EGE UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

(MASTER OF SCIENCE THESIS)

SYNTHESIS AND PROPERTIES OF BENZIMIDAZOLES BEARING COUMARIN

Begüm OLGUNDENİZ

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Begüm Olgundeniz tarafından Yüksek Lisans tezi olarak sunulan **"Kumarinli Benzimidazollerin Sentezi ve Özellikleri"** başlıklı bu çalışmada E.Ü. Lisansüstü Eğitim ve Öğretim Yönetmeliği ile E.Ü. Fen Bilimleri Enstitüsü Eğitim ve Öğretim Yönergesi'nin ilgili hükümleri uyarınca tarafımızdan değerlendirilerek savunmaya değer bulunmuş ve tarihinde yapılan tez savunma sınavında aday oybirliği/oyçokluğu ile başarılı bulunmuştur.

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ÖZET

KUMARİNLİ BENZİMİDAZOLLERİN SENTEZİ ve ÖZELLİKLERİ

OLGUNDENİZ, Begüm
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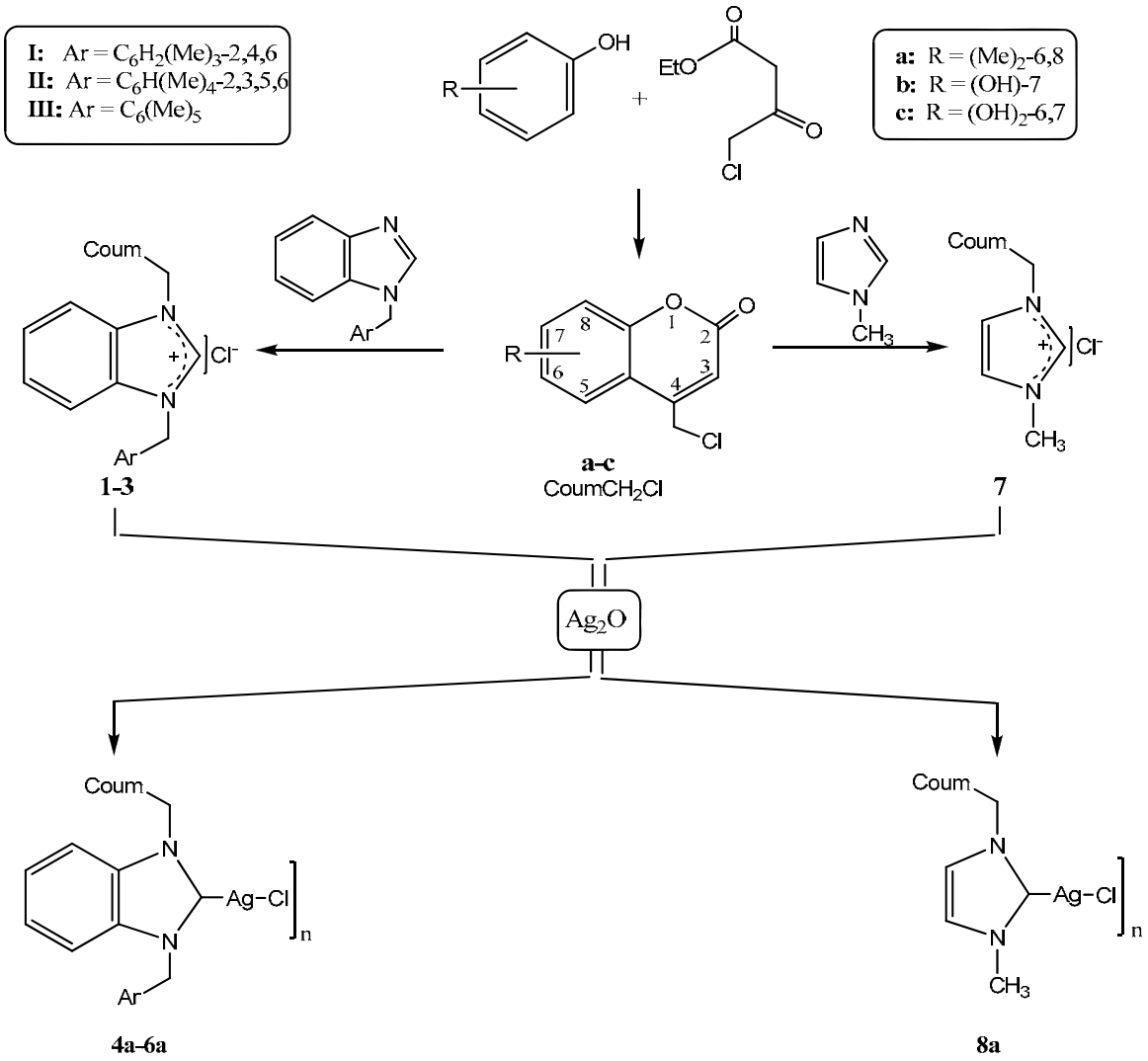
Tez Yöneticisi:Prof. Dr. Engin Çetinkaya
Eylül 2011, 77 sayfa

Bu tez N-3 atomuna $–CH_2-$ yoluyla bağlı kumarin türevlerini içeren NHC öncüleri ve NHC-Ag komplekslerinin sentezi, karakterizasyonu ve özelliklerini kapsamaktadır. Bazı kumarinlerin güçlü floresans özelliği ve kumarin yapısındaki lakton halkasının (suda çözünebilir yapıları oluşturmak için kolayca hidrolize olabilir) varlığı bu bileşiği önemli kılar.

Üç kısımdan oluşan bu tez kumarin içeren 1,3-disübstitüye benzimidazolyum ve imidazolyum klorürler ve bunların gümüş komplekslerinin sentezi ve özellikleriyle ilgilidir. Birinci bölüm benzimidazol, kumarin ve NHC'lere ait temel bilgiler, önemi ve kullanımları hakkında kısa bir derlemedir. İkinci bölümde deneysel veriler ayrıntılı bir biçimde açıklanmıştır. Üçüncü bölüm kumarin içeren 1,3-disübstitüye benzimidazolyum ve imidazolyum tuzlarının ve gümüş komplekslerinin sentezi, yapı aydınlatılması ve floresans özelliklerinin incelenmesini kapsamaktadır.

Bu çalışmada seri halinde azot atomuna bağlı kumarinli benzimidazolyum, imidazolyum tuzları ve gümüş kompleksleri sentezlenmiştir. Yeni bileşikler şemada gösterildiği şekilde sentezlenmiştir. İlk basamakta, Pechmann metoduyla 4-klorometil kumarin türevleri (**a-c**) sentezlenmiştir. İkinci basamakta, bu kumarin türevleri N-alkil benzimidazol (**I-III**) ve 1-metil imidazolü kuaternize etmek için kullanılmıştır. Son basamakta, simetrik olmayan diazolyum tuzları (**1-3** and **7**), NHC-Ag komplekslerini elde etmek için Ag_2O ile muamele edilmiştir.



4-Klorometil-6,8-dimetil kumarinden (**a**) türeyen tuzlardan beklenen NHC-Ag kompleksleri (**4a-6a** ve **8a**) oda sıcaklığında yüksek verimle elde edilirken benzen halkasında fenolik –OH içeren tuzlardan beklenen NHC-Ag kompleksleri elde edilememiştir. Tüm yeni bilşikler IR ve NMR spektroskopisiyle karakterize edilmiştir. Ayrıca absorbsiyon ve emisyon verileri değerlendirilmiştir.

Kompleks **8a**'daki lakton halkası sulu KOH çözeltisi ile muamele edilmiştir. Oluşan hidroliz ürünü başlangıç NHC-Ag kompleksine (**8a)** yüksek verimle tekrar dönüşebilmektedir. Bu tersinirlik, bazik şartlarda gerçekleşen katalitik reaksiyonlarda kullanılan homojen katalizörlerin geri kazanımı veya tekrar kullanılabilirliği için faydalı olabilir.

Anahtar Kelimeler: Benzimidazol, kumarin, benzimidazolyum tuzları, floresans özellik

ABSTRACT

SYNTHESIS and PROPERTIES of BENZIMIDAZOLES BEARING COUMARIN

OLGUNDENİZ, Begüm
MSc in Chemistry Department.
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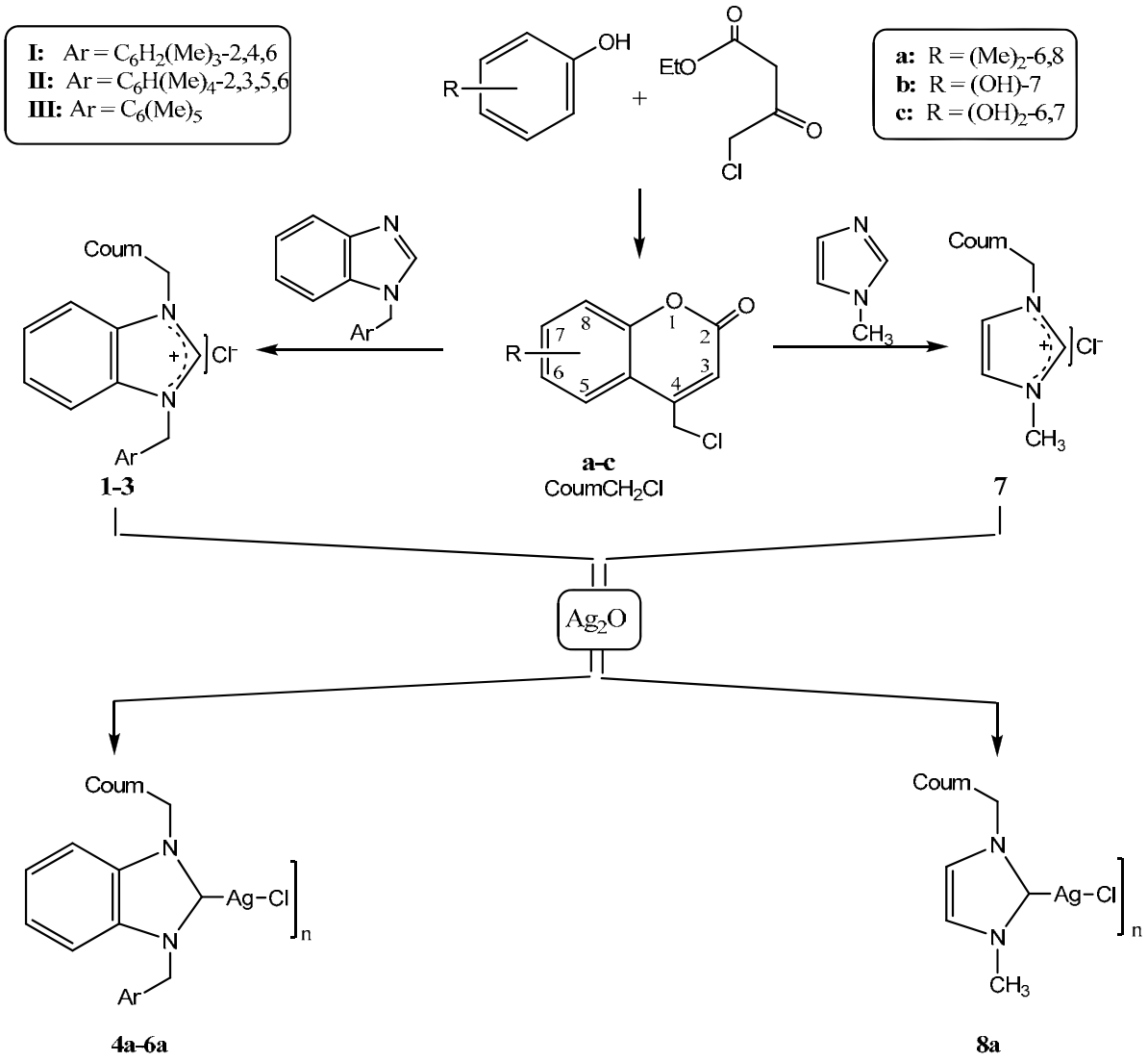
Eylül 2011, 77 sayfa

This thesis describes the synthesis, characterization and properties of N-heterocyclic carbene (NHC) precursors (**1**-**3** and **7**) and NHC-Ag complexes (**4a**-**6a** and **8a**) in which coumarin derivatives are linked to N-3 atom through -CH_2- entity. Strong fluorence of some coumarins and the presence of lactone moiety (readily hydrolyze to give water-soluble species) in the coumarin structure make it a valuable candidate.

The thesis divided into three main parts: The first part is a concise review about benzimidazoles, coumarins and NHC's with their importance and usage. In part two the experimental details were given. Part three covers the synthesis, characterization, emission and absorbsiton properties of 1,3-disubstituted benzimidazolium and imidazolium salts and their silver complexes including coumarin.

In this study, series of 1,3-disubstituted benzimidazoluim salts and their silver complexes which contains coumarin on nitrogen atom were synthesized. The synthesis of the new compounds was perfomed according to the pathways shown in the Scheme below. In the first step, 4-chloromethyleted coumarins (**a**-**c**) were synthesized by Pechmann method. In the second step they were used to quaternize N-alkylated benzimidazoles (**I**-**III**) and 1-methylimidazole. In the last step the unsymmetrical diazolium salts (**1**-**3** and **7**) were treated with Ag_2O to obtain NHC-Ag complexes.



The salts derived from 4-chloromethyl-6,8-dimethylcoumarin (**a**), afforded the expected NHC-Ag complexes (**4a**-**6a** and **8a**) in high yield at RT. Whereas the salts containing phenolic OH on the benzene ring failed. All new compounds have been fully characterized by IR and multinuclei NMR spectroscopy. Their absorption and emission data were also evaluated.

The lactone ring of complex **8a** was found to be viable to aqueous KOH. The hydrolysis product can be converted to the starting NHC-Ag complex (**8a**) in almost quantitative yield. This reversibility may be very useful for the recovery/or recycling of homogeneous catalysts in catalytic reactions taking place in basic conditions.

Key Words: Benzimidazole, Coumarin, Benzimidazolium salts, Photo-physical property

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BEGÜM OLGUNDENİZ

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SYMBOLS AND ABBREVIATIONS

Abbreviation	Explanations
abs	Absorbstion
Ar	Aryl
$CDCl_3$	Deuteriochloroform
dec.	Decompose
DMF	N-N^{l}-dimethylformamide
DMSO	Dimethyl sulfoxide
Et	Ethyl
Et_2O	Diethyl ether
em	Emission
e.r.o	Electron-rich-olefins
FT-IR	Fourier Transformation Infrared
Hz	Hertz
Me	Methyl
m.p	Melting Point
NHC	N-heterocyclic carbene
NMR	Nuclear magnetic resonance
RNA	Ribonucleic acid
RT	Room temperature
UV	Ultraviolet
d	Doublet
m	Multiplet
s	Singlet
t	Triplet
β	Beta

1. INTRODUCTION

1.1 Benzimidazoles

Benzimidazole is a dicyclic and heterocyclic compound which contains imidazole ring (having two nitrogen atoms at nonadjacent positions) fused to benzene. These N-atoms are situated in the 1- and 3-positions. Its systematic name is 1,3-benzodiazole.

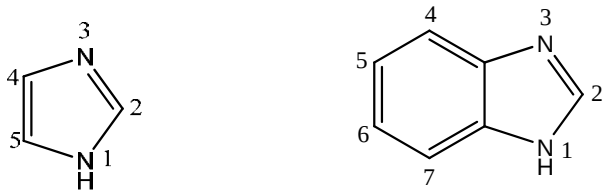


Figure 1.1 Imidazole and benzimidazole rings with numbering schemes

Three isomers of the benzimidazole molecules are known (Figure 1.2). The isomer called benzo[d]imidazole or shortly benzimidazole is the important one. Because a massive research effort has been expanded upon the chemistry of benzo[d]imidazoles with particular emphasis on the synthesis of new compounds for pharmacological importance (Kutlu, 1976).

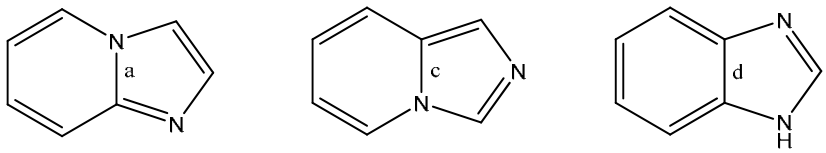


Figure 1.2 Benzimidazole isomers

Purine and indole are two of the analogs of benzimidazole. A purine is a heterocyclic aromatic organic compound and it is an analog of benzimidazole with two additional nitrogen atoms in the six-membered ring. Purines, including substituted purines and their tautomers, are the most widely distributed kind of nitrogen-containing heterocycle in nature (Rosemeyer, 2004). Purine itself, has not been found in nature, but it can be produced by organic synthesis.

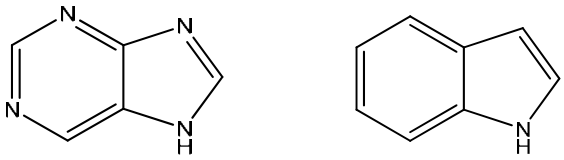


Figure 1.3 Purine and indole rings

Benzimidazoles are regarded as a promising class of bioactive heterocyclic compounds that exhibit a range of biological activities. Specifically, this nucleus is a constituent of vitamin-B_{12}. Benzimidazole ring system is present in numerous antioxidant, antiparasitic, antihelmintics, antiproliferative, anti-HIV, anticonvulsant, antiinflammatory, antihypertensive activities (Ansari and Lal, 2009; O'Niel et. al, 2001). Benzimidazole structure is a part of the nucleotide portion of vitamin B_{12} and the nucleus in some drugs such as proton pump inhibitors and anthelmintic agents.

Vitamin B_{12}, vitamin B12 or vitamin B-12, also called cyanocobalamin, is a water soluble vitamin with a key role in the normal functioning of the brain and nervous system, and for the formation of blood. B_{12} is the most chemically complex of all the vitamins. The structure of B_{12} is based on a corrin ring, which is similar to the porphyrin ring found in heme, chlorophyll, and cytochrome. The central metal ion is cobalt. Four of the six coordination sites are provided by the corrin ring, and a fifth by a dimethylbenzimidazole group. The sixth coordination site, the center of reactivity, is variable, being a cyano group (-CN), a hydroxyl group (-OH), a methyl group (-CH_3) or a 5'-deoxyadenosyl group (Jaouen, 2006)

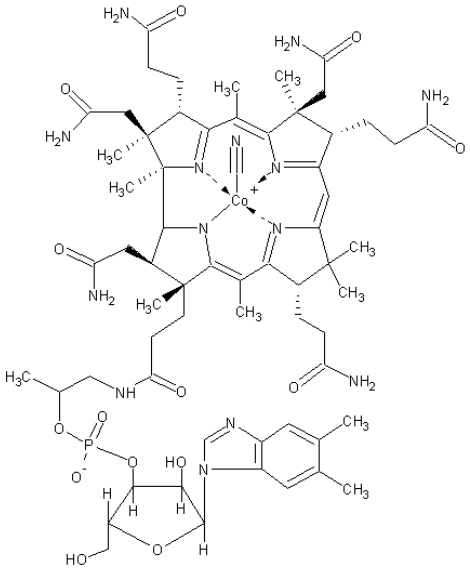


Figure 1.4 Vitamin B_{12} (cyanocobalamin)

1.2 Properties of Benzimidazoles

1.2.1 Physical properties

Benzimidazole is a white to slightly beige crystalline solid; melting at 172 ^{o}C, boils at 360 ^{o}C. The melting and boiling points of N-substituted benzimidazoles are lower than benzimidazole itself because of imino hydrogen. Benzimidazoles are soluble in polar solvents but slightly soluble in non polar solvents.

1.2.2 Chemical properties

As can be seen from Figure 1.2, benzimidazole is a fused-ring heterocycle that contain both a benzene ring and a heterocyclic aromatic ring (imidazole). The chemistry of benzimidazole is just what we expect from our knowledge of the simpler heterocycle imidazole. The reactions occur on the benzene ring or N atoms of the imidazole ring. Some reactions of unsubstituted benzimidazole was summarized in Figure 1.5.

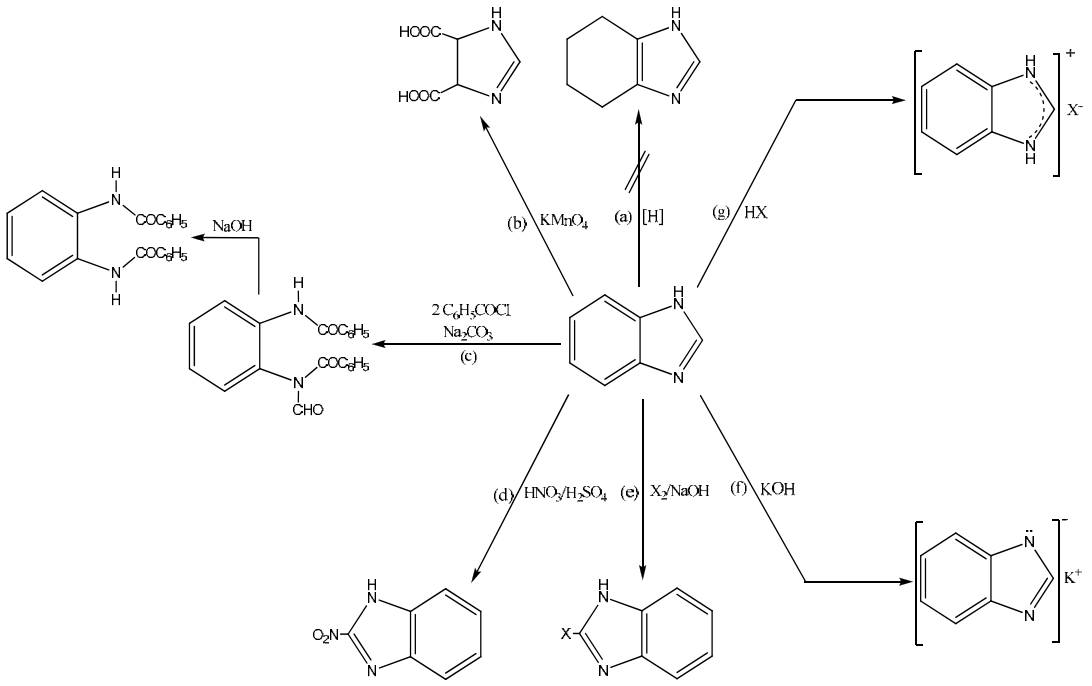
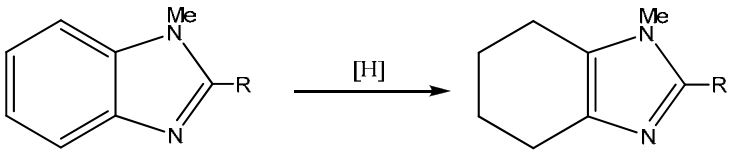


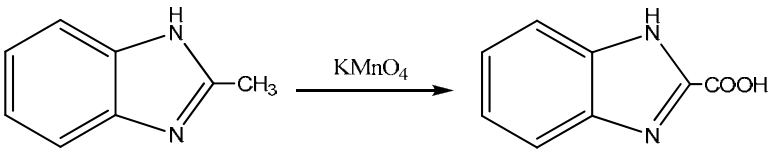
Figure 1.5 Chemical reactions of benzimidazole

Benzimidazoles cannot be reduced with nickel and hydrogen (a). However, 1-methyl-2-ethyl and 1,2-dimethyl benzimidazole can be converted to their tetrahydro derivatives when they are hydrogenated in glacial acetic acid on platinium oxide (Oelschlager and Giebenhain, 1973).



R= Me, Et

Chemical inertness can be mentioned as one of the most important properties of benzimidazoles. When benzimidazole is reacted with potassium permanganate benzene ring opens by oxidation and 4,5-imidazole dicarboxylic acid forms (b). However, 2-benzimidazole carboxylic acid forms by oxidation of 2-methyl benzimidazole with potassium permanganate.



2-Benzimidazolecarboxylic acid

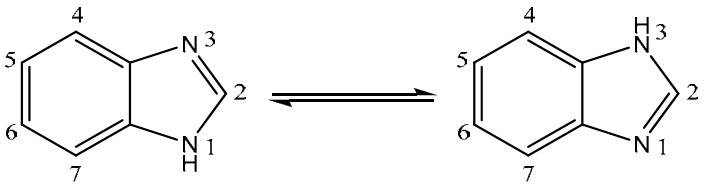
Imidazole ring in benzimidazole opens by benzoil chloride with Schotten-Baumann technique in basic conditions and as a result *o*-phenilendiamine dibenzoil derivatives form (c). Then, N,N'-diacyldiaminobenzene derivatives are formed by the interaction with NaOH.

Benzimidazole reacts with alkyl and acyl halides in 1-position and it binds with electrophilic reagents in 2 position (d)-(e).

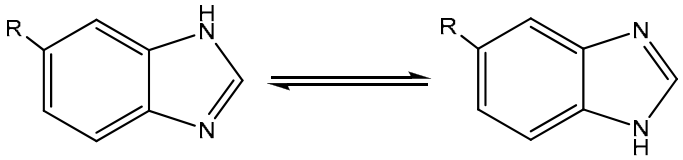
Unsubstituted benzimidazoles are amphoteric heterocycles. They can form salts with mineral acids (f)-(g). Their basic character is due to the presence of tertiary nitrogen which can bind a proton. This heterocyclic compound is also acidic, so easily react with bases (KOH, NaOH, NaH).

1.2.3 Tautomeric character

Imino hydrogens show tautomerism in heterocyclic systems.



In the substituted benzimidazoles, the two isomeric structures are at equilibrium. Therefore, for naming the position of the substituent (R) is shown as 5(6) respectively.

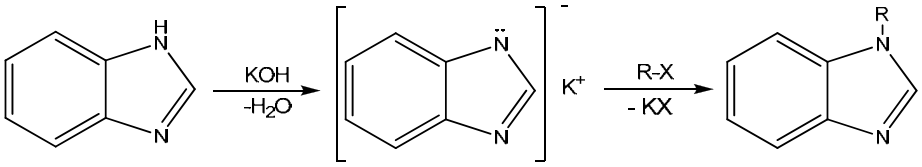


6-Alkylbenzimidazole 5-Alkylbenzimidazole

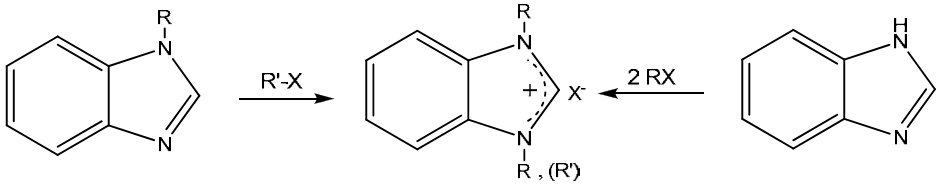
Tautomerism of this kind is not possible for N-substituted benzimidazoles. The tautomerism in these heterocycles were discovered by Kaiser for the first time (Kaiser,1885).

