CHAPTER III

A DESIGN FOR CONVENIENT AND GREENER ROOT TOWARDS ONE POT MULTI-COMPONENT SYNTHESIS OF SUBSTITUTED PYRANO-DICHROMENEO-DIONE AND CHROMENO-PYRIDO-PYRIMIDINONE DERIVATIVES USING RICE HUSK BASED HETEROGENEOUS CATALYST

III.1 Introduction

Coumarins are important class of heterocyclic compounds which contain a basic flavinoid like skeleton and have both natural and synthetic origin that show diverse pharmaceutical and biological activities.[1] As coumarin scaffolds are one of the important fused ring heterocyclic bioactive compounds, a considerable effort have been made by researchers towards the fruitful synthesis of these useful bio-active coumarine heterocycles. Coumarins can be derived from natural resources and scaffold can be used extensively in laboratory for generation of newer drug molecules. Their derivatives are no doubt a class of bioactive agents which show a broad range biological activities such as anti-inflamatory [2], anticancer [3], antitubercular [4], anti-viral [5], anti-fungal [6]. A varity of scientific research have been made towards the synthesis coumarin analogues to find their significant applications in the field of medicinal chemistry and a number of coumarin derivatives have been obtained by following famous reactions procedures such as Knoevenagel, Perkin, Reformatsky, Michael etc. [7] Some coumarine derivatives also showed excellent fluorescent properties and thus a series of coumarin based molecular probes are being used to investigate drug action in cellular biological researches.[8]

Among the coumarin-fused heterocycles 7-aryl substituted pyranodichromene-6,8-dione and 7-aryl substituted chromeno[4,3-d]pyrido[1,2-a]pyrimidinone derivatives have attracted our keen attention for organic synthesis under green condition. Because of having several biological and pharmaceutical activities the chromene moiety has been generally employed in the expansion of compounds and one-pot multi-component reactions (MCRs) in this regard has helped us a lot as because it provides convenient, energy and time saving root over multi-step process for the synthesis of annelated coumarine derivatives. In our described project, one pot three component and pseudo three component reactions have shown potential effectiveness in generating good product yield in a hassle-free manner. It is observed that both homogeneous and heterogeneous catalysts are capable enough to increase the productivity in MCRs but however, heterogeneous catalysts have more importance over homogeneous one because of their easy separation and recovery from the reaction mixture. In this context, rice husk (RH) based heterogeneous support has been chosen for the synthesis of our targeted substituted pyranodichromene-6,8-dione and chromeno[4,3-d]pyrido[1,2-a]pyrimidinone derivatives considering a sustainable way. Rice husk is an agricultural by-product having high

silica content and the characteristics like high porosity, light weight and high external surface area attracted us to use it as a good heterogeneous catalyst.[9-10] There are also more reasons to select rice husk based greener catalyst for chemical reactions due to its economic advantage, non-toxicity, high abundance, and bio-degradability and furthermore it is more economically cheaper than other heterogeneous materials.[11] The use of rice husk based eco-friendly catalysts and the use of safer and greener solvents are on demand in recent years for the greener synthesis of organic compounds to achieve a sustainable goal and so derived and modified natural substances from agricultural waste can make a major contribution as a bio-derived catalyst in future research for the synthesis of various important heterocyclic compounds. And following the principles of "Green Chemisty", applying the one-pot multi-component reaction technique (MCRs) along with greener catalyst (SRH), greener solvent, a versatile and powerful way has been presented in the whole work for the targeted synthesis of fused-ring coumarine derivatives. As a part of our research interest on the synthesis of substituted pyrano-dichromeneo-dione and chromeno-pyrido-pyrimidinone derivatives of biological significance, we report here the preparation of catalyst and the

whole synthetic process those above mentioned coumarin derivatives via a simplest hassle free route under sustainable and greener technique.

III.2 Chromene

According to IUPAC systems of nomanclatures, benzopyran systems are generally known as chromenes.[12] There are two isomers of benzopyran such as chromene and isochromene and additionally there are several types of chromenes reported in literature depending upon its structural variation and presence of ring substitution. Out of nine carbons in the ring system, eight carbons are sp^2 and one carbon is sp^3 hybridized and depending upon the position of sp^3 carbon with respect to ring oxygen naming of chromenes are done as 2*H*-, 3*H*- and 4*H*-chromenes and the replacement of sp^3 hybridized carbon by carbonyl group leads to make 2*H*-, 3*H*- and 4*H*- chromenone or chromone rings.[13-14] A list of various types of chromenes have been shown in **Figure III.1** containing triclic and tetracyclic rings also.

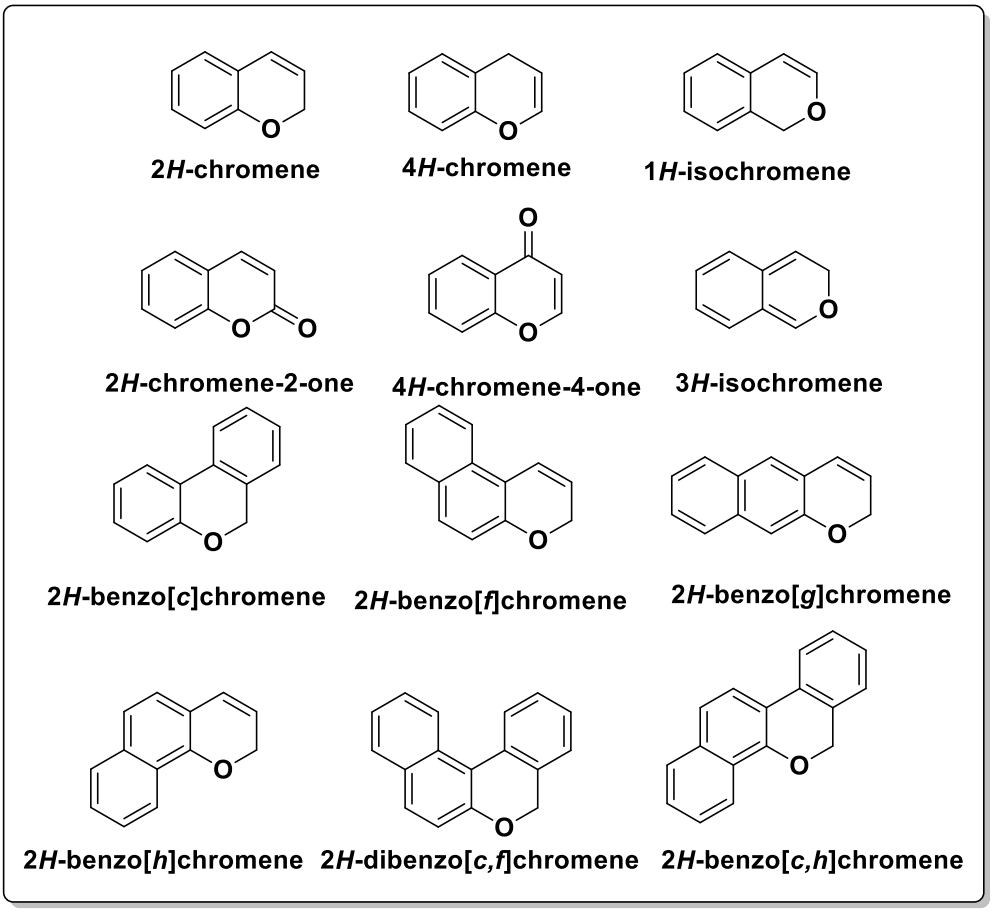


Figure III.1 Different types of chromene scaffolds

III.2.A Coumarine

Coumarine or 2*H*-chromene-2-one is an organic colourless solid compound with sweet odour having a lactone like ring fused with a benzene ring. Coumarines are also a class of chromene molecues where sp^3 hybridized carbon atom of 2*H*-chromene moelecule is replaced by carbonyl (C=O) group having both chemical and pharmaceutical importance. Coumarins are widely spread in the nature and can be found

in many plants as secondary metabolites.[15] There are several reported isolation process of coumarines from natural resources [16-30] and also there have methods of laboratory synthsis of both coumarine, substituted coumarines (**Figure III.2**) and other coumarine derivatives.

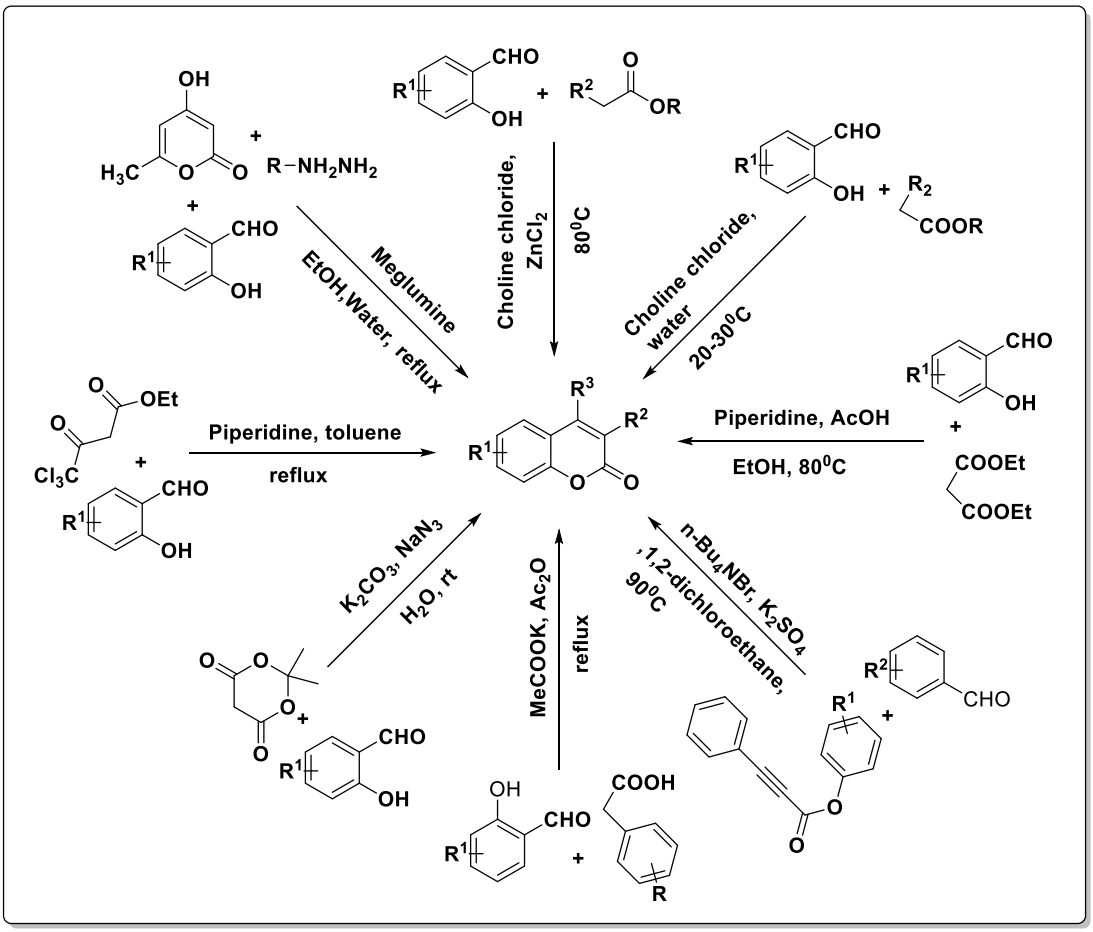


Figure III.2 Diverse synthetic routes for the synthesis of coumarine structures

III.3 Biological importance of chromenes and coumarines

Synthetic chromene derivatives possesses potent anticancer, antibacterial and antifungal, antirheumatic, anti-inflamatory properties and a vast number of chromene heterocycles are found to have

significant biological activity and some of them are used as potent drugs.[31] A large number of potent bioactive chromene heterocycles are reported in literature having anti-HIV, anti-inflamatory, anti-toumour, antihepatitic, anticancer, anticoagulant and antagonist activities(**Figure III.3**).[32-46] Therefore, synthetic chemists are always motivated to synthesize such potent analogous for pharmaceutical activities [47-50].

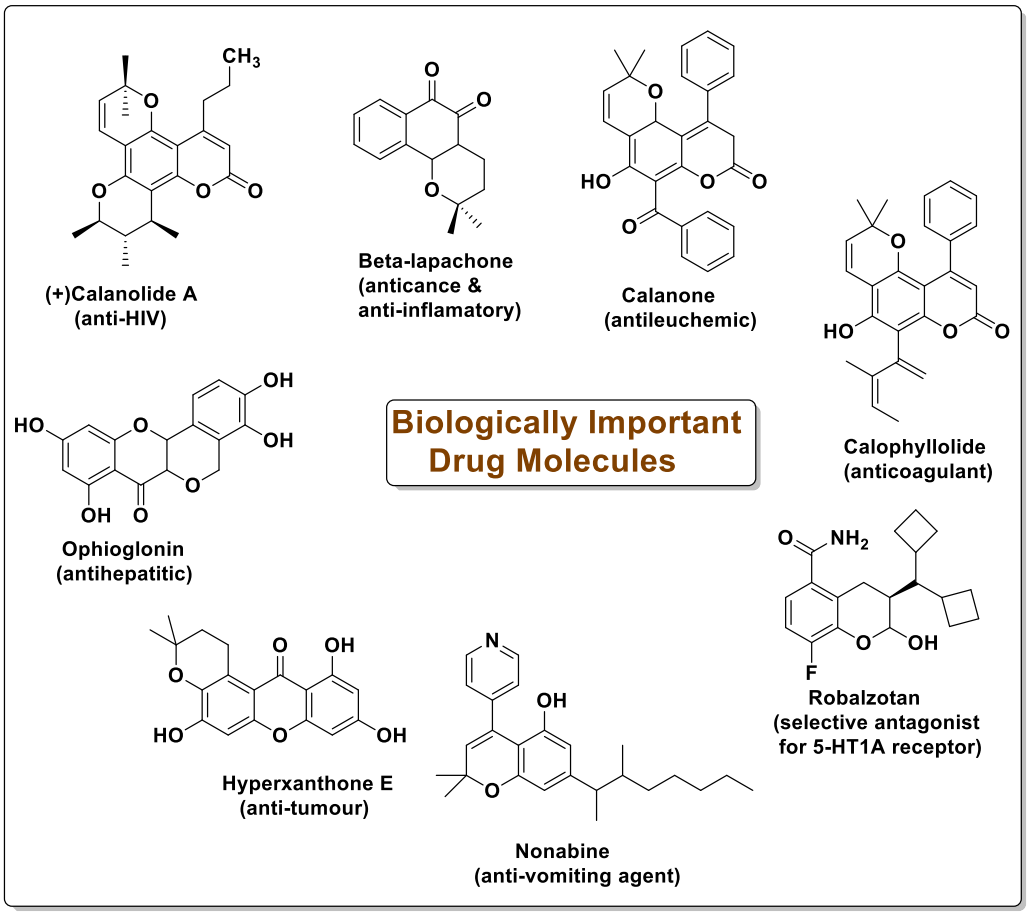


Figure III.3 Some important pharmaceutically active drug molecule containing chromene structural skeletons

Coumarins possess broad range of biological activities such as-antifungal, anti-bacterial, anti-inflammatory, anti-HIV, anticancer, antituberculosis, anticoagulant, antiviral and significant antioxidant activities (**Figure III.4)** [51-62]. Some coumarins are derived as acetylcholinesterase inhibitors and so are useful drug in Alzheimer disease treatment [63].

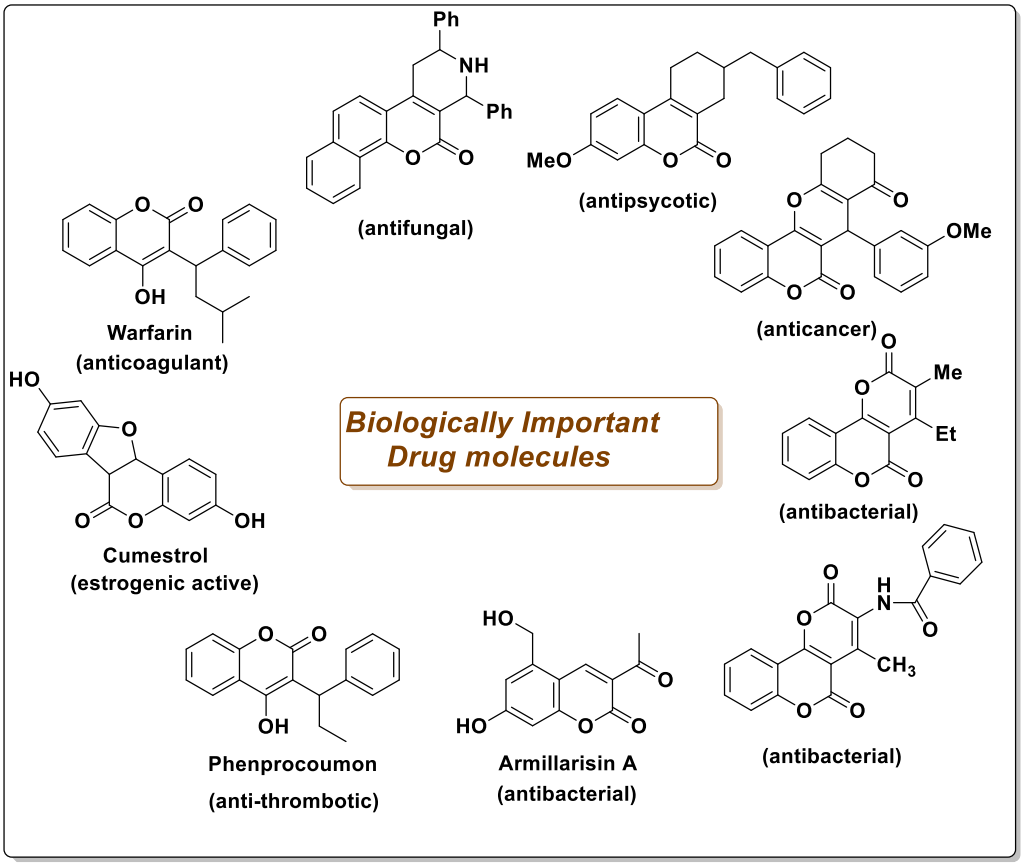


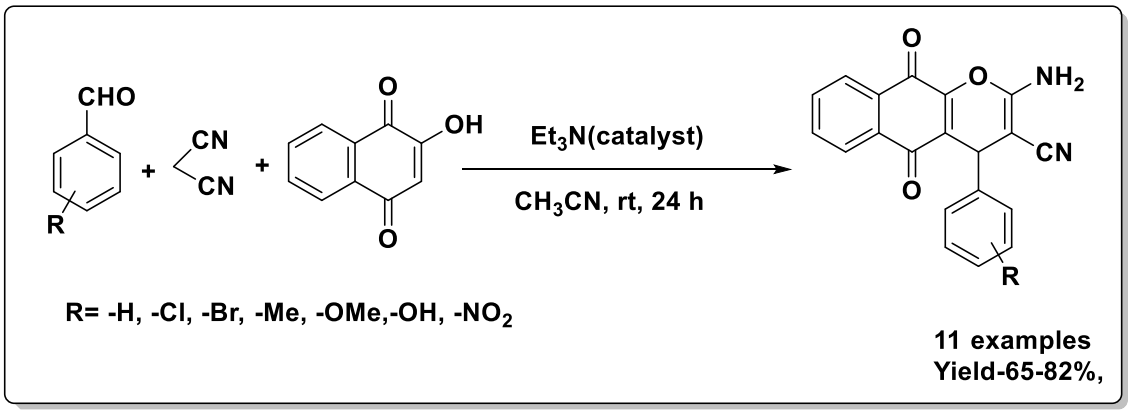
Figure III.4 Some important pharmaceutically active drug molecule containing coumarine structural skeletons

By doing studies on works in various journals related to chromenes, coumarines, and their derivatives and taking biological importances of

chromenes, coumarines, and their derivatives in knowledge in this following part of the chapter III, it has been focused on the chromene derivatives in a new and convenient manner using cheap laboratory chemicals.

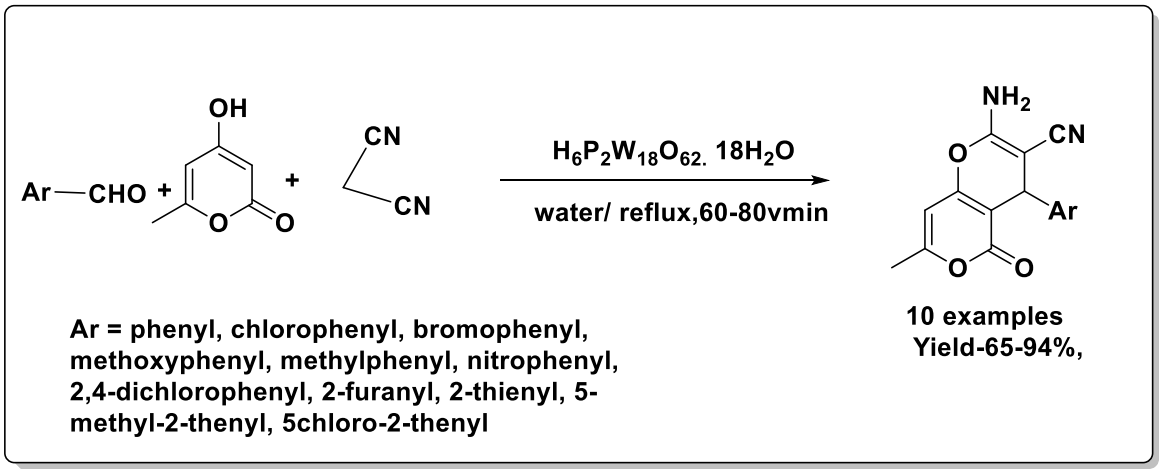
III.4 Previous methods for synthesis of chromene and coumarine derivatives

In 2009, Shaabani *et al*. reported a room-temperature based synthesis of benzo[g]chromene derivatives via one-pot multicomponent reaction of aldehyde, malononitrile with 2-hydroxynaphthalene-1,4-dione or 2,5- dihydroxycyclohexa-2,5-diene-1,4-dione in presence of base catalyst Et_3N in CH_3CN solvent (**Scheme III.1**). [64].



