	C ₂₈ H ₂₂ O ₂
Formula weight	354.43	340.40	390.46
Crystal system	orthorhombic	monoclinic	orthorhombic,
Space group	P2(1)2(1)2(1)	P2(1)/c	Pbca

Unit Cell dimensions	a = 8.7476(19) Å b = 9.924(2) Å c = 21.511(5) Å	a = 13.6932(10) Å b = 10.0550(7) Å c = 12.8131(10) Å γ = 100.296 (4)°	a = b = c = 23.1193(6) Å
Volume (Å ³)	1867.4(7)	1735.8(2)	5045.5 (2)
Z	4	4	10
Density (ρ _{cal})	1.261 mg/m ³	1.303 Mg/m ³	1.285 mg/m ³
Absorption μ (mm ⁻¹)	0.078	0.081	0.079
F (000)	752	720	2060
Reflection collected /unique	16665 / 4412	18230 / 4280	31248 / 5895
Refinement method	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²	Full-matrix least-squares on F ²
Final R indices [I > 2σ _I]	R1 = 0.0481 wR2 = 0.0829	R1 = 0.0424 wR2 = 0.1022	R1 = 0.0758 wR2 = 0.1448
R indices (all data)	R1 = 0.0865 wR2 = 0.0952	R1 = 0.0558 wR2 = 0.1108	R1 = 0.2498 wR2 = 0.2109
Goodness of fit	0.991	1.029	0.963

Table 3. Crystallographic Data for the Compounds 82q-84q

Crystal parameters	Compound (82q)	Compound (83q)	Compound (84q)
Crystal dimension (mm)	0.23 x 0.19 x 0.17	0.19 x 0.16 x 0.12	0.26 x 0.14 x 0.12
Formula	C ₂₃ H ₂₀ O ₂	C ₂₅ H ₂₄ O ₂	C ₂₄ H ₂₂ O ₄
Formula weight	328.39	356.44	374.42
Crystal system	orthorhombic	orthorhombic	orthorhombic,
Space group	P2(1)2(1)2(1)	Pbca	P2(1)2(1)2(1)
Unit Cell dimensions	a = 9.4523 (2) Å b = 11.6668 (3) Å c = 16.0143 (4) Å	a = 10.5359 (3) Å b = 18.7269 (6) Å c = 19.5093 (7) Å	a = 9.7748(2) Å b = 10.7497(2) Å c = 19.0446(3) Å
Volume (Å ³)	1766(7)	3849 (2)	2001.13(6)
Z	4	8	4
Density (ρ _{cal})	1.235 mg/m ³	1.230 mg/m ³	1.137 mg/m ³
Absorption μ (mm ⁻¹)	0.077	0.076	0.071

<i>F</i> (000)	696	1520	728
Reflection collected /unique	13210 / 3646	29068 / 4758	25811 / 4861
Refinement method	Full-matrix least-squares on <i>F</i> ²	Full-matrix least-squares on <i>F</i> ²	Full-matrix least-squares on <i>F</i> ²
Final R indices [<i>I</i> > 2σ _{<i>i</i>}]	R1 = 0.0381 wR2 = 0.0498	R1 = 0.0589 wR2 = 0.1406	R1 = 0.0465 wR2 = 0.1024
R indices (all data)	R1 = 0.0623 wR2 = 0.0515	R1 = 0.0920 wR2 = 0.1596	R1 = 0.0814 wR2 = 0.1175
Goodness of fit	1.847	1.049	1.056

Table 4. Crystallographic Data for the Compounds 85q-86q

Crystal parameters	Compound (85q)	Compound (86q)
Crystal dimension (mm)	0.23 x 0.20 x 0.16	0.63 x 0.19 x 0.13
Formula	C ₂₈ H ₂₂ O ₂	C ₂₅ H ₂₂ O ₄
Formula weight	390.46	386.42
Crystal system	monoclinic	monoclinic
Space group	P2(1)/n	P2(1)/c
Unit Cell dimensions	a = 9.7125(5) Å b = 13.4710(7) Å c = 16.0757(8) Å, γ = 96.890(3)°	a = 22.8334(8) Å b = 9.7959(4) Å, β = 102.171(2)° c = 18.5098(6) Å
Volume (Å ³)	2088.11(18)	4047.1(3)
Z	4	4
Density (ρ _{cal})	1.242 mg/m ³	1.268 mg/m ³
Absorption μ (mm ⁻¹)	0.077	0.085
<i>F</i> (000)	824	1632
Reflection collected /unique	14011 / 4305	42156 / 9385
Refinement method	Full-matrix least-squares on <i>F</i> ²	Full-matrix least-squares on <i>F</i> ²
Final R indices [<i>I</i> > 2σ _{<i>i</i>}]	R1 = 0.0602 wR2 = 0.1158	R1 = 0.0565 wR2 = 0.1198
R indices (all data)	R1 = 0.1990 wR2 = 0.1627	R1 = 0.1162 wR2 = 0.1437
Goodness of fit	0.99	0.992

Research Publications

1. Reinvestigation of the mechanism of *gem*-diacylation: chemoselective conversion of aldehydes to various *gem*-diacylates and their cleavage under acidic and basic condition. **Veerababurao Kavala** and Bhisma K. Patel. *Eur. J. Org. Chem.* **2005**, 441-451.
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6. Tetrabutylammonium tribromide mediated condensation of carboxylic acids with alcohols. Sarala Naik, **Veerababurao Kavala**, Rangam Gopinath and Bhisma K. Patel. *Arkivoc* **2006** (i) 119-127.
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