1.2.4 Dialkylbenzimidazolium salts

As mentioned above, the hydrogen in the 1-position of benzimidazole has an acidic character (f). Therefore, 1-substituted benzimidazoles are formed by the reaction between benzimidazole with base catalyst.



1,3-Dialkylbenzimidazolium salts can be prepared by the reaction of 1 mol mono alkyl benzimidazole and 1 mol alkyl halide or by the reaction of non-substituted alkyl benzimidazole and 2 mol alkyl halide:



Recently a variety of 1,3-disubstituted benzimidazoles have been reported and some of them have been included in Table 1.1.

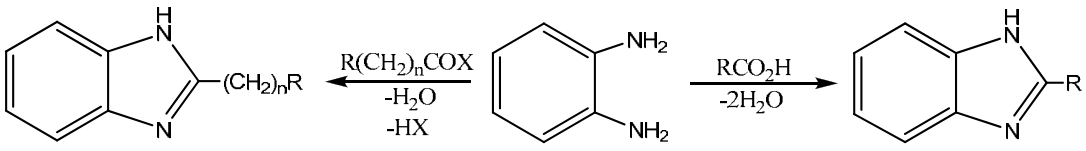
Table 1.1 Dialkylbenzimidazole salts

R	R'	X^-	References
methyl	methyl	I	Jiang and Shi, 1998
iso-propyl	*iso*-propyl	Br	Starikova et. al., 2003
iso-butyl	methyl	Br	Starikova et. al., 2003
iso-butyl	*iso*-butyl	Br	Starikova et. al., 2003
iso-butyl	*iso*-butyl	I	Starikova et. al., 2003
benzyl	benzyl	Cl	Starikova et. al., 2003
hexyl	hexyl	Br	Lee et. al., 2010
hexyl	hexyl	I	Lee et. al., 2010
hexyl	hexyl	PF_6	Lee et. al., 2010
benzhydryl	1-methoxypropane methyl propyl ether	Br	Doğan et. al., 2009
benzhydryl	1-ethoxypropane ethyl propyl ether	Br	Doğan et. al., 2009
benzhydryl	2-ethyl-1,3,5-trimethyl benzene	Br	Doğan et. al., 2009
benzhydryl	5-ethyl-1,2,3-trimethoxybenzene	Br	Doğan et. al., 2009
(1-phosphanylferrocen-1'yl)methyl	(2,4,6-trimethylphenyl)methyl	BF_4	Gülcemal et. al., 2009
ferrocenyl	(2,4,6-trimethylphenyl)methyl	I	Gülcemal et. al., 2009
2,4,6-trimethylbenzyl	$(CH_2)_1$-Ar	Br	Demir et. al., 2006
2,4,6-trimethylbenzyl	$(CH_2)_2$-Ar	Br	Demir et. al., 2006
2,4,6-trimethylbenzyl	$(CH_2)_3$-Ar	Br	Demir et. al., 2006
2,4,6-trimethylbenzyl	$(CH_2)_4$-Ar	Br	Demir et. al., 2006
3,4,5-trimethoxybenzyl	$(CH_2)_2$-Ar	Br	Demir et. al., 2006

3,4,5-trimethoxybenzyl	$(CH_2)_4$-Ar	Br	Demir et. al., 2006
benzhydryl	methoxyethyl	Cl	Özdemir et. al., 2010
benzhydryl	ethoxyethyl	Cl	Özdemir et. al., 2010
benzhydryl	2,4,6-trimethylbenzyl	Cl	Özdemir et. al., 2010
benzhydryl	3,4,5-trimethoxybenzyl	Cl	Özdemir et. al., 2010
2,4,6-trimethylbenzyl	2-ethyl-1,3-dioxane	Br	Özdemir et. al., 2010
methoxyethyl	1-methyl-1,3-dioxalane	Br	Özdemir et. al., 2010
neopentyl	neopentyl	Cl	Kühl et. al., 2008
neopentyl	neopentyl	BF_4	Kühl et. al., 2008
neopentyl	neopentyl	PF_6	Kühl et. al., 2008
neopentyl	neopentyl	HCOO	Kühl et. al., 2008
iso-propyl	*iso*-propyl	Br	Starikova et. al., 2003
iso-butyl	*iso*-butyl	Br	Starikova et. al., 2003
benzyl	benzyl	Cl	Ennajih et. al., 2010
butyl	1-naphtylmethyl	I	Wang et. al., 2009
methyl	methyl	I	Yun Xia et. al., 2003
1H-benzimidazol-1-ylmethyl	[2-(diisopropylamino)ethyl]	Br	Arslan et. al., 2009
3-phenylpropyl	3-phenylpropyl	Br	Akkurt et. al., 2008

1.3 Synthesis of Benzimidazole and Derivatives

2-Substitued benzimidazoles are formed by the reaction of benzimidazole with carboxylic acid and carboxylic acid derivatives.



It is easier to obtain N,N'-diacyl derivatives of *o*-phenylendiamin which includes substituent than mono acyl derivatives.

Benzimidazoles are derived from pyrolysis of diacyl derivatives of *o*-phenylendiamines at 200-350 ^{o}C or heating up with aqueous acids.

It is sometimes not possible to obtain an appropriate product. It is needed more compulsive conditions in those situations.

1.4 Usage of Benzimidazoles

1.4.1 Pharmaceutical importance of benzimidazoles

Because of its synthetic utility and broad range of pharmacological activities, the benzimidazole nucleus is an important heterocyclic ring. Benzimidazole has been an important pharmacophore and privileged structure in medicinal chemistry, encompassing a diverse range of biological activities (Kuş, 2002).

A number of benzimidazole derivatives are known to posses versatile pharmacological activities (Küçükbay et. al, 2001) such as antimicrobials (Küçükbay et. al, 1995; Durmaz et. al, 1997; Çetinkaya et. al, 1999) and antifungals, antiulcers (Güven et. al, 2007), antiinflammatuars (Ersan et. al, 1997), antihypertensives (Dorsch et. al, 1994), antivirals (Starcevic et. al, 2007), antihistaminics (Settimo et. al, 1992), anticancers (Huang et. al, 2006) and cytotoxic (Dahiya et. al, 2007).

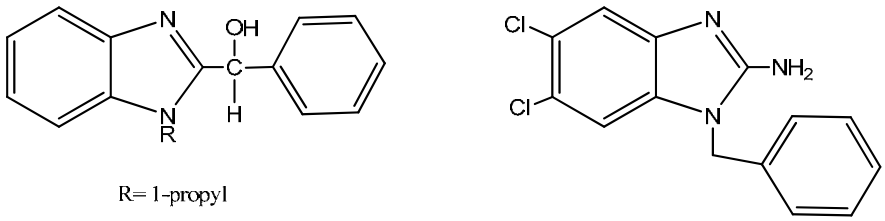
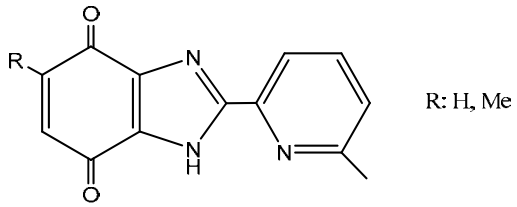


Figure 1.6 Potent inhibitors of RNA

Many reports have revealed that the influence of the substitution at the 1,2 and 5 positions of the benzimidazole ring is very important for their pharmacological effects. The substituents at the 1- and 2-positions of this heterocycle have been intensively studied and led to derivatives with good

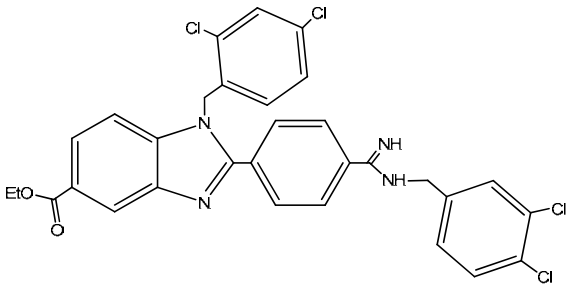
antiviral activity It is well known that several 1,2-disubstituted benzimidazoles were potent inhibitors of RNA viruses and this effect prompted intensive efforts to prepare and evaluate other derivatives (Göker and Kuş, 1995; Garuti et. al, 2000).

An example of these activities; a number of benzimidazolediones displays good antitumor activity. In most cases the activity is related to the ability of quinone to accept one or two electrons to form reactive species toxic to cells (Garuti et. al, 2004).

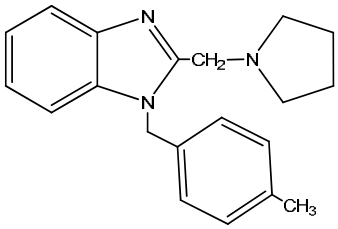


Among them aromatic amidines exhibit broad antimicrobial activity including antifungal, antibacterial, antiviral, and antiprotozoal activities. However, despite the broad activity, toxicity of diamidino compounds has restricted their clinical usage. Only one compound, pentamidine, has been used clinically (Alagöz et. al, 2006; Del Poeta et al., 1998).

The versatility of benzimidazole and its potentiality to yield derivatives with a wide range of biological activity made it a useful structure for further molecular exploration.

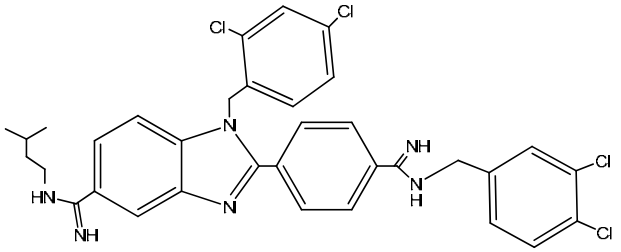


2-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphtalen-2-yl)1H-benzimidazole-5-carboxamidine analogue

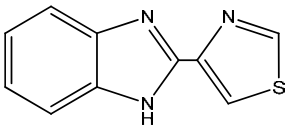


Clemizole (Bactericide)

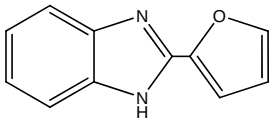
Figure 1.7 Some drugs containing benzimidazole ring



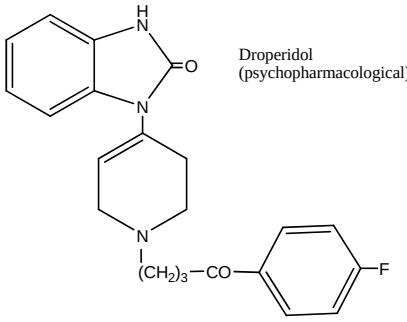
2-(5.5.8.8-tetramethyl-5.6.7.8-tetrahydronaphtalen-2-yl)1H-benzimidazole-5-carboxamidine analogue



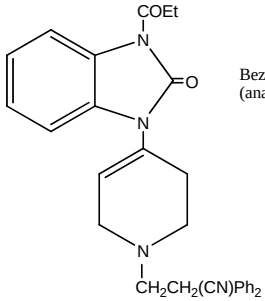
Thiabendazole
(antihelmintic)



Fuberidazole
(fungicide)



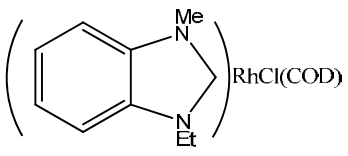
Droperidol
(psychopharmacological)

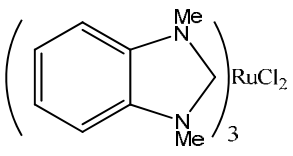


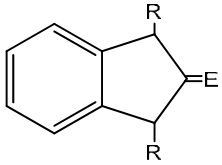
Bezitramide
(analgesic)

Figure 1.7 Some drugs containing benzimidazole ring (continue)

Benzimidazoles and their metal complexes, bound via C_2 to metal or calcogen atom show biological activity. The antimicrobial activity of benzimidazole-ruthenium(II) and benzimidazole-rhodium(I) complexes were first described by Çetinkaya et al in 1996, and benzimidazole ureas (oxygen, sulphur, selenium and tellurium) have also exhibit biological activity (Çetinkaya et. al, 1996; Sandoval et. al, 2008).







E= O, S, Se

Figure 1.8 Benzimidazole derivatives were tested on microorganisms (Enterococcus Feacalis and Staphlococcus Aereus) and they were very efficient.

1.4.2 Polybenzimidazoles

Poly(2,2'-(*m*-phenylene)-5,5'-bibenzimidazole), named PBI, is a class of high-temperature, high-performance polymer that has been commercialized. PBIs are heterocyclic polymers that are attractive because of their outstanding mechanical and dielectric properties at high temperatures.

Polybenzimidazole or PBI fiber is a synthetic fiber with an extremely high melting point that also does not readily ignite, because of its exceptional thermal and chemical stability. PBI is used to fabricate high-performance protective apparel such as fire fighter turnout coats and suits, astronaut space suits, high temperature protective gloves, welders apparel, race driver suits, braided packings, and aircraft wall fabrics (Hiroshi and Tadahiko, 2005).

Polybenzimidazoles are generally prepared via melt polymerization of aromatic bis (*o*-diamine)s with aromatic dicarboxylic acid derivatives.

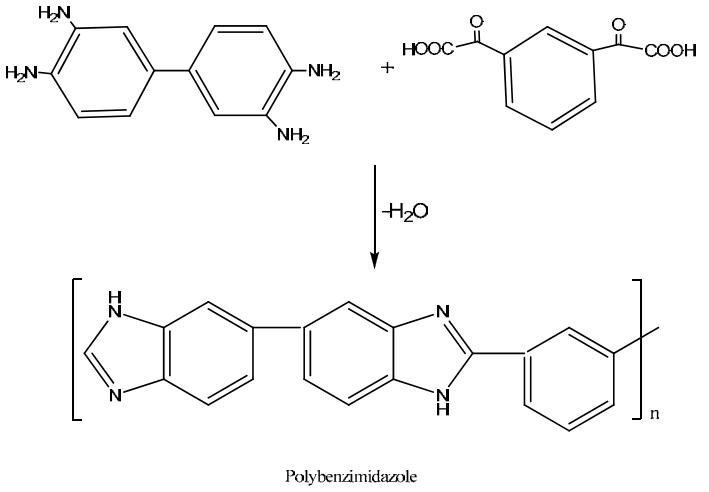


Figure 1.9 Reaction of polybenzimidazole

1.5 Coumarins

Coumarins are also called benzopyrans. IUPAC name of coumarin is 2*H*-chromen-2-one. Benzopyrans are heterocyclic compounds which are formed by the condensation of pyron ring and benzene ring. These are categorized into two main groups. One of them is named 2H-1-benzopyran-2-one and the other one is 4H-1-benzopyran-4-one.These compounds have a different structure because of the position of carbonyl group on benzopyrane ring. If the carbonyl group is in α-position, it is called coumarin and if the carbonyl group is in γ-position, it is called chromone.

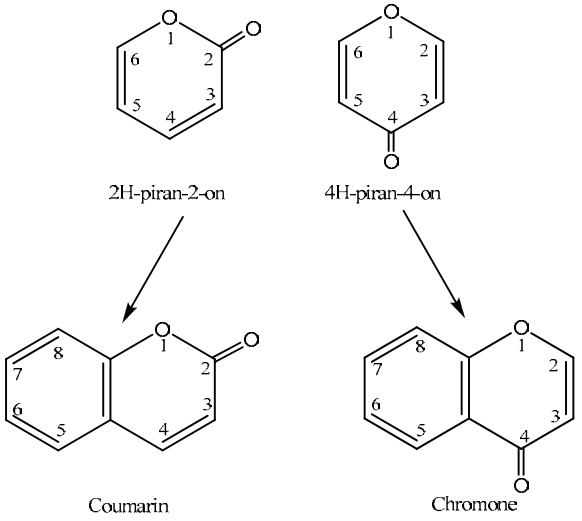
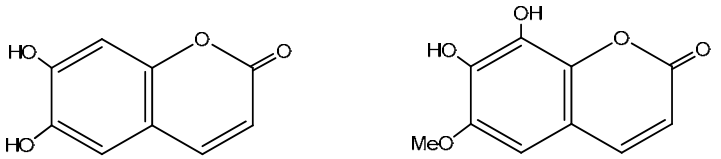


Figure 1.10 Benzopyrans

Coumarins occupy an important place in the realm of natural and synthetic organic chemistry. They are used as anticoagulants, additives in food and cosmetics and in the preparation of insecticides, optical brighteners and dispersed fluorescent and laser dyes (Potdar et. al, 2001). Coumarin is often found in tobacco products and artificial vanilla substitutes, despite having been banned as a food additive in numerous countries since the mid-20th century.

Coumarin is found nearly 200 years ago by Vogel. It is isolated from odorous seed of tree called “coumarouna odarata” which comes from tonquin bean. Therefore, when it is first isolated due to its type, it is named coumarin. The chemical structure of coumarin is clarified by Strecker (1867) and Fitting (1870).

Moreover, coumarins have been isolated from over 800 species of plants and microorganisms, and more than 1000 coumarin derivatives have been described (Yu et. al, 2010). Coumarin derivatives are obtained from approximately 600 kind of plants apart from tonquin bean. For instance, these derivatives exist in natural compounds such as aesculetine (6,7-dihydroxycoumarin) and fraccetine (7,8-dihydroxy-6-methoxycoumarin), and also in some flowers of plants as a free form or glycoside form.



Aesculetine
(6,7-Dihydroxycoumarin)

Fraccetine
(7,8-Dihydroxy-6-methoxycoumarin)

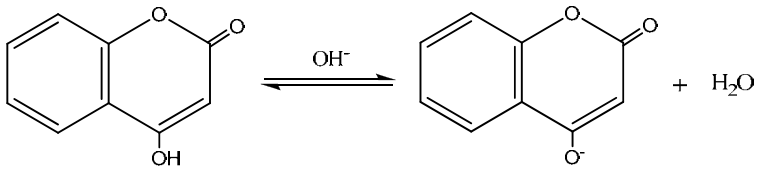
Figure 1.11 Aesculetine and fraccetine

Lavander, apricot, cherry, blackberry, sweet clover, hartstongue, strawberry, cinnamon and much more plants include coumarin ring in their structure. These plants contains coumarin ring on their shells, leaves, carcasses and branches.

1.6 Properties of Coumarin

1.6.1 Physical properties

It boils at 301 ^{o}C and melts at 71 ^{o}C. Coumarin and its derivatives are soluble in ethanol and methanol, they normally do not dissolve in water but 4-hydroxycoumarin derivative turns up a different derivative which is dissolved by water in dilute alkaline situation.



1.6.2 Chemical properties of coumarin

Some chemical reactions of coumarin can be seen in Figure 1.12.

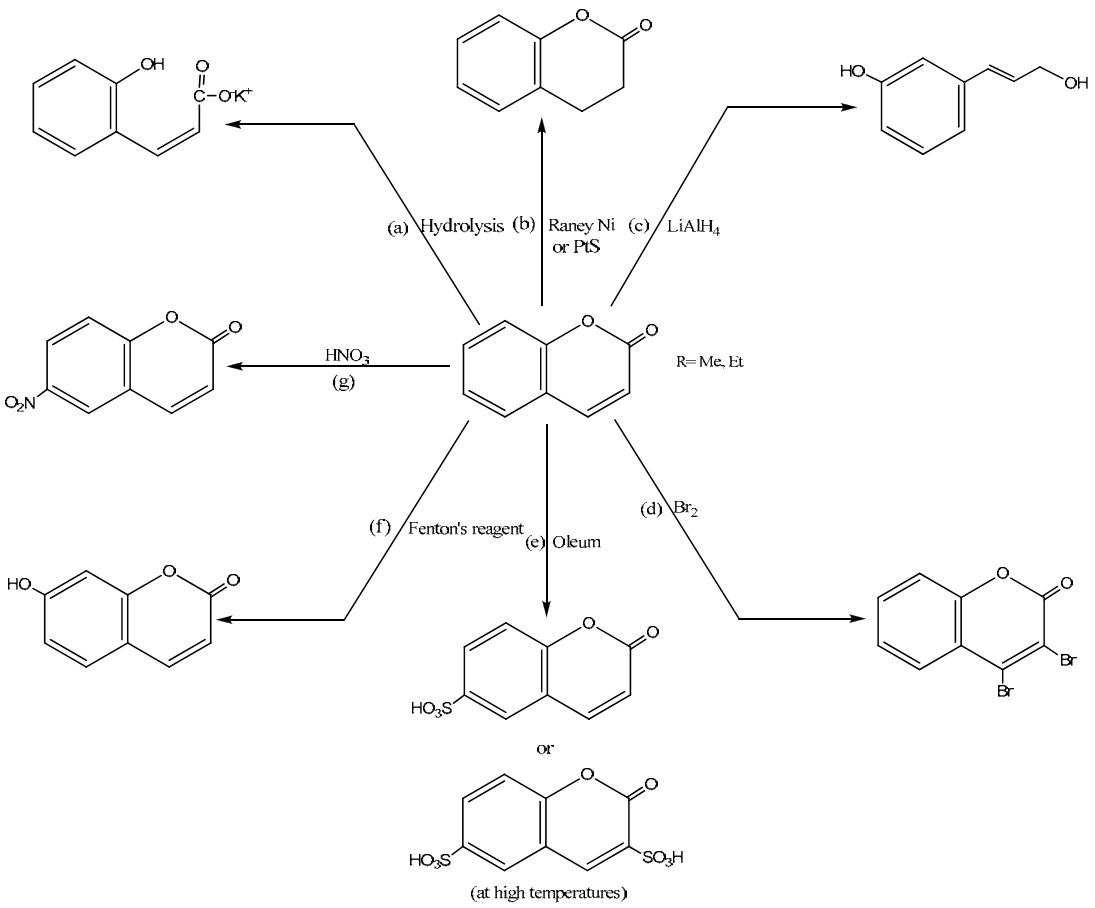


Figure 1.12 Chemical reactions of coumarin

Hydrolysis

If carboxylic acids have hydroxyl group on their δ and the other carbons, there comes a molecular esterification and lactones are formed (a). Coumarins are cyclic esters so they are lactones. Generally, all reactions of esters are applicable to the lactons. The lactone is easily hydrolyzed by aqueous alkalies to the corresponding salts of coumarinic acid or *o*- hydroxy-*cis*- cinnamic acid. Reaction came true with acid catalyst. Coumarinic acid and salts revert to coumarin upon acidification with inorganic acids.

Hydrogenation

Hydrogenation of coumarin gives several different products depending on conditions. Hydrogenation with a Raney nickel catalyst under moderate conditions yields 3,4-dihydrocoumarin (b) (Dominguez et. al, 1961) but continued hydrogenation especially at higher temperatures leads to the formation of the

saturated octahydrocoumarin. 3,4-Dihydrocoumarin is also obtained selectively by hydrogenation over a platinum sulfide catalyst (Amidon and Greenfield, 1972).

Reduction

Coumarin is reduced to *o*-hydroxy cinnamyl alcohol (c) by reaction with lithium aluminum hydride (Karrer and Banerjea, 1949).

Halogenation

Coumarin reacts with bromine under moderate conditions to give 3,4-dibromocoumarin (d). The 3-bromocoumarin and 3,6-dibromocoumarin are formed under more rigorous conditions. 3-Chlorocoumarin is formed by reaction with chlorine in dichloroethane or without solvent (Fuson, 1955).

Sulfonation

Fuming sulfuric acid (a solution of sulfur trioxide in sulfuric acid) reacts with coumarin to give coumarin-6-sulfonic acid at moderate temperature and coumarin-3,6-disulfonic acid at higher temperature (e).

Oxidation

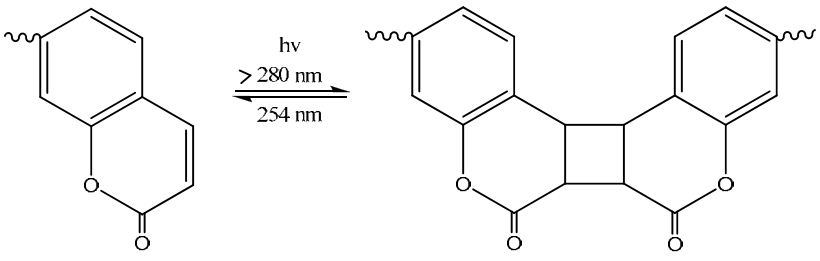
Coumarin is not readily oxidized by chromic acid but, by action of the Fenton's reagent (a solution of hydrogen peroxide and an iron catalyst), it is converted into 7-hydroxycoumarin (umbelliferone) (Boyland and Sims, 1953) (f).

Nitration

Fuming nitric acid forms 6-nitrocoumarin (g) (Sethna and Shah, 1945).

1.6.3 Dimerization

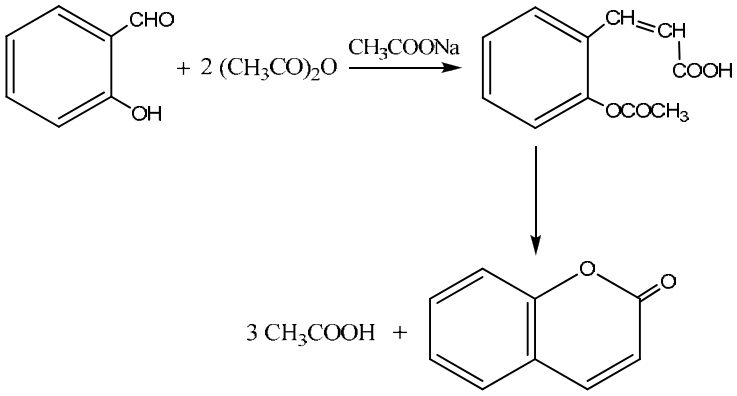
A coumarin dimer is formed by prolonged exposure of coumarin to sunlight or UV radiation. Photodimerization is also catalyzed by boron trifluoride (Lewis et. al, 1983; Nishida, 2011).