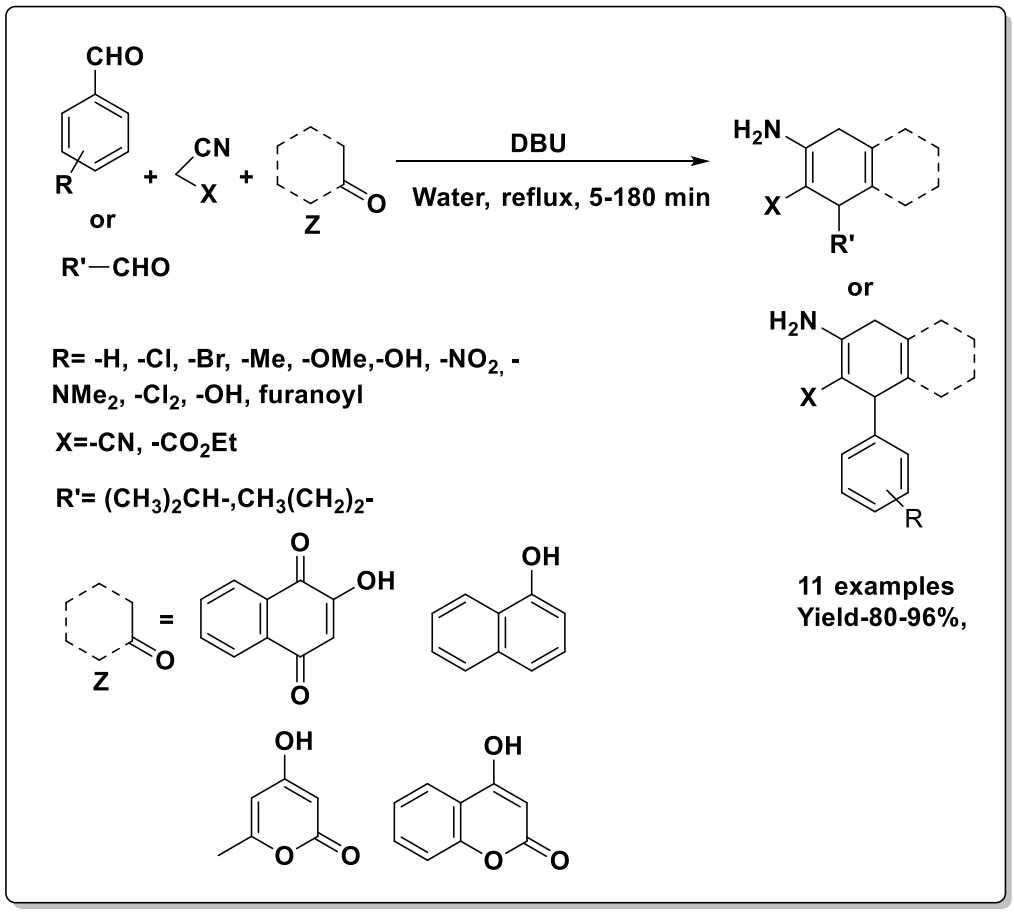
Scheme III.1 One pot synthesis of benzo[g]chromene derivatives by Shaabani *et al.*

In 2013, Rajguru *et al*. had reported a synthetic procedure for the synthesis of 4*H*-chromenes using aromatic aldehyde, malononitrile and C-H activated pyran-2-one to synthesise 2-amino-4*H*-chromene derivatives (**Scheme III. 2**). [65].



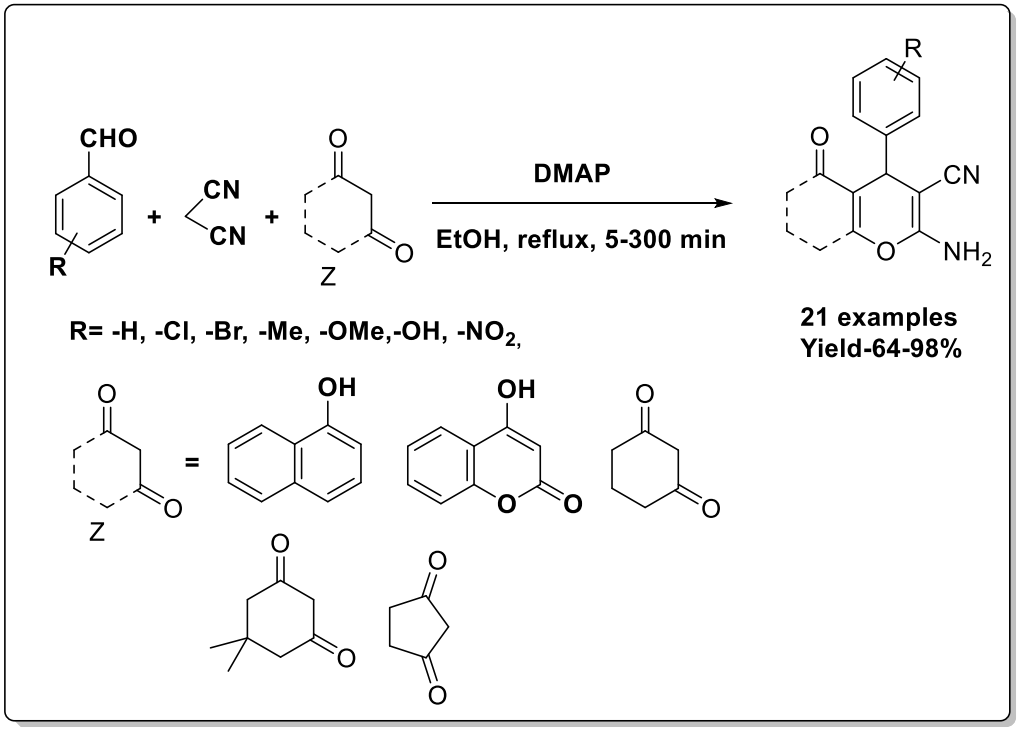
Scheme III.2 One pot synthesis of chromene heterocycles derivatives by Rajguru *et al*.

In 2010, Khurana *et al*. reported a synthetic procedure for pyran annulated heterocycles in one pot using DBU catalyst at reflux condition using 4-hydroxycoumarin, 4-hydroxy-6-methylpyrone, 1-naphthol and 2-hydroxynaphthalene-1,4-dione, with good yields (**Scheme III.3**).[66]



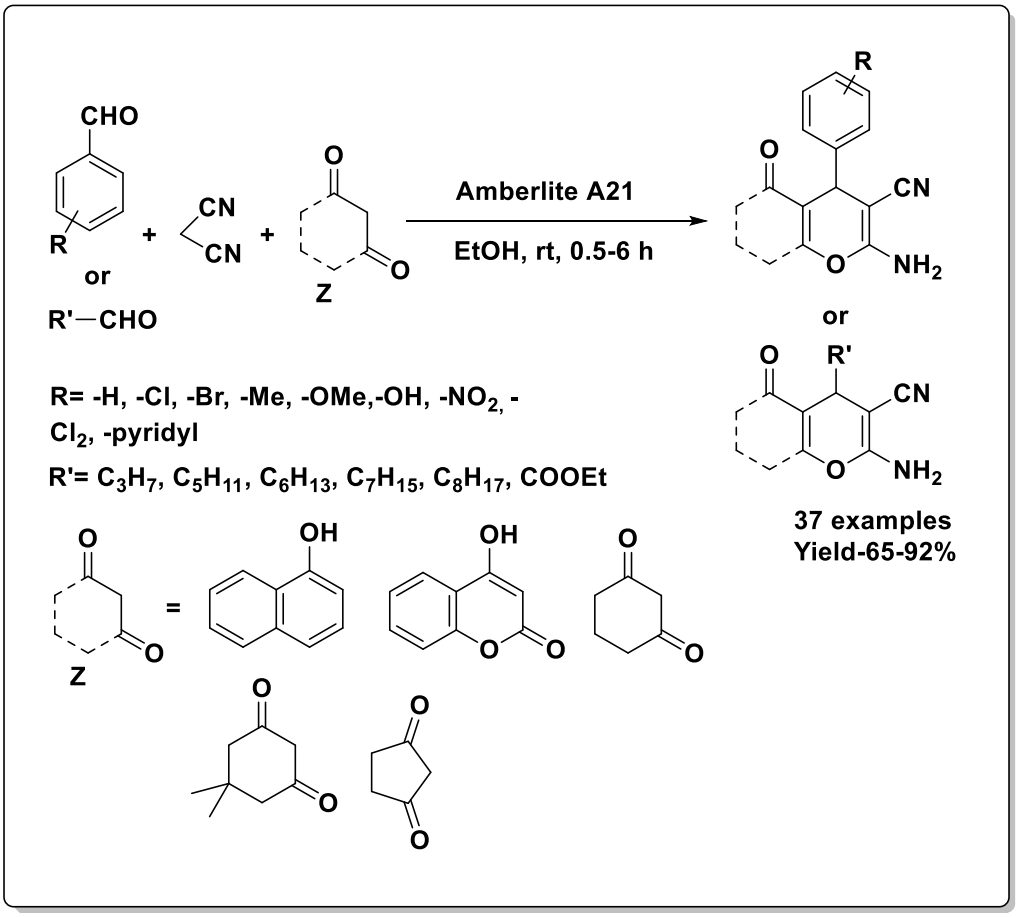
Scheme III.3 One pot synthesis of chromene heterocycles derivatives by Khurana *et al.*

In 2011, Khan *et al*. repoted a three-component condensation reactions between aromatic aldehydes, ethyl cyanoacetate or malononitrile and diverse C–H activated acidic compounds (Z) in the presence of catalytic amount of DMAP in ethanol under reflux conditions for the synthesis of chromenes (**Scheme III.4**). [67].



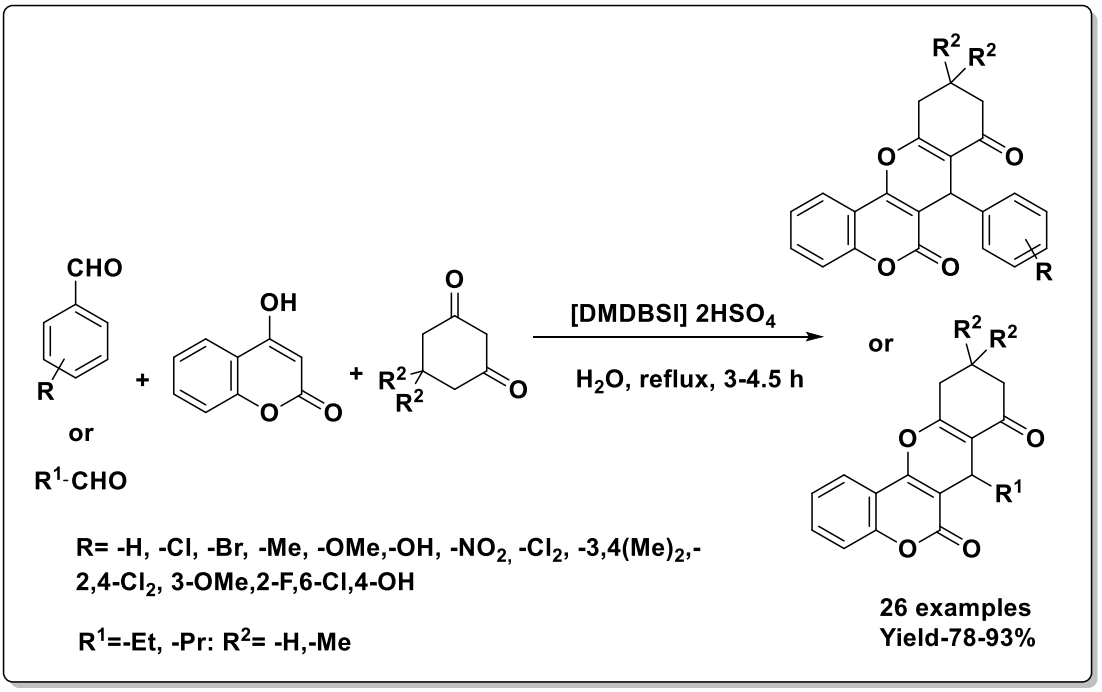
Scheme III.4 One pot synthesis of chromene heterocycles derivatives by Khan et al.

In 2013, Bihani *et al.* synthesized chromenes and annulated heterocycles using aldehyde, malononitrile and diverse C–H activated acidic compounds (Z) in presence of amberlyst-A21 in ethanolic medium at room temperature (**Scheme III.5**). [68]



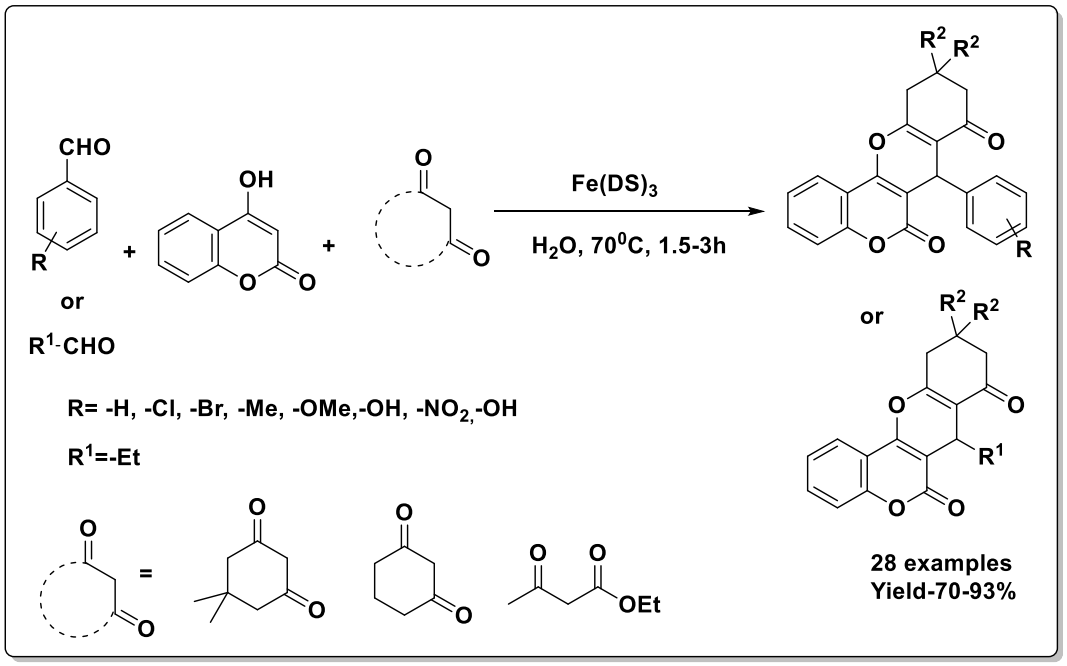
Scheme III.5 One pot synthesis of chromene heterocycles derivatives by Bihani *et al*.

In 2011, Chen *et al*. reported a three-component reaction between 4-hydroxycoumarin, aldehydes, and cyclic 1,3-dicarbonyl compounds in water at reflux condition to produce a series of 10,11-dihydrochromeno[4,3-*b*]chromene-6,8-(7*H*,9*H*)-dione derivatives in good yields task specific ionic liquid, short reaction time, easy product separation and purification (**Scheme III.6**). [69].



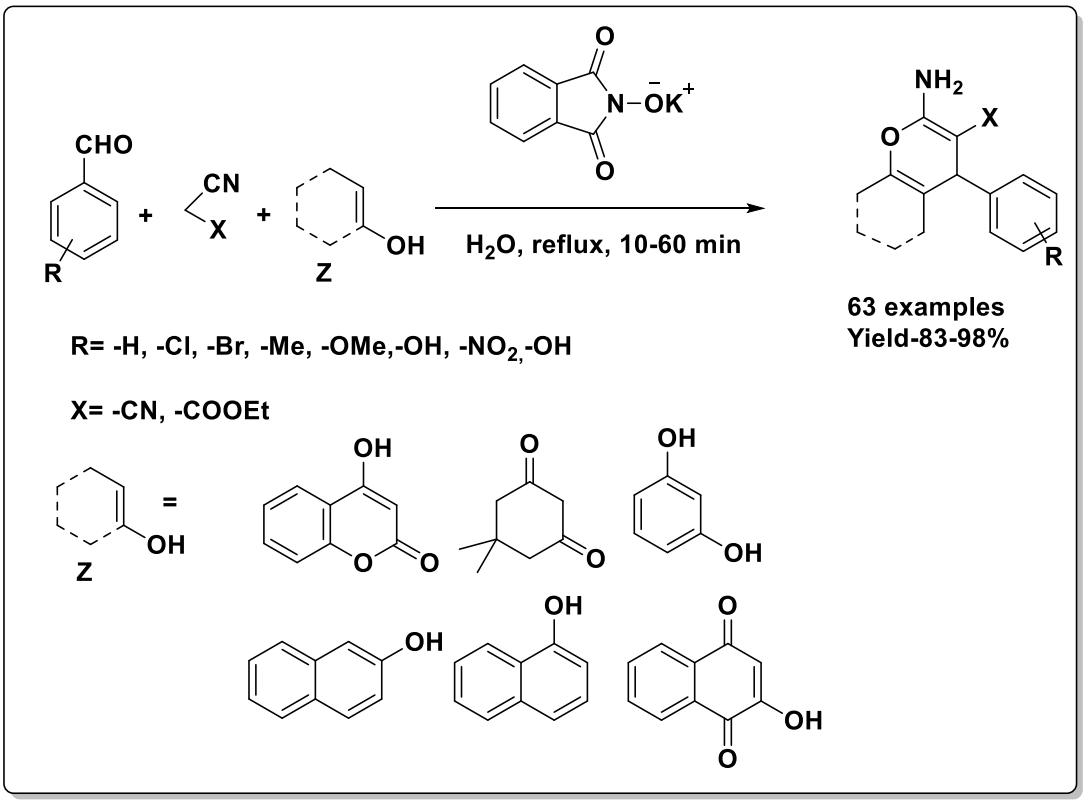
Scheme III. 6 One pot synthesis of chromene heterocycles derivatives by Chen *et al.*

In 2013, Pradhan *et al*. described the synthesis of a series of chromeno[4,3-*b*]chromene derivatives via three-component reaction of aldehydes, 1,3-diketones, and 4-hydroxycoumarin in aqueous medium under reflux condition by using a Lewis acid-surfactant-combined catalyst [$Fe(DS)_3$] (**Scheme III.7**) [70].



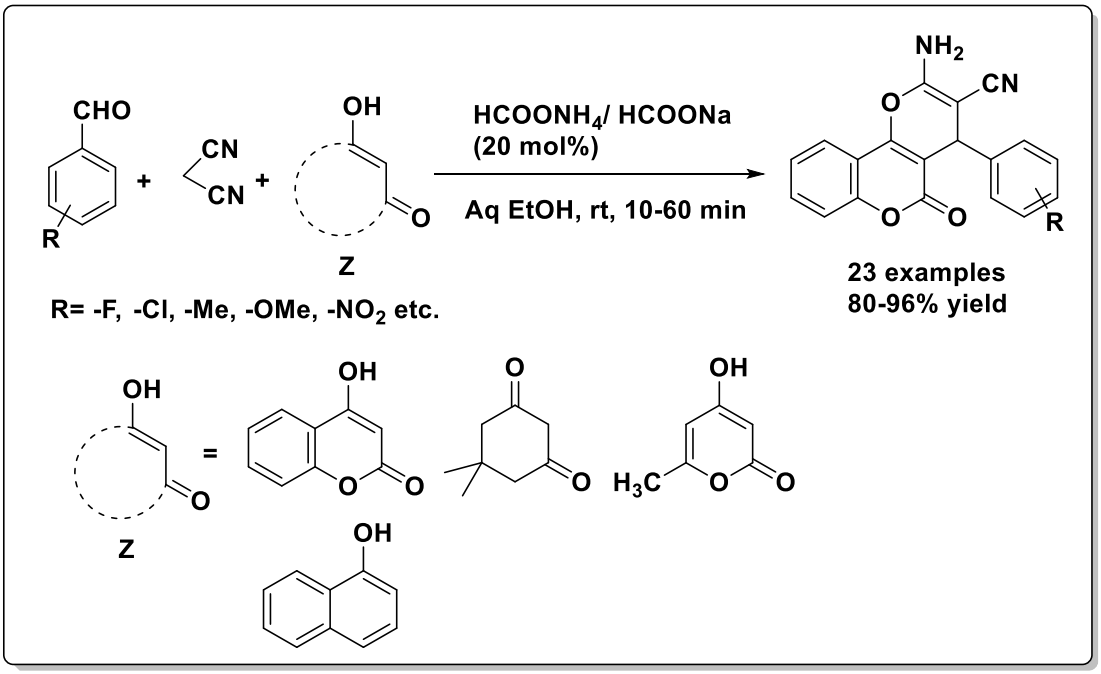
Scheme III.7 One pot synthesis of chromene heterocycles derivatives by Pradhan *et al*.

In 2013, Deacamin *et al*. synthesized chromene derivatives via three component coupling of aldehydes, active methylene compounds, and C-H activated compounds (Z) like dimedone, 4-hydroxycoumarin, 2-hydroxynaphthalene-1,4-dione, activated phenols in the presence of potassium phthalimide-N-oxyl as organocatalyst in aqueous medium under reflux condition (**Scheme III.8**). [71].



Scheme III.8 One pot synthesis of chromene heterocycles derivatives by Deacamin *et al*.

In 2014, Bramhachari *et al*. reported MCR synthesis of substituted chromene heterocycles via three-component condensation reaction of aldehydes, malononitrile, and C-H activated acidic compounds (Z) in aqueous ethanol using 20 mol% ammonium or sodium formate and 20 mol% urea as organo catalyst (**Scheme III.9**). [72]



Scheme III.9 One pot synthesis of chromene heterocycles derivatives by Bramhachari *et al*.