1.7 Synthesis of Coumarins

1.7.1 From salicylaldehyde

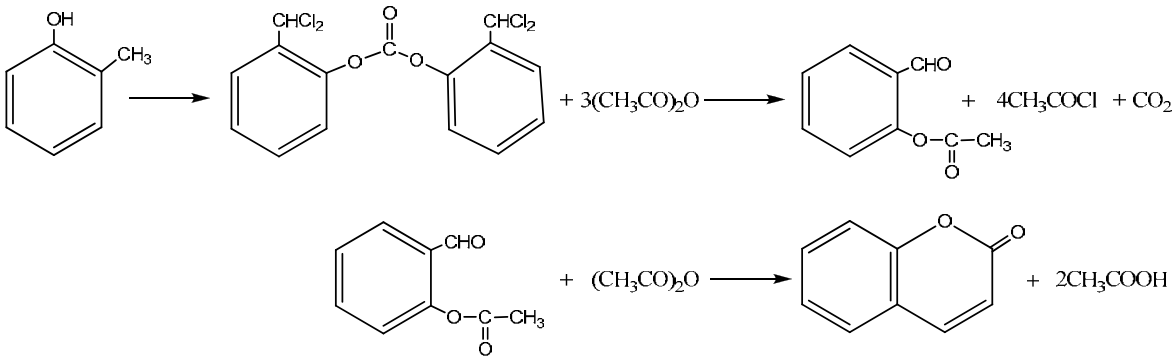
Perkin first synthesized coumarin in 1868 by reaction of the sodium salt of salicylaldehyde with acetic anhydride and it was found later that the reaction could be made from salicylaldehyde itself by using sodium acetate as a catalyst, through the intermediary of cis-*o*-acetoxycinnamic acid.



This reaction was also extended to other aromatic aldehydes for the preparation of α,β-unsaturated carboxylic acids. Several mechanisms of the reaction have been proposed (Johnson, 1942). The most accepted mechanism involves the reaction of the aldehyde with the enol form of the acid anhydride which is promoted by the presence of the sodium salt or of another base. The resulting reaction product is then dehydrated into an unsaturated carboxylic acid (Perkin, 1877; Perkin, 1868).

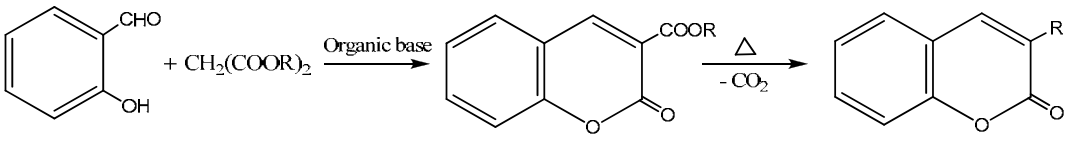
1.7.2 From *o*-cresol

The hydroxyl group of *o*-cresol is first protected by a phosphate or, a carbonate group and the methyl group is converted into a benzal chloride intermediate by dichlorination. The α,α-dichlorocresyl ester then reacts with an alkali acetate in an alkali fusion reaction or with acetic anhydride in the presence of a metal catalyst such as cobalt oxide to yield *o*-acetylsalicylaldehyde, acetyl chloride, and CO_2. Ring closure of *o*-acetyl salicylaldehyde with acetic anhydride gives coumarin and acetic acid (Raschig, 1909)



1.7.3 Knoevenagel reaction

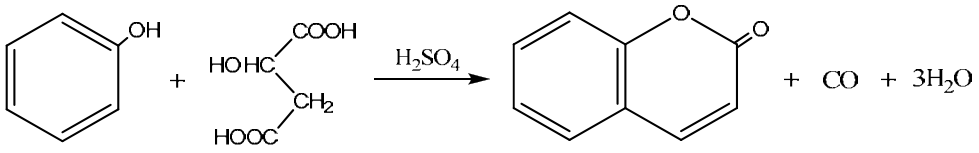
3-Substituted coumarins can be synthesized by the Knoevenagel reaction, which involves the condensation of *o*-hydroxyaldehydes such as salicylaldehyde with acetic acid derivatives containing an active methylene group such as acetoacetic acid, malonic acid, cyanoacetic acid, and their esters. Ammonia or organic bases such as pyridine, piperidine, and primary and secondary amines are used as catalysts (Jones, 1967). Removal of the substituted group in the 3-position by heating or hydrolysis can produce coumarin. Thus coumarin 3-carboxylic acid obtained by the condensation of salicylaldehyde with malonic acid is decarboxylated into coumarin by heating to 290°C. The decarboxylation reaction can be done at a lower temperature and with a better yield in the presence of mercuric salts (Knoevenagel, 1898).



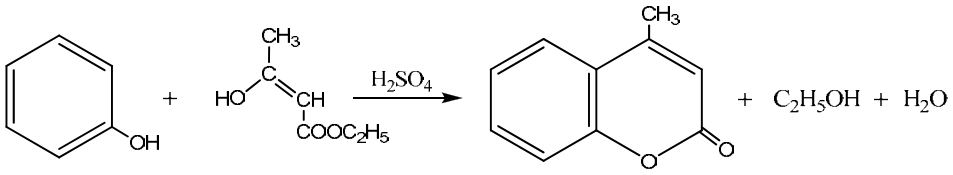
1.7.4 From phenol

This type of condensation discovered by von Pechmann in 1883. Coumarin is formed by reaction of phenol with malic, maleic or fumaric acids in the presence of concentrated sulfuric acid. The Pechmann reaction is most widely applied for the synthesis of coumarins due to simple reaction conditions and good yields. Several acid catalysts are used for the Pechmann reaction including sulfuric acid, phosphorus pentoxide, aluminum chloride, and trifluoroacetic acid. However these catalysts have to be used in an excess. Also this reaction was

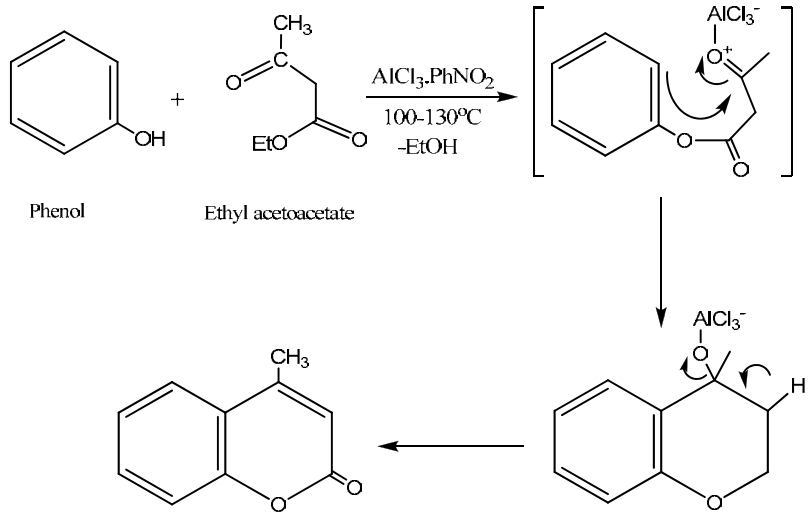
reported using ionic liquids, clays, and microwave irradiations (Kokare et. al, 2007).



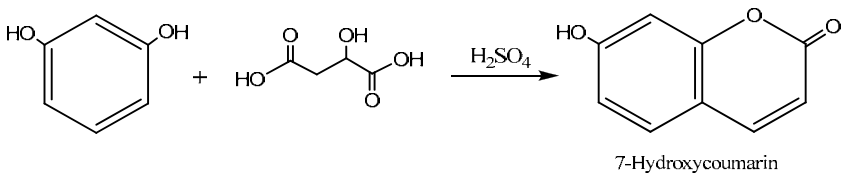
The Pechmann reaction has found extensive applications for the synthesis of numerous coumarin derivatives (Sethna, 1953) and gives good yields of 4-substituted coumarins. Coumarin derivatives substituted in the pyrone ring can be obtained by condensing phenol with beta-ketoesters. For example, 4-methylcoumarin is obtained with ethyl acetoacetate.



Pechmann Reaction Mechanism has been presented below: (Joule and Mills, 2000)



Similarly, diphenols can react with hydroxycarboxylic acids or beta-ketoesters to give hydroxycoumarin derivatives. The reaction of resorcinol with malic acid produces umbelliferone (7-hydroxycoumarin) and its reaction with ethyl acetoacetate gives beta-methyl umbelliferone (7-hydroxy-4-methylcoumarin).



7-Hydroxycoumarin

1.8 Importance of Coumarins

Coumarins are phytochemical compounds which contain a vanilla smell in their structure and they have a crucial place in natural and synthetic organic chemistry. Coumarin and its derivatives have a widespread range of usage such as additives in food, parfumes, cosmetics, pharmaceuticals, optical brighteners, solar energy collectors, dispersed fluorescent and laser dyes (Reddy et al., 2008).

1.8.1 Pharmaceutical properties

Coumarins occur extensively in the plant kingdom, and many of them exhibit a variety of biological activity such as antihelmintic, anticoagulant, hypnotic, antifungal and insecticide activities (Patil et. al, 2006; O'Kennedy and Thornas, 1997).

Several coumarin derivatives have been shown to posses cardiovascular properties. Many of them are selective coronary vasodilators, an effect that may be related to a Ca^{+2} – antagonist activity. Carbochromen (3-diethylaminoethyl-7-ethoxycarbonylmethoxy-4-methylcoumarin) vasodilator which has been used for many years in the treatment of angina pectoris. Although the exact mechanism of action remains stil unknown (Toimil et. al, 2002).

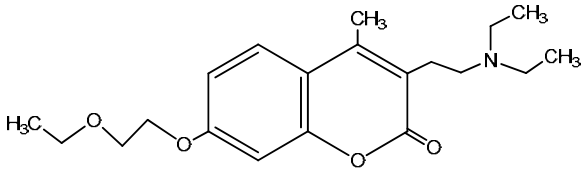


Figure 1.13 Carbochromen

The anti-HIV agent "calanolide A" includes coumarin ring in its structure. This antiviral nucleoside agent has been aproved for clinical treatment of AIDS and AIDS-related complex (Flavin et al., 1996).

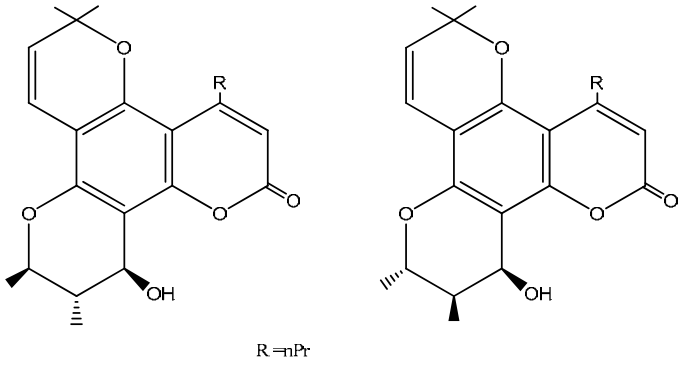


Figure 1.14 (+)- Calanolide

Derivatives of 4-hydroxycoumarin such as dicoumarol, warfarin and cyclocoumarol are synthetic blood anticoagulants. They block the regeneration and recycling of vitamin K.

Some of the 4-hydroxycoumarin anticoagulant class of chemicals are designed to have very high potency and long residence times in the body, and these are used specifically as poison rodenticides. Death occurs after a period of several days to two weeks, usually from internal hemorrhaging.

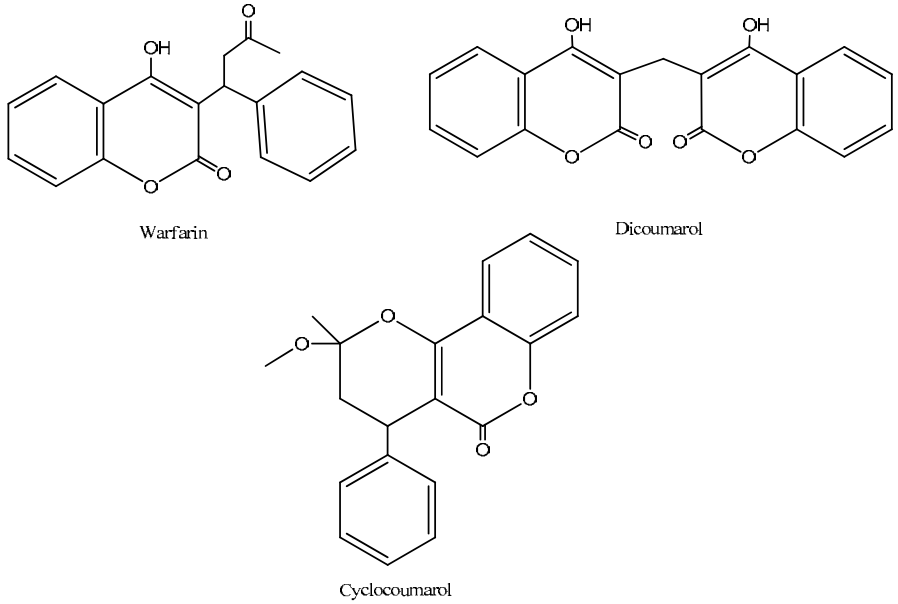


Figure 1.15 Some anticoagulants including coumarin ring

3-Phenylcoumarin and 4-phenylcoumarin are good antioxidants.

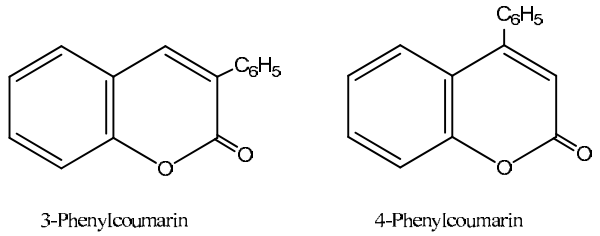


Figure 1.16 3-Phenylcoumarin and 4-phenylcoumarin

Coumarin is moderately toxic to the liver and kidneys, with an LD_{50} of 275 mg/kg—low compared to related compounds. Although only somewhat dangerous to humans, coumarin is a potent rodenticide: rats and other rodents largely metabolize it to 3,4-coumarin epoxide, a toxic compound that can cause internal hemorrhage and death. Humans largely metabolize it to 7-hydroxycoumarin, a compound of lower toxicity (Marles et. al, 1986).

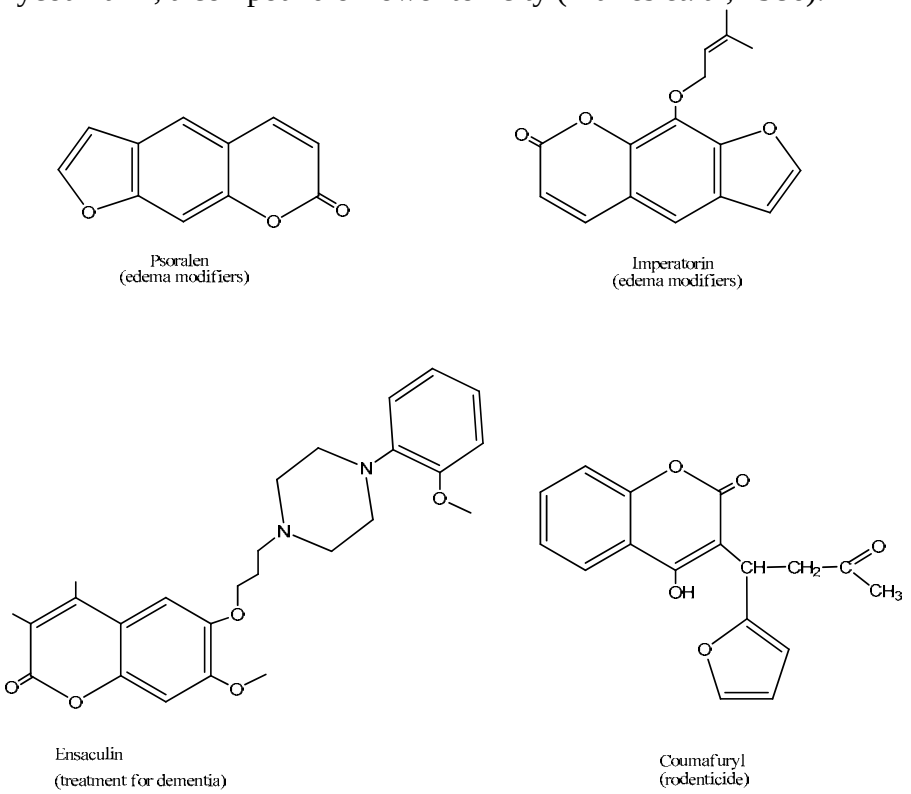
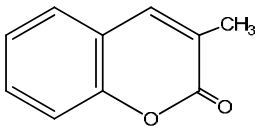


Figure 1.17 Some drugs including coumarin ring

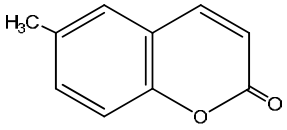
1.8.2 Usage of coumarin

3,4-Dihydrocoumarin is prepared by catalytic hydrogenation of coumarin which is also used in the perfumery industry for its odor. It is less powerful than coumarin but its higher solubility in alcohol may make it preferable in some applications. It can be used as a food flavor ingredient with a sweet caramel-like taste.

3-Methylcoumarin and 6-methylcoumarin have some use in the perfume industry. The 6-methyl derivative is permitted in flavor compositions.



3-methylcoumarin



6-methylcoumarin

1.8.3 Photo-physical properties of coumarins

Compounds based on the coumarin ring system give rise to one of the most extensively investigated and commercially significant groups of organic fluorescent materials (Krasovtskii and Bolotin, 1988).

Coumarin derivatives provide some of the most important commercial fluorescent brightening agents and appropriately substituted compounds are also used as fluorescent dyes for use on synthetic fibres and in daylight fluorescent pigments, which impart a vivid brilliance to a range of paint and printing ink applications (Voedisch, 1973).

Coumarins owe their importance as fluorescent brightening agents and dyes to their efficient light emission properties, their reasonable stability and their relative ease of synthesis (Christie and Lui, 1999).

In addition, fluorescent coumarins may be used in a range of applications which specifically exploit their light emission properties, including non-destructive flaw detection, tunable dye lasers and solar energy collectors.

The photophysical properties of the compounds depend on the nature and position of a substituent group in the parent molecule and also due to a change in the surrounding media. Its found that the nature of solvents and substituents brings about a change in the values of fluorescence wavelenght maxima, quantum yield, lifetime, polarization and excited state dipole moment of the coumarin (Giri, 2004).

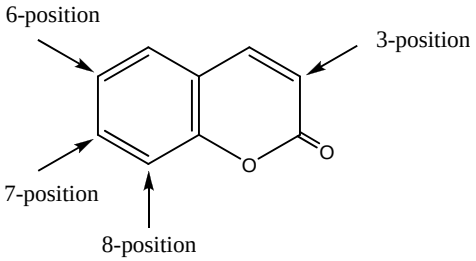
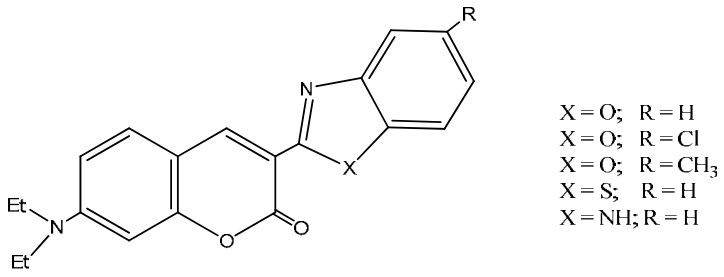


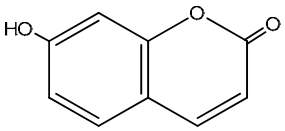
Figure 1.18 Positions for fluorescent property

When the electron-releasing group is in the 3- or 7-position, the longest wavelenght band becomes by far the strongest absorption band, wheares, in contrast, when the group is in the 6- or 8-position, the bathochromic shift is accompanied by a reduction in the band intensity (Christie and Lui, 1999).

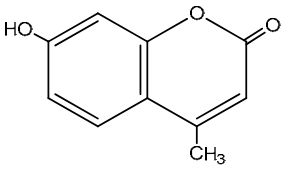
Additionally, coumarins that contain an electron-releasing group on 7-position and a heterocyclic electron-acceptor residue on 3-position, are recognized as fluorescent dyes suitable for application to synthetic fibers (Zakerhamidi et. al, 2010; Sokodowska et. al, 2001).



For example: 7-hydroxycoumarin, known as umbelliferone, occurs naturally in gum resins of umbelliferae and is an important coumarin metabolite. It is readily manufactured from resorcinol and maleic or fumaric acid. Umbelliferone and β-methylumbelliferone are used as fluorescent brighteners. It absorbs ultraviolet light strongly at several wavelengths. Despite several indications that this chemical is photomutagenic it is used in sunscreens (Dean, 1963).



7-Hydroxycoumarin

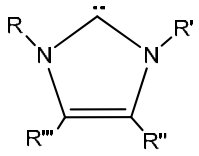


7-Hydroxy-4-methylcoumarin

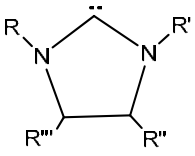
1.9 N-Heterocyclic Carbens (NHC's) and Their Metal Complexes

Carbenes are neutral, electron deficient molecular species that contain a divalent carbon atom surrounded by a sextet of electrons.

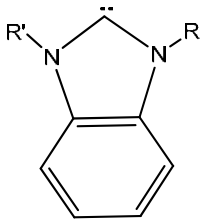
Heterocycles bearing at least one α-amino substituent are known as N-heterocyclic carbenes (NHCs) (Nolan et. al, 2009). NHCs were first reported in the early 1960s (Wanzlick and Schikora, 1961). During the following decade Wanzlick, Öfele and Lappert reported various transition metal complexes with NHC ligands (Wanzlick and Schoenherr, 1968; Öfele, 1968; Lappert et. al, 1971; Cardin et. al, 1973; Cardin et. al, 1972). Isolation of a stable NHC, 1,3-di(1-adamantyl)imidazol-2-ylidene, by Arduengo et al in 1991 revived interest in NHC ligands (Arduengo et. al, 1991) and the subject have been reviewed by several authors [Diez-Gonzalez(Ed.), 2010]. The most commonly studied NHCs, derived from 5-membered rings, are shown below (Note: -ylidene tag is introduced to the name of the heterocycle).



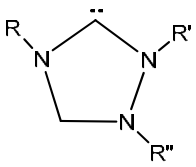
imidazolylidene



imidazolinylidene



benzimidazolylidene

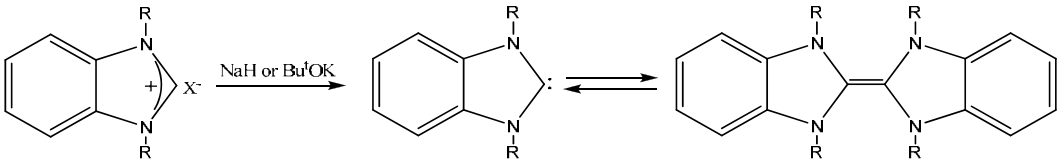


triazolinylidene

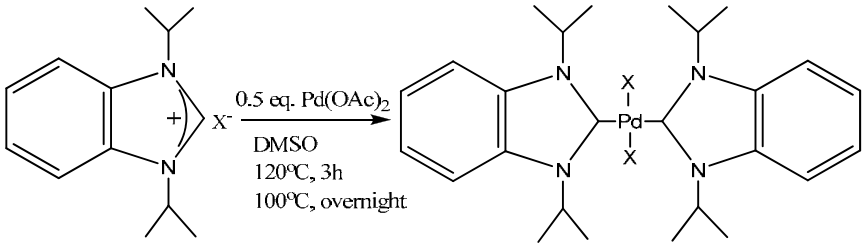
Currently they have been considered as alternative to the phosphine ligands in the field of catalysis (Herrmann, 2002). Subtle changes on the NHC structures, i.e. the ring size, ring atoms or the substituents have a dramatic change on the electron donor properties of the carbene moieties and finally on the metal centre. The successful application of NHC complexes is attributed to strong σ-electron donating properties and strong NHC-M bond which prevents decomposition during the catalysis.

There are various reliable routes to prepare NHCs and NHC complexes. One of the most straightforward is deprotonation of diazol(in)ium salts with a strong base under anaerobic and anhydrous conditions.

1,3-Diazol(in)um salts are converted into N-heterocyclic carbenes (NHCs) with the strong bases such as NaH, KOBu^t under inert atmosphere and anhydrous conditions. Deprotonation of the corresponding azolium salts usually give the free carbene or e.r.o:



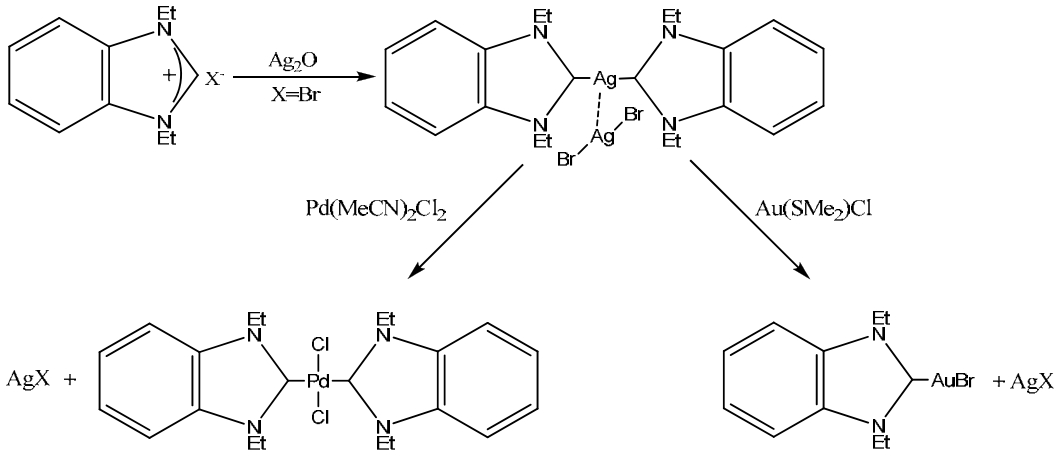
Some basic metals also deprotanate the diazolium salts. For instance, Palladium-NHC complex of benzimidazolium salt and its catalytic activities have been investigated and reported in another literature (Han et. al, 2007).



X: Br, I

On the other hand, NHC-silver complexes can be synthesized in air and aqueous media by means of basic silver compounds such as Ag_2O, Ag_2CO_3 and AgOAc (Wang and Lin, 1998; Lin and Wang, 2007). This procedure involves deprotonation and subsequently coordination of the resulting NHC to the silver atom. The NHC-Ag complexes are very frequently used to transfer the NHC ligand to the noble metals. They also show strong antimicrobial activities (Garrison and Youngs, 2005; Hindi et. al, 2009). In addition, NHC-Ag complexes have been recently used as catalysts in a limited number of transformations (Ramirez et. al, 2005; Sentman et. al, 2005; Samantaray et. al, 2006; Fu et. al, 2011; Li et. al, 2011).

For example, the structural characterization of benzimidazolium salt and its Ag(I) and trans-metallation reactions to the other metal complexes have been investigated and reported in the literature as early as 1998 (Wang and Lin, 1998).



1.10 The Aim of This Study

As stated in section 1.9, NHC ligands described as alternative to phosphines are more strongly electron donating and more strongly bound to the metal. Under normal conditions, M-NHC bond dissociation is unlikely. The introduction of functional groups on the NHC rings via N atoms expanded their catalytic and biological applications to a great extend (Cavell et. al, 2011).

However, as far as we are aware, functionalization with coumarin groups have been not reported so far. The NHC's carrying coumarin skeleton have attracted our attention for two reasons: (i) The lactone ring of the coumarin is easily hydrolyzed by aqueous alkalies to the corresponding salts of coumarinic acid which consequently increases the water solubility of the derived NHC-metal complex. Water solubility of an organometallic catalyst is a very important and desired property from point of environmental and economical view point (Cadierno et. al, 2010). (ii) Coumarin frames are known to be fluorophor group. Tagging with a fluorescent dye enables the dedection of metal complexes down to the single molecule limited as demostrated with fluorescence microscopy (Canham et. al, 2008).

Therefore, one may assume that direct information about species in the catalytic cycle or biological application can be obtained when relevant ligands are attached with fluorophores. As a consequence of these facts, we have planned to synthesize coumarin tagged NHC precursors and silver complexes of the type $[NHC\text{-}Ag\text{-}X]_n$.

2. EXPERIMENTAL

Starting compounds, solvents like dichlormethane, ethanol, diethyl ether, hexane, acetonitrile and N,N-dimetylformamide and reagents were obtained from Merck, Fluka, Alfa Aesar and Acros Organics.

Commercially obtained chemicals were used without further purification. Unless otherwise noted all operations were carried out without taking precautions to exclude air and moisture.

Benzimidazole was provided from Merck. 2,4,6-Trimethylbenzyl bromide, 2,3,5,6-tetramethylbenzyl bromide, 2,3,4,5,6-pentamethylbenzyl bromide were prepared according to literature method (Van der Made, 1993).

Representative protocol was given for the same class of compounds bearing different substituents and data were presented in Tables.

Anhydrous sodium sulphate was used as drying agent.

Melting points were recorded with Gallenkamp electrothermal melting point apparatus.

^{1}H NMR and ^{13}C NMR spectra were taken with Varian AS 400 Mercury instrument at Ege University. As solvent $CDCl_3$ and d_6-DMSO were employed, *J* values were in Hz. Chemical shifts were internally referenced by the residual solvent signals relative to tetramethylsilane (TMS).

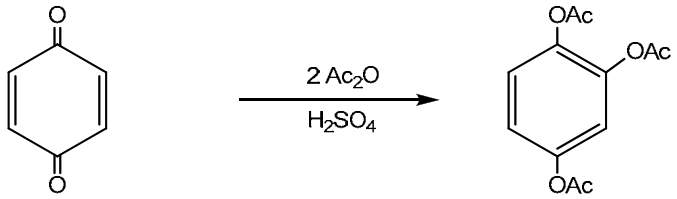
FTIR Spectra were recorded on a Perkin Elmer Spectrum 100 series.

UV Spectra were recorded on a Varian Cary 100 Bio UV Visible Spectrophotometer.

Fluoresans Spectra were recorded on a RF-5301 PC Shimadzu Spectroflurophotometer.

^{1}H, ^{13}C NMR, IR, emission and absorption spectra of known compounds were shown in experimental part. Whereas, spectra (^{1}H, ^{13}C NMR, IR, emission and absorption) of new compounds will be shown in Result and Discussion part.

2.1 Synthesis of 1,2,4-triacetylbenzene



H_2SO_4 (0.57 mL; 10.2 mmol ; %96) was added to acetic anhydride (13.86 mL, 147 mmol) carefully. Afterward, *p*-benzoquinone (8.0 g; 73.5 mmol) was added to a mixture during 1 h (At higher temperatures product was decomposed). The Brown mixture was poured onto cold water (150 mL), the solid was formed, filtered off and was washed several times with water (3x10 mL). The product dried in vacuum desicator in dark place. Yield: 10.63 g; 91.7 % ; m.p: 93-95^{o}C.

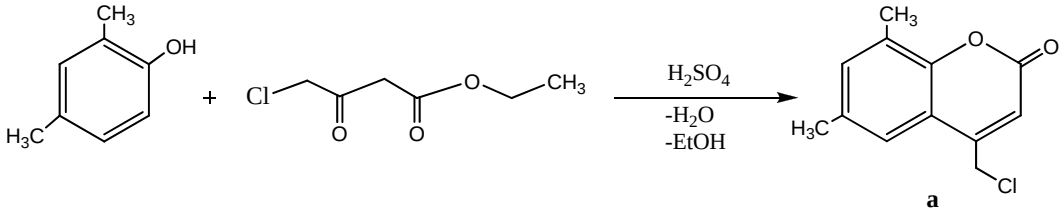
^{1}H NMR (d_6 DMSO): δ (ppm): 7.07 (d, H, *J* =8 Hz, *H*-5); 7.14 (d, H, *J* =8 Hz, *H*-3); 7.29 (d, H, *J* =8 Hz, *H*-6); 2.25; 2.26; 2.48 (s, O=C-C*H*$_3$)

^{13}C NMR (d_6 DMSO): δ (ppm): Carbonyl : 168.6, 168.9, 169.6; aromatics : 120.6, 123.4, 124.5, 140.3, 142.8, 148.5; alkyl: 20.9, 21.4, 21.5

ν (C=O) cm^{-1} : 1760

2.2 Synthesis of 4-chloromethylcoumarine derivatives

2.2.1 Synthesis of 6,8-dimethyl-4-(chloromethyl)-2H-chromen-2-on, a



a

A mixture of ethyl 4-chloroacetoacetate (3.32 mL; 24.5 mmol) and the corresponding 2,4-dimethylphenol (2.96 mL; 24.5 mmol) was added to H_2SO_4 (50 mL ; %75), stirred for 24 h at room temperature. The mixture was poured onto

ice. The resulting precipitate was filtered off and crystallized from ethanol Yield : 5.0 g; 91 % ; m.p: 143-145 (Frasinyuk et al., 2007).

^{1}H NMR (d_6 DMSO): δ (ppm): 2.34 (s, 3H, C*H*$_3$); 2.36 (s, 3H, C*H*$_3$); 5.00 (s, 2H, C*H*$_2$); 6.64 (s, H, *H-3*); 7.36 (s, H, *H-5*); 7.49 (s, H, *H-7*)

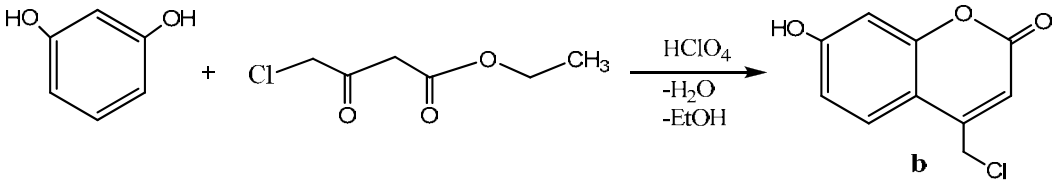
^{13}C NMR (d_6 DMSO): δ (ppm): 42.1 (*C*H$_2$); 115.7 (*C*H); 151.4 (*C*); Carbonyl: 160.4; aromatics: 117.1; 123.1, 125.9; 133.7; 135.0; 150.4; Alkyl: 15.7; 21.1

ν (C=O) cm^{-1}: 1722

λ_{abs} (nm): 217 (2.59); 285 (1.77)

λ_{em} (nm): 377.504 Intensity: 20.617.

2.2.2 Synthesis of 4-chloromethyl-7-hydroxy-2H-chromen-2-on, b



A mixture of resorcinol (3.0 g; 27.2 mmol), ethyl 4-chloroacetoacetate (3.69 mL ; 27.2 mmol) and $HClO_4$ (5.32 ml ; 88 mmol) was stirred for 3 h at 80-90 ^{o}C . After cooling, the mixture was poured onto cold water and then filtrered off. The brown solid was crystallized from methanol Yield: 3.09 g; 54% ; m.p: 173-175 ^{o}C (dec.)

^{1}H NMR (d_6 DMSO): δ (ppm): 4.92 (s, 2H, C*H*$_2$); 6.38 (s, H, *H*-3); 6.72 (d, H, J= 2 Hz, *H*-8); 6.81 (d, H, *J*= 8.4 Hz, *H*-6); 7.64 (d, H, *J*= 8.4 Hz, *H*-5); 10.62 (s, H, O*H*)

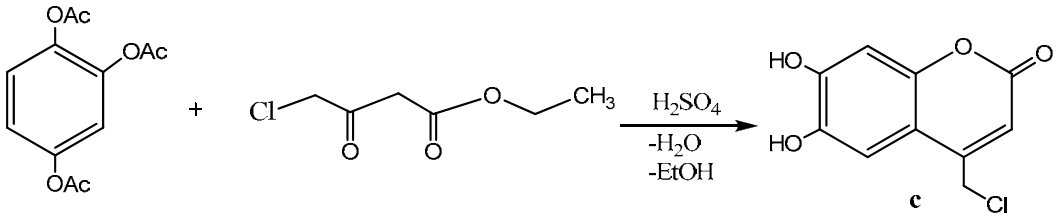
^{13}C NMR (d_6 DMSO): δ (ppm): 42.0 (*C*H$_2$); 110.0 (*C*H); 151.6 (*C*); Carbonyl: 162.1; aromatics: 103.2; 111.7; 113.8; 127.2; 155.9; 160.8

ν (C=O) cm^{-1}: 1683

λ_{abs}(nm): 223 (3.72); 259 (1.51); 315 (4.34); 317 (4.35); 319 (4.40); 332 (4.20); 354 (2.13)

λ_{em} (nm): 393.262 Intensity: 28.148.

2.2.3 Synthesis of 4-chloromethyl-6,7-dihydroxy-2H-chromen-2-on, c



This reaction was carried out under dry argon using standart Schlenk techniques . H_2SO_4 (100 mL ; %75) was added dropwise to a mixture of 1,2,4-triacetylbenzene (8.0 g ; 31.7 mmol) and ethyl 4-chloroacetoacetate (4.29 mL ; 31.7 mmol) in ice bath. The resulting solution was stirred for 2 h. Then the mixture was poured into cold water and the solid was filtrered off. The residue was washed with diethyl ether for several times. Yield : 6.97 g ; 97.2 % ; m.p: 179-182^{o}C.

^{1}H NMR (d_6 DMSO): δ (ppm): 4.85 (s, 2H, C*H*$_2$); 6.38 (s, H, *H*-3); 6.76 (s, H, *H*-8); 7.09 (s, H, *H*-5); 9.31, 10.42 (s, O*H*)

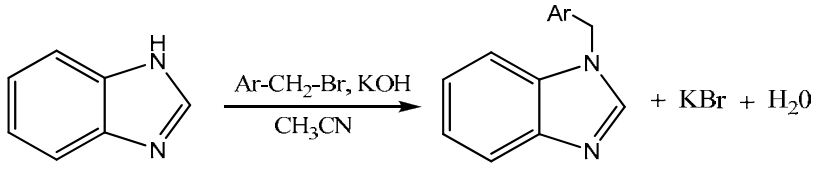
^{13}C NMR (d_6 DMSO): δ (ppm): 42.3 (*C*H_2); 111.8 (*C*H); 151.4 (*C*); Carbonyl: 161.1; aromatics: 103.6, 109.5, 110.1, 143.6, 149.0, 151.3

ν (C=O) cm$^{-1:}$ 1663

λ_{abs} (nm): 213 (2.85); 231 (2.55); 264 (0.76); 303 (0.92); 348 (1.79); 359 (1.89)

λ_{em} (nm): 429.000 Intensity: 48.272.

2.3 Synthesis of 1-benzyl substituted benzimidazoles , I-III



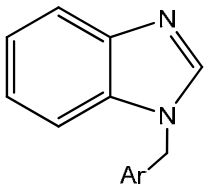
I-III

Benzimidazole (2.0 g; 16.9 mmol) and KOH (1.41 g; 25.3 mmol) were dissolved in acetonitrile (15 mL) and stirred overnight at room temperature. 1-(bromomethyl)-2,4,6-trimethylbenzene was added and the mixture was refluxed for 8 h. Following the completion of the process acetonitrile was removed. The residue was extracted with dichloromethane and extracted phase was dried over Na_2SO_4. Compund **I** was recrystallized from CH_2Cl_2/hexane.

The compounds **II** and **III** were synthesized in the same manner as described for **I.**

Table 2.1 Melting points and yields of the compounds **I-III**

Compound No	Ar-CH_2-Br	m.p (^{o} C)	Yield (%)
I	-$CH_2C_6H_2(CH_3)_3$	104-107	70
II	-$CH_2C_6H(CH_3)_4$	172-174	74
III	-$CH_2C_6(CH_3)_5$	105-108	74



I	Ar: -$CH_2C_6H_2(CH_3)_3$
II	Ar: -$CH_2C_6H(CH_3)_4$
III	Ar: -$CH_2C_6(CH_3)_5$

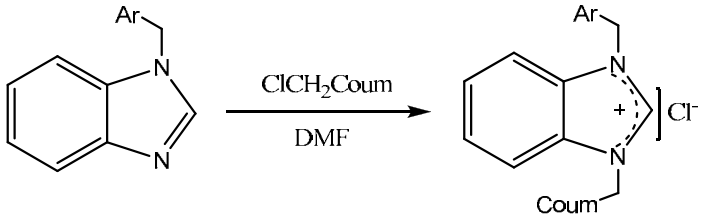
Table 2.2 ^{1}H NMR data for **I-III**

Compound No	H^2(s)	Aromatics	Others
I	7.39	7.81 (d, *J* 7.6 Hz); 7.52 (d, *J* 6.8 Hz); 7.28-7.36 (m)	5.29 (s, 2,4,6-C*H*$_2$C$_6$H$_2$(CH$_3$)$_3$); 2.24; 2.33 (s, 2,4,6-CH$_2$C$_6$H$_2$(C*H*$_3$)$_3$); 6.96 (s, 2,4,6-CH$_2$C$_6$*H*$_2$(CH$_3$)$_3$)
II	7.34	7.80 (dd, *J* 7.2 Hz); 7.48 (dd, *J* 6.8 Hz); 7.25-7.32 (m)	5.29 (s, 2,3,5,6-C*H*$_2$C$_6$H(CH$_3$)$_4$); 2.15; 2.28 (s, 2,3,5,6-CH$_2$C$_6$H(C*H*$_3$)$_4$); 7.06 (s, 2,3,5,6-CH$_2$C$_6$*H*(CH$_3$)$_4$)
III	7.36	7.79 (d, *J* 6.8 Hz); 7.49 (d, *J* 8.4 Hz); 7.27-7.36 (m)	5.28 (s, 2,3,4,5,6-C*H*$_2$C$_6$(CH$_3$)$_5$); 2.20; 2.26; 2.30 (s,2,3,4,5,6-CH$_2$C$_6$(C*H*$_3$)$_5$)

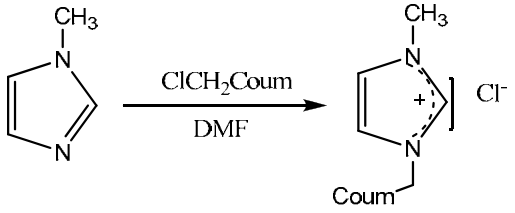
Table 2.3 ^{13}C NMR data for **I-III**

Compound No	2-*C*H	Aromatics	Alkyl
I	144.2	109.8; 120.6; 122.5; 123.1; 127.4; 129.9; 134.4; 138.2; 139.0; 141.9	19.8; 21.3 (2,4,6-$CH_2C_6H_2(CH_3)_3$); 43.4 (2,4,6-$CH_2C_6H_2(CH_3)_3$)
II	143.9	109.8; 120.5; 122.7; 123.2; 130.0; 132.9; 134.1; 134.3; 134.9; 141.9	44.1 (2,3,5,6-$CH_2C_6H(CH_3)_4$); 20.7; 15.7 (2,3,5,6-$CH_2C_6H(CH_3)_4$)
III	144.1	109.8; 120.5; 122.6; 123.1; 127.3; 133.6; 133.7; 134.3; 136.5; 142.0	16.7; 17.1; 17.4 (2,3,4,5,6-$NCH_2C_6(CH_3)_5$; 44.6 (2,3,4,5,6-$NCH_2C_6(CH_3)_5$

2.4 The reaction of 4-chloromethylcoumarin derivatives with 1-methyl imidazole and 1-substituted benzimidazoles



1-3



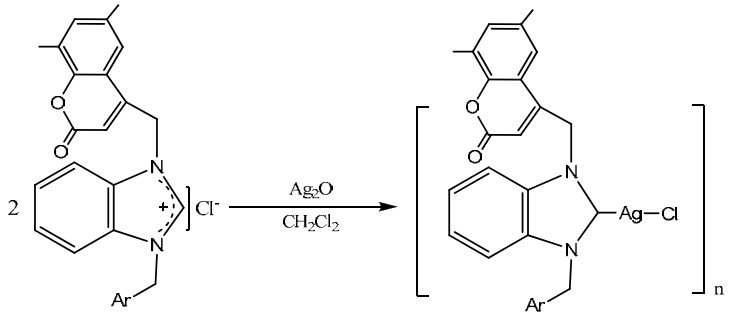
7

A mixture of 1-substituted benzimidazole (0.72 g; 2.37 mmol) and 4-chloromethyl coumarin derivatives (**a, b, c**) (0.44 g; 1.98 mmol) dissolved in DMF (5 mL), and were stirred at RT overnight. And then, the mixture was heated

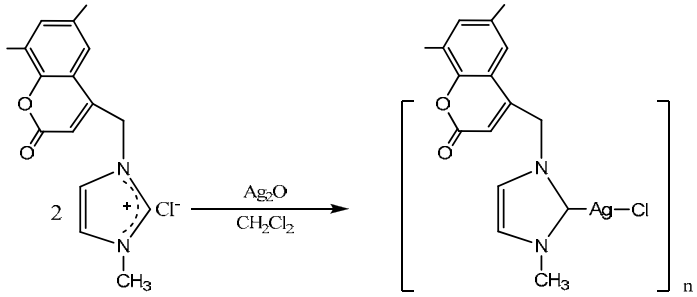
at 110 ^{o}C for 3 h. After cooling DMF was removed under vacuo. The product was recrystallized from ethanol/diethyl ether.

Other compounds was synthesized using the same procedure and their selected physical properties were listed in Table 3.1 and 3.2.

2.5 Deprotonation of imidazolium and benzimidazolium salts with silver oxide



4a, 5a, 6a

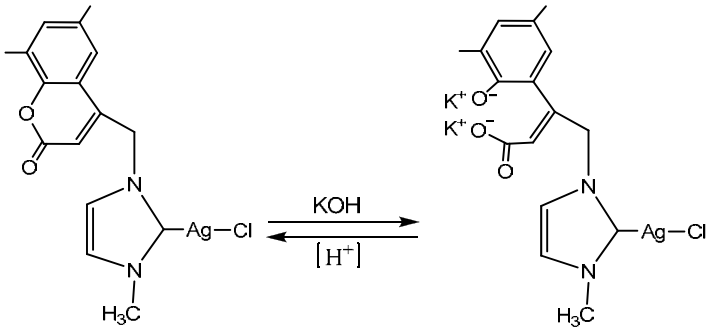


8a

1,3-Disubstituted benzimidazolium chloride (0.7 g; 1.39 mmol) was dissolved in dichloromethane, treated with Ag_2O (0.16 g, 0.69 mmol) overnight. During the stirring the Schlenk was protected from sunlight. Then the solid that seperated out was filtered off. The filtrate was concentrated and the products were crystallized from CH_2Cl_2/Et_2O.

Other compunds was synthesized using the same procedure.

2.6 Hydrolysis of Lactone Ring, 8a



8a

KOH (0.053 g; 0.96 mmol) was added to the suspension of compound **8a** (0.2 g; 0.48 mmol) in solvent mixture [water (15 mL) / ethanol (15 mL)]. It was stirred at 65 ^{o}C, lactone ring opened and dissolution was observed. After that HCl was added to the mixture and the precipitate was occured which showed that the formation of ring closure. Yield : 0.15 g; 62 %.

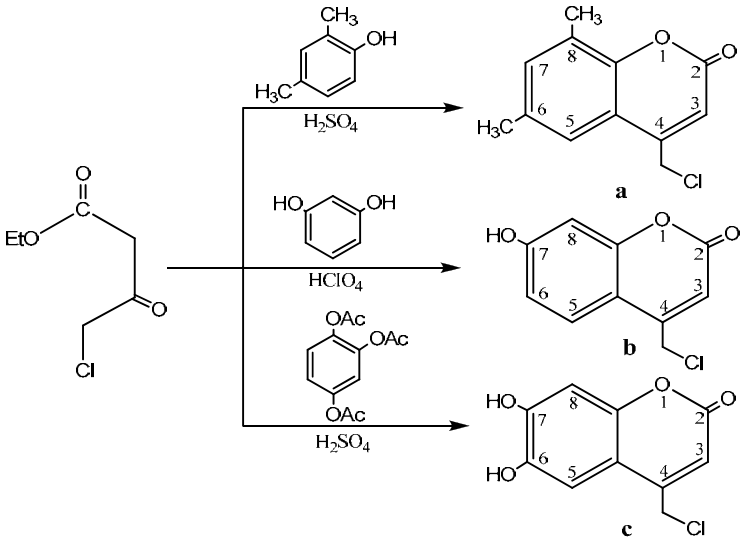
3. RESULT AND DISCUSSION

In this part of the thesis, the synthesis and characterization of unsymmetrical substituted diazolium salts and some of their silver complexes were described. Their chemical and physical (fluorescent) properties were examined. The general route to the target NHC ligand precursors and NHC silver complexes is shown in Schemes 3.1-3.3.

3.1.1 Chloromethylated coumarines as alkylating reagents

Coumarins, as a family of molecules, exhibit a wide range of biological and therapeutical properties. Furthermore, they are used as additive in food, perfumes, optical brighteners, and dispersed florescent. In many cases, this fluorescence is extremely sensitive to the local environment of the molecule, especially the local polarity and microviscosity. In addition, coumarins show a wide range of size, shape, and hydrophobicity. The sensitivity of coumarin has led to their widespread application as sensitive fluorescent probes of a wide range of systems, including homogeneous solvents and mixtures, and heterogeneous materials (Wagner, 2009)

As indicated in the Introduction, coumaris have been synthesized by several methods. Here, in order to reach the target NHCs, containing coumarin framework, initially three chloromethylated coumarins (**a**-**c**) have been synthesized via Pechmann method (Section 1.7.2; Scheme 3.1). The compound **a** was previously synthesied from 2,4-dimethylphenol. Similarly, the compounds **b** and **c** were prepared. In the Pechmann condensation, phenol derivatives (in the case of **c**, 1,2,4-triacetylbenzene) were allowed to react with commercially available β-keto ester, ethyl chloroacetoacetate in the presence of an acid catalyst such as H_2SO_4 or $HClO_4$. Chloromethylated coumarines were identified by NMR spectroscopy. The ^{1}H NMR spectra of **a**-**c** in d*6*-DMSO showed singlets at 4.85-5.00 ppm for the CoumCH_2Cl proton characteristic of chloromethyl groups. It is worth noting that the H_7 singlet is more succeptible than any other proton to the substituent change benzene ring.



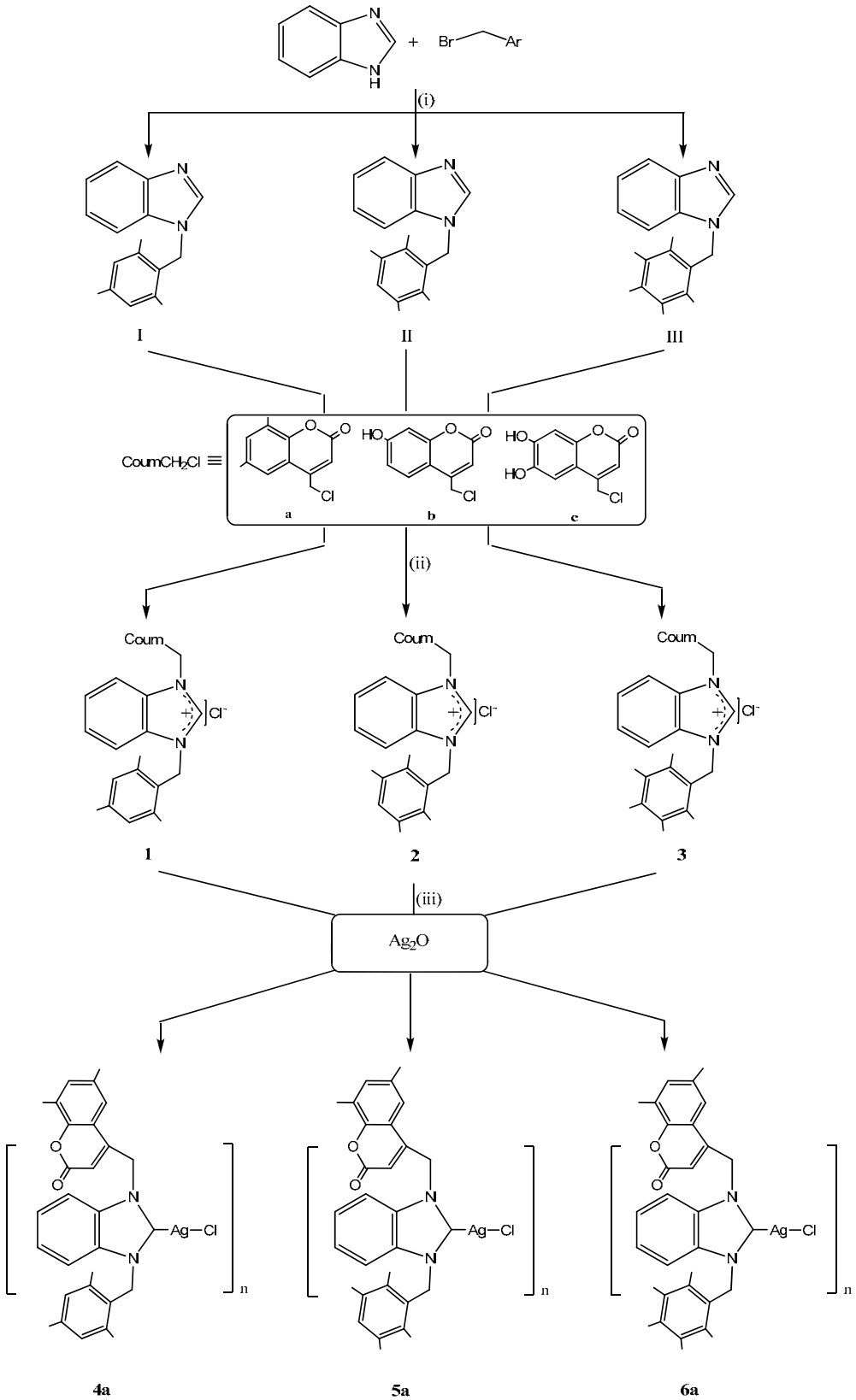
Scheme 3.1 Synthesis of 4-chloromethyleted coumarin derivatives which are abbreviated as CoumCH_2Cl.