III.5. Pyrido-pyrimidine

The pyridopyrimidines are a of class of heterocyclic organic compounds having 6–6 bicyclic systems containing two or three nitrogen atoms in both six-membered rings. The compounds are also named as diaza- or triaza-naphthalenes which shows the structure of all possible types of pyridopyrimidines such as 4*H*-Pyrido[1,2-*a*]pyrimidin, 1*H*-Pyrido[1,2c]pyrimidin, Pyrido[2,3-*d]*pyrimidin, Pyrido[3,2-*d*]pyrimidin, Pyrido[3,4-*d*]pyrimidin, Pyrido[4,3-*d*]pyrimidin. (**Figure. III. 5**). Inspite of being natual abundance of pyridopyriminines and their

derivatives there are several reported methods of the synthesis of such kind of bicyclic-aza compounds.[73] Among these pyridopyrimidines, 4*H*-Pyrido[1,2-*a*]pyrimidin, 1*H*-Pyrido[1,2-*c*]pyrimidin show tatumeric effect in solid state and solution phase depend upon the pH condition of the supporting medium and in acidic medium their structure acquires cationic characteristics and in basic medium the shows anionic character.[74]

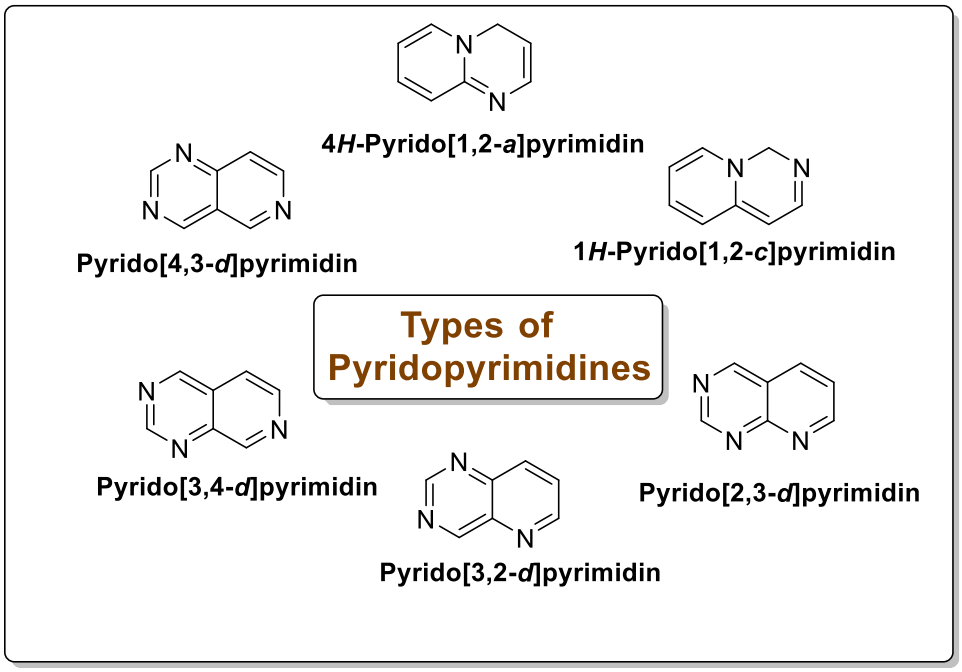


Figure. III. 5 Various types of pyrido-pyrimidine skeleton

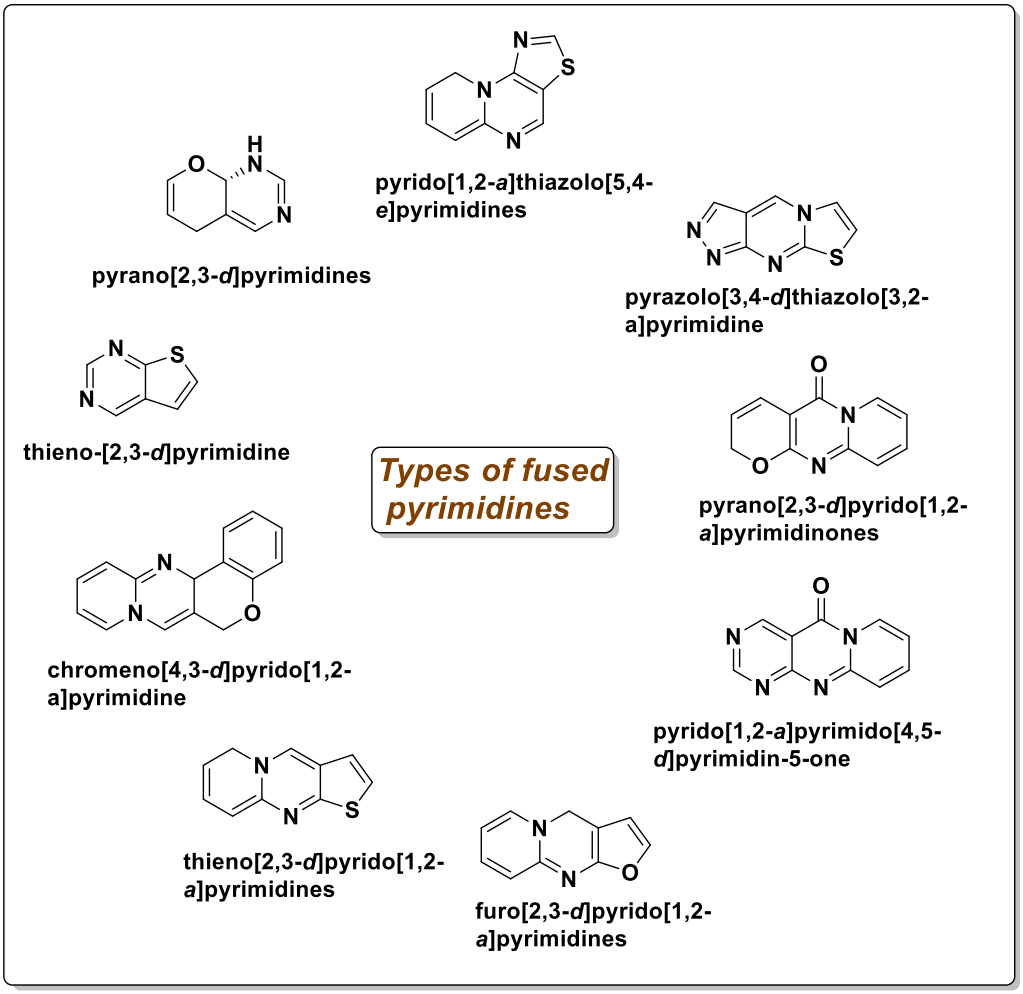


Figure. III. 6 Various types of fused pyrimidine skeleton

The compounds are generally basic in nature due to the presence of available donatable electron pairs over 'N'-atoms to protons and have broad range of biological importance in medicinal and biochemistry fields. There are also examples of other fused ring pyrimidines such as chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidine, thieno-[2,3-*d*]pyrimidine, pyrano[2,3-*d*]pyrimidines, pyrazolo[3,4-*d*]thiazolo[3,2-*a*]pyrimidine,

furo[2,3-*d*]pyrido[1,2-*a*]pyrimidines, pyrido[1,2-*a*]thiazolo[5,4-*e*]pyrimi-dines, pyrido[1,2-*a*]pyrimido[4,5-*d*]pyrimidin-5-one, pyrano[2,3-*d*]pyrido[1,2-*a*]pyrimidinones, pyrimido-thienopyrido[1,2-*a*]pyrimidinone, thieno[2,3-*d*]pyrido[1,2-*a*]pyrimidines, pyrazolo-pyrido[1,2-*a*]pyrimidines and isoxazolo-pyrido[1,2-*a*]pyrimidines (**Figure III.6**) have already been reported. Fused pyrimidines can act as interesting scaffolds and key structures in chemistry and medicine as they show diverse biological and medical properties.

III.6. Biological importance of pyrido-pyrimidines

Among several types pyridopyrimidines, pyrido[2,3-*d*]pyrimidines are the most abundance isomer in the literature and have wide range of biological activities. Pyrido[2,3-*d*]pyrimidines have anti-inflammatory, antihypertensive, anticancer, antimicrobial, analgesic, antiviral activity and with addition they also act as tyrosine kinase inhibitor , CDK4-inhibitor, and anti-diuretic drugs.[75-79] However, the pyrido[3,2-*d*]pyrimidine, pyrido[3,4-*d*]pyrimidines, pyrido[4,3-*d*]pyrimidines, Pyrido[1,2-*a*]pyrimidines, and pyrido[1,2-*c*]pyrimidines have also biological activities like pyrido[2,3-*d*]pyrimidines such as anti-inflammatory, antimicrobial activities anticancer, antimalarial, anti-psychotropic, antibacterial, antituberculars tyrosinekinases inhibitor,

antiallergic, anti-ulcer, CNS stimulant, urease inhibitor activities activities (**Figure III. 7**).[80-88]

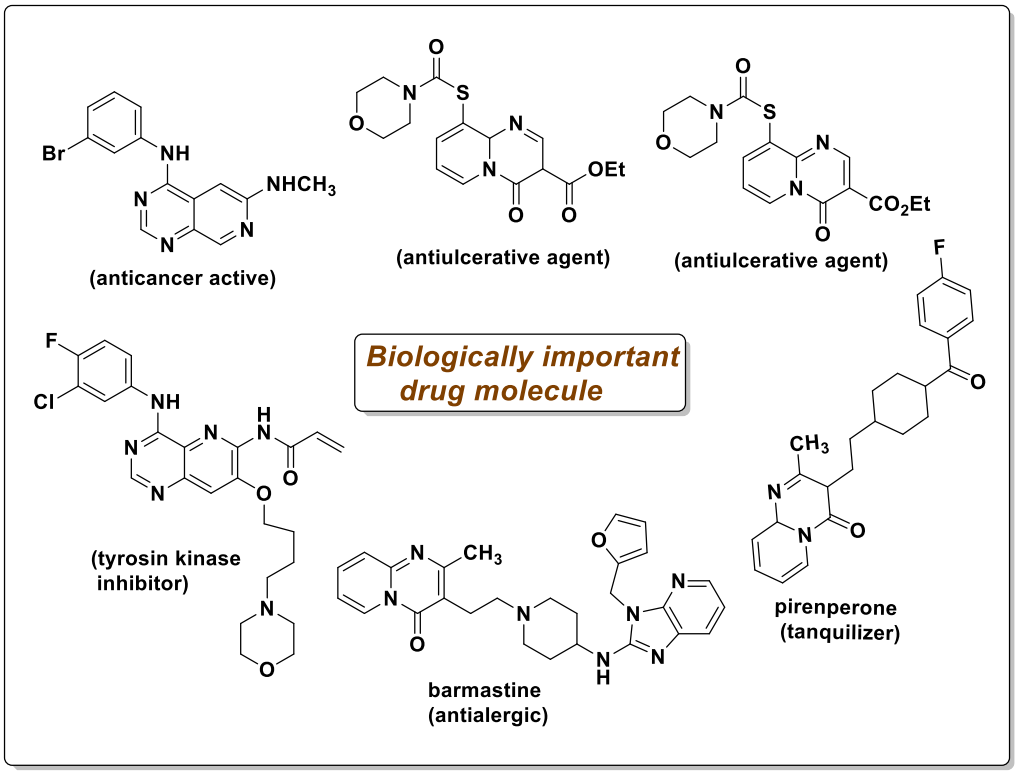
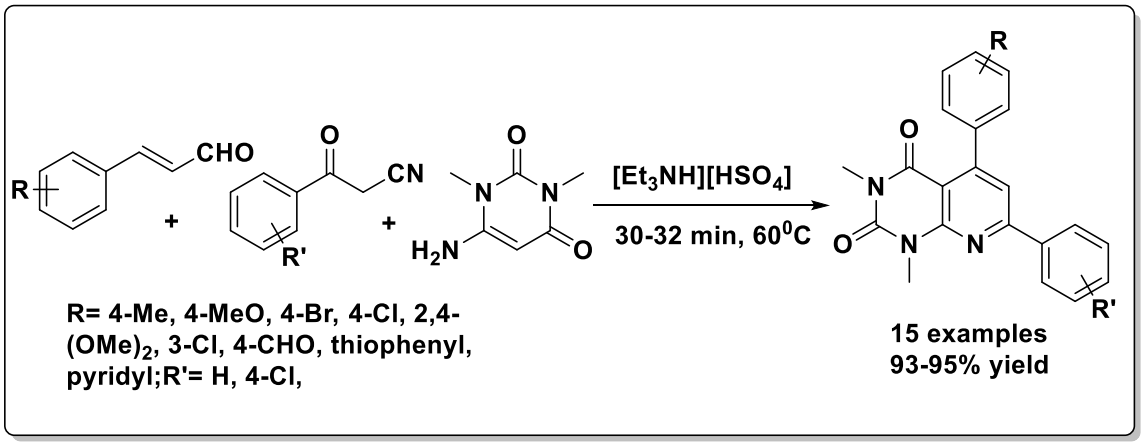


Figure III. 7 Some important pharmaceutically active drug molecule

By doing studies on works in various journals and literature reviews related to pyrido-pyrimidines and their various derivatives derivatives and following their biological importances and keeping innovative ideas in knowledge in this following part of the chapter III, it has been focused on the synthesis of pyrido-pyrimidine derivatives in a new and convenient manner using cheap laboratory chemicals.

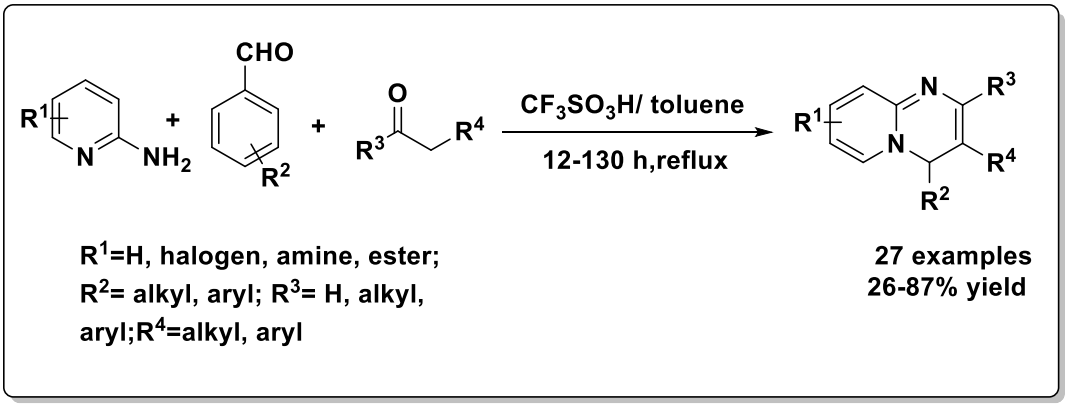
III.7 Previous works on synthesis of pyrido-pyrimidine derivatives

In 2021, Jadhav *et al*. synthesised pyrazolo[3,4-*b*]pyridine derivatives in excellent yields (92−94%) via one-pot multicomponent reaction method using aminouracils and aminopyrazoles, aldehyde, and acyl acetonitrile in presence of $[Et_3NH][HSO_4]$ under solvent-free conditions (**Scheme III.10**). [89]



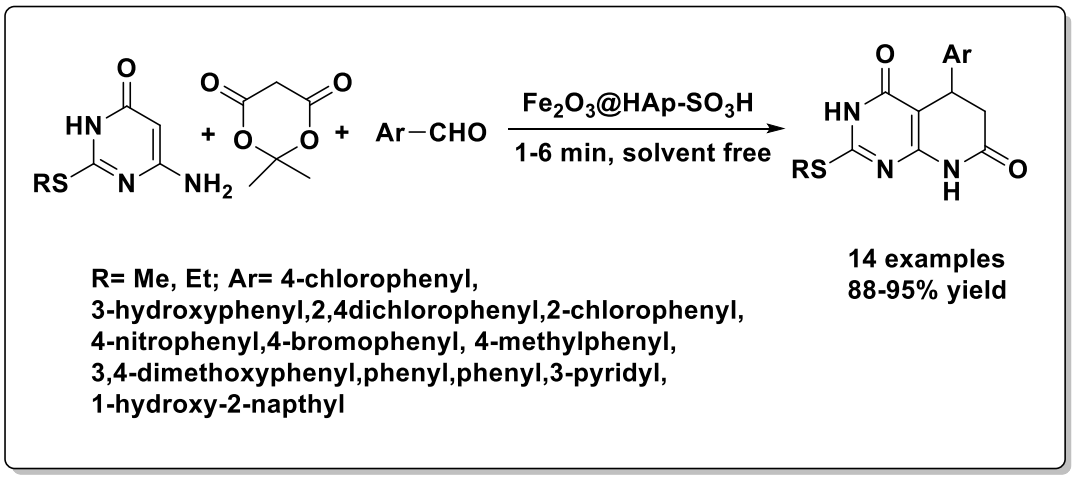
Scheme III.10 One pot synthesis of pyrido-pyrimidine derivatives by Jadav *et al.*

In 2013, Yang *et al*. reported a one-pot three-component reaction method for the synthesis of 4*H*-pyrido[1,2-*a*]pyrimidines by condensation of 2-aminopyridines, aldehydes, and ketones/ aldehydes in presence of CF_3COOH acid catalyst in toluene solvent (**Scheme III.11**). [90]



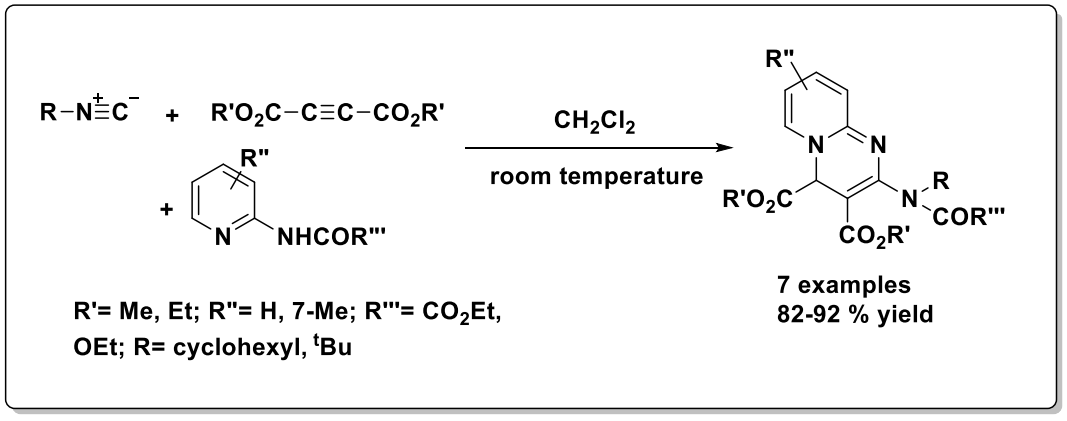
Scheme III.11 One pot synthesis of pyrido-pyrimidine derivatives by Yang *et al*.

In 2014, Mohssenimehra *et al.* designed a synthesis for Novel pyrido[2,3-*d*]pyrimidine derivatives were synthesized via one-pot threevcomponent methodology taking 6-amino-2-(methylthio or ethylthio)pyrimidin-4(3*H*)-one, 2,2-dimethyl-1,3-dioxane-4,6-dione and aryl aldehydes using HAp-encapsulated-γ-Fe_2O_3 catalyst at 60^0C and under solvent-free conditions (**Scheme III.12**). [91]



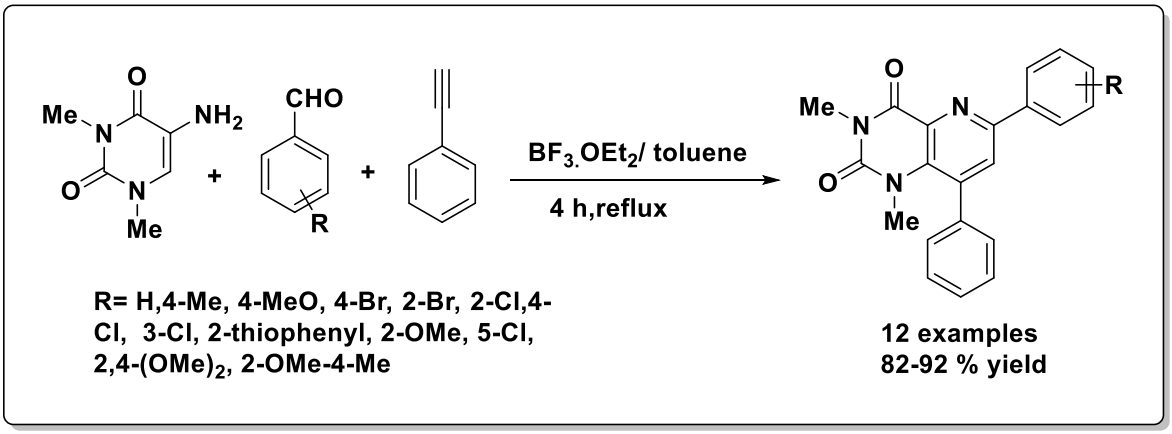
Scheme III.12 One pot synthesis of pyrido-pyrimidine derivatives by Mohssenimehra *et al.*

In 2007, Adib *et al*. had reported a new, one-pot and three-component synthesis of 4*H*-pyrido[1,2-*a]*pyrimidines by using isocyanides, alkynes and N-substituted-2-aminopyridines at room temperature condition (**Scheme III.13**). [92]



Scheme III.13 One pot synthesis of pyrido-pyrimidine derivatives by Adib *et al.*

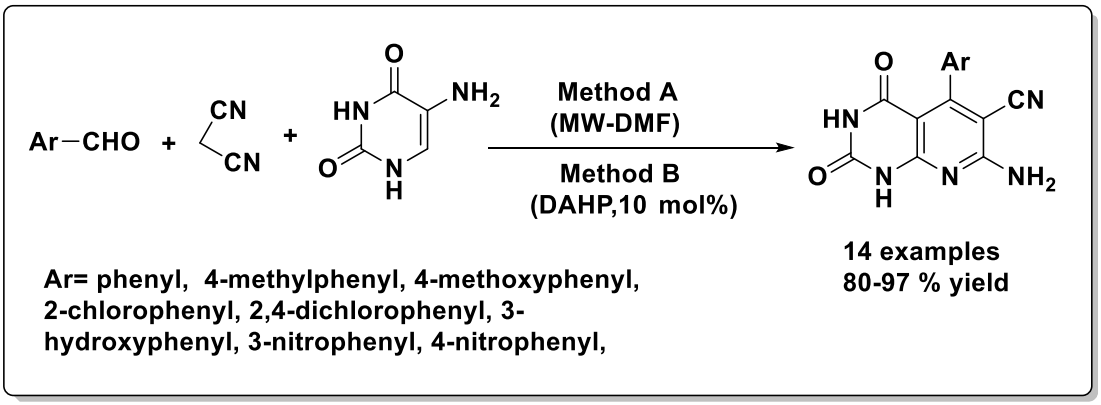
In 2011, Majumdar *et al*. had reported a mild and efficient synthetic method for the synthesis of pyrido[3,2-*d*]pyrimidine derivatives via three-component reaction between amines, aldehydes, and terminal unactivated alkynes in presence of using $BF_3.OEt_2$ as Lewis acid catalyst in one pot. The features of this procedure are mild reaction conditions, good to high yields, and shorter reaction time with operational simplicity (**Scheme III.14**). [93]



Scheme III.14 One pot synthesis of pyrido-pyrimidine derivatives by Majumdar *et al.*

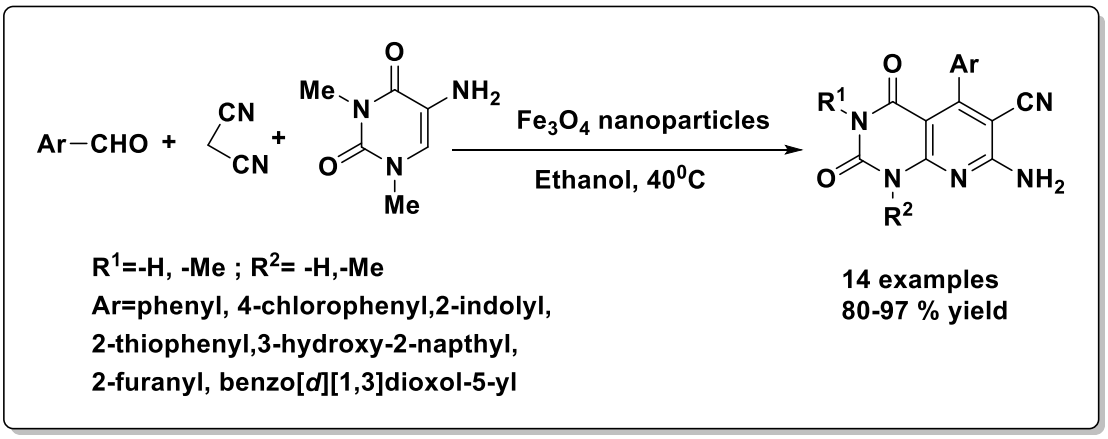
In 2012, Abdolmohammadi *et al*. sythesised a series of pyrido[2,3-*d*]pyrimidines via one-pot three-component reaction between aminouracil, malononitrile and aromatic aldehydes. using catalytic

amount of diammonium hydrogen phosphate (DAHP) in aqueous medium. The reaction proceeds via domino Knoevenagel-Michael-cyclization reactions to give the Pyrido[2,3-*d*]pyrimidine derivatives. (**Scheme III.15**). [94]



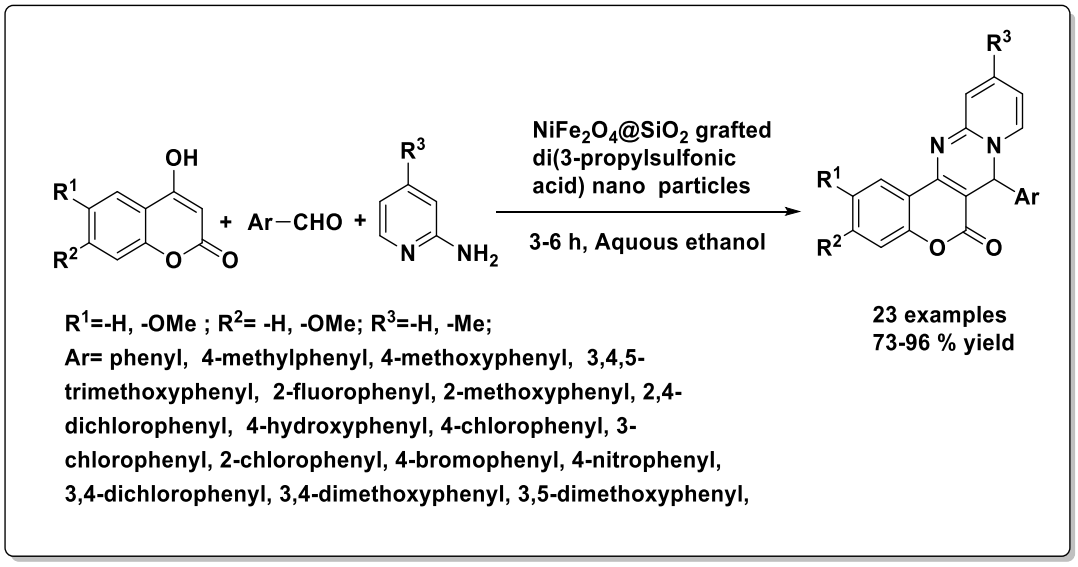
Scheme III.15 One pot synthesis of pyrido-pyrimidine derivatives by Abdolmohammadi *et al*.