The synthesized 4-chloromethylcoumarin derivatives have been used as alkyl chlorides to quaternize mono-alkylated diazoles, namely N-benzylbenzimidazoles (**I-III**) and 1-methylimidazole (Scheme 3.2).

3.1.2 Synthesis of N-benzyl substituted benzimidazoles

The N-substituted alkyl halides on benzimidazoles were prepared by treating benzimidazole with variously methylated benzyl bromides under basic conditions as white crystalline solids. The synthetic procedure was illustrated in Scheme 3.2.

The compounds have been characterized by ^{1}H and ^{13}C NMR spectroscopy. The C_2-hydrogens were observed as a singlet at 7.39, 7.34 and 7.36 ppm for **I, II** and **III** respectively. The C_2 carbons appeared at 144.2, 143.9 and 144.1 ppm

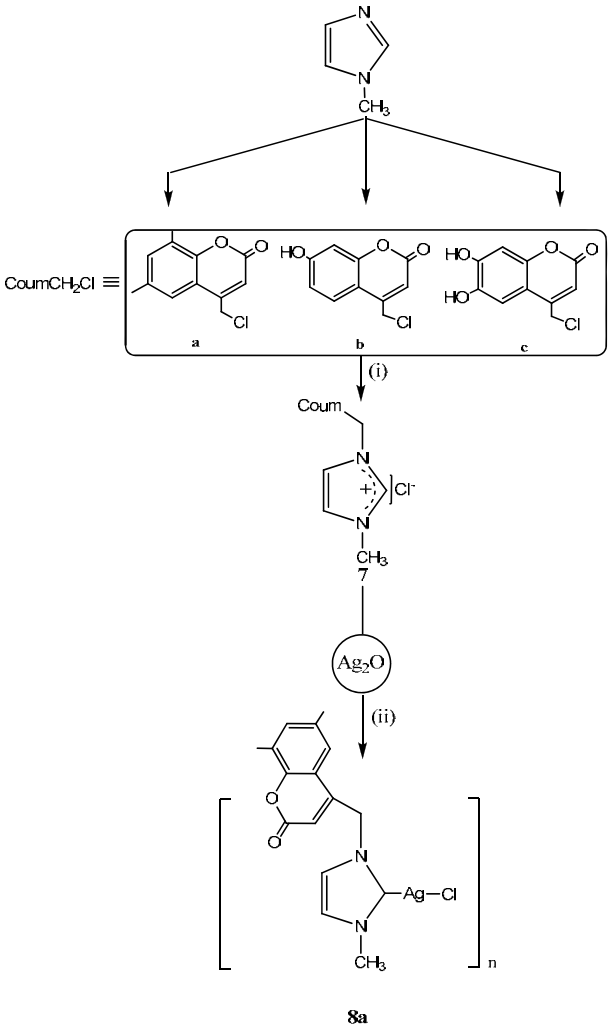


Scheme 3.2 Reagents and conditions of reactions: (i) KOH, acetonitrile, 80 °C; (ii) DMF, 110 °C; (iii) CH_2Cl_2, 25 °C.

3.1.3 Synthesis of unsymmetrical azolium salts

The 1,3-disubstituted benzimidazolium salts (**1**-**3**) and imidazolium salts (**7**) were prepared by treating N-substituted benzimidazoles and/or 1-methylimidazole with chloromethylated coumarin derivatives in DMF at 110 ^{o}C. The synthetic procedure was also illustrated in Scheme 3.2 and Scheme 3.3.

The compounds have been characterized by ^{1}H and ^{13}C NMR spectroscopy. ^{1}H NMR chemical shifts were consistent with the proposed structures; the resonances for C_2-hydrogens were observed as sharp singlets between 9.14-11.06 ppm for benzimidazolium salts, 9.29-11.07 ppm for imidazolium salts. ^{13}C NMR of these benzimidazolium salts showed the C_2 carbon at 160.1-163.1 ppm and for imidazolium salts at 160.2-162.8 ppm. The carbonyl carbons on coumarin derivatives were observed at 150.1-160.6 ppm for benzimidazolium salts, 150.2-160.6 ppm for imidazolium salts on ^{13}C NMR spectrum.



Scheme 3.3 Reagents and conditions of reactions: (i) DMF, 110 ^{o}C; (ii) CH_2Cl_2, 25 ^{o}C.

3.2 Synthesis of NHC-silver Complexes

NHC-silver complexes are very useful due to their straightforward synthesis, high yield and applicability to a variety of carbenes and the stability of the complexes towards air and moisture.

Silver complexes of imidazol and benzimidazol salts were prepared by treating **4a**-**6a** and **7a** silver oxide in dichlormethane at RT. The synthetic procedure was illustrated in Scheme 3.2 and Scheme 3.3. In order to study the substituent effect in mor detail, other diazolium salts bearing OH groups on the benzene ring (**1b**, **1c**, **2b**, **2c**, **3b**, **3c** and **7b**, **7c**) was subjected to complexation. However, the reaction with Ag_2O in CH_2Cl_2 at RT or in MeCN at 83 ^oC did not proceed as expected. Non-tractable mixtures were obtained. No evidence supporting the formation of NHC-Ag complexes were obtained. Apperantly, the phenolic OH in these salts may act as reducing agent for Ag^+.

The IR data for 1,3-disubstituted benzimidazolium salts (**1-3)**, N-methyl imidazoluim salts (**7**) and silver complexes (**4a, 5a, 6a, 8a**) clearly indicate the presence of the –C=O group with a ν(C=O) vibrations between (1713-1733 cm^{-1}) for benzimidazolium salts and (1710-1713) for imidazolium salts. These values are consistent with the literature value (Williams, 1966).

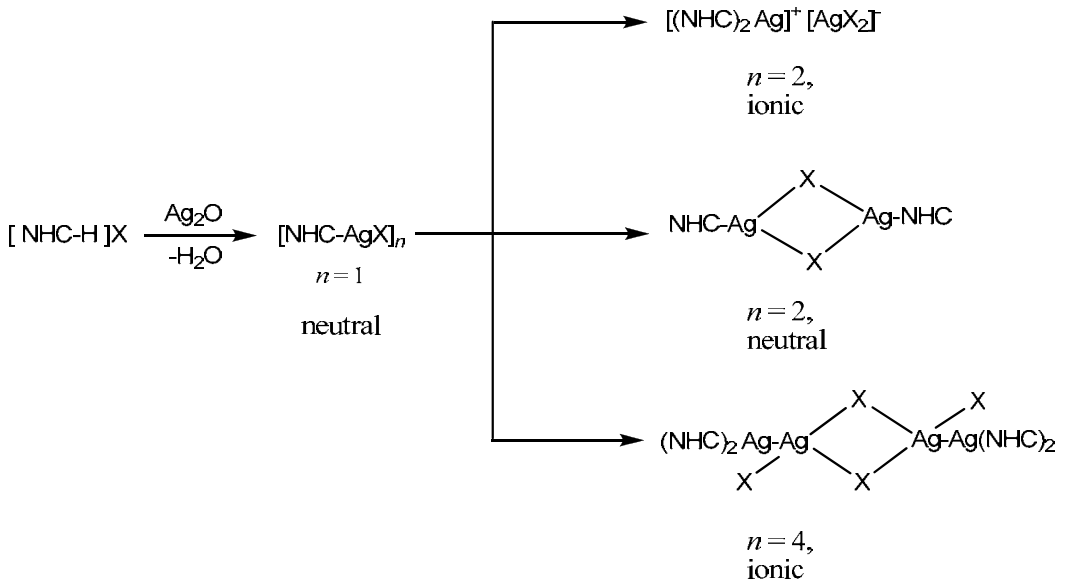
From the comparison of IR data the following conclusions can be drawn:

- In the coumarin series IR data increased in the sequence; 6,7-dihydroxycoumarin < 7-hydroxycoumarin < 5,7-dimethylcoumarin.
- For imidazol salts and benzimidazol salts IR data increased in the sequence; imidazol salts < benzimidazol salts.

In addition, the compounds have been characterized by ^1H and ^{13}C NMR spectroscopy. ^1H NMR chemical shifts were consistent with the proposed structures; the resonances for C_2-hydrogens dissappeared. The chemical shifts of other hydrogens were similar to those of the corresponding precursors. ^{13}C NMR of these complexes showed that carbene carbons at 159.9-164.7 ppm as broad singlets. Absence of ^{13}C-Ag couplings suggest occurrence of a fast exchange between the species in solution. Unfortunately, we failed to obtaine suitable crystals for X-ray studies. The carbonyl carbons on the coumarin entities were observed at 150.3-159.9 ppm.

Literature inspection indicates that the reaction of Ag_2O with diazolium halides (X = Cl, Br, I) give various neutral and ionic structures in the solid state. All of which corresponds to NHCAgX emprical formula. However, NMR and mass spectrometry techniques reveal fluxional behaviour between neutral and ionic species, an unusual property which was attributed to the lability of NHC-Ag bond. Ag….halide and argentophilic Ag…Ag interactions complicates the picture furthermore (Scheme 3.4)

Consequently, these properties make it difficult to establish the real value of ‘’*n*’’ in the $[NHC\text{-}Ag\text{-}X]_n$ representations. However, the chloride salts tend to give neutral complexes and an increase in the solvent polarity favours the formation of ionic bis-carbene species [P.de Fremont et al, Organometallics, 2005, 24, 630]



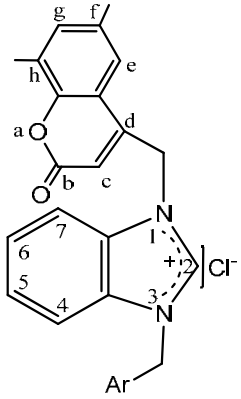
Scheme 3.4 The solid state structures of Ag-NHCs depends on the nature of halide ion, chain length, carbene core and the crystallization condition. The chloride salts tend to form neutral structures whereas bromide salts tend to form ionic Ag-NHCs. Increased polarity of the solvent also favours ionic structures. Imidazol-2-ylidene ligands with long-chain alkyl affords self-assembled Ag-NHCs.

Table 3.1 Melting points, yields and ν (C=O) cm^{-1} data of the compounds **a-c** and **1-8**

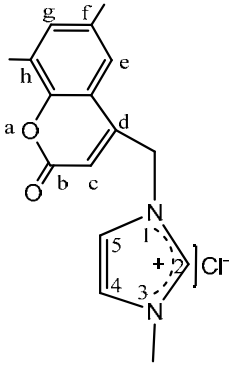
Compound No	m.p (^oC)	Yield (%)	ν (C=O) cm^{-1}
a	176-178	91	1722
b	173-175 (dec.)	54	1683
c	179-182	97	1663
1a	200-203	52	1727
1b	255-258	45	1732
1c	230-233	53	1713
2a	228-230	71	1732
2b	285-288	72	1731
2c	279-281	35	1715
3a	210-213	71	1733
3b	273-277	67	1731
3c	241-244	66	1713
4a	254-257 (dec.)	50	1717
5a	228-231 (dec.)	68	1720
6a	248-252 (dec.)	89	1719
7a	248-252	96	1713
7b	280-283 (dec.)	70	1712
7c	167-171	69	1710
8a	205-208 (dec.)	35	1715

Table 3.2 Emission and absorbstion data for compounds **1-8**

Compound No	λ_{em}(nm)	Intensity	λ_{abs}(nm)
1a	438.745	16.543	224 (3.75); 250 (2.41); 272 (3.64); 278 (3.55); 329 (0.88)
1b	412.993	23.333	222 (3.34); 257 (2.06); 271 (2.27); 330 (2.48)
1c	476.085	11.111	215 (2.61); 257 (0.93); 301 (0.38); 359 (0.87)
2a	435.518	21.358	223 (3.61); 249 (2.45); 273 (3.24); 329 (0.64)
2b	412.433	36.420	212 (2.18); 272 (0.73); 278 (0.69); 329 (0.81)
2c	474.333	46.543	207 (0.77); 232 (0.41); 267 (0.26); 359 (0.23)
3a	434.115	69.136	221 (3.61); 223 (3.63); 250 (2.07); 273 (2.95); 329 (0.66)
3b	406.752	25.926	218 (2.85); 257 (1.03); 272 (1.15); 278 (1.07); 329 (1.36)
3c	462.000	34.444	213 (2.75); 270 (1.05); 359 (0.66)
4a	435.296	22.123	(202 (-0.60); 272 (0.03); 274 (0.01); 291 (1.27); 294 (1.32); 297 (1.28); 353 (0.92)
5a	430.834	49.630	216 (0.45); 233 (0.57); 250 (0.65); 295 (3.22); 329 (2.05)
6a	427.143	59.062	201 (0.37); 214 (0.41); 216 (0.42); 226 (0.49); 228 (0.49); 230 (0.51); 243 (0.59); 256 (0.66); 291 (3.02); 329 (1.69)
7a	442.156	13.210	220 (3.01); 248 (0.97); 283 (2.59); 329 (0.97)
7b	469.277	32.716	226 (2.85); 257 (1.37); 321 (3.36); 332 (3.34); 350 (1.95)
7c	477.333	37.901	211 (2.06); 265 (0.36); 355 (0.36)
8a	441.365	95.062	202 (0.56); 207 (0.60); 214 (0.61); 236 (0.75); 238 (0.76); 241 (0.79); 243 (0.80); 246 (0.81); 249 (0.83); 252 (0.85); 257 (0.89); 297 (3.37)



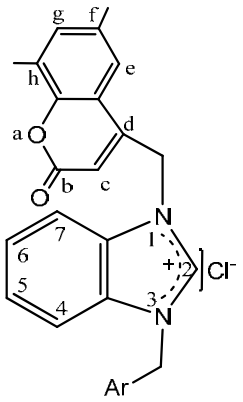
1a-3a



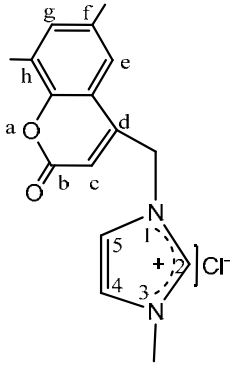
7a

Table 3.3 ^{1}H NMR data for **1a-3a, 7a**

Compound No	H_2 (s)	H_c (s)	Aromatics$_{(4-7)}$	Aromatics$_{(e-g)}$(s)	Others
1a	9.33	5.94	7.72 (t, *J* 7.2 Hz); 7.79 (t, *J* 7.2 Hz); 8.01 (d, *J* 8 Hz); 8.21 (d, *J* 8.4 Hz)	7.43; 7.49	2.28; 2.33 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 2.35; 2.37 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.70 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 6.08 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 6.99; 7.04 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$
2a	9.28	5.89	7.71 (t, *J* 8 Hz); 7.78 (t, *J* 8 Hz); 7.99 (d, *J* 8 Hz); 8.27 (d, *J* 8 Hz)	7.41; 7.48	2.17; 2.23 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 2.33; 2.35 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.76 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 6.08 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 7.13 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$)
3a	9.43	5.89	7.75 (t, *J* 8.4 Hz); 7.81 (t, *J* 7.6 Hz); 8.01 (d, *J* 8.4 Hz); 8.31 (d, *J* 8.4 Hz)	7.43; 7.49	2.22; 2.23; 2.25 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$); 2.35; 2.37 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.77 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 6.07 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$)
7a	9.37	6.06	7.85 (d, *J* 24.8 Hz); 7.89 (d, *J* 2 Hz)	7.42; 7.53	2.35; 2.38 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 3.91 (s, CH_3); 5.34 (s, $CH_2C_9HO_2H_2(CH_3)_2$)



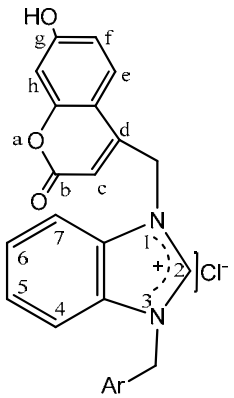
1a-3a



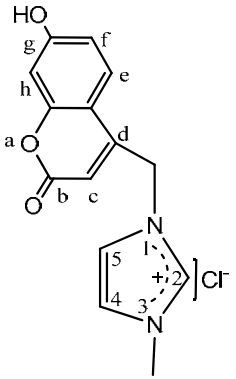
7a

Table 3.4 ^{13}C NMR data for **1a-3a, 7a**

Compound No	2-*C*H-	Aromatics	Alkyl
1a	163.1	112.7; 114.5; 116.9; 122.4; 126.1; 126.2; 127.7; 127.9; 130.2; 132.3; 132.5; 134.1; 135.4; 139.1; 139.6; 143.0; 149.7; 150.1;160.2	15.7; 19.9 ($CH_2C_9HO_2H_2(\mathit{C}H_3)_2$); 21.0; 21.3 (2,4,6-$CH_2C_6H_2(\mathit{C}H_3)_3$); 36.5 (2,4,6-$\mathit{C}H_2C_6H_2(CH_3)_3$); 46.1 ($\mathit{C}H_2C_9HO_2H_2(CH_3)_2$)
2a	160.1	112.6; 114.6; 117.0; 122.5; 126.1; 127.7; 127.9; 128.9; 132.4; 132.6; 132.8; 133.6; 134.5; 134.6; 135.1; 135.4; 142.9; 149.8; 150.1	15.9; 21.8 ($CH_2C_9HO_2H_2(\mathit{C}H_3)_2$); 17.7 ; 20.8 (2,3,5,6-$CH_2C_6H(\mathit{C}H_3)_4$); 34.8 (2,3,5,6-$\mathit{C}H_2C_6H(CH_3)_4$); 47.3 ($\mathit{C}H_2C_9HO_2H_2(CH_3)_2$)
3a	160.1	112.6; 114.6; 114.9; 117.0; 122.5; 126.1; 126.3; 127.6; 127.9; 132.4; 132.5; 133.7; 133.9; 134.6; 135.4; 137.0; 142.9; 149.9; 150.1	15.8; 21.1 ($CH_2C_9HO_2H_2(\mathit{C}H_3)_2$); 17.1; 17.4 ; 17.8 (2,3,4,5,6-$CH_2C_6(\mathit{C}H_3)_5$); 34.7 (2,3,4,5,6-$\mathit{C}H_2C_6(CH_3)_5$); 47.3 ($\mathit{C}H_2C_9HO_2H_2(CH_3)_2$)
7a	160.2	110.0; 114.1; 117.0; 122.5; 123.7; 124.9; 126.1; 134.2; 135.4; 138.5; 150.1; 150.2	15.8; 21.0; ($CH_2C_9HO_2H_2(\mathit{C}H_3)_2$); 36.8 ($\mathit{C}H_3$); 49.0 ($\mathit{C}H_2C_9HO_2H_2(CH_3)_2$)



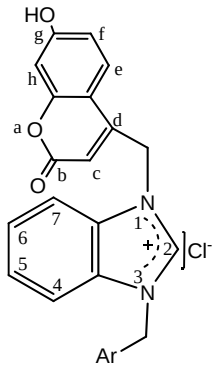
1b-3b



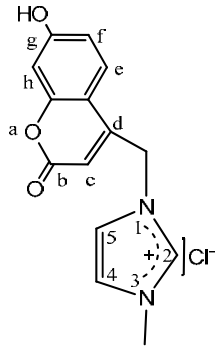
7b

Table 3.5 ^{1}H NMR data for **1b-3b, 7b**

Compound No	H_2 (s)	H_c (s)	Aromatics$_{(4-7)}$	Aromatics$_{(e-h)}$	Others
1b	10.98	5.60	7.72 (t, *J* 7.6 Hz); 7.78 (t, *J* 7.2 Hz); 8.01 (d, *J* 8.4 Hz); 8.21 (d, *J* 8.4 Hz)	6.85 (d, $CH_2C_9HO_2H_2$(OH)H , *J* 2.4 Hz); 6.94 (dd, $CH_2C_9HO_2H_2$(OH)*H*, *J* 2 Hz); 7.67 (d, $CH_2C_9HO_2H_2$(OH)H, *J* 8.4 Hz)	2.26; 2.28 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 5.71 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 6.05 (s, $CH_2C_9HO_2H_2$(OH)H); 9.33 (s, OH)
2b	10.89	5.60	7.68 (t, *J* 6.4 Hz); 7.80 (t, *J* 7.6 Hz); 8.01 (d, *J* 7.2 Hz); 8.28 (d, *J* 6.8 Hz)	6.83 (d, $CH_2C_9HO_2H_2$(OH)H , *J* 2.4 Hz); 6.92 (dd, $CH_2C_9HO_2H_2$(OH)*H*, *J* 8 Hz); 7.01 (d, $CH_2C_9HO_2H_2$(OH)H, *J* 8 Hz)	2.19; 2.24 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 5.76 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 6.03 (s, $CH_2C_9HO_2H_2$(OH)H); 9.23 (s, OH)
3b	11.06	5.57	7.72 (t, *J* 8.4 Hz); 7.80 (t, *J* 7.6 Hz); 8.02 (d, *J* 8.4 Hz); 8.31 (d, *J* 8.4 Hz)	6.87 (d, $CH_2C_9HO_2H_2$(OH)H , *J* 2.4 Hz); 6.94 (dd, $CH_2C_9HO_2H_2$(OH)*H* , *J* 8 Hz); 7.67 (d, $CH_2C_9HO_2H_2$(OH)H, J 8.8 Hz)	2.19; 2.22; 2.25 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$); 5.76 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$); 6.01 (s, $CH_2C_9HO_2H_2$(OH)H); 9.19 (s, OH)
7b	11.07	5.82	7.84 (d, *J* 18.4 Hz); 7.87(d, *J* 1.2 Hz)	6.86 (d, $CH_2C_9HO_2H_2$(OH)H , *J* 2.4 Hz); 6.92 (dd, $CH_2C_9HO_2H_2$(OH)*H*, *J* 2.4 Hz); 7.69 (d, $CH_2C_9HO_2H_2$(OH)H, *J* 9.2 Hz)	3.90 (s, CH_3); 5.79 (s, $CH_2C_9HO_2H_2$(OH)H); 9.33 (s, OH)



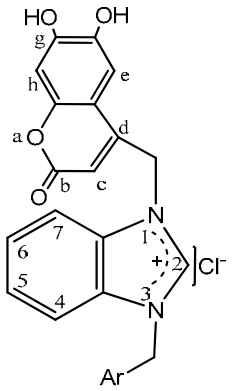
1b-3b



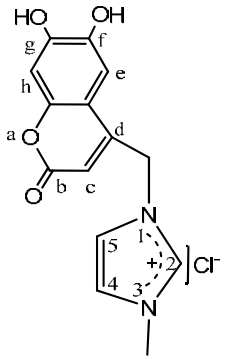
7b

Table 3.6 ^{13}C NMR data for **1b-3b, 7b**

Compound No	2-*C*H-	Aromatics	Alkyl
1b	162.7	103.2; 108.1; 109.6; 114.0; 114.6; 114.8; 124.6; 126.3; 127.6; 127.9; 130.2; 132.4; 132.5; 139.1; 139.5; 143.1; 150.2; 155.6; 160.6	20.0; 21.4 (2,4,6-$CH_2C_6H_2(CH_3)_3$); 46.1 ($CH_2C_9HO_2H_2$(OH)H); 47.4 (2,4,6-$CH_2C_6H_2(CH_3)_3$);
2b	162.7	103.3; 108.1; 109.7; 114.0; 114.6; 114.8; 126.4; 127.6; 127.9; 129.0; 132.4; 132.5; 133.6; 134.9; 135.1; 142.9; 150.2; 155.6; 160.6	16.1; 20.8 (2,3,5,6-$CH_2C_6H(CH_3)_4$); 46.8 (2,3,5,6-$CH_2C_6H(CH_3)_4$); 47.4 ($CH_2C_9HO_2H_2$(OH)H)
3b	162.8	103.3; 108.0; 109.6; 114.0; 114.6; 114.9; 126.3; 127.6; 127.9; 132.4; 132.5; 133.7; 134.6; 137.0; 142.9; 143.8; 150.3; 155.6;160.6	17.1; 17.4; 17.7 (2,3,4,5,6-$CH_2C_6(CH_3)_5$); 40.8 (2,3,4,5,6-$CH_2C_6(CH_3)_5$) ; 47.3 ($CH_2C_9HO_2H_2$(OH)H)
7b	162.8	103.3; 109.6; 109.8; 114.1; 123.7; 124.9; 126.4; 138.5; 150.3; 155.6; 160.6	36.8 (CH_3); 49.0 ($CH_2C_9HO_2H_2$(OH)H)



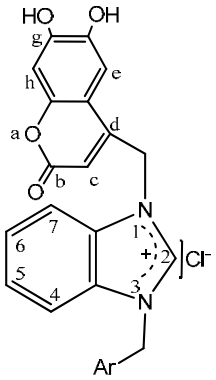
1c-3c



7c

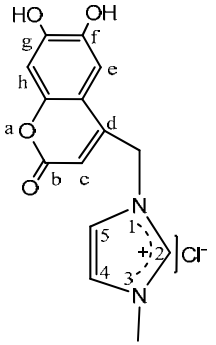
Table 3.7 ^{1}H NMR data for **1c-3c, 7c**

Compound No	H_2 (s)	H_c (s)	Aromatics$_{(4-7)}$	Aromatics$_{(e-h)}$ (s)	Others
1c	9.23	5.49	7.69 (t, *J* 8.4 Hz); 7.76 (t, *J* 8 Hz); 7.97 (d, *J* 8.8 Hz); 8.17 (d, *J* 8.0 Hz)	7.01; 7.09	2.26; 2.34 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 5.68 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 5.94 (s, $CH_2C_9H_2(OH)_2HO_2$); 6.83 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$) ; 9.57; 10.55 (s, OH)
2c	9.20	5.51	7.72 (t, *J* 7.6 Hz); 7.79 (t, *J* 6.4 Hz); 7.99 (d, *J* 7.6 Hz); 8.26 (d, *J* 8.4 Hz)	7.12; 7.14	2.19; 2.24 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 5.76 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 5.95 (s, (s, $CH_2C_9H_2(OH)_2HO_2$); 6.87 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 9.59; 10.59 (s, OH)
3c	9.14	5.46	7.70 (t, *J* 8 Hz); 7.78 (t, *J* 7.2 Hz); 7.97 (d, *J* 8.4 Hz); 8.27 (d, *J* 8.4 Hz)	6.83; 7.08	2.17; 2.19; 2.22 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$); 5.74 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$); 5.93 (s, $CH_2C_9H_2(OH)_2HO_2$); 9.54; 10.56 (s, OH)
7c	9.29	5.75	7.80 (d, *J* 12.4 Hz) 7.84 (d, *J* 12.4 Hz);	6.88; 7.15	3.91 (s, CH_3); 5.71 (s, $CH_2C_9H_2(OH)_2HO_2$); 9.62; 10.60 (s, OH)



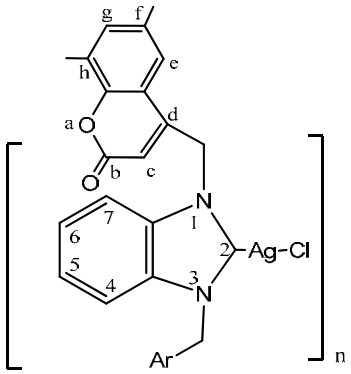
1c-3c

Table 3.8 ^{13}C NMR data for **1c-3c, 7c**

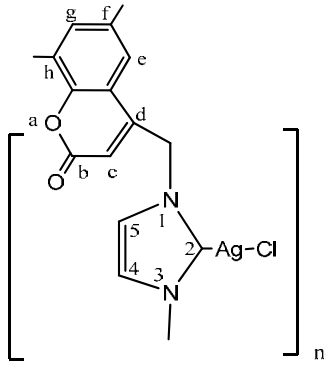


7c

Compound No	2-*C*H	Aromatics	Alkyl
1c	160.9	103.6; 108.0; 109.2; 114.5; 114.7; 124.4; 126.2; 127.7; 128.3; 130.0; 130.2; 132.3; 138.4; 138.7; 139.7; 142.9; 148.6; 149.9; 151.6	19.9; 21.3 (2,4,6-$CH_2C_6H_2(CH_3)_3$); 46.1 (2,4,6-$CH_2C_6H_2(CH_3)_3$); 47.3 ($CH_2C_9H_2(OH)_2HO_2$)
2c	161.5	103.6; 108.3; 108.9; 109.1; 114.1; 114.6; 128.4; 132.0; 132.1; 132.7; 133.7; 134.3; 134.8; 134.9; 135.2; 143.8; 148.6; 149.7; 151.5	15.7; 20.5 (2,3,5,6-$CH_2C_6H(CH_3)_4$); 47.2 (2,3,5,6-$CH_2C_6H(CH_3)_4$) ; 57.1 ($CH_2C_9H_2(OH)_2HO_2$)
3c	160.9	103.6; 107.9; 109.1; 109.2; 114.5; 114.8; 126.2; 127.7; 128.0; 132.3; 132.4; 133.7; 134.5; 137.1; 142.8; 143.9; 148.5; 149.9; 151.7	17.1; 17.3; 17.6 (2,3,4,5,6-$CH_2C_6(CH_3)_5$); 40.6 (2,3,4,5,6-$CH_2C_6(CH_3)_5$); 47.4 ($CH_2C_9H_2(OH)_2HO_2$)
7c	160.8	103.6; 109.3; 109.7; 114.2; 123.8; 124.9; 126.5; 138.4; 149.5; 150.3; 151.6	36.5 (CH_3); 48.7 ($CH_2C_9H_2(OH)_2HO_2$)



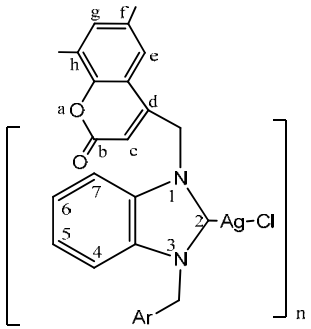
4a-6a



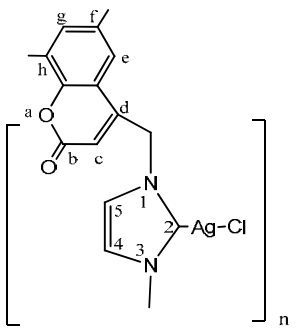
8a

Table 3.9 ^{1}H NMR data for **4a-6a, 8a**

Compound No	H_2 (s)	H_c (s)	Aromatics$_{(4-7)}$	Aromatics$_{(e-g)}$ (s)	Others
4a	-	5.40	7.24 (t, *J* 7.2 Hz); 7.26 (t, *J* 7.2 Hz); 7.33 (d, *J* 8 Hz); 7.37 (d, *J* 8.4 Hz)	7.15; 7.22	2.27; 2.35 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 2.39; 2.41 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.50 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.83 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$); 6.99; 7.05 (s, 2,4,6-$CH_2C_6H_2(CH_3)_3$
5a	-	5.38	7.41 (t, *J* 7.2 Hz); 7.46 (t, *J* 6.8 Hz); 7.56 (d, *J* 7.6 Hz); 7.58 (d, *J* 7.6 Hz)	7.26; 7.28	2.18; 2.30 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 2.41; 2.43 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.53 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.77 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$); 7.16 (s, 2,3,5,6-$CH_2C_6H(CH_3)_4$
6a	-	5.36	7.40 (t, *J* 7.6 Hz); 7.48 (t, *J* 7.2 Hz); 7.61 (d, *J* 8.4 Hz); 7.63 (d, *J* 8.4 Hz)	7.25; 7.27	2.23; 2.29; 2.33 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$); 2.40; 2.42 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.54 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 5.75 (s, 2,3,4,5,6-$CH_2C_6(CH_3)_5$)
8a	-	5.67	7.24 (d, *J* 7.2 Hz); 7.27 (d, *J* 7.2 Hz)	7.03; 7.09	2.37; 2.41 (s, $CH_2C_9HO_2H_2(CH_3)_2$); 3.90 (s, CH_3); 5.58 (s, $CH_2C_9HO_2H_2(CH_3)_2$)



4a-6a



8a

Table 3.10 ^{13}C NMR data for **4a-6a, 8a**

Compound No	2-*C*	Aromatics	Alkyl
4a	159.9	111.7; 113.0; 117.2; 122.8; 125.1; 125.3; 126.1; 128.7; 130.1; 133.8; 134.1; 134.7; 135.3; 138.1; 138.6, 150.1; 151.8	15.8; 20.7 (2,4,6-$CH_2C_6H_2(CH_3)_3$); 21.1; 21.3 ($CH_2C_9HO_2H_2(CH_3)_2$); 47.7 (2,4,6-$CH_2C_6H_2(CH_3)_3$); 49.8 ($CH_2C_9HO_2H_2(CH_3)_2$)
5a	164.7	116.5; 117.7; 121.9; 127.5; 129.9; 130.1; 130.7; 136.6; 137.5; 138.6; 138.7; 138.9; 139.1; 139.3; 139.6; 140.1; 154.8; 156.7	20.5; 20.7 (2,3,5,6-$CH_2C_6H(CH_3)_4$); 25.5; 25.8 ($CH_2C_9HO_2H_2(CH_3)_2$); 44.4 (2,3,5,6-$CH_2C_6H(CH_3)_4$); 45.6 ($CH_2C_9HO_2H_2(CH_3)_2$)
6a	162.1	111.9; 112.8; 112.9; 122.7; 125.1; 125.3; 126.0; 126.1; 128.6; 133.5; 133.8; 133.9; 134.1; 134.5; 135.3; 136.2; 150.1; 151.7; 159.9	15.7; 17.0; 17.3 (2,3,4,5,6-$CH_2C_6(CH_3)_5$); 17.4; 17.5 ($CH_2C_9HO_2H_2(CH_3)_2$); 39.7 (2,3,4,5,6-$CH_2C_6(CH_3)_5$); 40.9 ($CH_2C_9HO_2H_2(CH_3)_2$)
8a	160.5	77.5; 110.0; 113.0; 116.5; 120.9; 122.1; 123.5; 126.9; 134.3; 135.5; 150.2; 150.3	39.3 (CH_3); 15.8; 21.2 ($CH_2C_9HO_2H_2(CH_3)_2$); 51.9 ($CH_2C_9HO_2H_2(CH_3)_2$)