In 2012, Kidwai *et al*. reported a synthetic procedure for the synthesis of pyrido[2,3-*d*]pyrimidines through environmentally benign process by the reaction of aldehyde, malononitrile, 5-amino-1,3-dimethylpyrimidine-2,4(1*H*,3*H*)-dione and utilizing Fe_3O_4 magnetic nanoparticles at 40^0C (**Scheme III.16**). [95]



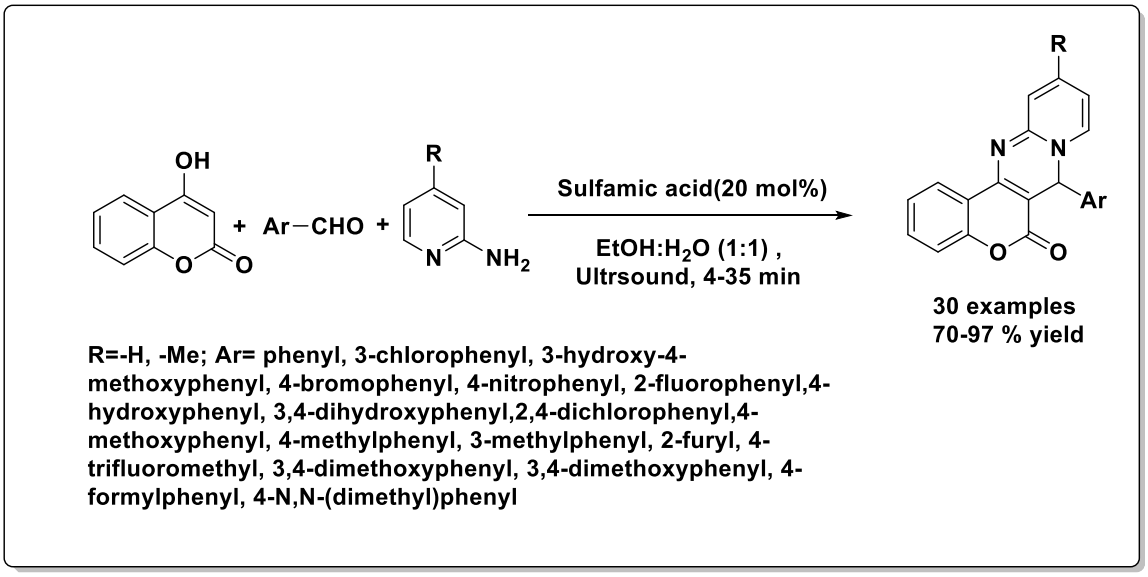
Scheme III.16 One pot synthesis of pyrido-pyrimidine derivatives by Kidwai *et al*.

Recently in 2021 Khalaj *et al*. synthesized a variety of chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidine derivatives via the three-component condensation reaction between 4-hydroxycoumarin, aldehydes, and 2-aminopyridines in presence of $NiFe_2O_4@SiO_2$ grafted di(3-propylsulfonic acid) nanoparticles (**Scheme III.17**).[96]



Scheme III.17 One pot synthesis of pyrido-pyrimidine derivatives by Khalaj *et al*.

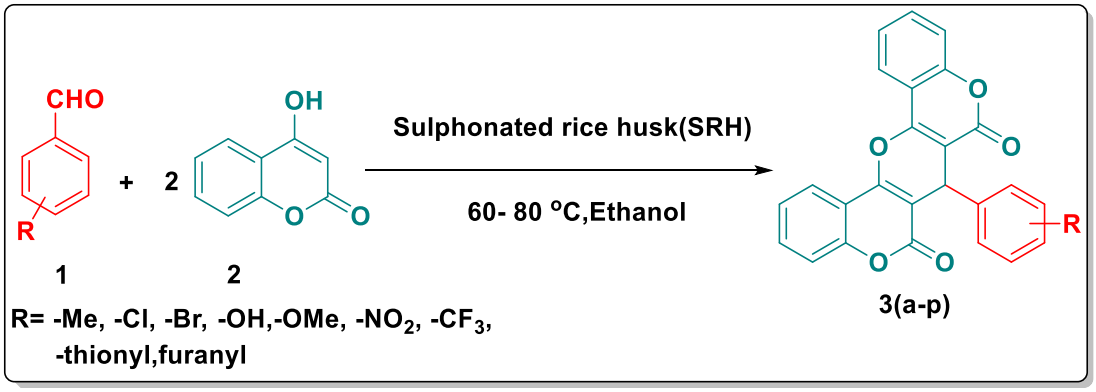
In 2018, Brahmachari *et al*. applied an ultrasound-assisted methods for one-pot synthesis of a new series of pharmaceutically relevant and diversely functionalized 7-aryl/heteroarylchromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6(7*H*)-ones. A one pot three-component tandem reaction between 4-hydroxycoumarin, substituted aromatic aldehydes, and 2-aminopyridines were subjected for doing reaction in the presence of sulfamic acid as a catalyst (**Scheme III.18**). [97]



Scheme III.18 One pot synthesis of pyrido-pyrimidine derivatives by Bramhachari et al.

III.8 Present work

The present work leads to the synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione derivatives (**Scheme III.19)** by using greener heterogeneous catalyst sulphonated rice husk (SRH) .



Scheme III.19 Synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione derivatives [a]

III.8.A Results and discussion

III.8.A.1 Catalyst Characterization

The prepared catalyst was characterized by FTIR spectroscopy first and the comparison with FTIR spectrum of rice husk clearly indicated the transformation of rice husk into sulphonated rice husk (SRH) (Figure III. 8b). The new broad band at 3420 cm^{-1} along with the band at 1100

cm^{-1} both denoting the incorporation of $–SO_3H$ groups into rice husk after sulphonation. The band with a peak $1100cm^{-1}$ represents the symmetric and asymmetric streatching of S=O bonds of $–SO_3H$ groups and the broadened band at $3420cm^{-1}$ represent the -OH groups vibration after the incorporation of $–SO_3H$ groups [98]. Scanning electron microscopy (SEM) analysis (**Figure III.9**) and powder X-ray diffraction (p-XRD) (**Figure III.8a**) have also made a clear path for confirmation of the prepared catalyst from the rice husk. The powder XRD analysis shows characteristics peaks at $2\theta = 20.83^{o}$ which is a broad peak indicating some carbon composed aromatic sheets oriented in a random manner.[99] The rough surfaces in SEM images of SRH has been considered to be resulted from sulphonation of rice husk material and which is a indication of a promising change in surface morphology after sulphonation. The Comparison of EDX images of SRH & RH also reflecting a visible changes in the elemental composition and a considerable changes in atomic weight percentage of certain elements such as C, Si, O, & S was noticed from the EDX data analysis of RH & SRH. Detailed information of EDX data are included in experimental section (**III.7.A.12.i**) of the Chapter III.

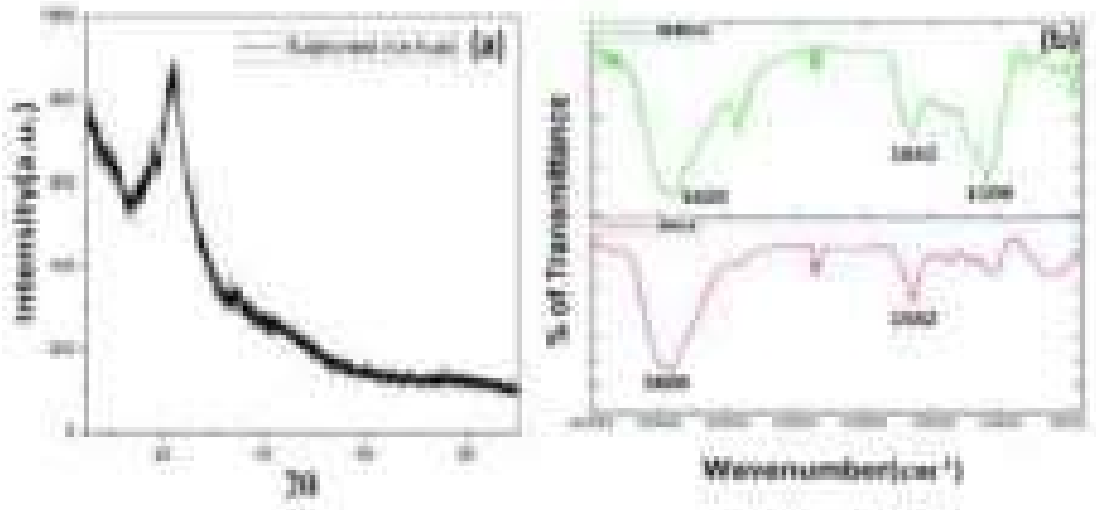


Figure III. 8 (a) Powder XRD image of SRH. (b) FTIR images of RH & SRH

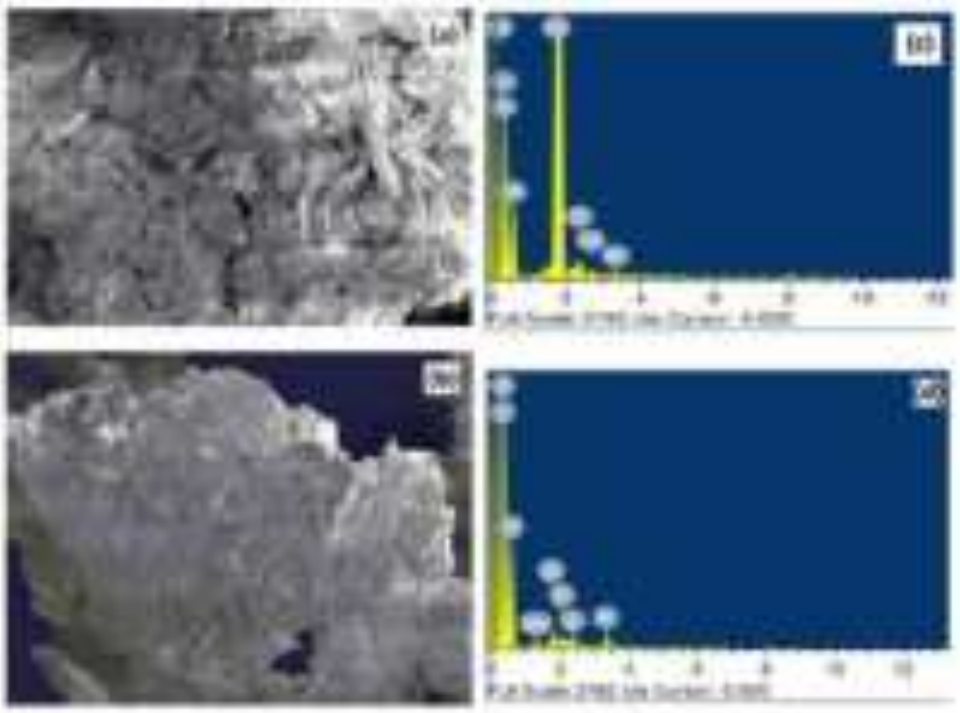


Figure III. 9 (a) SEM image of SRH. (b) SEM image of RH. (c) EDX image of SRH (d) EDX image of RH.

The above promising data analysis and literature survey has given us a sound confirmation that the heterogeneous catalyst (SRH) has been formed without any doubt and not demanding any further quantitative analytical support and is now finally ready for suitable organic reactions to be used up as heterogeneous catalyst under greener reaction condition.

III.8.A.2 Optimisation of reaction condition 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione derivatives

Initially, the reaction was carried out by taking anisaldehyde (1 mmol), 4-hydroxycumarine (2 mmol) at a time in a 25 mL round bottom flusk and in presence of catalyst the expected product was obtained with an excellent yield. Satisfactory yield was obtained in presence of 90 mg of SRH catalyst in ethanol solvent at 80^0C temperature (**Table III.1**, entry 2). However, in absence of catalyst the formation of the desired product was not obtained (**Table III.1**, entry 11,12). With decreasing the amount of catalyst, the yield of the product decreased slightly along with reaction temperature and time of the reaction. Optimized condition was determined by taking anisaldehyde (1mmol) and 4-hydroxycoumarine(2 mmol) in a 25 mL round bottom

flask fitted with condenser and it was observed that at 70^0C temperature with minimum 70 mg of catalyst SRH in ethanol giving best result with yield up to 96% (**Table III.1**, entry 6). From this optimization table (**Table III.1**), it is clear that SRH catalyst is suitable for one pot synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione with excellent yield in short reaction time. The amount of the catalyst and time of the reaction was further checked again to report the accurate optimized condition of the reaction. Role of methanol (**Table III.1**,entry 7,12) and water (**Table III. 1**,entry 13,14,15,16) have also been observed and it was observed that the product yield in methanol is quite unaltered to that of ethanol and in distilled water the reaction did not happened due to damage of the catalyst in water medium. Observation with addition of water into ethanol solvent revealed that the role of water is unfriendly until the ratio of ethanol/water exceeds 3:1(v/v) (**Table III.1**, entry 15) with decreased amount of yield. The catalyst can sustain its activity in alcohol/water mixed solvent with minimum quantity of water with a satisfactory product yield and for greener aspect of reaction, methanol is advised to be avoided for its toxicity and adversity in reaction medium. From the optimized reaction condition, it is clear that SRH

catalyst is undoubtedly a suitable one for the synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione with excellent yield in short reaction time.

Table III.1. Optimisation of the reaction condition for the synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c*']dichromene-6,8-dione derivatives [a]

Entry	Catalyst (mg)	Solvent	Temperature (^{o} C)	Time (min)	Yield (%)[b]
1	90	Ethanol	90	310	98
2	90	Ethanol	80	280	98
3	85	Ethanol	80	260	98
4	85	Ethanol	80	240	96
5.	80	Ethanol	70	220	96
6.	**70**	**Ethanol**	**70**	**190**	**96**
7.	70	Methanol	70	190	96
8.	65	Ethanol	60	190	94
9.	60	Ethanol	60	180	94
10.	60	Ethanol	60	160	92
11.	None	Ethanol	70	190	-
12.	None	Methanol	70	190	-
13.	70	H_2O	70	190	-
14.	70	Ethanol/H_2O(6:1)	70	190	84

15.	70	Ethanol/H_2O(3:1)	70	190	78
16.	70	Ethanol/H_2O(1:1)	70	190	54

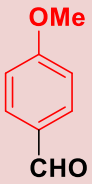
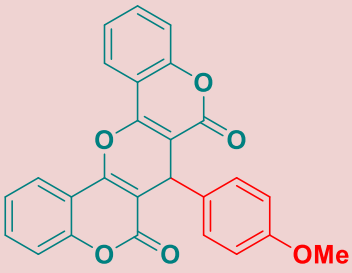
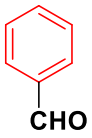
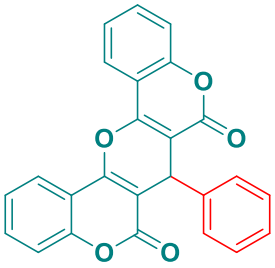
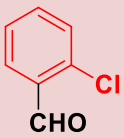
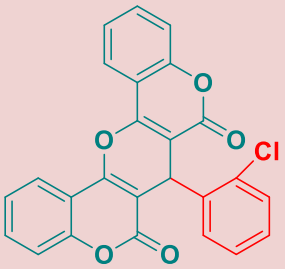
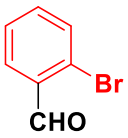
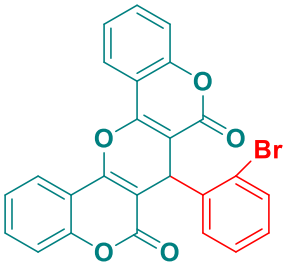
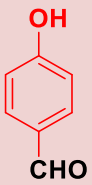
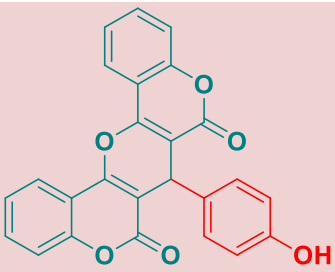
[a]Reaction of anisaldehyde (1mmol), 4-hydroxycumarine (2mmol) and SRH .

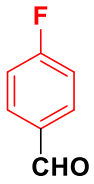
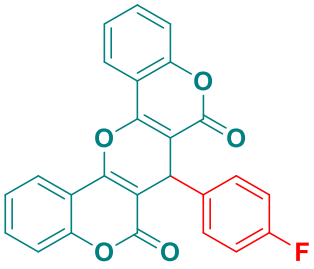
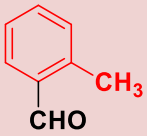
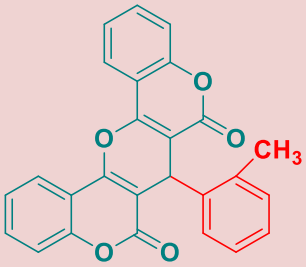
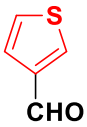
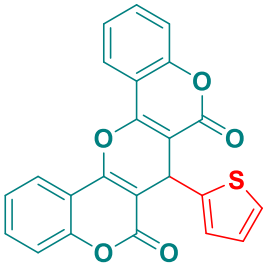
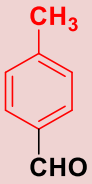
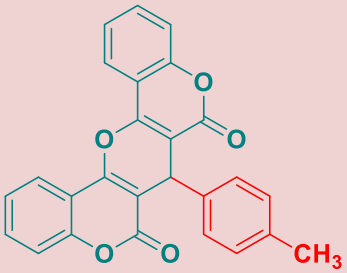
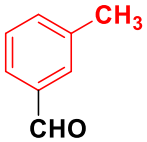
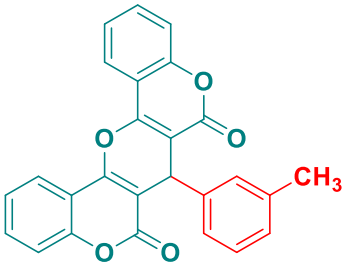
[b]Isolated yield through recrystalysation.

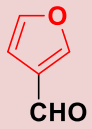
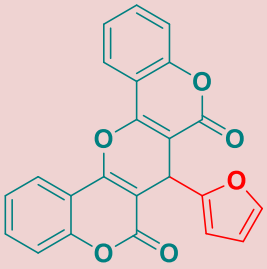
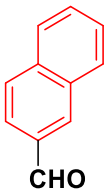
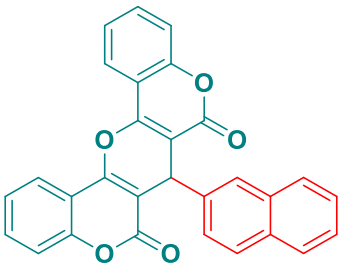
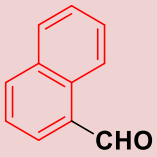
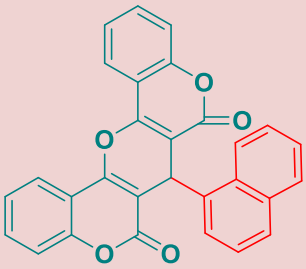
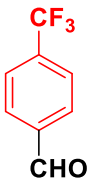
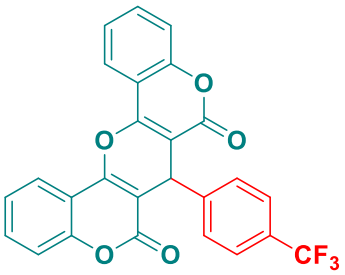
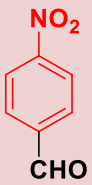
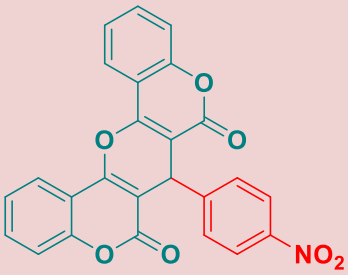
III.8.A.3 Synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione derivatives

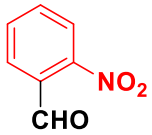
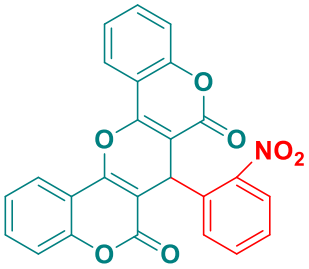
The generality of the reaction was observed with a variety of aromatic and heterocyclic aldehydes (**Scheme III.19**) with electron donating and electron withdrawing substituent at *ortho*, *meta* and *para* position. The targeted compounds (3a-3o) are successively synthesized using sulphonated rice husk (SRH) as efficient catalyst under greener reaction condition and within short reaction time. The generality of the reaction was observed with a variety of aromatic and heterocyclic aldehydes (**Scheme III.19**) with electron donating and electron withdrawing substituent at *ortho*, *meta* and *para* position. The targeted compounds (3a-3o) are successively synthesized using sulphonated rice husk (SRH) as efficient catalyst under greener reaction condition and within short reaction time.