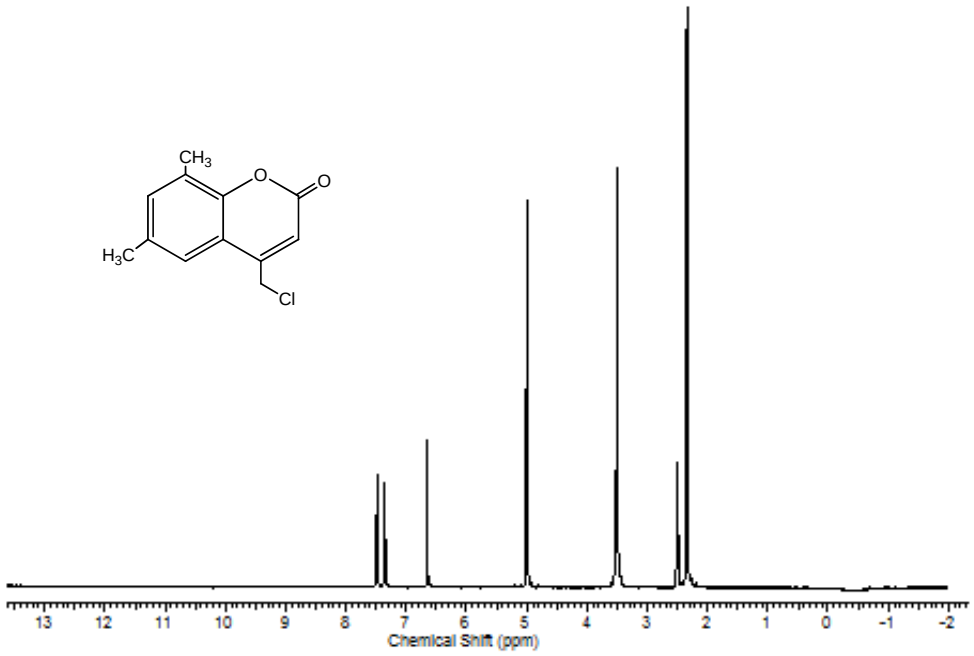


Figure 3.1 ^{1}H NMR Spectrum of compound **a**

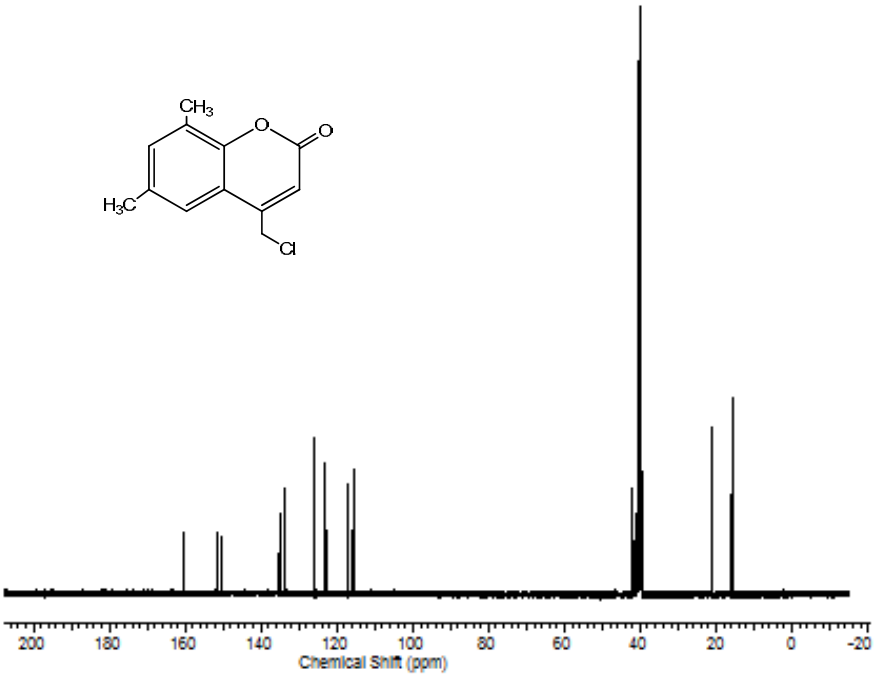


Figure 3.2 ^{13}C NMR Spectrum of compound **a**

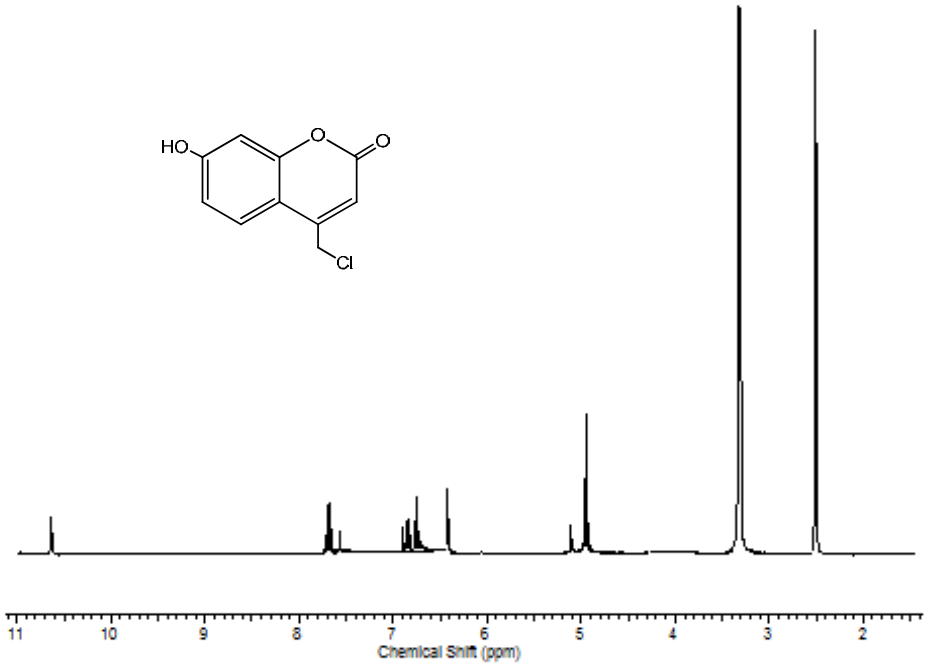


Figure 3.3 ^{1}H NMR Spectrum of compound **b**

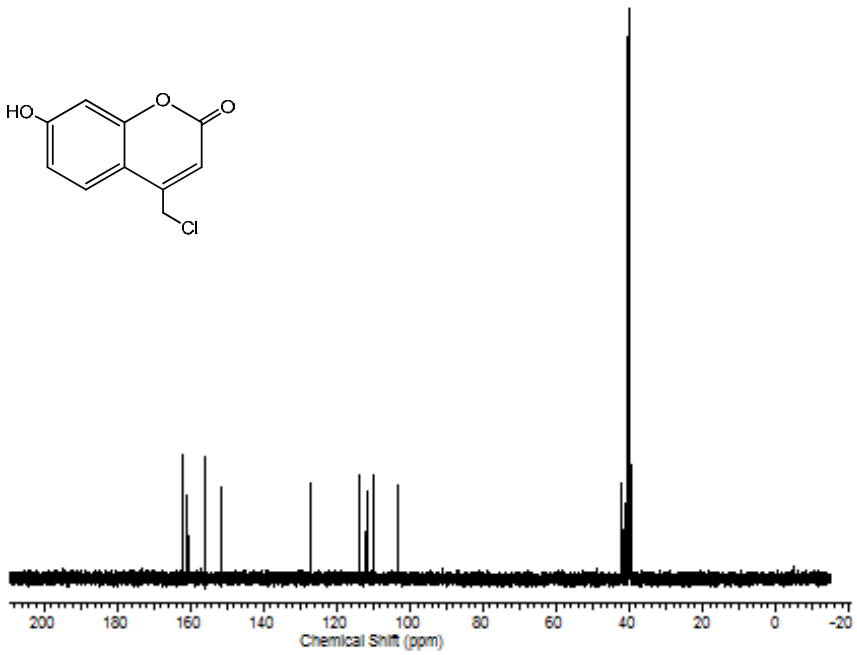


Figure 3.4 ^{13}C NMR Spectrum of compound **b**

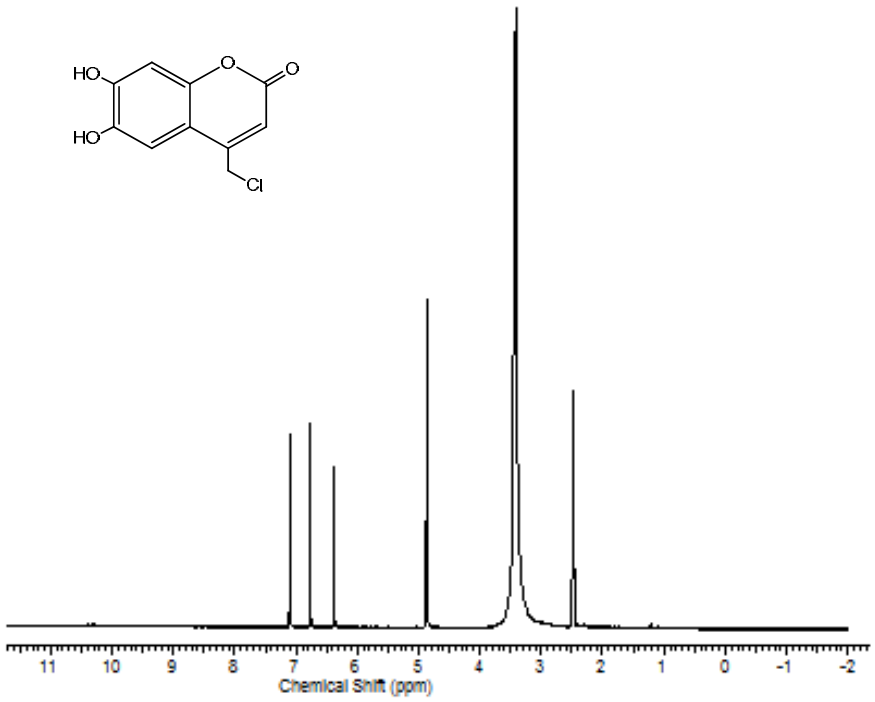


Figure 3.5 ^{1}H NMR Spectrum of compound **c**

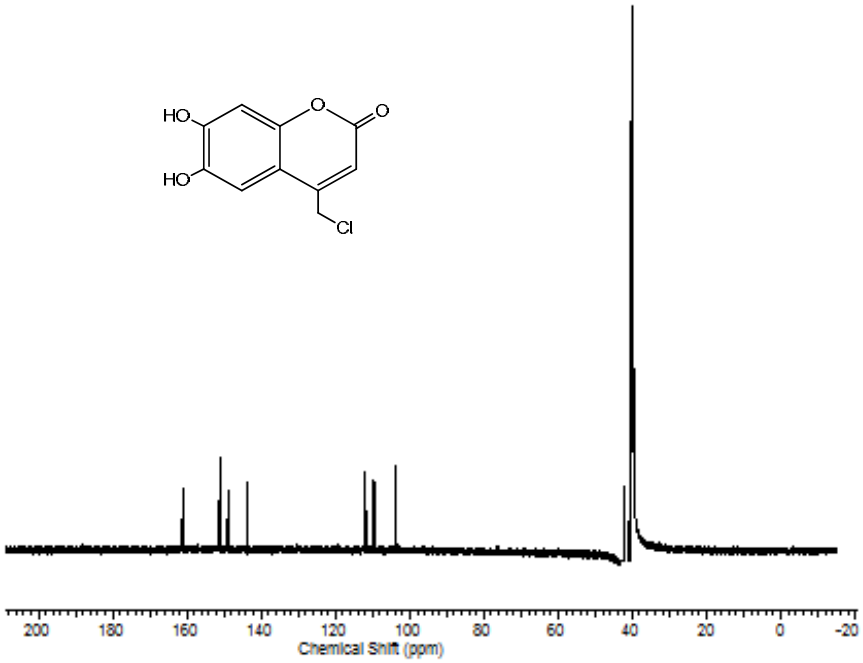


Figure 3.6 ^{13}C NMR Spectrum of compound **c**

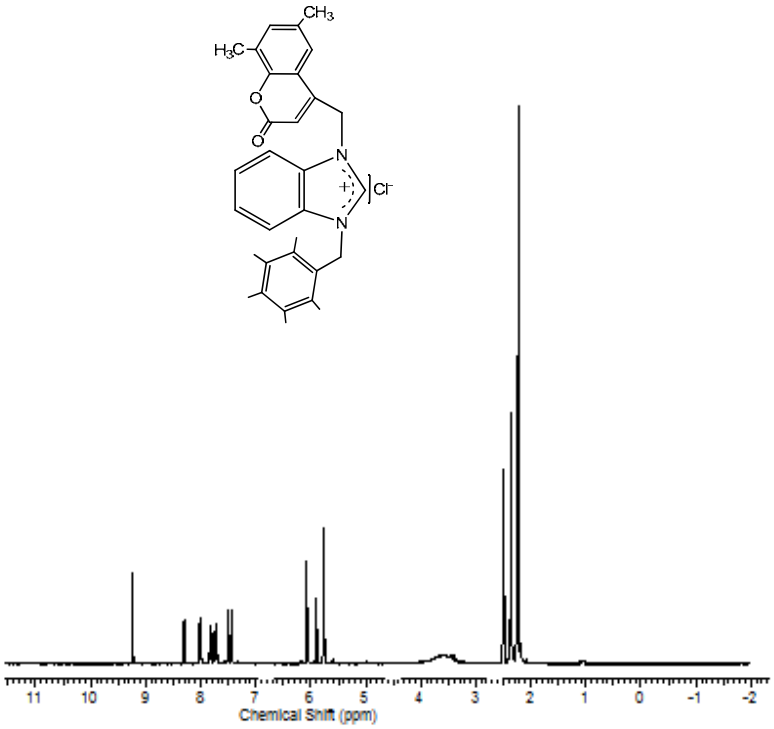


Figure 3.7 ^{1}H NMR Spectrum of compound **3a**

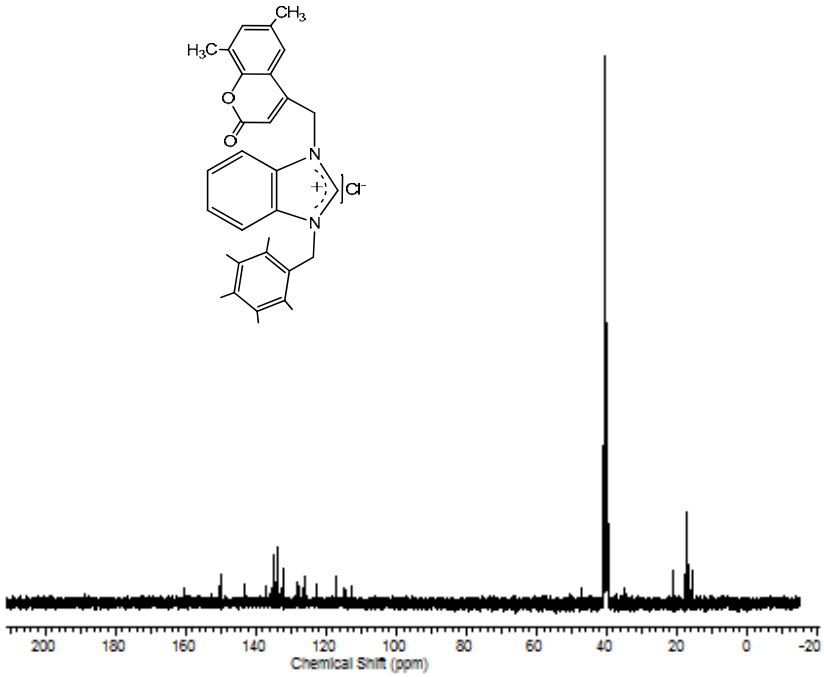


Figure 3.8 ^{13}C NMR Spectrum of compound **3a**

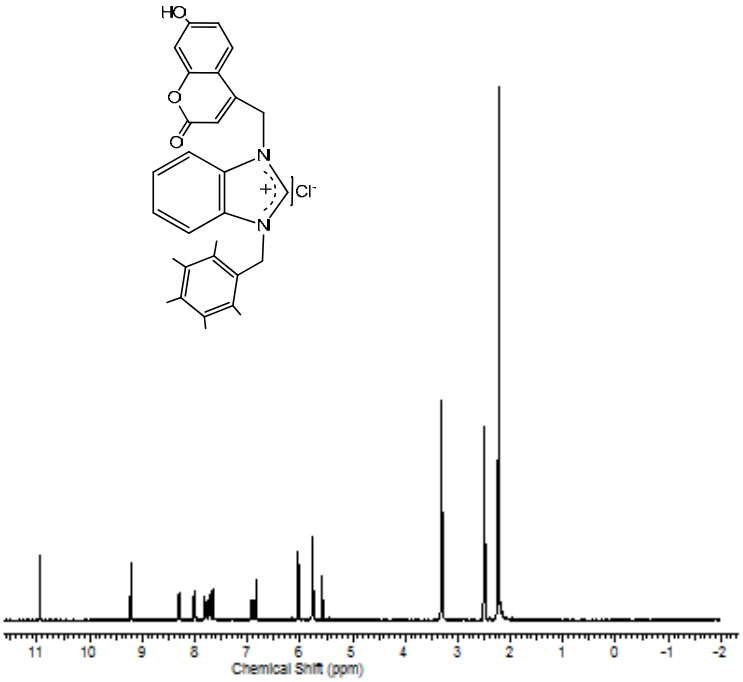


Figure 3.9 ^{1}H NMR Spectrum of compound **3b**

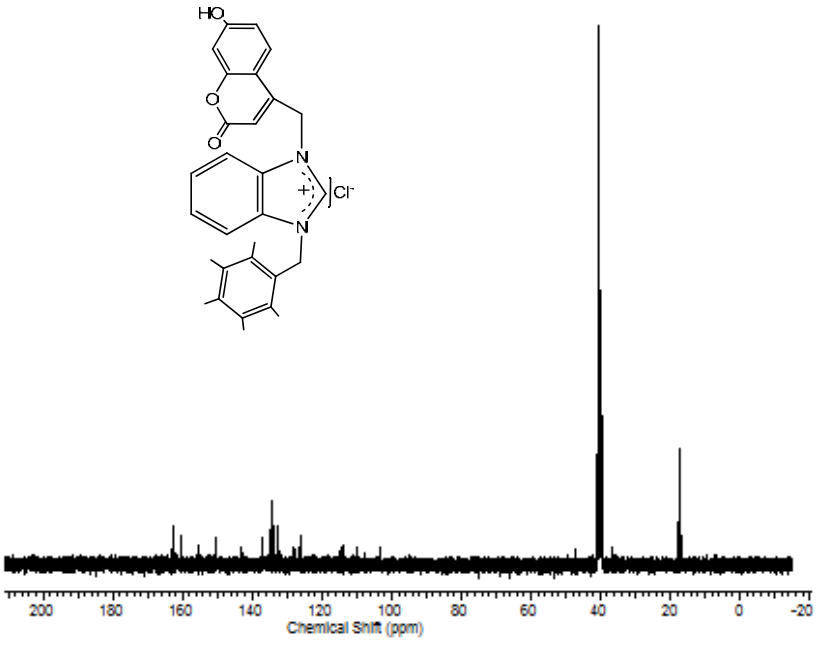


Figure 3.10 ^{13}C NMR Spectrum of compound **3b**

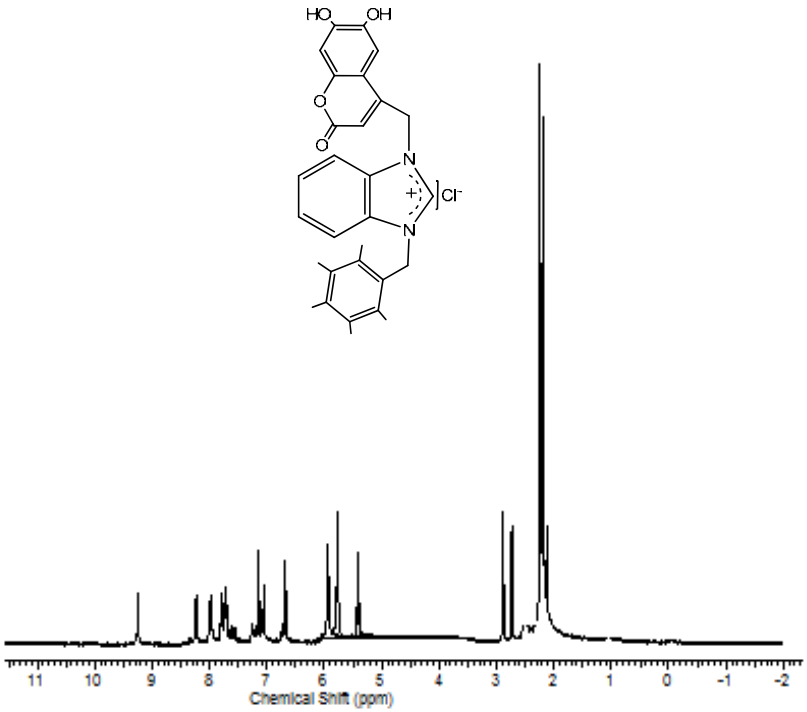


Figure 3.11 ^{1}H NMR Spectrum of compound **3c**

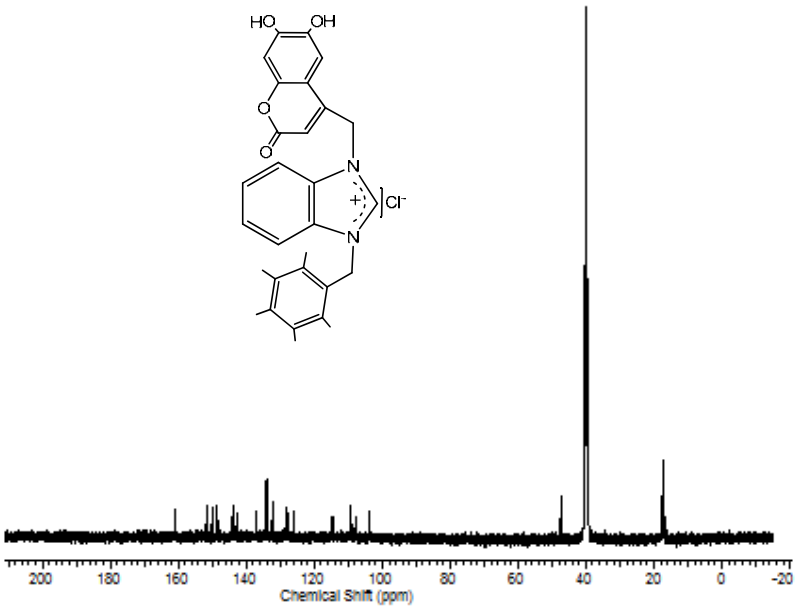


Figure 3.12 ^{13}C NMR Spectrum of compound **3c**

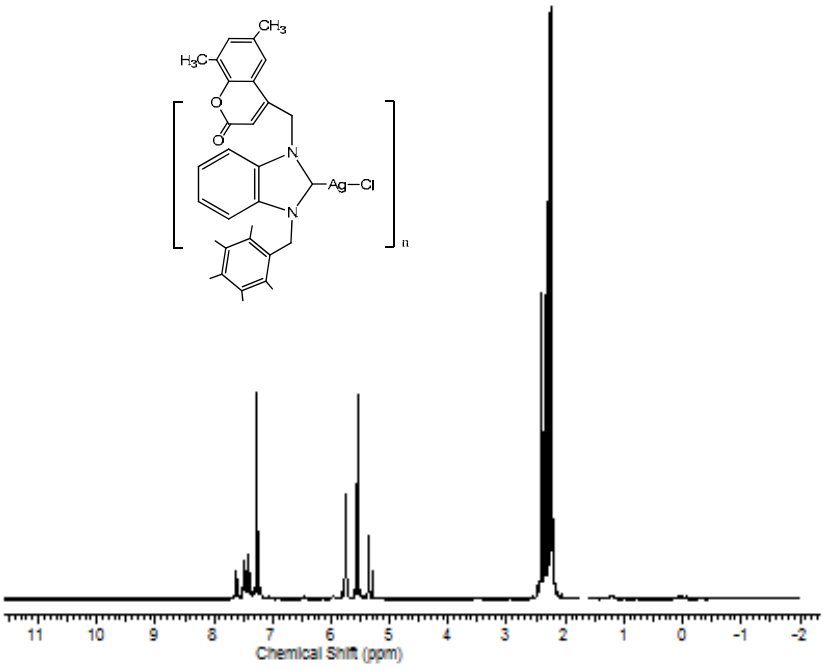


Figure 3.13 ^{1}H NMR Spectrum of compound **6a**

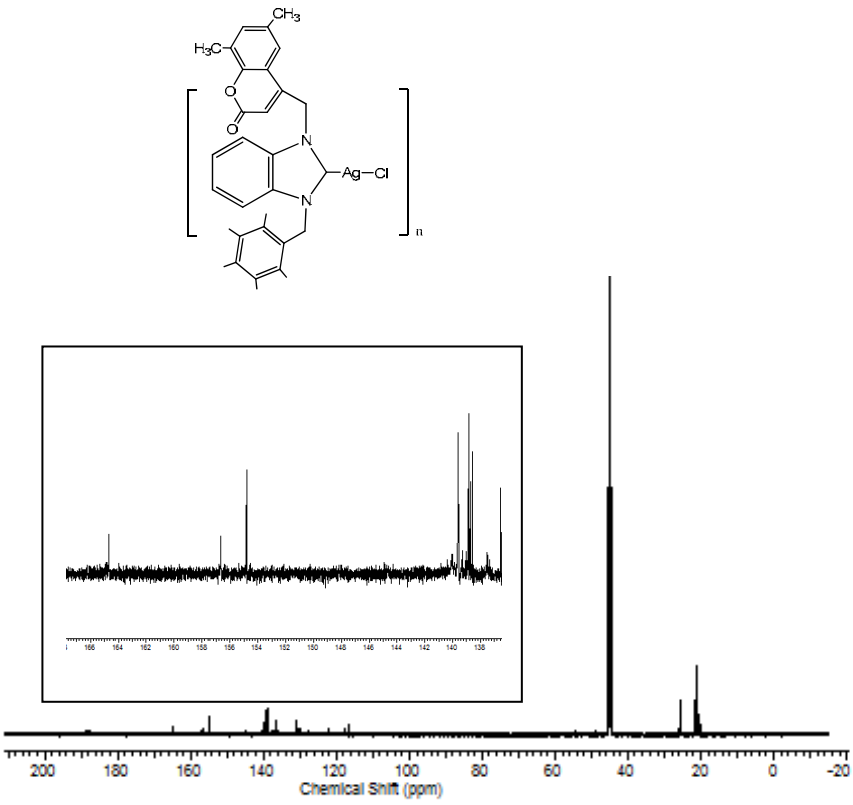


Figure 3.14 ^{13}C NMR Spectrum of compound **6a**

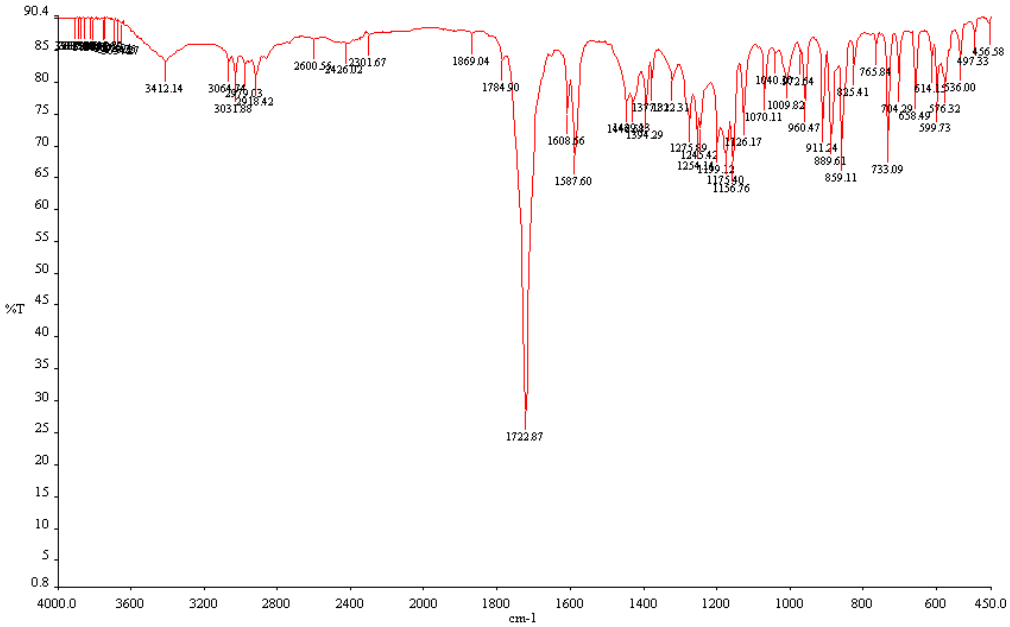


Figure 3.15 IR Spectrum of compound **a**

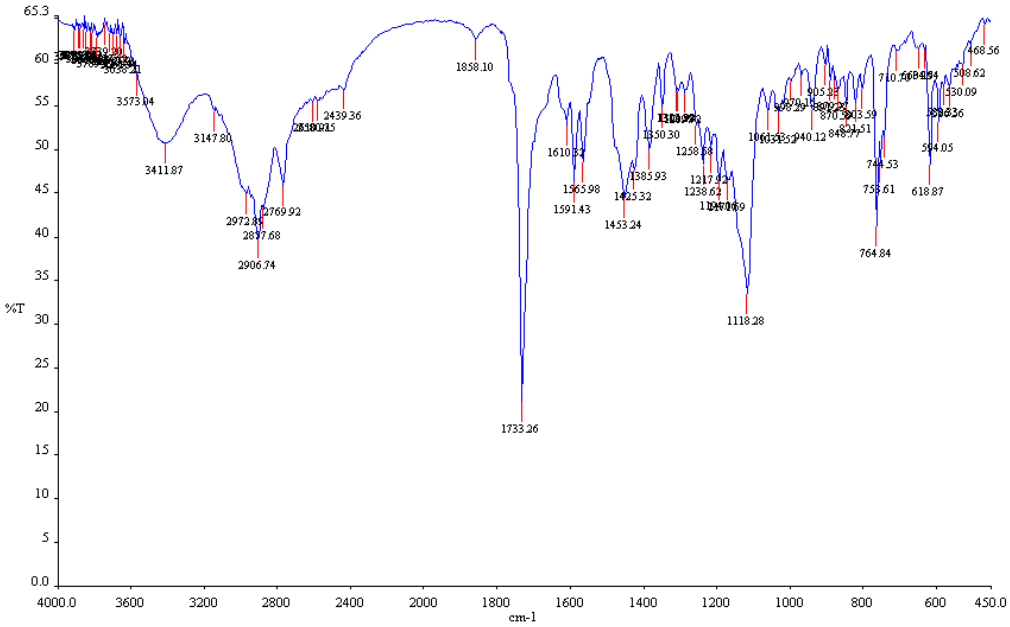


Figure 3.16 IR Spectrum of compound **3a**

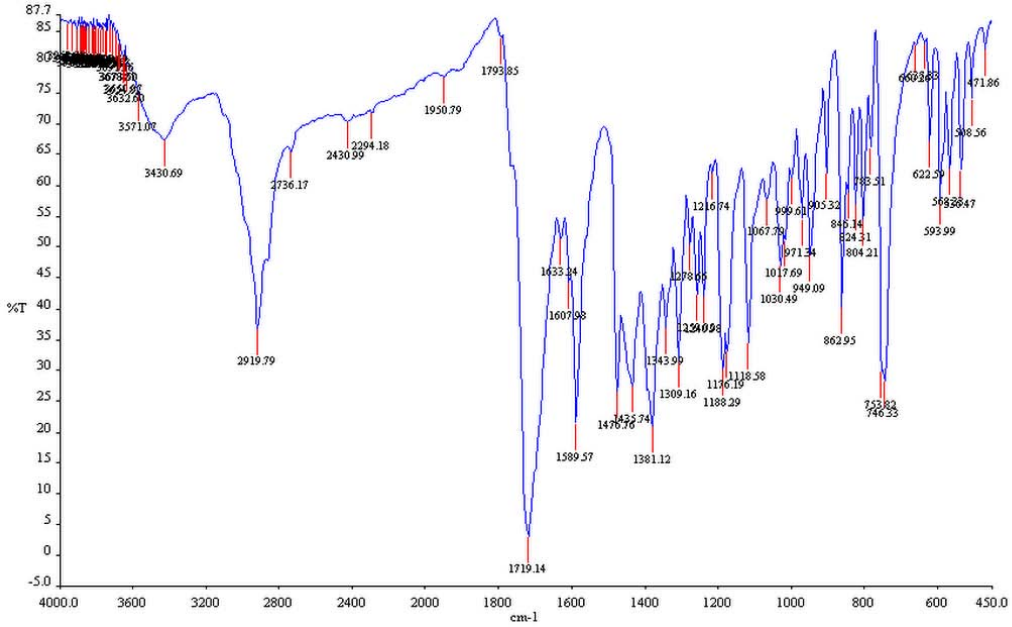


Figure 3.17 IR Spectrum of compound **6a**

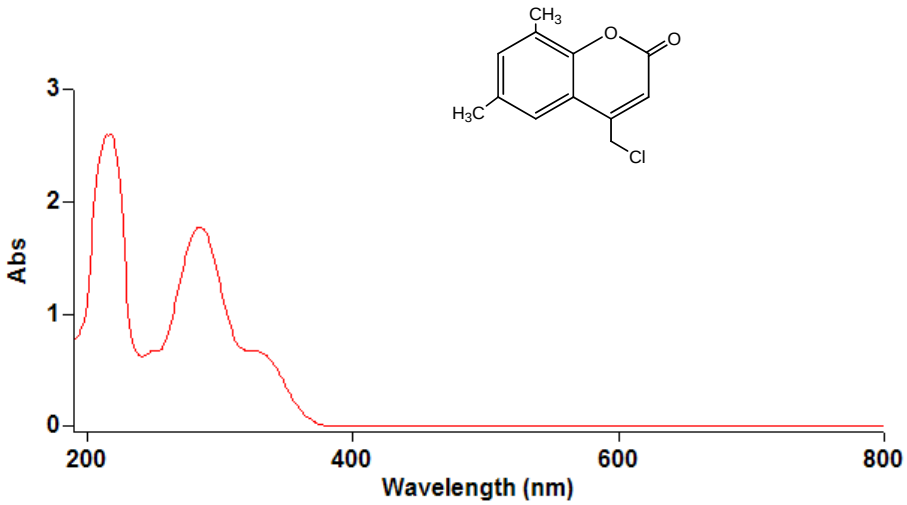


Figure 3.18 UV Visible Spectrum of compound **a**

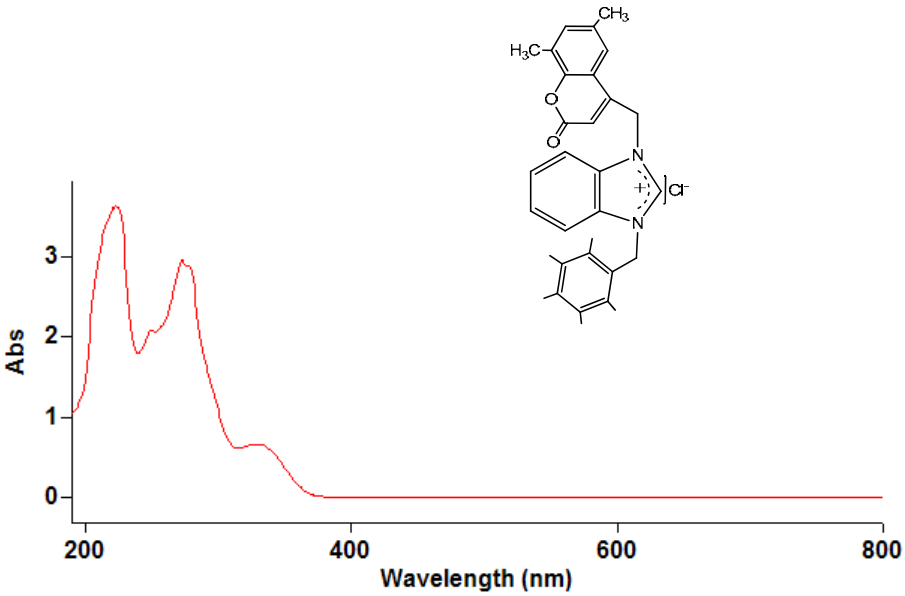


Figure 3.19 UV Visible Spectrum of compound **3a**

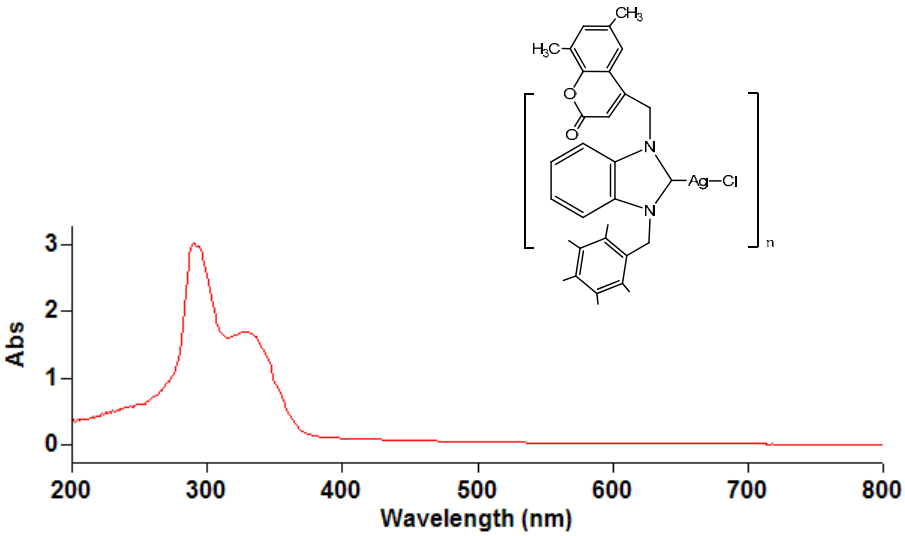


Figure 3.20 UV Visible Spectrum of compound **6a**

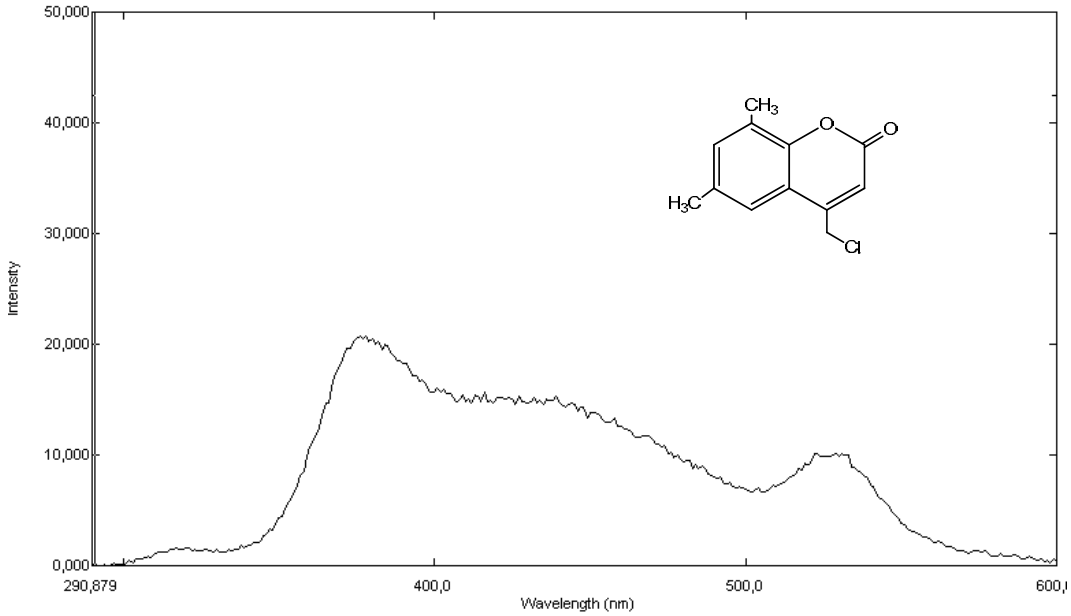


Figure 3.21 Fluoresance Spectrum of compound **a**

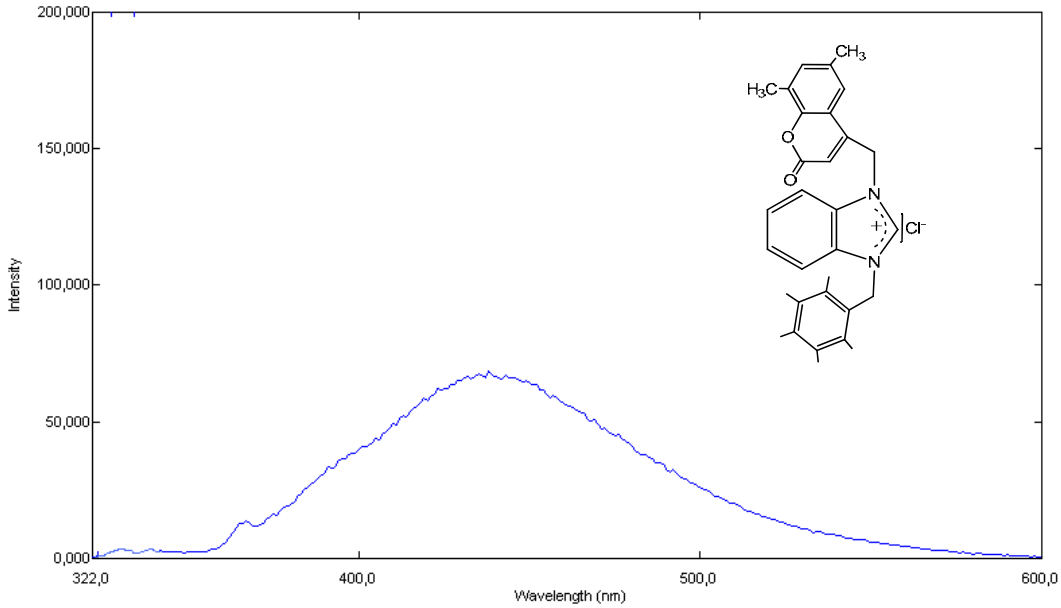


Figure 3.22 Fluoresance Spectrum of compound **3a**

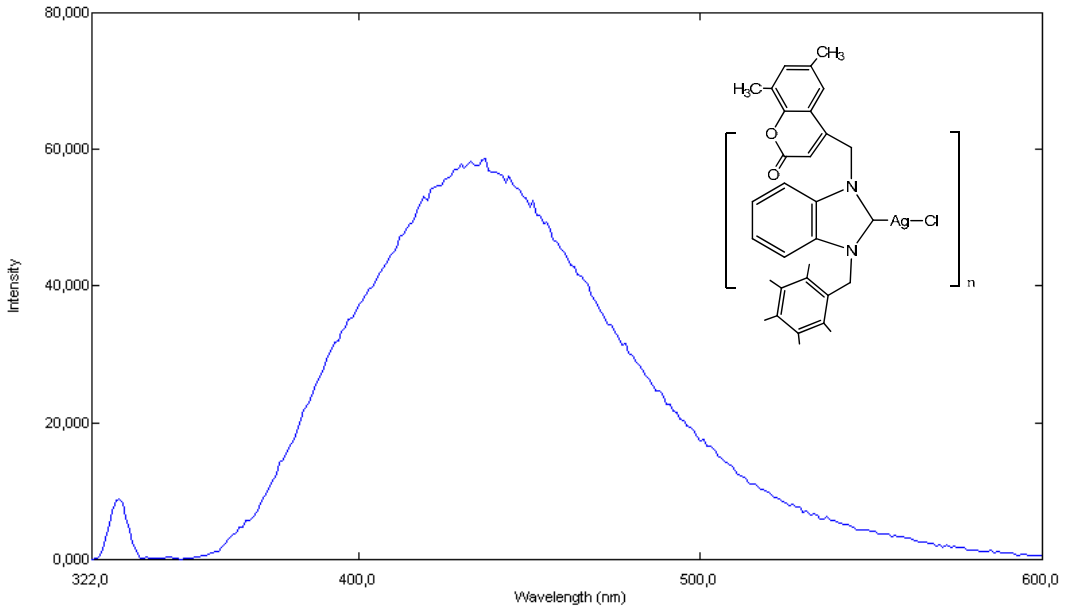


Figure 3.23 Fluoresance Spectrum of compound **6a**

3.3 Base Hydrolysis of the Lactone Moiety of Coumarin of NHC-Ag Complexes

Recycling is becoming significantly more important in chemistry nowadays as environmental harms increase and as resources are becoming scarcer. Chemists continue to develop new catalysts that are more efficient, robust and devise new methods to recover and reuse them. Towards this goal, the water-solubilization of well known catalysts often facilitates the recycling of these catalysts. As described above, organometallic NHC complexes are useful in the synthesis of complex molecules that have applications ranging from drug precursors to polymers. These vital applications make the NHC ligand a perfect candidate to be supported. However, it must be demonstrated that the catalytic activity of the supported NHC complexes does not change with the nature of the support.

We envisioned that the hydrolysis of lactone moiety in the NHC-Ag complexes is viable as in the other coumarins. This hypotysis was realized in a manner as illustrated in Section 2.6. Treatment of **8a** with an excess of KOH in H_2O:EtOH (in 1:1 ratio) at 65 ^oC leads leads to a clear solution which gives a white precipitate upon additin of conc HCl or H_2SO_4. This precipitate, recoverd in (62% yield) was identified as **8a** by NMR analysis. We beleive that this behaviour has important implications for separation of homogenous NHC-M based catalyts.

4. CONCLUSION

In this thesis nine new 1,3-disubstituted benzimidazolium (**1**-**3**) and three new N-methylimidazolium salts (**7**) have been prepared and four of which have been converted into NHC-silver complexes (**4a**-**6a**, **8a**). All of the salts have been synthesized by quaternision of N-alkyldiazoles with chloromethyleted coumarins (**a, b, c**) obtained by the Pechmann reaction.The new compounds synthesized were fully characterized by means of spectroscopy.

One of the NHC silver complexes (**8a**) was found to be soluble in aqueous KOH which indicates hydrolysis of lactone moiety of the coumarin entity.The addition of aqueous acids reverts the reaction to give the lactone-containing complex (**8a**) This property is considered to have important implications in the field of green catalaysis.

In order to determine photo-physical properties, emission and absorption spectra of coumarin containing compounds were recorded. The results for were summarized in Table 3.2. The salent features of emission;

- In the chloromethylatedcoumarins the emission increased in the sequence; 6,8-dimethyl coumarin < 7-hydroxy coumarin < 6,7-dihydroxy coumarin. This observation indicates the electron-releasing influence of -OH group.
- In the 1,3-disubstituted benzimidazolium salts the emission increased in the sequence; pentamethyl substituent < tetramethyl substituent < trimethyl substituent. This observation indicates the influence of methyl substituent.
- For benzimidazolium and imidazolium salts emission property decreased in the sequence; 1,3-disubstituted imidazolium salts > 1,3-disubstituted benzimidazolium salts.
- In the silver complexes, the emission increased in the sequence; benzimidazol silver complexes < imidazol silver complex

For future, we are planning to explore transmetallation potential of the NHC-Ag complexes to other transition metal centers and study the catalytic efficiency of our system in aqueous phase.

REFERENCES

Amidon, R.W. and Greenfield, H., 1972, Ger. Offen.

Akkurt, M., Karaca, S., Yılmaz, Ü., Küçükbay, H. and Büyükgüngör, O., 2008, 1,3-Bis(3-phenylpropyl)benzimidazolium bromide monohydrate, *Acta Crystallographica*, E64(10), 2019-2020.

Ansari, K.F. and Lal, C., 2009, Synthesis, physicochemical properties and antimicrobial activity of some new benzimidazole derivatives, *European Journal of Medicinal Chemistry*, 44, 4028-4033.

Arduengo, A.J., Harlow, R.L. and Kline, M., 1991**,** A stable crystalline carbene, *J. Am. Chem. Soc*., 113(1),361-363.

Arslan, H., Vanderveer, D., Demir, S., Özdemir, I. and Çetinkaya, B., 2009, 1-(1H-Benzimidazol-1-ylmethyl)-3-[2-(isopropylamino)ethyl]-1H-benzimidazolium bromide 0,25-hydrate, *Acta Crystallographica*, E65(4), 699-700.

Ates-Alagöz, Z., Alp, M., Kus, C., Yıldız, S., Buyukbingöl, E. and Göker, H., 2006, Synthesis and potent antimicrobial activities of some novel retinoidal monocationic benzimidazoles, *Arch. Pharm. Chem. Life Sci*., 339, 74-80.

Boyland, E. and Sims, P., 1953, The action on some free radicals on naphthalane, *J. Chem. Soc*., 2966-2972.

Cadierno, V., Diez, J., Francos, J. and Gimeno, J., 2010, Bis(allyl) ruthenium (IV) complexes containing water-soluble phosphane ligands: synthesis, structure and application as catalysts in the selective hydration of organonitriles into amides, *Chem. Eur. J*., 16, 9808-9817.

REFERENCES (continue)

Canham, S.M., Bass, J.Y., Navarro, O., Lim, S.G., Das, N. and Blum, S.A., 2008, Toward the single-molecule investigation of organometallic reaction mechanisms: single-molecule imaging of fluorophore-tagged palladium (II) complexes, *Organometallics*, 27(10), 2172-2175.

Cardin, D.J., Çetinkaya, B., Çetinkaya, E., Lappert, M.F., Randall, E.W. and Rosenberg, E., 1973, Carbene complexes. III. Carbon-13 nuclear magnetic resonance studies of carbene complexes of 1,3-diorganoimidazolin-2-ylidenes, *Dalton Trans*., 19, 1982-1985.

Cardin, D.J., Çetinkaya, B. and Lappert, M.F., 1972, Transation metal-carbene complexes, *Chem. Rev*., 72(5), 545-574.

Cavell, K.J., Dunsford, J. J. and Kariuki, B., 2011, Expanded ring N-heterocyclic carbene complexes of zero valent platinum dvtms (divinyltetramethyldisiloxane): highyl efficient hydrosilylation catalysts, *J. Organo. Med. Chem.,* 696, 188-194.

Christie, R.M. and Lui, C., 1999, Studies of fluorescent dyes: part 1. An investigation of the electronic spectral properties of substituted coumarins, *Dyes and Pigments*, 42, 85-93.

Çetinkaya, B., Çetinkaya, E., Küçükbay, H. and Durmaz, R., 1996, Antimicrobial Activity of carbene complexes of rhodium(I) and ruthenium(II), *Arzneim. Forsch./ Drug Res*., 46, 821-823.

Çetinkaya, E., Alıcı, B., Gök, Y., Durmaz, R. and Günal, S., 1999, New derivatives of benzimidazole and their antimicrobial activity, *J. Chemotheraphy*, 11, 83-89.

Dahiya, R. and Devender, P., 2007, Synthetic studies on novel benzimidazole peptides with antimicrobial, cytotoxic and anthelmintic potential, *Eur. J. Med. Chem*., 42, 772-798.

REFERENCES (continue)

Dean, F.M., 1963, Naturally occuring oxygen ring compounds, Butterworths.

Demir, S., Özdemir, İ. and Çetinkaya, B., 2006, Use of bis(benzimidazolium)-palladium system as a convenient catalyst for Heck and Suzuki coupling reactions of aryl bromides and chlorides, *Organometal. Chem*., 20, 254-259.

Diez-Gonzalez(Ed.), 2010, N-Heterocyclic Carbenes From Laboratory Curiosities to Efficient Synthetic Tools, Royal Society of Chemistry.

Doğan, Ö., Gürbüz, N., Özdemir, İ., Çetinkaya, B., Şahin, O. and Büyükgüngör, O., 2009, Synthesis, characterization and catalytic activity of novel N-heterocyclic carbene-palladium complexes, *Dalton Trans*, 7087-7093.

Dominguez, X.A., Lopez, I.C. and Franco, R., 1961, Simple preparation of a very active Raney Ni catalyst, *J. Org. Chem*., 26,1626.

Dorsch, D., Werner, W.K.R.Mederski, Beier, N., Lues, I., Minck, K.O. and Schelling, P., 1994, (6-oxo-3-pyridazinyl)-benzimidazoles as potent angiotensin II receptor antogonists, *Bioorg. & Med. Chem. Lett*., 4, 11: 1297-1302.

Durmaz, R., Küçükbay, H., Çetinkaya, E. and Çetinkaya, B., 1997, Antimicrobial activity of rhodium(I) and ruthenium(II) carbene complexes derived from benzimidazole against Staphyla Coccus aureus Isolates, *Turk J. Med. Sci*., 27, 59-61.

Ennajih, H., Bouhfid, R., Zouihri, H., Essassi, E.M. and Weng, S., 2010, 1,3-Dibenzyl-2-methylbenzimidazolium chloride, *Acta Crystallographica*, E66(2), 455/1-455/7.

REFERENCES (continue)

Ersan, S., Nacak, S., Noyanalpon, N. and Yeşilada, E., 1997, Anti-inflammatuar effect studies on analgesic and anti-inflammatorr activities of 1-dialkylaminomethyl-2-(p-substituted phenyl)-5-substituted benzimidazole derivatives, *Arzneim.- Forsch. / Drug Res*., 47, 834-836.

Flavin, M.T., Rizzo, J.D., Khilevich, A., Kucherenko, A., Sheinkman, A.K., Vilaychack, V., Lin, L., Chen, W., Greenwood, E.M., Pengsuparp, T., Pezzuto, J.M., Hughes, S.H., Flavin, T.M., Cibulski, M., Boulanger, W.A., Shone, R.L. and Xu, Z., 1996, Synthesis, chromatographic resolution, and anti-human ımmunodeficiency virus activity of calanolide A and its enantiomers, *J. Med. Chem.*, 39, 1303-1313.

Frasinyuk, M.S., Vinogradova, V.I., Bondarenko, S.P. and Khilya, V.P., 2007, Synthesis of cytisine derivatives of coumarins, *Chemistry of Natural Compounds*, 43, No: 5.

Fu, X-P.,. Liu, L., Wang, D., Chen Y-J. and Li, C-J., 2011, **"** On water**"**-promoted direct alkynylation of isatins catalyzed by NHC–silver complexes for the efficient synthesis of 3-hydroxy-3-ethynylindolin-2-ones, *Green Chem.*, 13**,** 549-553.

Fuson, R.C., 1955, Organic Synthesis Collective, John Wiley & Sons., 3, 209.

Garrison, J.C. and Youngs, W.J., 2005, Ag(I) N-Heterocyclic carbene complexes: synthesis, structure and application, *Chem. Rev*., 105(11), 3978-4008.

Garuti, L., Roberti, M., Pizzirani, D., Pession, A., Leoncini, E., Cenci, V. and Hrelia, S., 2004, Differential antiproliferatve activity of new benzimidazole-4,7-diones, *Il Farmaco*, 59, 663-668.

REFERENCES (continue)

Garuti, L., Roberti and M., Gentilomi, G., 2000, Synthesis and antiviral assays of some 2-substituted benzimidazole-N-carbamates, *Il Farmaco*, 55, 35-39.

Giri, Rajesh., 2004, Fluorescence quenching of coumarins by Halide ions, *Spectrochimica Acta Part A*, 60: 757-763.

Goker, H., Kus, C. and Abbasoglu, U., 1995, Synthesis of 1,2,5(6)-trisubstituted benzimidazoles and evaluation of their antimicrobial activities, *Arch. Pharm.(Weinheim),* 328, 425-430.

Gülcemeal, S., Labande, A., Daran, J.C., Çetinkaya, B. and Poli, R., 2009, Rhodium(I) complexes of new ferrocenyl benzimidazole-2-ylidene ligands; the importance of the chelating effect for ketone hydrosilylation catalysis, *Eur. J. Inorg. Chem.,* 1806-1815.

Güven, Ö.Ö., Erdoğan, T., Göker, H. and Yıldız, S., 2007, Synthesis and antimicrobial activity of some novel phenyl and benzimidazole substituted benzyl ethers, *Bioorganic & Med. Chem. Lett*., 17, 2233-2236.

Güven, M., 2000, Benzimidazol türevlerinin sentezi ve özelliklerinin incelenmesi, Yüksek Lisans Tezi, İnönü Üniversitesi Fen Bilimleri Enstitüsü, 71.

Hadei, N., Kantchev, E.A.B., O'Brien, C.J. and Organ, M.G., 2005, Electronic nature of N-heterocyclic carbene ligands : effect on the Suzuki reaction, *Org. Lett*., 7(10), 1991-1994.

Hahn, F.E., Wittenbecher, L., Boese, R. and Blaser, D., 1999, N,N'-Bis(2,2-dimethylpropyl)benzimidazolin-2-yliden: a stable nucleophilic carbene derived from benzimidazole, *Chem. Eur. J.*, 5, 1931-1935.

Han, Y., Huynh, H.V. and Koh, L.L., 2007, Pd(II) complexes of a sterically bulky, benzannulated *N*-heterocyclic carbene and their catalytic activities in the Mizoroki-Heck reaction, *J. Org. Chem*., 692, 3606-3613.

REFERENCES (continue)

Hegedüs, A. and Hell, Z., 2006, Zeolite-catalyzed pechmann synthesis of coumarins, *Catalysis Letters*, 112,1-2.

Hermann, W.A., 2002, N-heterocyclic carbenes; A new concept in organometallic catalysis, *Angew. Chem. Int. Ed*., 41: 1290-1309.

Hermann, W.A., Reisinger, C.P. and Spiegler, M., 1998, Chelating *N*-heterocyclic carbene ligands in palladium-catalyzed Heck type reactions, *J. Organomet. Chem*., 557, 93.

Hindi, K.M., Matthew, J.P., Claire, A.T.,Carolyn, L.C. and Wiley, J.Y., 2009, The medicinal applications of imidazolium carbene-metal complexes, *Chem. Rev*., 109(8), 3859-3884.

Hiroshi, M. and Tadahiko, T., 2005, High- Performance Fibers, Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH, Weinheim.

Jaouen, G., 2006, Bioorganometallics: Biomolecules, Labelling Medicine, Wiley-VCH, ISBN 3-527-30990-X.

Jiang, J.L. and Shi, Z., 1998, Novel synthetic method for symmetric diketones from benzimidazolium salts & bis-grignard reagents, *Synthetic Communications*, 28(22), 4137-4142.

Johnson, J.R., 1942, Organic reactions, John Wiley & Sons, Inc.,1, 210.

Jones, G., 1967, Organic reactions, John Wiley & Sons, Inc., 15, 204.

Joule, J.A. and Mills, K., 2000, Heterocyclic Chemistry, 4th edition, Blackwell Science.

REFERENCES (continue)

Kaiser, 1885, Ber., 18: 2942.

Karrer, P. and Banerjea, P., 1949, Reduction of coumarin and o-coumaric acid esther with lithium aluminum hydride, *Helv. Chim. Acta*, 32, 1692-1693

Knoevenagel, E., 1898, Condensation of malonic acid with aromatic aldehydes by ammonia and amines, *Berichte*, 31, 2596-2619.

Kokare, N.D., Sangshetti, J.N. and Shinde, D.B., 2007, Oxalic acid catalyzed solvent-free one pot synthesis of coumarins, *Chinese Chemical Letters*, 18, 1309-1312.

Krasovitskii B.M. and Bolotin, BM., 1988, Organic Luminescent Materials, Weinheim, VCH.

Kus, C., 2002, Synthesis of new substituted 6-(morpholin-4-yl)-1H-benzimidazole derivatives, *Turk J. Chem*., 26, 559-564.

Kutlu, H., 1976, Farmasötik kimya IV (Heterosiklik seri ilaçlar 1), İstanbul Üniverisitesi Eczacılık Fak. Farmasötik Kimya Kürsüsü, 512.

Küçükbay, H., Durmaz, R., Güven, M. and Günal S., 2001, Synthesis of some benzimidazole derivatives and their antibacterial and antifungal activities, *Arzneim.-Forsch./Drug Res*., 51(I), 420-424.

Küçükbay, H., Çetinkaya, E. and Durmaz, R., 1995, Synthesis and Antimicrobial Activity of Substituted Benzimidazole, Benzothiazole and Imidazole Derivatives, *Arzneim. – Forsch. / Drug Res*., 45(II), 1331-1334.

REFERENCES (continue)

Kühl, O., Saravanakumar, S., Ullah, F., Kindermann, M.K., Jones, P.G., Köckerling, M. and Heinicke, J., 2008, Anellated N-heterocyclic carbenes: 1,3-Dineopentyl-benzimidazole-2-ylidene structural aspects of C-protonated precursor salts and an AgCl complex, *Polyhedron*, 27, 2825-2832.

Lappert, M.F., Cardin, D.J.,Çetinkaya, B., Monojlovic-Muir, L. and Muir, K.W., 1971, Electron-rich olefin as a source of coordinated carbene; synthesis of trans-$PtCl_2[C(NPhCH_2)_2]PEt_3$, *Chem. Commun*., 8, 400-401.

Lee, K.M., Lee, C.K. and Lin, I.J.B., 2010, N,N'-Dihexylbenzimidazolium salts. Anion-controlled bilayer structures via π-π dimer or C-H….π catemer motifs, *Cryst. Eng. Comm*., 12, 4347-4351.

Lewis, F., Howard, D.K. and Oxman, J.D., 1983, Lewis acid catalysis of coumarin photodimerization, *J. Am. Chem. Soc*., 105(10), 3344-3345.

Li, Y., Chen, X., Song, Y., Fang, L. and Zou, G., 2011, Well-defined N-heterocyclic carbene silver halides of 1-cyclohexyl-3-arylmethylimidazolylidenes: synthesis, structure and catalysis in A^3-reaction of aldehydes, amines and alkynes *Dalton Trans.*, 40, 2046-2052.

Lin, I.J.B. and Vasam, C.S., 2007, Preparation and application of N-heterocyclic carbene complexes of Ag(I), *Coord. Chem. Rev*., 251, 642-670.

Marles, R.J., Compadre, C.M. and Fornsworth, N.R., 1986, Coumarin in vanilla extracts: Its detection and significance, *Economic Botany*, 41, 41-47.

Nishida, H., 2011, Development of materials and Technologies for control of polymer recycling, *Polymer Journal*, 43, 435-447.

REFERENCES (continue)

Nolan, S.P, Diez-Gonzalez, S. and Marion, N., 2009, N-Heterocyclic carbenes in late transation metal catalysis, *Chem. Rev*., 109(8), 3612-3676.

Oelschlager, H. and Giebenhain, G., 1973, Hydrogenation of benzimidazole and indazole, *Archiv der Pharmazie*, 306(7), 485-489.

O'Kennedy, R. and Thornas, R.D., 1997, Coumarins: Biology, Application and Mode of Action, Wiley, Chichester.

O'Niel, M.J., Smith, M. and Heckelman, P.E., 2001, The Merck Index, 13th edition Merck & Co. Inc., 1785.

Öfele, K., 1968, N-heterocyclic carbenes: state of the art in transation metal complex, *J. Org. Chem.*, 12, 42.

Özdemir, İ. Gürbüz, N., Doğan, Ö., Günal, S. and Özdemir, İ., 2010, Synthesis and anti-microbial activity of Ag(I)-N-heterocyclic carbene complexes derived from benzimidazol-2-ylidene, *Appl. Organometal. Chem*., 24, 758-762.

Padhye, M.R., Varadarajan, T.S. and Deshpande, A., 1982, Some new laser dyes-solvent effect on QE [quantum efficiency] and lasing action, *Spectrosc. Lett*., 15(8), 597-608.

Patil, S.B., Bhat, R.P., Raje, V.P. and Samant, S.D., 2006, Ultrasound-assisted pechmann condensatin of phenols with β-ketoesters to form coumarins in the presence of bismth(II) chloride catalyst, *Synthetic Communications*, 36, 525-531.

Perkin, W.H., 1868, On the artificial production of coumarin and formation of its homologues, *J. Chem. Soc*., 21, 53-63.

REFERENCES (continue)

Perkin, W.H., 1877, On the formation of coumarin and of cinnamic and of other analogous acids from the aromatic aldehydes, *J. Chem. Soc.*, 31, 388-427.

Poeta, M., Schell, W.A., Dykstra, C.C., Jones, S., Tidwell, R.R., Czarny, A., Bajic M., Kumor, A., Boykin, D. and Perfect, J.R., 1998, Structure-in vitro activity relationships of pentamidine analogues and dication-substituted bis-benzimidazoles as new antifungal agents, *Antimicrob. Agents. Chemother*., 42(10), 2495-2502.

Potdar, M.K., Swapnil, S. and Salunkhe, M.M, 2001, Coumarin synthesis via pechmann condensation in lewis acidic chloroaluminate ionic liquid, *Tetrahedron Letters*, 42, 9285-9287.

Ramirez, J., Corberan, R., Sanau, M., Peris, E. and Fernandez, E., 2005, unprecedented use of silver(I) N-heterocyclic carbene complexes for the catalytic preparation of 1,2-bis(boronate) esters, *Chem. Commun*., 3056-3058.

Rasching, F., 1909, Ger. Pat.

Rauwald, H.W., Brehm, O. and Odenthal, K.P., 1993, The involvement of a Ca^{+2} channel blocking mode of action in the pharmacology of Ammi visnaga fruits, *Planta Med*., 60, 10

Reddy, Y.T., Sonar, V.N., Crooks, P.A., Dasari, P.K., Reddy, P.N. and Rajitha, B., 2008, Ceric ammonium nitrate: An efficient catalyst for the coumarin synthesis via pechmann condensation using conventional heating and microwave ırradiation, *Synth. Commun*., 38, 2082-2088.

Rosemeyer, H., 2004, The Chemodiversity of Purine as a Constituent of Natural Products, Chemistry& Biodiversity, 1,361-401.

REFERENCES (continue)

Samantaray, M.K., Katiyar, V., Roy, D., Pang,. K., Nanavati, H., Stephen, R., Sunoj, R.B. and Ghosh, P., 2006, A Cationic (N-Heterocyclic carbene)silver Complex as Catalyst for Bulk Ring-Opening Polymerization of L-Lactides, *Eur. J. Inorg. Chem*., 2975–2984

Sandoval, H.L., Lemos, M.E.L, Velasco, R.G., Melendez, I.P., Macias, P.G., Mora, I.G. and Behrens, N.B., 2008, Synthesis, structure and biological activities of cobalt (II) and zinc (II) coordination compounds with 2-benzimidazole derivatives, *J. Inorg. Biochem*., 102, 1267-1276.

Sentman, A.C., Szilard, C., Waymouth, R.M. and Hedrick, J.L., 2005, Synthesis of well-defined N-heterocyclic carbene complexes, *J. Org. Chem*., 70, 2391-2393.

Sethna, S.M. and Phadke, R., 1953, Organic Reactions, John Wiley & Sons Inc., 7, 1-58.

Sethna, S.M. and Narsinh, S.M., 1945, The chemistry of coumarins , *Chem.Rev*. , 36, 1-62.

Settimo, A.D., Primofiore, G., Settimo, F.D., C alzolari, L., Cazzulani, P., Passoni, A. and Tofanetti, O., 1992, 1-Substituted 2-benzylamino benzimidazole derivatives; compounds with H_1 antihistaminic activity, *Euro. J. Med. Chem*., 27, 4: 395-400.

Sokolowska, J., Czajkowski, W. and Podsiadly, R., 2001, The photostability of some fluorescent disperse dyes derivatives of coumarin, *Dyes and Pigments*, 49, 187-191.

REFERENCES (continue)

Starcevic', K., Kralj, M., Ester, K., Sabol, I., Grce, M., Pavelic', K. and Zamola, G.K., 2007, Synthesis, antiviral and antitumor activity of 2-substituted-5-amidino-benzimidazoles, *Bioor. & Med. Chem.*, 15, 13: 4419-4426.

Starikova, O.V., Dolgushin, G.V., Larina, L.I., Ushakov, P.E., Komarova, T.N. and Lopyrev, V.A., 2003, Synthesis of new stable carbenes from the corresponding 1,3-Dialkylimidazolium and benzimidazolium salts, *ARKIVOC*, 13, 119-124.

Starikova, O.V., Dolgushin, G.V., Larina, L.I., Ushakov, P.E., Komarova, T.N. and Lopyrev, V.A., 2003, Synthesis of 1,3-Dialkylimidazolium and 1,3-Dialkylbenzimidazolium salts, *Russian Journal of Chemistry*, 39, No:10, 1467-1470.

Toimil-Campos, M., Orallo, F., Santana, L. and Uriarte, E., 2002, Synthesis and vasorelaxant activity of new coumarin and furocoumarin derivatives, *Bioorganic & Medicinal Chemistry Letters*, 12, 783-786.

Wagner, B. D., 2009, The Use of Coumarins as Environmentally-Sensitive Fluorescent Probes of Heterogeneous Inclusion Systems, *Molecules*, 14, 210-237.

Wang, Z.Q., Shen, G., Zheng, Z.Y., Wu, X.M. and Liu, Q.X., 2009, 1-Butyl-3-(1-naphtylmethyl) benzimidazolium hemi{di-μ-iodido-bis [diiodidomercurate(II)]} dimethyl sulfoxide monosulfate, *Acta Crystallographica*, E65(12), 1639.

Wang, H.M.J. and Lin, I.J.B., 1998, Facile synthesis of silver (I)-carbene transfer agents, *Organnometallics*, 17, 972-975.

Wanzlick, H.W. and Schoenherr, H.J., 1968, Chemistry of nucleophilic carbenes. XIV. Direct synthesis of a mercury salt-carbene complex, *Angew. Chem. Int. Ed*., 7(2), 141-142.

REFERENCES (continue)

Wanzlick, H.W. and Schikora, E., 1961, A nucleophilic carbene, *Chem. Ber*., 94, 2389-2393.

Van der Made, A.W. and Van der Made, R.H., 1993, A convenient procedure for bromomethylation of aromatic compounds. Selective mono-, bis-, or trisbromomethylation, *J. Org. Chem*., 58: 1262-1263.

Voedisch, R.W., 1973, Luminescent pigments, organic. In: Patton TC, editor. The pigment handbook, 2nd edition, John Wiley, 1, 891.

Yu, T., Yang, S., Zhao, Y., Zhang, H., Han, X., Fan, D., Qiu, Y. and Chen, L., 2010, Synthesis, crystal structures and fluorescence properties of 3-(2-pyridyl)coumarin derivatives, *Journal of Photocemistry and Photobiology A*: *Chemistry*, 214, 92-99.

Yun Xia, W., Lin, J. and Zhen, S., 2003, Reaction of benzimidazolium salt with amines, *Chinese Chemical Letters*, 14(6), 561-564.

Zakerhamidi, M.S., Ghanadzadeh, A., Tajalli, H., Moghadam, M., Jassas, M. and Hosseinina, R., 2010, Substituent and solvent effects on the photo-physical properties of some coumarin dyes, *Spectrochimica Acta Part A*, 77, 337-341.

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