Table III.2. Synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione derivatives [a]

Entry	Reactant	Product	Time	Yield(%)[b]
1		 (3a)	200 min	98
2		 (3b)	200 min	94
3		 (3c)	200 min	97
4		 (3d)	200 min	96
5		 (3e)	200 min	98

6		 (3f)	200 min	96
7		 (3g)	200 min	90
8		 (3h)	200 min	87
9		 (3i)	200 min	98
10		 (3j)	200 min	97

11		 (3k)	200 min	87
12		 (3l)	200 min	98
13		 (3m)	200 min	91
14		 (3n)	200 min	96
15		 (3o)	200 min	95

16		 (3p)	200 min	92

[a]Reaction of aromatic aldehyde (1mmol), 4-hydroxycumarine (2mmol) and SRH .

[b] Isolated yield through recrystalysation.

III.8.A.4 Comparison of catalyst efficiency

Table III.3. Comparison of catalyt efficiency for the reaction under scheme III.19[a]

Entry	Catalyst	Solvent	Temperature (^{o} C)	Time(min)	Yield (%)[b]
1	PTSA(60mg)	Ethanol	70	190	83
2	PEG-200(3mL)	-	70	240	70
3	H_2SO_4(3mL)	-	70	220	80
4	Glycerol(5mL)	-	70	220	72
5	AcOH(0.1mL)	Ethanol	70	190	74
6	Fe_3O_4 (60 mg)	Ethanol	70	190	81
7	K_2CO_3 (60mg)	Ethanol	70	190	70
8	Et_3N(2mL)	-	70	190	95
9	$FeCl_3$(60 mg)	Ethanol	70	180	78
10	SRH (70mg)	**Ethanol**	**70**	**190**	**96**

[a]Reaction of anisaldehyde (1mmol), 4-hydroxycumarine (2mmol) and catalyst (x mg). [b] Isolated yield through recrystalysation.

Taking this as a model reaction (**Scheme III.19**), a few experiments were carried out to compare catalyst efficiency of (SRH) with other conventional homogeneous acid and base catalysts as well as metal catalysts also (**Table III.3** entry 1-10). It was observed that the results of most of the acid catalysts as well as base catalysts in ethanol showed good activity at 70 ^{o}C temperature (**Table III.3** entry 1,3,5,7,8) and the comparison of results to that of the performance of SRH revealed a satisfactory result over other homogeneous catalysts with respect to reaction time and yield of the product (**Table III.3**, entry 10). The progress of the reaction was monitored by thin layer chromatography (TLC) and the pure product was obtained by recrystallization in petroleum ether/ethyl acetate (v/v ratio80/20) mixture. The effectiveness of SRH over other acid catalyst was established as it requires short reaction time and is easily separable from the reaction mixture (**Table III.3**, entry 10)

III.8.A.5 Plausible mechanism

A plausible mechanism (**Figure III.10**) for the synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione derivatives is established by considering the porosity, active rough surface (**Figure III.10**) and the acidic behaviour of the surface of the catalyst. At the very first step of the reaction as usual protonation occurs at aldehyde oxygen of aromatic aldehyde and then a condensation reaction starts with 1 mol 4-hydroxycoumarine giving a aryledine-chromanedione intermediate and after that fast Michael addition reaction occurs between another remaining 1 mol of 4-hydroxycoumarine and aryledine-chromanedione intermediate to give bis-coumarol as another intermediate.[97] Finally, a intramolecular cyclization followed with expulsion of 1 mol of water results in the formation of the desired product 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c*']dichromene-6,8-dione.

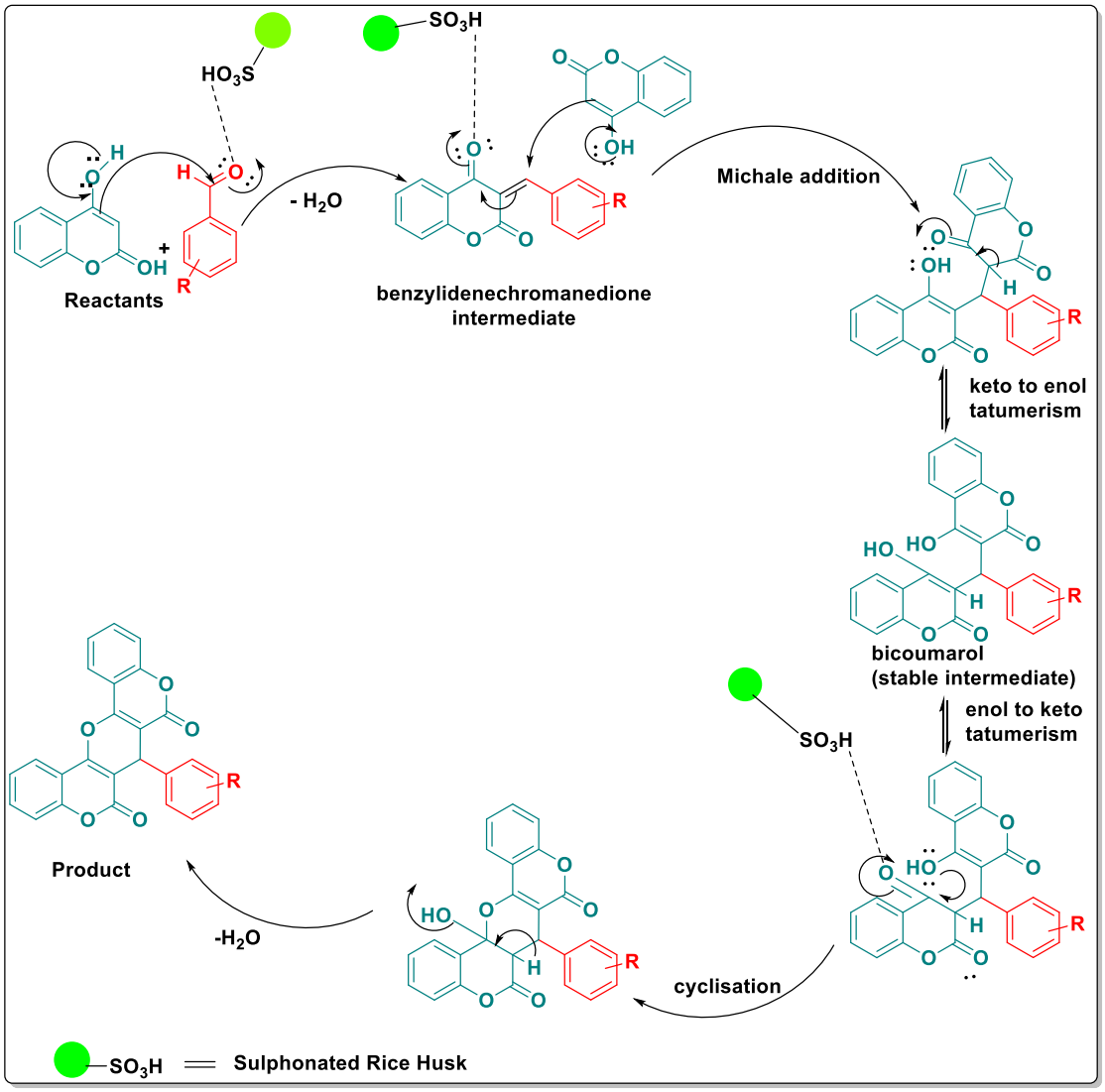
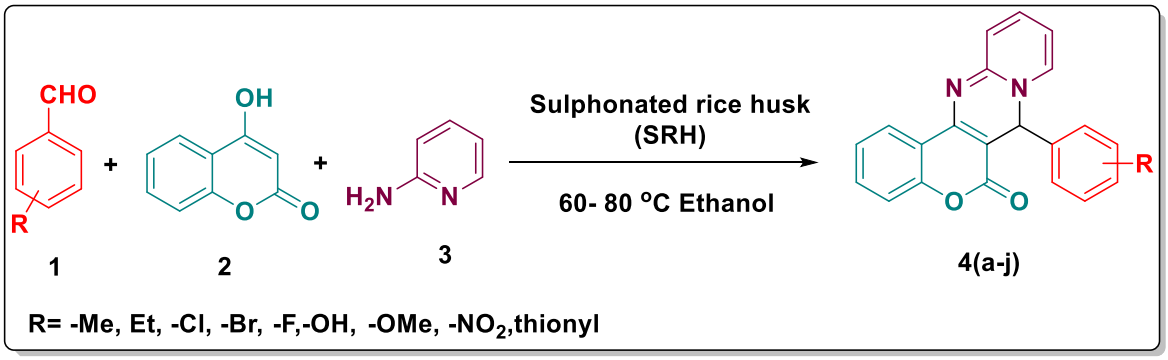


Figure III.10 The plausible mechanism for the synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-c:5,6-c']dichromene-6,8-dione

The next present work leads to the synthesis of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives (**Scheme III.20**)) by using greener catalyst heterogeneous catalyst sulphonated rice husk (SRH) .



Scheme III.20 Synthesis of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno [4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives using sulphonated rice husk[a]

III.8.A.6 Optimisation of reaction condition Synthesis of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives

Initially, the reaction was carried out with Anisaldehyde (1 mmol), 4-hydroxycumarine (1mmol), 2-aminopyridine (1 mmol) in a 25 mL round bottom flask. Excellent yield was observed for a varity of aldehydes in presence of 80 mg of SRH catalyst in ethanol solvent at 70^{o}C temperature with reaction time of 190 minutes. From the optimization table (**Table III.4**) it is clear that with decrease in the amount of catalyst, the yield of the product decreases slightly and in absence of catalyst yield of the product was diminished (**Table III.4**, entry 10,11). The performance of the reaction is almost similar in methanol (**Table III.4**, entry 5 & 12) but for greener aspect ethanol is more safer solvent than methanol whether to achieve the maximum yield. The role of water in

ethanol and methanol was also observed in this case and the results reflecting the some short of lower yield than that of pure ethanol and methanol. It may be due to the reduced efficacy of the catalyst in presence of water. From the optimized condition it is clear that SRH catalyst is a suitable one for the conversion of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives with excellent yield in short reaction time. It was observed that at 60^{o}C temperature using minimum amount of catalyst SRH (60 mg) in ethanol giving the best result (**Table III. 4**, entry 7).The progress of the reaction was monitored by thin layer chromatography (TLC) and finally the off white solid crude product was isolated from concentrated ethylacetate extract of reaction mixture by adding mixed solvent containing ethyl acetate and petroleum ether (1:10v/v) slowly dropwise. Finally the obtained solid was purified by slowly washing the crude with solvent containing ethyl acetate and petroleum ether (1:4v/v).

Table III.4. Optimisation of the reaction condition for the synthesis of Synthesis of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one derivatives[a]

Entry	Catalyst (mg)	Solvent	Temperature (^{o} C)	Time (min)	Yield (%)[b]
1	100	Ethanol	90	320	98

2	90	Ethanol	90	280	98
3	80	Ethanol	80	260	98
4	80	Ethanol	70	230	96
5.	70	Ethanol	70	210	96
6.	60	Ethanol	70	180	96
7.	**60**	**Ethanol**	**60**	**180**	**94**
8.	60	Ethanol	60	160	92
9.	50	Ethanol	50	160	80
10.	None	Ethanol	70	215	53
11	None	Methanol	70	220	53
12.	70	Methanol	70	190	96
13	80	H_2O	70	190	-
14	80	Ethanol/H_2O (6:1)	70	220	92
15	80	Ethanol/H_2O (3:1)	70	250	82
16	80	Ethanol/H_2O (1:1)	70	300	72

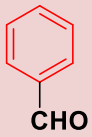
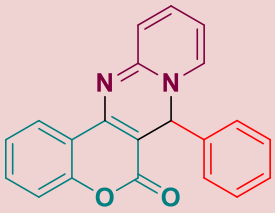
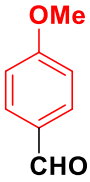
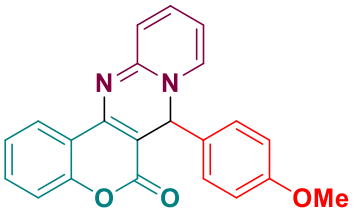
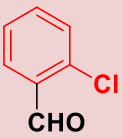
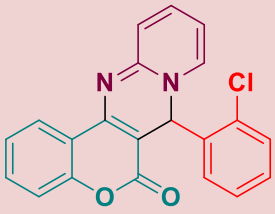
[a]Reaction of anisaldehyde (1mmol), 4-hydroxycumarine (1mmol), 2-aminopyridine (1 mmol) and SRH. [b]The yields are isolated through recrystalisation.

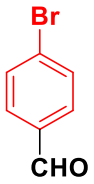
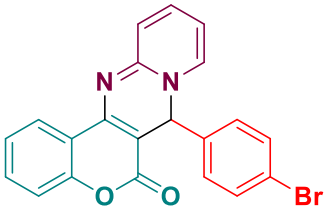
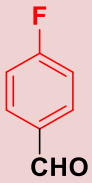
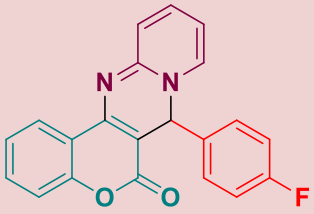
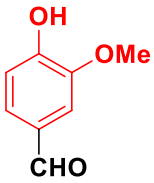
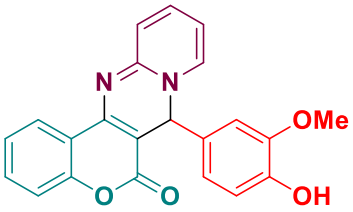
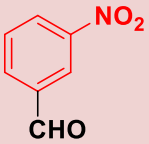
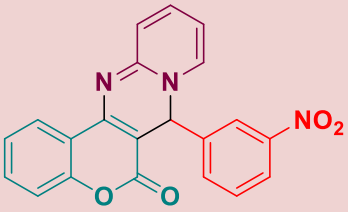
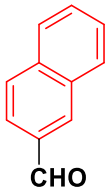
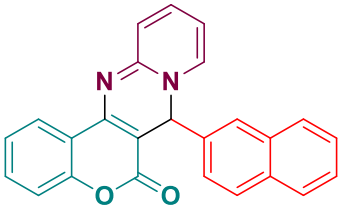
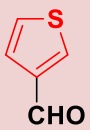
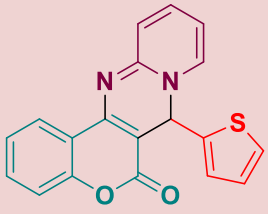
III.8.A.7 Synthesis of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives

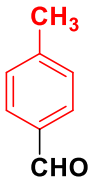
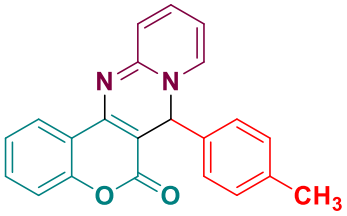
The generality of the reaction was observed with a variety of aromatic and heterocyclic aldehydes (**Scheme III. 20**) with electron donating and

electron withdrawing substituents at *ortho*, *meta* and *para* position also under optimized reaction condition and the targeted compounds (4a-4j) are successively synthesized using SRH as efficient catalyst under green reaction condition.(**Table III. 5**)

Table III.5. Table for synthesis of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives using sulphonated rice husk[a]

Entry	Reactant	Product	Time	Yield(%)[b]
1		 (4a)	200 min	95
2		 (4b)	200 min	98
3		 (4c)	200 min	96

4		 (4d)	200 min	98
5		 (4e)	200 min	97
6		 (4f)	200 min	96
7		 (4g)	200 min	95
8		 (4h)	200 min	98
9		 (4i)	200 min	92

10		 (4j)	200 min	97

[a]Reaction of aromatic aldehydes (1mmol), 4-hydroxycumarine (1mmol), 2-aminopyridine (1 mmol) and SRH. [b] The yields are isolated through recrystalisation.

III.8.A.8 Plausible Mechanism

A plausible mechanism of synthesis (**Figure III.11**) of 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives are established by considering the acidic behaviour of the catalyst. Initially a fast protonation at aldehyde oxygen followed by condensation reaction with 1 mol of 4-hydroxycoumarine to give a aryledine-chromanedione intermediate and then Michael addition reaction occurs between 2-aminopyridine and aryledine-chromanedione followed by intramolecular cyclisation along with fast condensation results in the formation of desired 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives.[97]

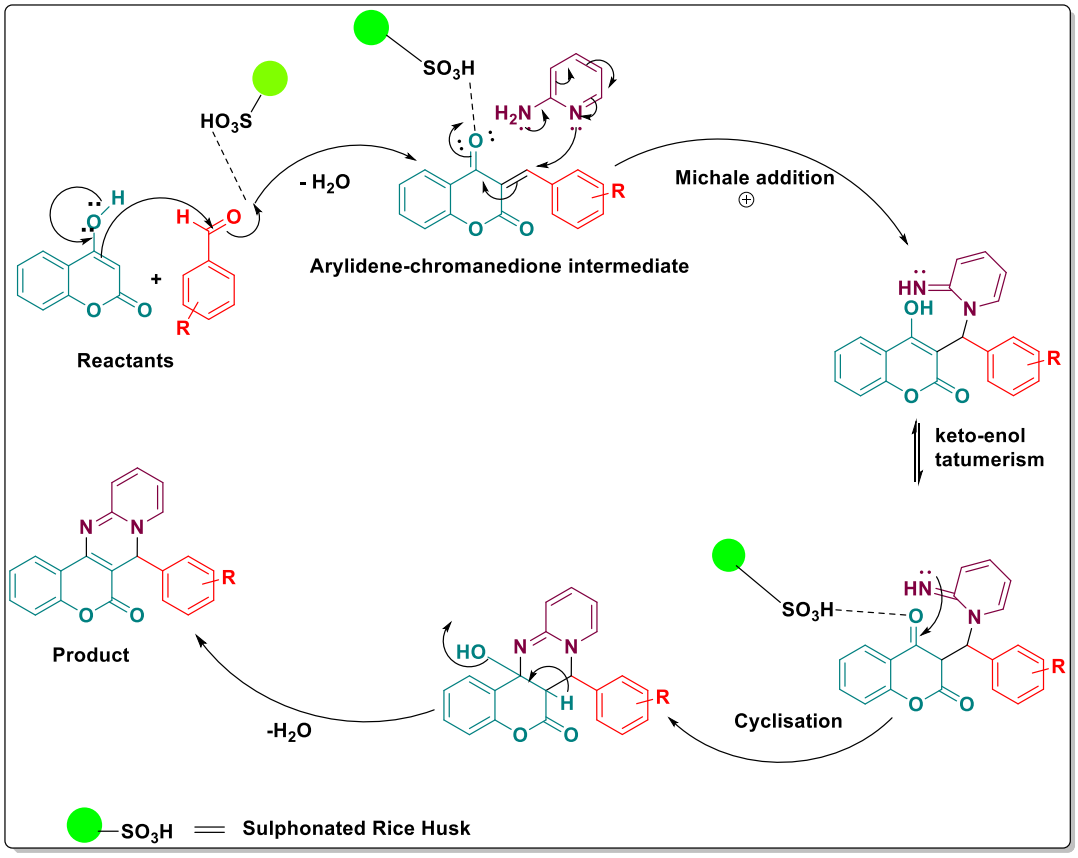


Figure III.11 The plausible mechanism for the synthesis 7-aryl/heteroaryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-d]pyrido[1,2-a]pyrimidin-6-one derivatives

III.8.A.9 Catalyst Recyclability Experiment

To check the recyclability of the catalyst, a model reaction was performed between anisaldehyde(1.8mmol), 4-hydroxycoumarine (1.8mmol), 2-aminopyridine(1.8 mmol) in presence of 110 mg of sulphonated rice husk following the optimized reaction condition (**Scheme III.20, Table III.4**, entry 7). After the successful completion of the each reaction step the reaction mixture was extracted with ethyl acetate until the catalyst was completely washed off. The catalyst was further

washed with ethanol at the end finally then it was dried under vaccum and the recovered catalyst weight was measured. After every recovery step of the catalyst the next reaction was repeated following optimized reaction condition (mentioned in **Table III.4** above) with required proportion of the reactants to that of weight of the recovered catalyst (**Table III.6**). Amount of catalyst, aldehyde, reaction time, temperature and yield percentage of the product have been shown in the table (**Table III.6**, entry 1-5). The catalyst was easily recovered from the reaction mixture with minimum loss by centrifugation and it was found to retain its acidic property, even after 5th run for this particular model reaction (**Figure III.13**). This was further supported by FTIR spectra of the recovered SRH catalysts after successive reactions (**Figure III.12**).

Table III.6. Table for the amount of recovered catatyst with isolated product yield [a]

Entry	Catalyst (mg)	Aldehyde (x mmol)	Temperature (^{o} C)	Time (min)	Yield (%)[b]
1	110	1.80	70	180	96
2	80	1.30	70	180	94
3	60	0.90	70	180	87
4	50	0.75	70	180	83

5.	40	0.60	70	180	72

[a] Reaction of anisaldehyde(x mmol), 4-hydroxycoumarine (x mmol), 2-aminopyridine (x mmol).[b] Isolated yield.

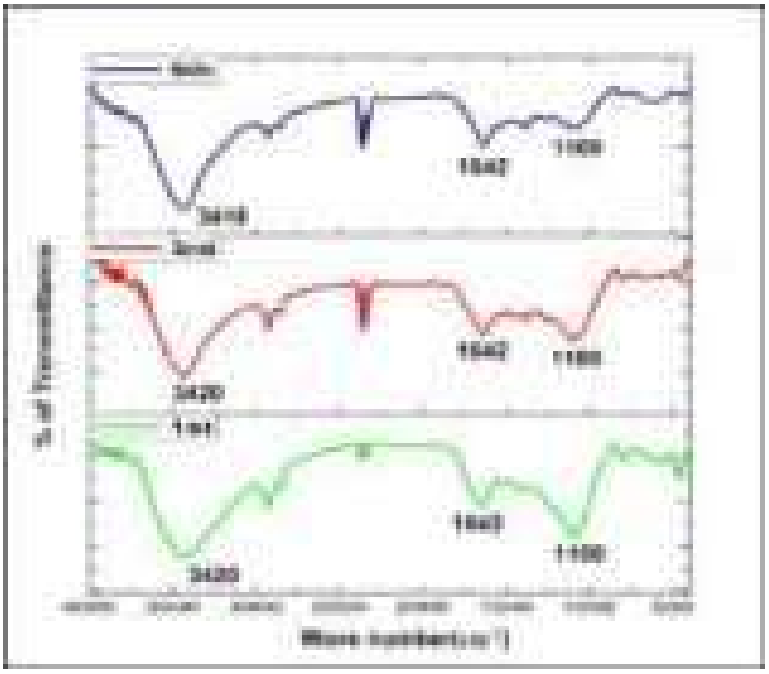


Figure III.12. FTIR spectra of reused catalysts after 1st , 3rd and 5th and run

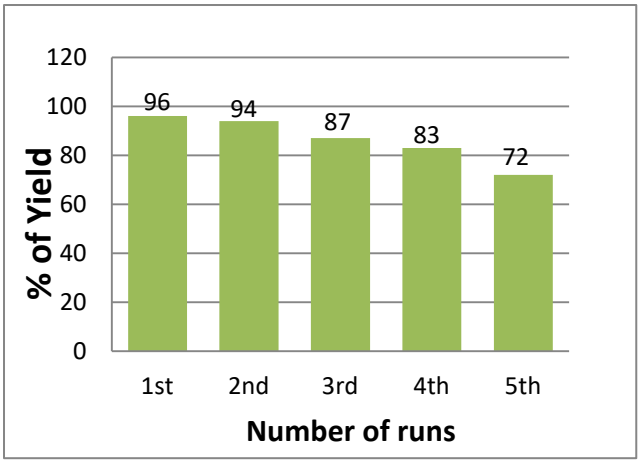


Figure III.13. Recyclability experiment

III.8.A.10 Conclusion

In conclusion, a simple and greener methodology for the synthesis of variety of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione and 7-aryl/heteroaryl-6*a*,13*a*-dihydro-6*H*,7*H*-chromeno [4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one derivatives from commercially available aldehydes has been established. We have introduced a new greener method using newly developed cheaper heterogeneous catalyst Sulphonated rice husk (SRH) for the synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c*']dichromene-6,8-dione and 7-aryl/ heteroaryl-6*a*,13*a*-dihydro-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimi din-6-one derivatives with excellent yield. This heterogeneous catalyst is found to be highly efficient for the synthesis 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c*']dichromene-6,8-dione and 7-aryl/hetero-aryl-6a,13a-dihydro-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one derivatives in short reaction time. The catalyst is recyclable up to 5^{th} run for above mentioned model reaction and has broad aspect to catalyze a wide range of multi-component reactions bearing condensation and cyclization steps.

III.8.A.11 Acknowledgement

One of the authors (S.D) is thankful to UGC, New Delhi for financial support, USIC (NBU) for SEM, EDX analysis, & Panjab University SAIF for powder XRD analysis for this work.

III.8.A.12 Experimental

III.8.A.12.a Materials and methods

Crude rice-husk was collected from nearby rice mill and the chemicals including aldehydes, 4-hydroxycumarine, 2-aminopyride were supplied from Sigma Aldrich chemical Co. (USA) which have been used directly without further purification. The chemical purity of the compounds was confirmed by Thin layer Chromatography(TLC) on commercial alluminium baked plates of silica gel, 60 F254. NMR spectra of all the products were taken in DMSO-d_6 (TMS as an internal standard) using a Bruker 400MHz spectrometer(operating for ^{1}H at 400 MHz and for ^{13}C at 100 MHz) and Bruker Advance NEO 500MHz spectrometer(operating for ^{1}H at 500 MHz and for ^{13}C at 125 MHz). IR spectra of the prepared catalyst were recorded on Perkin Elmer-Spectrum RX-IFTIR spectrophotometer, Powder XRD and SEM-EDX analysis of the prepared catalyst was carried out by Panalytical's X'pert

Pro X-Ray diffractometer and JSM-IT700HR Advanced SEM Spectrometer.

III.8.A.12.b General procedure for catalyst preparation

The heterogeneous catalyst (SRH) was prepared by direct sulphonation of rice husk (RH) following our previous synthetic method. [100] The rice husk (RH) was collected from a nearby rice mill and was blended finely before use. The fibrous part of the blended rice husk was first washed with dilute H_2SO_4 continuously for several times and next the whole aggregate was thoroughly washed with water and finally by ethanol. After washing the solvent was fully evaporated through rotary evaporator and then fully dried 5g of chemically treated rice husk material was taken into 250 mL of a round bottom flask followed by addition of 150 mL dichloromethane (DCM). Then, 5 mL of pure Chlorosulphonic acid (98%) was added dropwise with continuous stirring until the whole suspension turned into brownish and finally set to stir for 20 hours on a magnetic stirrer at room temperature. After the completion of reaction the solid material was filtered off and washed with water to remove excess chlorosulphonic acid and finally acetone repeatedly to remove other organic substances till the filtrate shows very light brownish appearance. After leaching, the final material was

dried in reduced pressure and later characterised by different spectroscopic techniques.[100]

III.8.A.12.c General procedure for synthesis of 7-aryl/heteroaryl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione derivatives

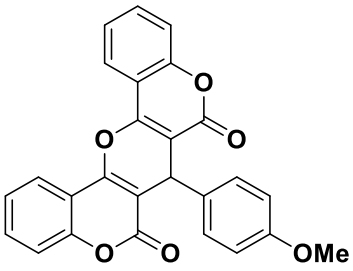
A mixture of 4-hydroxycumarine (2 mmol), aromatic aldehyde (1.0 mmol), and SRH (80 mg) in a 25-mL round bottom flusk was stirred at 60-80 ^{o}C temperature for 240 minutes and the progress of the reaction was monitored by thin-layer chromatography (TLC) (**Scheme III.19**). After completion of the reaction, the product was extracted with ethyl acetate and the catalyst was removed by filtration. Then ethyl acetate extract was concentrated and white crude product was isolated by the addition of petroleum ether slowly dropwise until white precipitation appears. Then white crude product was further purified by recrystallisation in petroleum ether/ethyl acetate (v/v ratio 80/20) mixture to get the pure product. All the synthesized compounds were characterized by ^{1}H and ^{13}C NMR spectroscopy and the spectral data were compared with the reported spectral data of corresponding compound.

III.8.A.12.d General procedure for synthesis of 7-aryl/heteroaryl-6*a*,13*a*-dihydro-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one derivatives

A mixture of 2-aminopyridine (1 mmol), 4-hydroxycumarine (1 mmol), aromatic aldehyde (1 mmol), and SRH (60 mg) in a 25-mL round bottom flusk was stirred at 60-80 ^{o}C temperature for 210 minutes. The progress of the reaction was monitored by thin-layer chromatography (TLC) (**Scheme III.20**). After completion of the reaction, the product was extracted with ethyl acetate and the catalyst was separated by simple filtration and the ethyl acetate extract was concentrated and crude product was separated by simple precipitation with addition of mixed solvent containing ethyl acetate and petroleum ether (1:10v/v) slowly dropwise. Finally the obtained solid was purified by slowly washing the crude with solvent containing ethyl acetate and petroleum ether (1:4v/v). After isolation, all the synthesized compounds were characterized by ^{1}H and ^{13}C NMR spectroscopy and the spectral data were compared with the reported spectral data of corresponding compound.

III.8.A.12.e Spectral data of the compounds mentioned in scheme III.19

7-(4-methoxyphenyl)-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3a)



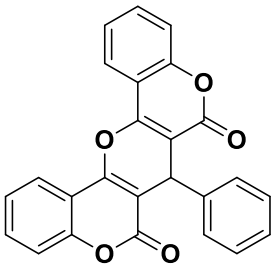
^{1}H-NMR(400MHz,DMSO-d_6)

δ(ppm)3.65(s,3H),6.17(s,1H),6.70(d,3H),6.96(d,2H),7.18-7.24(m,4H),7.45-7.49(m,2H),7.78(dd,2H).

^{13}C-NMR(400MHz,DMSO-d_6)

δ(ppm)35.90,55.43,104.26,113.68,116.00,120.40,123.42,124.62,128.16,131.43,134.50,153.02,157.36,165.08,167.96.

7-phenyl-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3b)



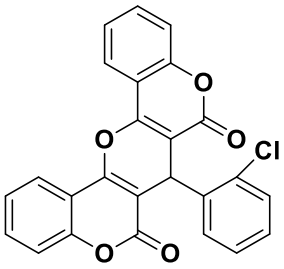
^{1}H-NMR(400MHz,DMSO-d_6)

δ(ppm)6.24(s,1H),7.02-7.08(m,3H),7.11-7.15(m,2H),7.22-7.29(m,4H),7.45-7.50(m,2H),7.77(q,2H).

^{13}C-NMR(400MHz,DMSO-d_6)

δ(ppm)36.68,103.95,116.00,120.50,123.41,124.67,125.34,127.20,128.23,131.44,142.93,153.06, 165.12,168.25.

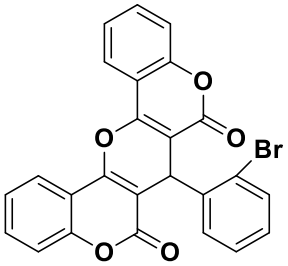
7-(2-chlorophenyl)-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3c)



^{1}H-NMR(400MHz,DMSO-d_6)
δ(ppm)6.12(s,1H),7.08-7.18(m,3H),7.21(d,4H),7.37(d,1H),7.44-7.77(m,2H),7.78(d,2H).

^{13}C-NMR(400MHz,DMSO-d_6)
δ(ppm)36.66,103.32,115.99,120.46,123.44,124.59,126.52,127.57,129.88,130.91,131.37,133.24,140.95,152.96,164.41,168.24.

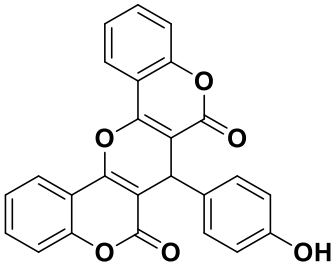
7-(2-bromophenyl)-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3d)



^{1}H-NMR(400MHz,DMSO-d_6)
δ(ppm)5.99(s,1H),7.02(t,1H),7.17-7.22(m,5H),7.38(dd,2H),7.46(t,2H),7.77(d,2H).

^{13}C-NMR(400MHz,DMSO-d_6)
δ(ppm)38.89,103.46,116.00,120.47,123.43,124.57,127.06,127.88,131.11,131.34,133.32,152.97,164.35,168.17.

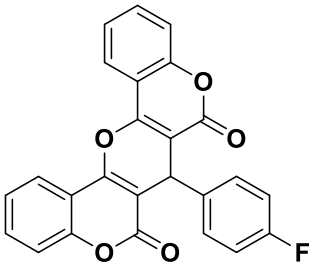
7-(4-hydroxyphenyl)-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3e)



^{1}H-NMR(400MHz,DMSO-d_6)
δ(ppm)6.12(s,1H),6.52(d,2H),6.84(d,2H),7.17-7.22(m,4H),7.44-7.48(m,2H),7.77(dd,2H),8.90(s,1H).

^{13}C-NMR(400MHz,DMSO-d_6)
δ(ppm)35.86,104.36,115.04,115.95,120.58,123.34,124.64,128.08,131.31,132.83,153.03,155.17.165.12, 168.11.

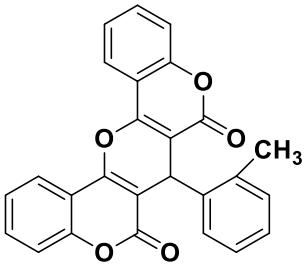
7-(4-fluorophenyl)-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3f)



^{1}H-NMR(400MHz,DMSO-d_6)
δ(ppm)6.21(s,1H),7.02-7.08(m,3H),7.11-7.15(m,2H),7.22-7.29(m,4H),7.45-7.50(m,2H),7.77(q,2H).

^{13}C-NMR(400MHz,DMSO-d_6)
δ(ppm)36.68,103.95,116.00,120.50,123.41,124.67,125.34,127.20,128.23,131.44,142.93,153.06,165.12,168.25.

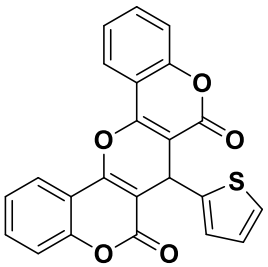
7-(2-methylphenyl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3g)



^{1}H-NMR(400MHz,DMSO-d_6)
δ(ppm)1.96(s,3H),6.09(s,1H),6.97(s,3H),7.22-7.27(m,5H),7.47(d,2H),7.80(d,2H).

^{13}C-NMR(400MHz,DMSO-d_6)
δ(ppm)21.63,36.55,105.20,116.14,120.03,123.66,124.64,126.31,127.78,128.31,131.68,137.06,142.16, 152.96,165.26,168.96.

7-(thiophen-2-yl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3h)



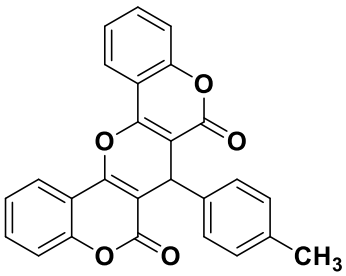
^{1}H-NMR(400MHz,DMSO-d_6)

δ(ppm)6.38(s,1H),6.57(t,1H),6.78(t,1H),7.12(d,1H),7.19-7.30(m,3H),7.40-7.52(m,2H),7.82(t,2H).

^{13}C-NMR(400MHz,DMSO-d_6)

δ(ppm)33.47,104.27,116.06,120.42,123.21,123.52,123.56,124.77,126.66,131.66,148.61,153.03,164.67,168.48.

7-(4-methylphenyl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3i)



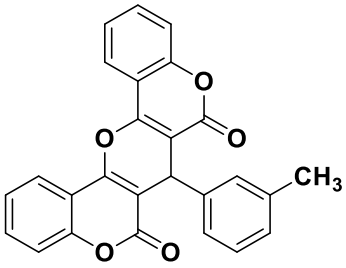
^{1}H-NMR(400MHz,DMSO-d_6)

δ(ppm)2.19(s,3H),6.19(s,1H),6.94(s,4H),7.20(q,4H),7.46-7.50(m,2H),7.78(d,2H).

^{13}C-NMR(400MHz,DMSO-d_6)

δ(ppm)21.06,36.30,104.09,115.99,120.50,123.42,124.64,127.11,128.84,131.42,134.04,139.73,153.03,165.16,168.21.

7-(3-methylphenyl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3j)



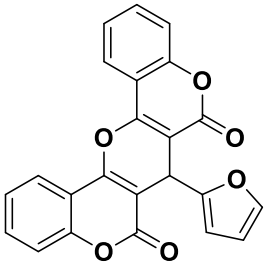
^{1}H-NMR(400MHz,DMSO-d_6)

δ(ppm)2.16(s,3H),6.24(s,1H),6.89(d,3H),7.04(t,1H),7.21-7.28(m,4H),7.48-7.53(m,2H),7.82(dd,2H).

^{13}C-NMR(400MHz,DMSO-d_6)

δ(ppm)21.83,104.20,116.14,120.03,123.66,124.44,124.64,126.31,127.78,128.21,131.69,137.06, 142.36,152.96,165.25,167.74

7-(furan-2-yl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3k)



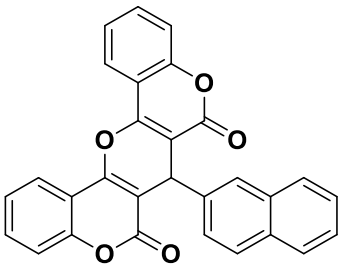
^{1}H-NMR(400MHz,DMSO-d_6)

δ(ppm)6.36(s,1H),6.56(t,1H),6.77(t,1H),7.12(d,1H),7.18-7.31(m,3H),7.42-7.52(m,2H),7.80-7.85(m,2H).

^{13}C-NMR(400MHz,DMSO-d_6)

δ(ppm)32.47,105.26,116.06,120.42,123.21,123.52,123.56,124.77,126.66,131.66,148.61,153.03,164.67,168.48.

7-(naphthalen-2-yl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3l)



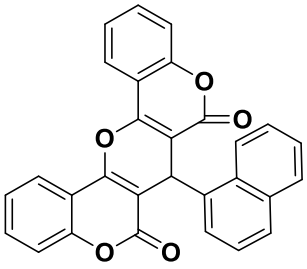
^{1}H-NMR(500MHz,DMSO-d_6)

δ(ppm)6.42(s,1H),7.22-7.30(m,5H),7.37-7.39(m,2H),7.51-7.54(m,3H),7.57-7.72(m,2H),
7.78-7.83(m,3H).

^{13}C-NMR(500MHz,DMSO-d_6)

δ(ppm)36.42,103.28,114.39,115.30,115.42,119.87,122.71,122.82,124.04,124.06,124.66,125.43,126.20,127.01,127.03,127.35,127.42,130.86,131.28,132.92,140.03,152.37,152.46,164.53,167.83.

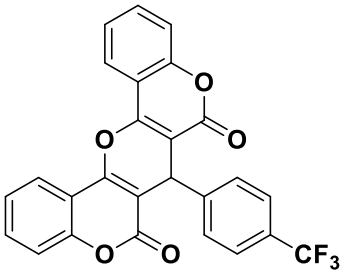
7-(naphthalen-1-yl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3m)



^{1}H-NMR(400MHz,DMSO-d_6)
δ(ppm)6.73(s,1H),7.18-7.26(m,3H),7.33-7.37(m,3H),7.45-7.50(m,3H),7.68(d,1H),
7.76-7.83(m,3H),7.99(dd,1H).

^{13}C-NMR(400MHz,DMSO-d_6)
δ(ppm)35.46,104.80,116.07,120.27,123.59,124.60,124.73,125.42,125.54,125.94,126
.27,126.69,129.05,131.53,132.19,134.22,138.67,152.84,164.78,168.64.

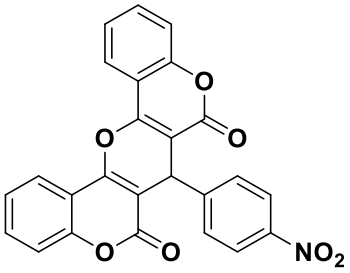
7-(4-(trifluoromethyl)phenyl)-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3n)



^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)6.34(s,1H),7.23-7.34(m,6H),7.51-7.56(m,4H),7.83(q,2H).

^{13}C-NMR(500MHz,DMSO-d_6)
δ(ppm)36.30,102.85,115.47,119.69,122.93,123.48,124.10,124.61,124.64,125.56,125
.64,125.81,127.30,131.06,147.49,152.47,164.47,167.86.

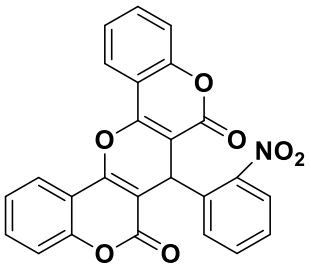
7-(4-nitrophenyl)- 6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3o)



^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)6.37(s,1H),7.23-7.30(m,4H),7.38(d,2H),7.51-
7.55(m,2H),7.83(dd,2H),8.08(d,2H).

^{13}C-NMR(500MHz,DMSO-d_6)
δ(ppm)36.67,102.68,115.50,119.61,122.98,123.03,124.11,127.79,131.15,145.22,151
.37,152.48,164.34,167.93

7-(2-nitrophenyl)-6*H*,7*H*,8*H*-pyrano[3,2-*c*:5,6-*c'*]dichromene-6,8-dione(3p)



^{1}H-NMR(500MHz,DMSO-d_6)

δ(ppm)6.50(s,1H),7.21-7.26(m,4H),7.34-7.38(m,2H),7.49-7.55(m,4H),7.78(d,2H).

^{13}C-NMR(500MHz,DMSO-d_6)

δ(ppm)33.83,102.14,115.43,119.46,122.86,123.76,124.02,126.53,129.52,130.94,131.81,135.23,149.52,152.44,163.54,167.88.

III.8.A.12.f Sanned copies of compounds mentioned in Scheme III. 19

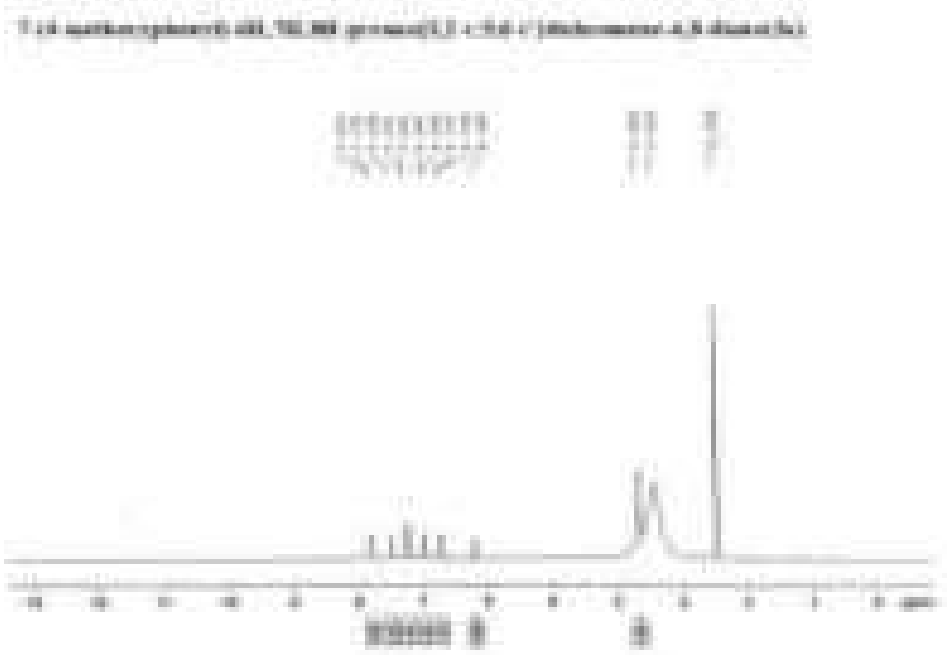


Figure III.14-^{1}H-NMR of compound 3a

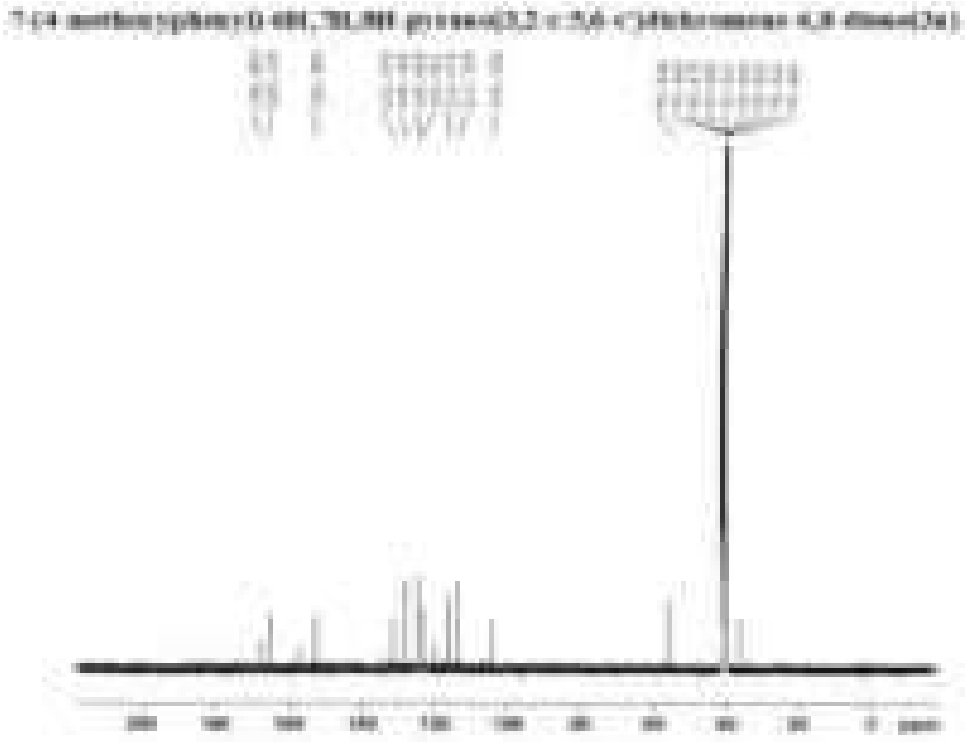


Figure III.15-^{13}C-NMR of compound 3a

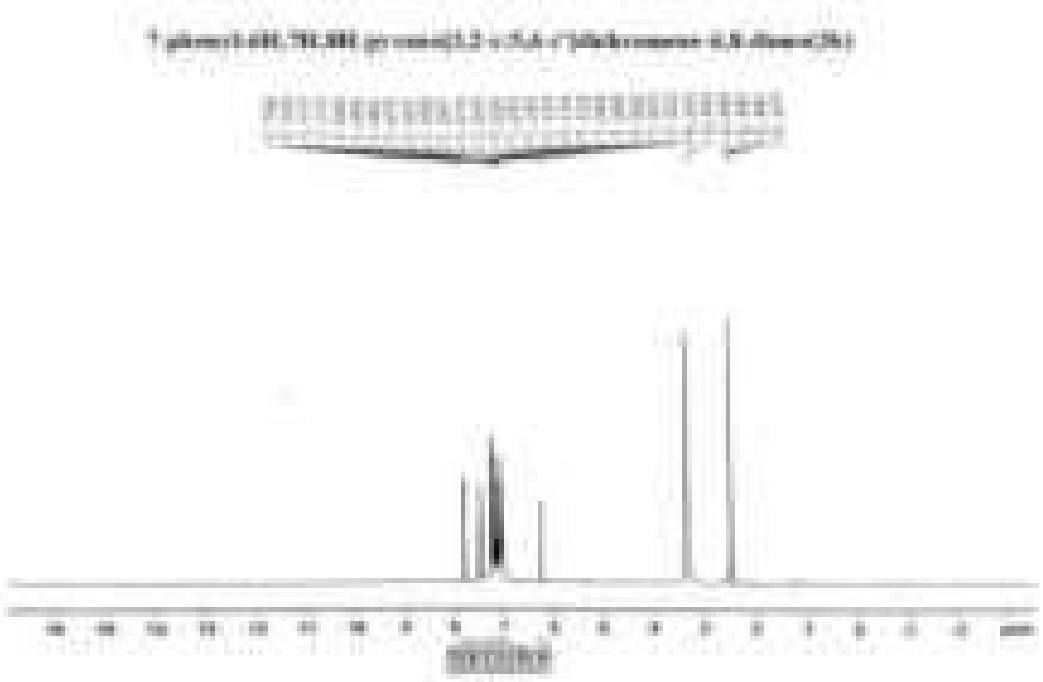


Figure III.16-^{1}H-NMR of compound 3b

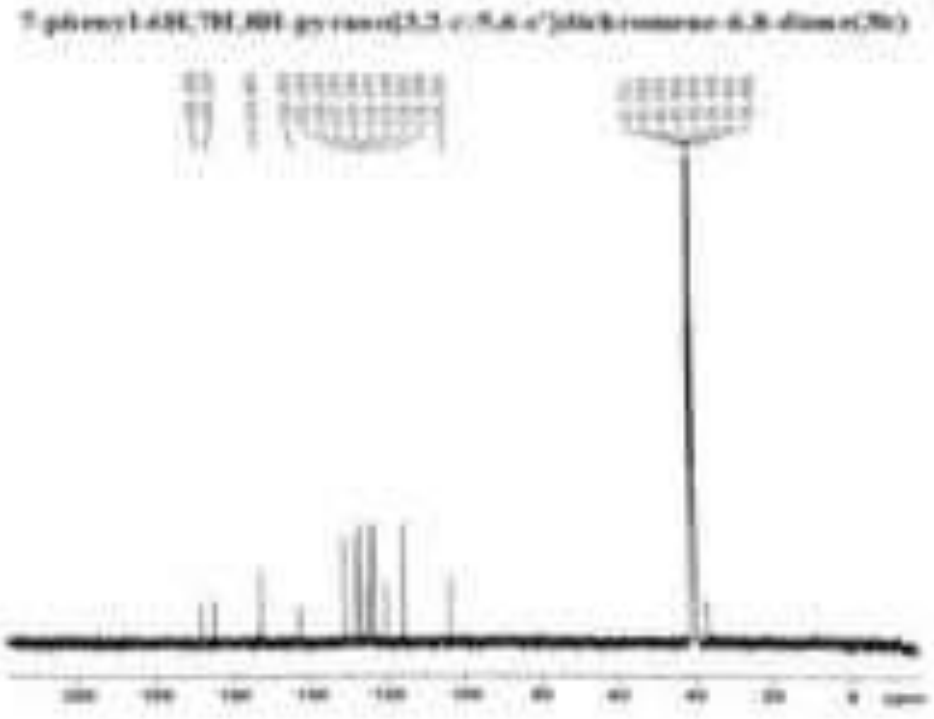


Figure III.17-^{13}C-NMR of compound 3b

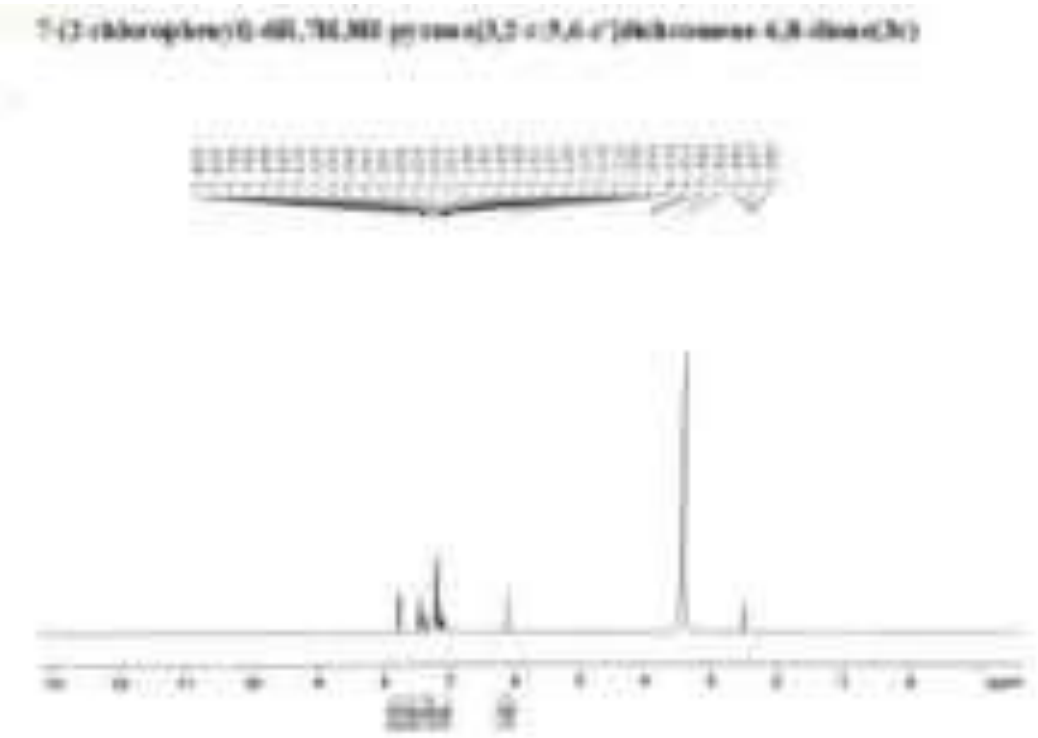


Figure III.18-^{1}H-NMR of compound 3c

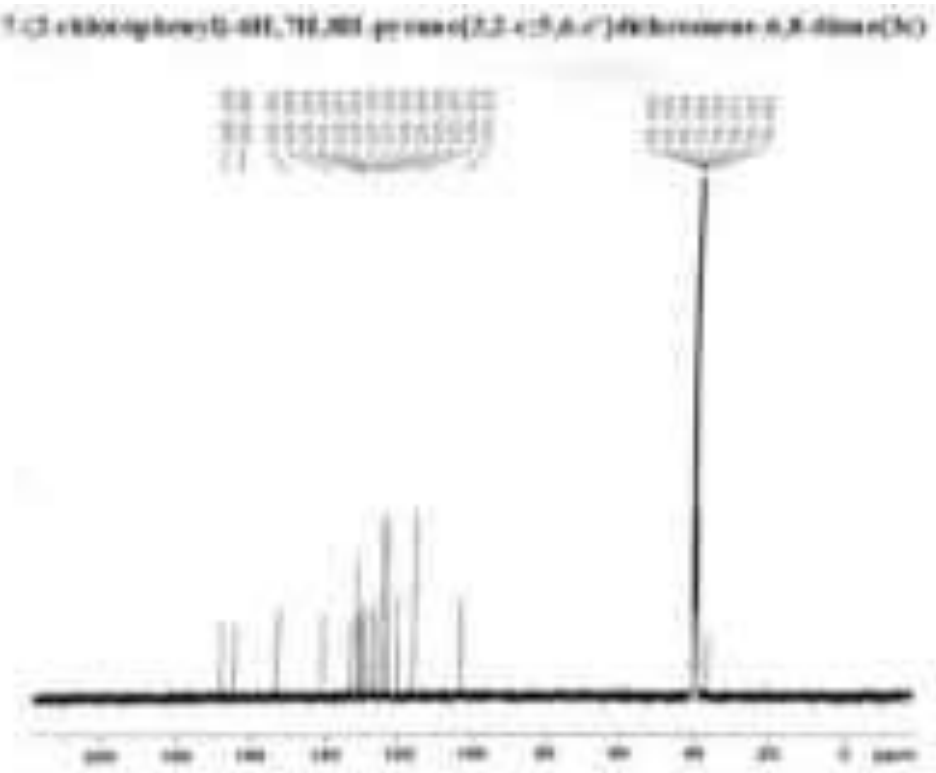


Figure III.19-^{13}C-NMR of compound 3c

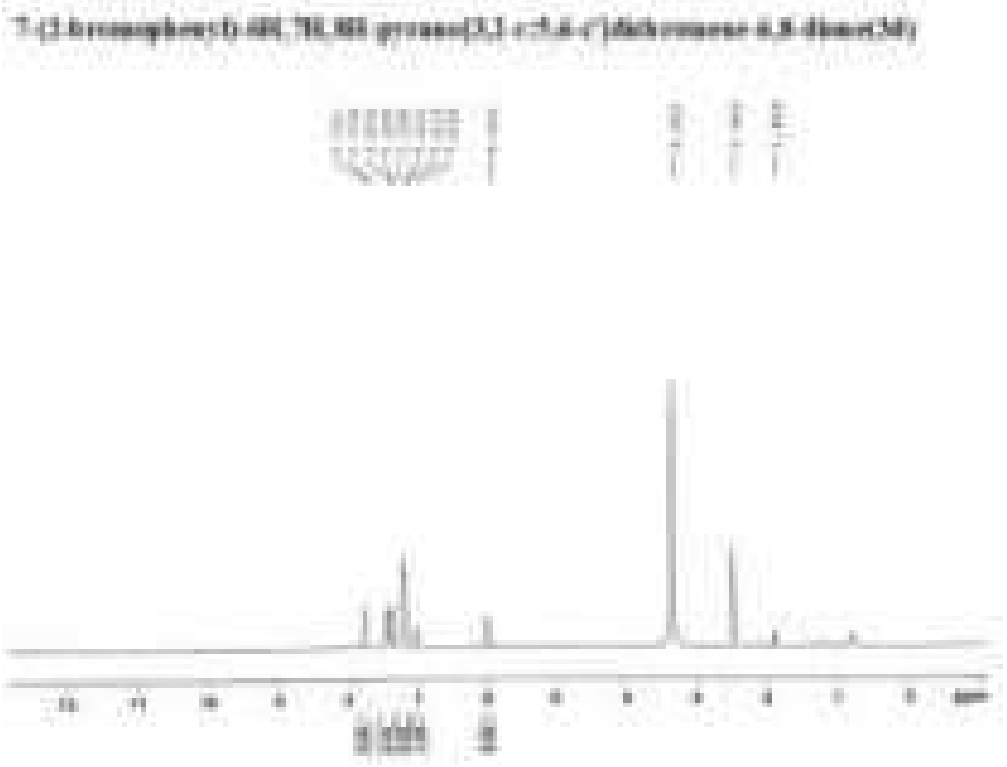


Figure III.20-^{1}H-NMR of compound 3d

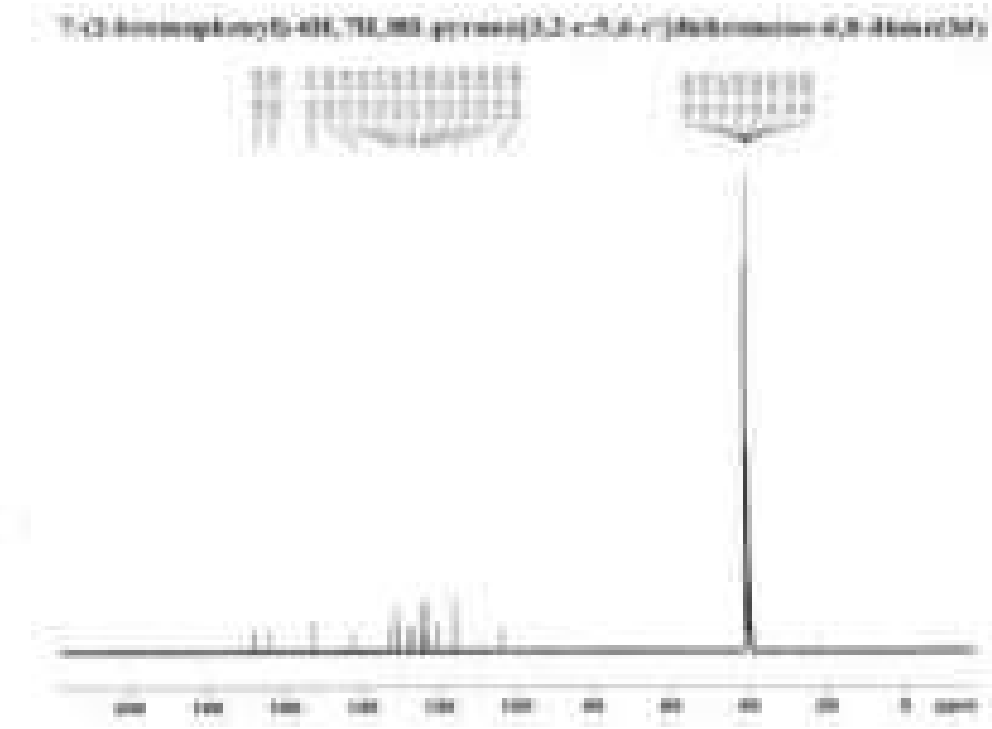


Figure III.21-^{13}C-NMR of compound 3d

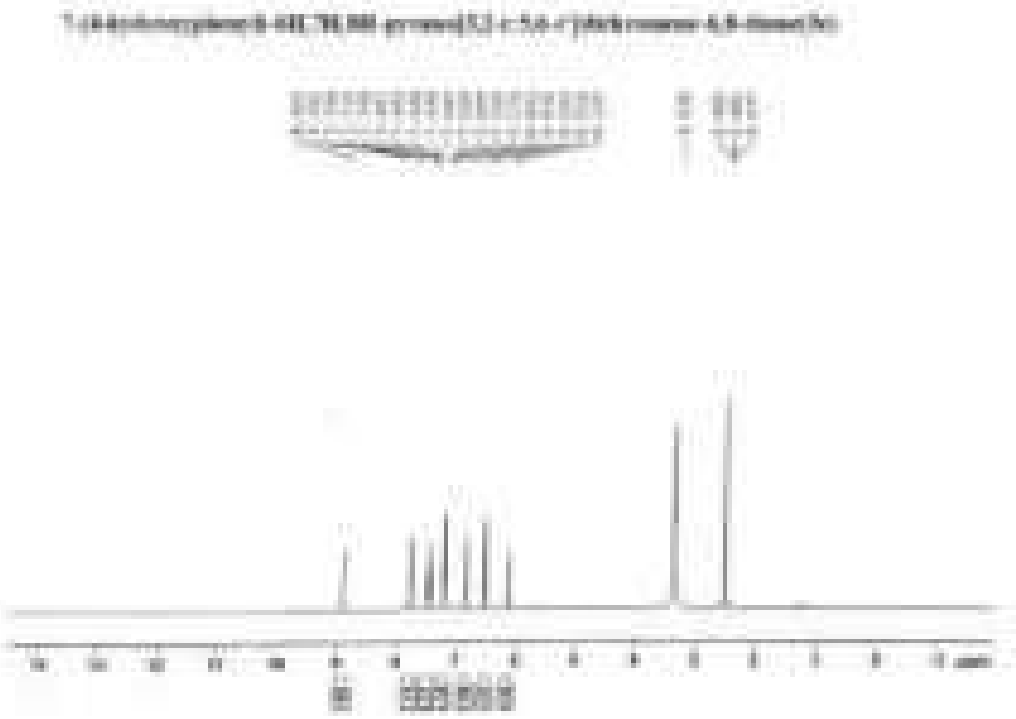


Figure III.22-^{1}H-NMR of compound 3e

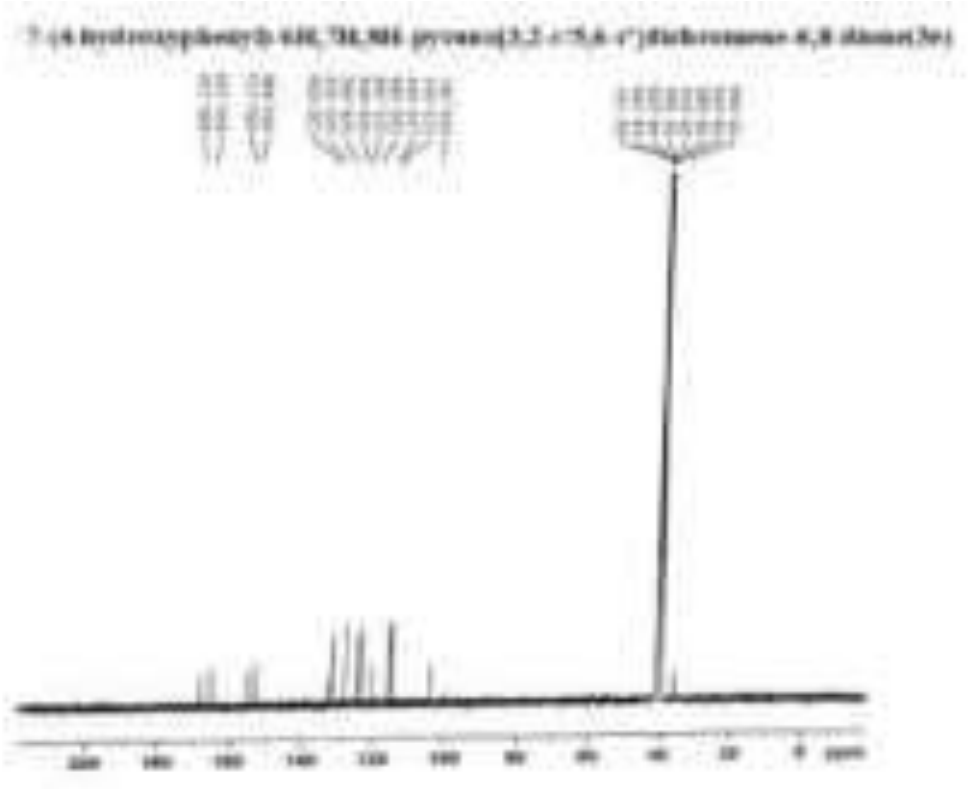


Figure III.23-^{13}C-NMR of compound 3e

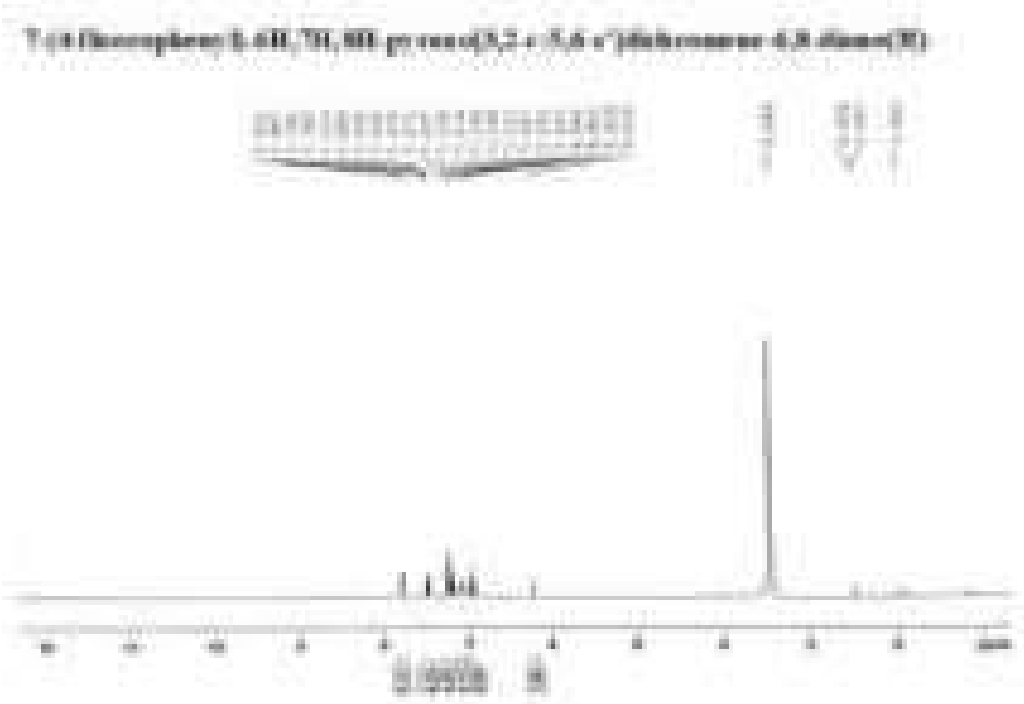


Figure III.24-^{1}H-NMR of compound 3f

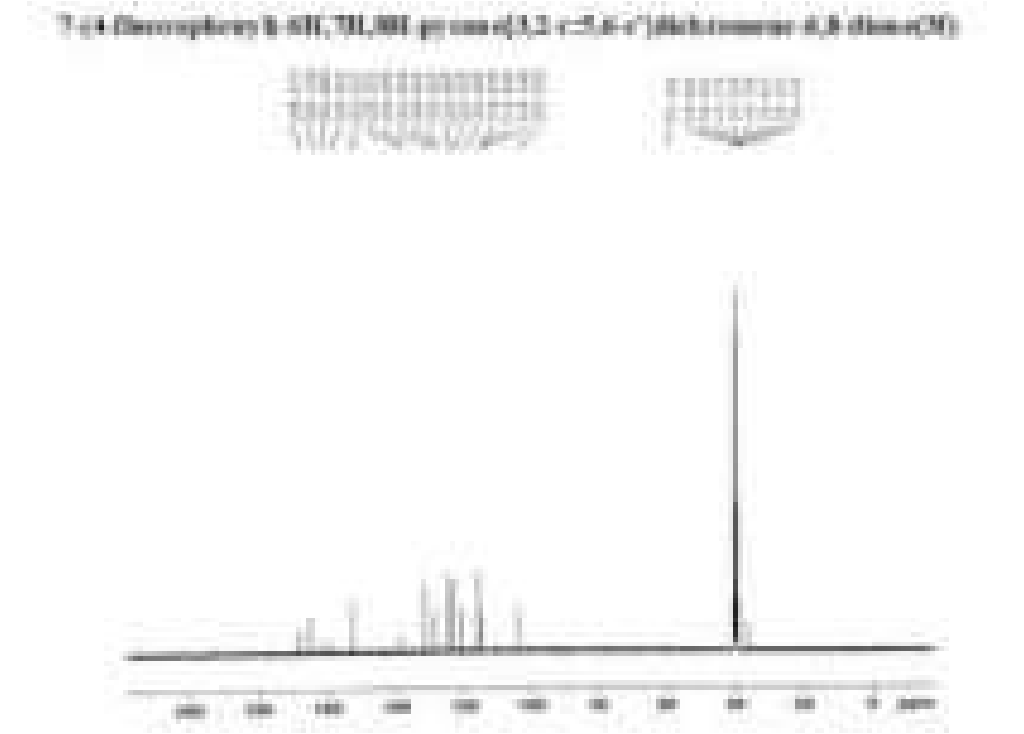


Figure III.25-^{13}C-NMR of compound 3f

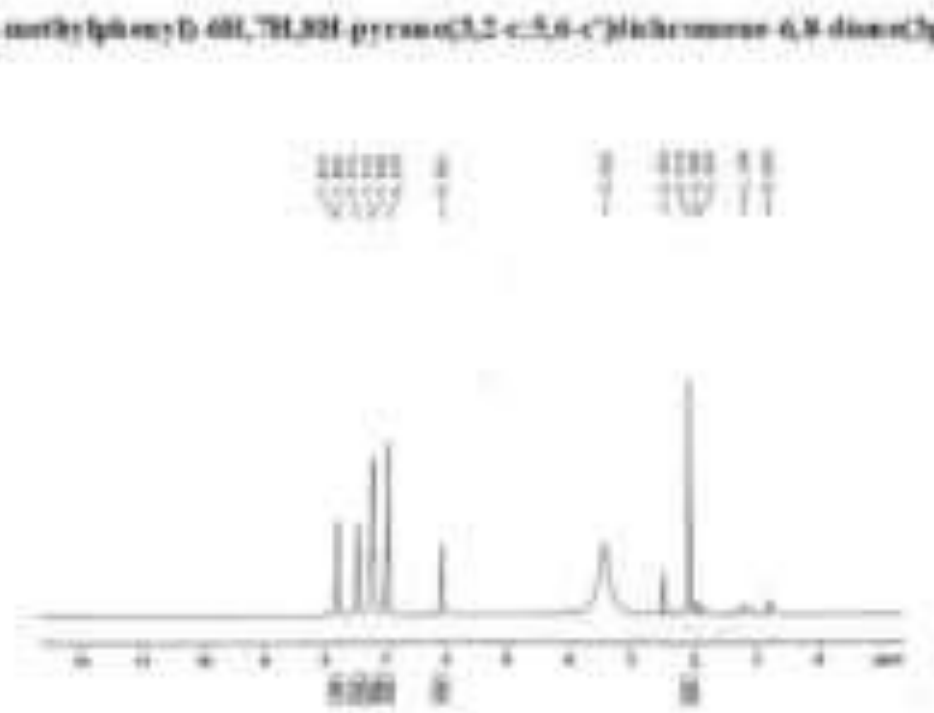


Figure III.26-^{1}H-NMR of compound 3g

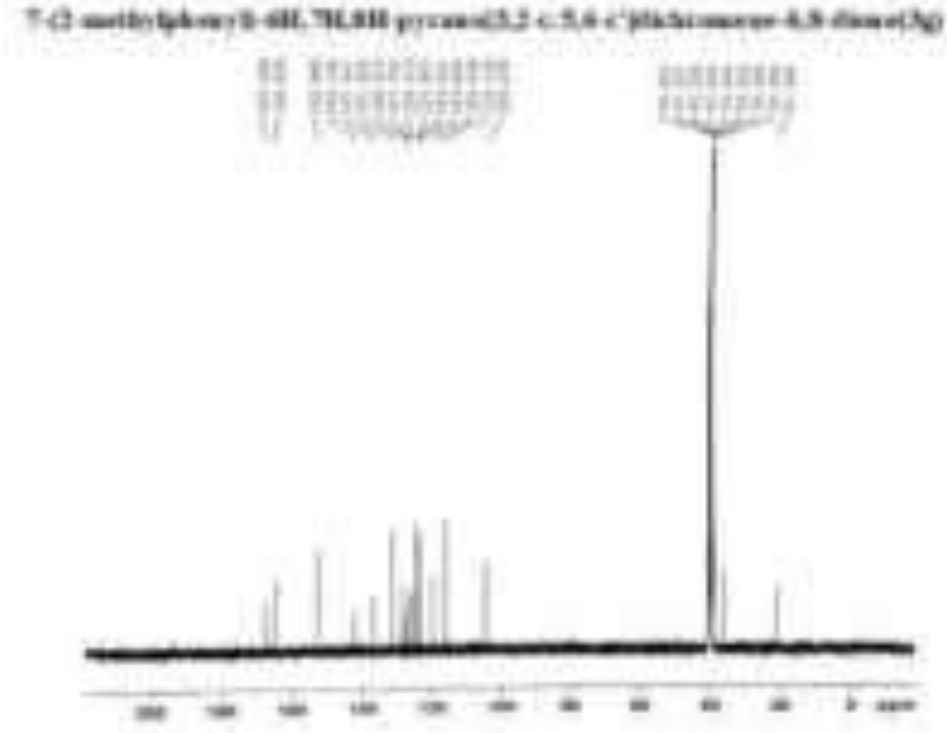


Figure III.27-^{13}C-NMR of compound 3g

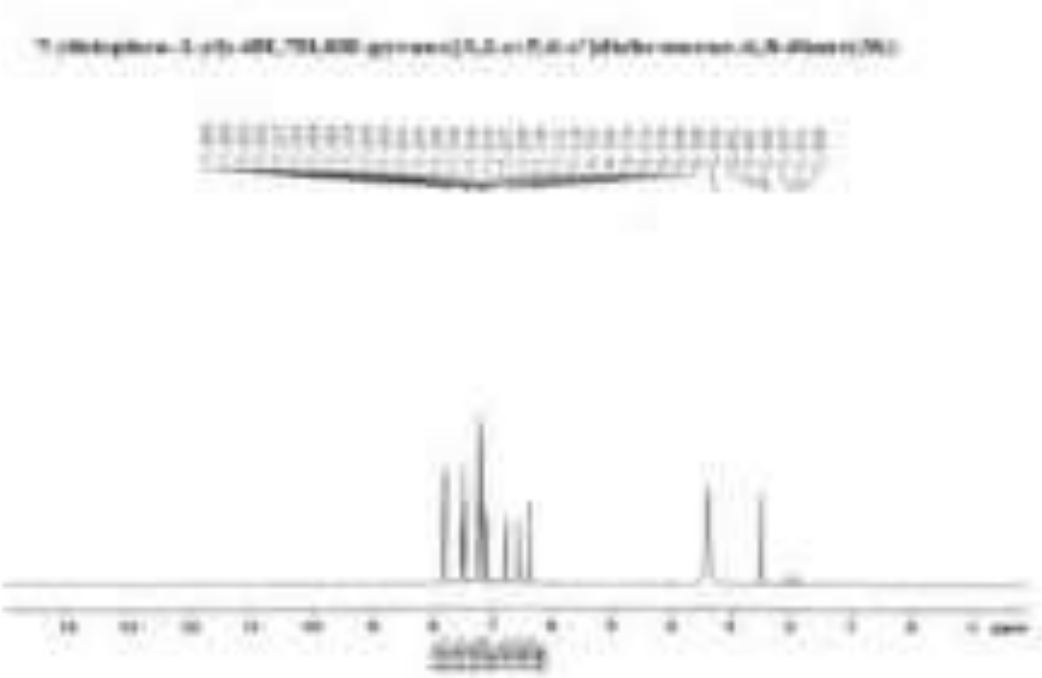


Figure III.28-^{1}H-NMR of compound 3h

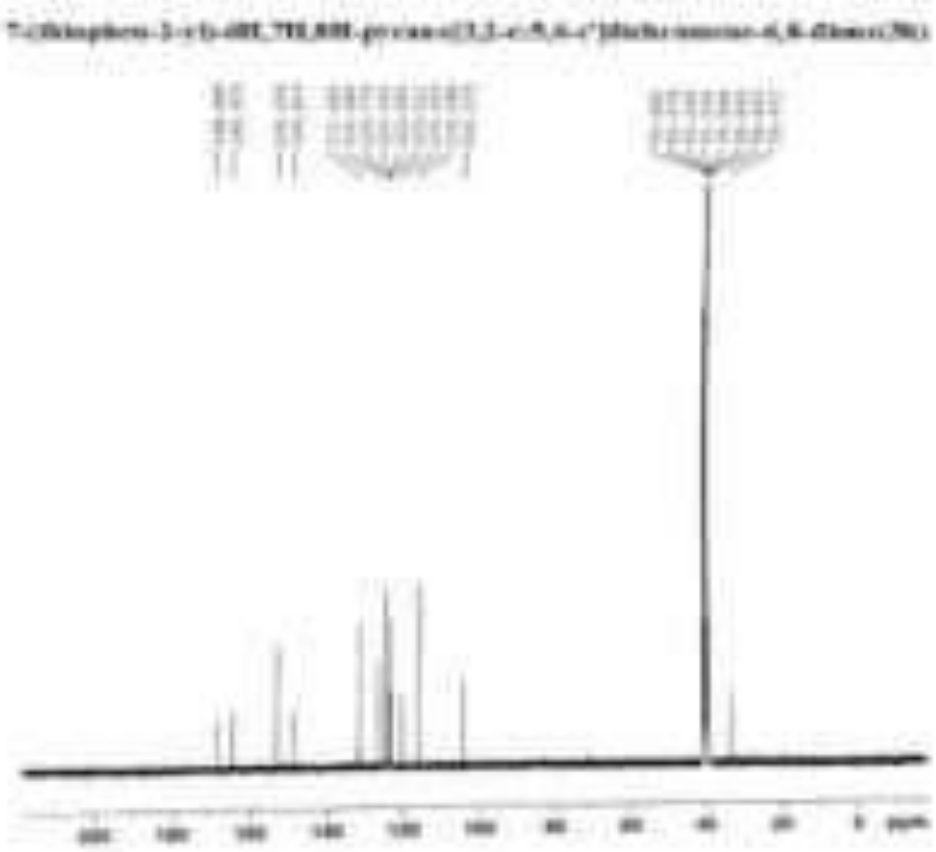


Figure III.29-^{13}C-NMR of compound 3h

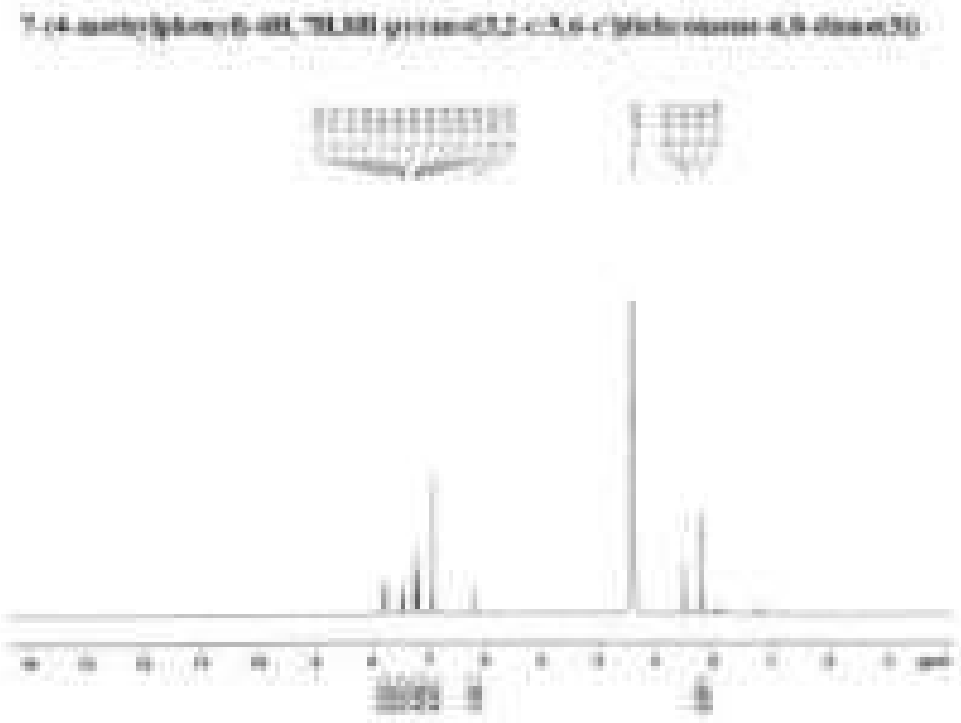


Figure III.30-^{1}H-NMR of compound 3i

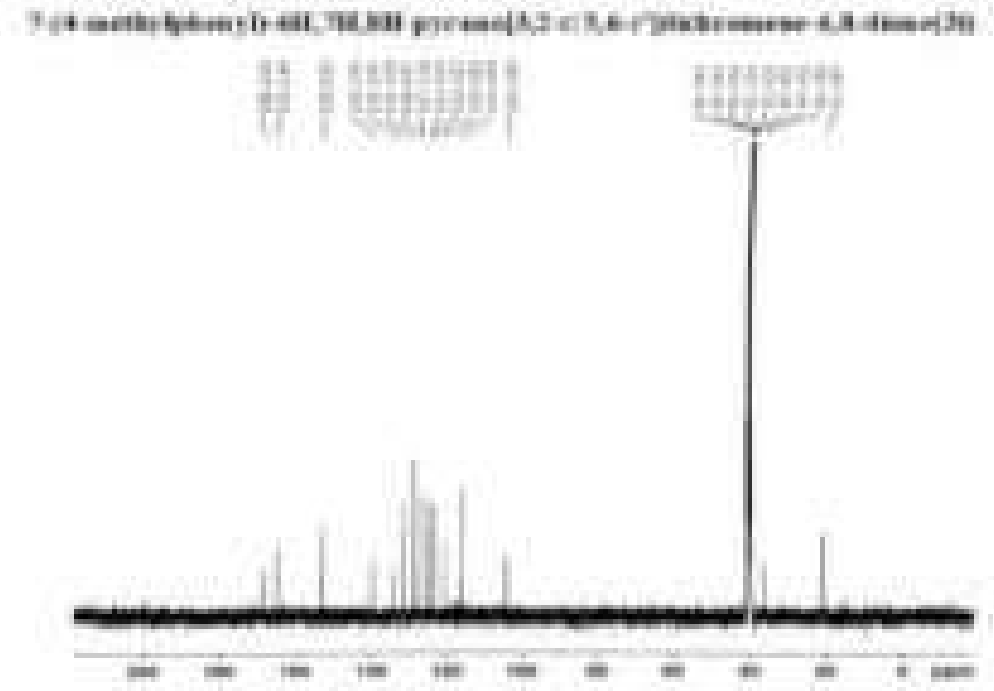


Figure III.31-^{13}C-NMR of compound 3i

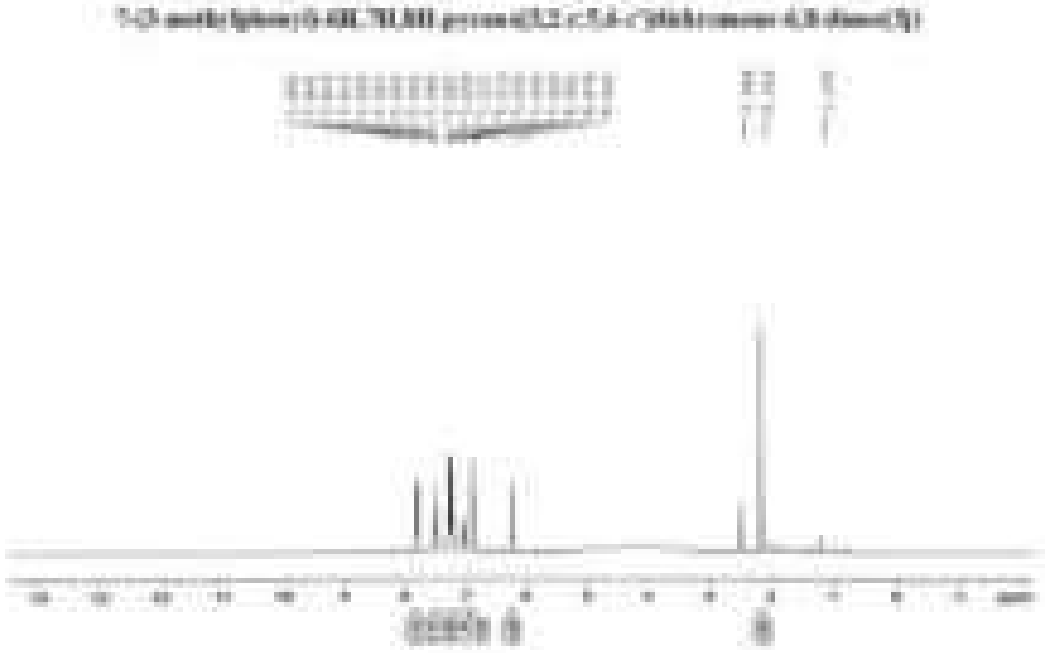


Figure III.32-^{1}H-NMR of compound 3j

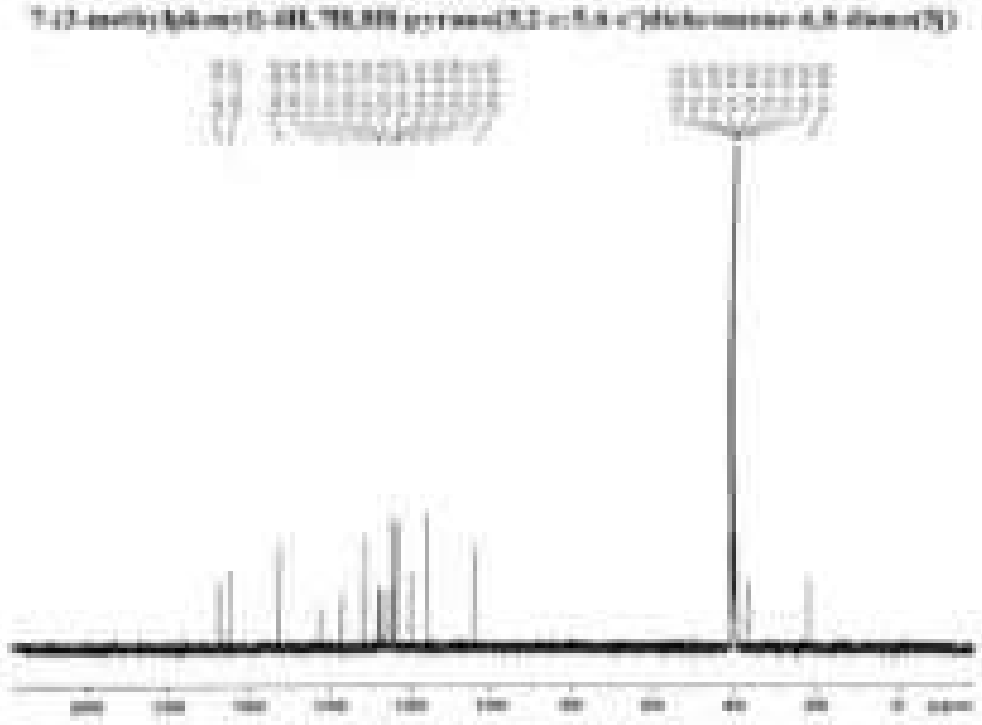


Figure III.33-^{13}C-NMR of compound 3j

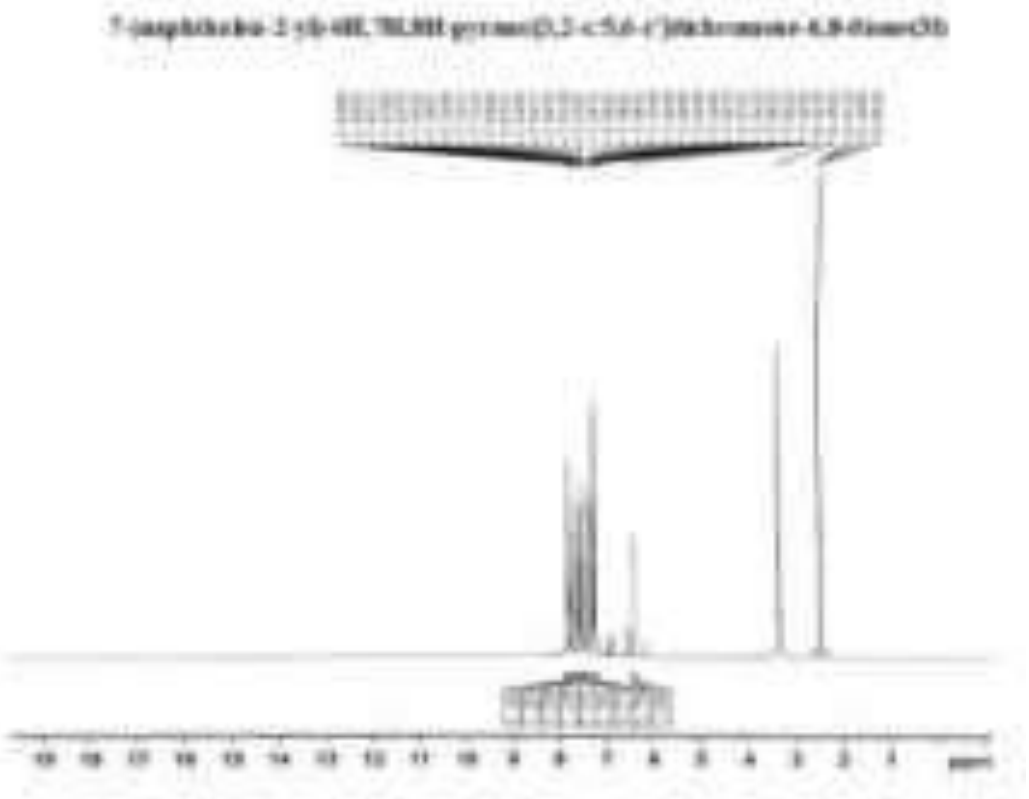


Figure III.34-^{1}H-NMR of compound 3l

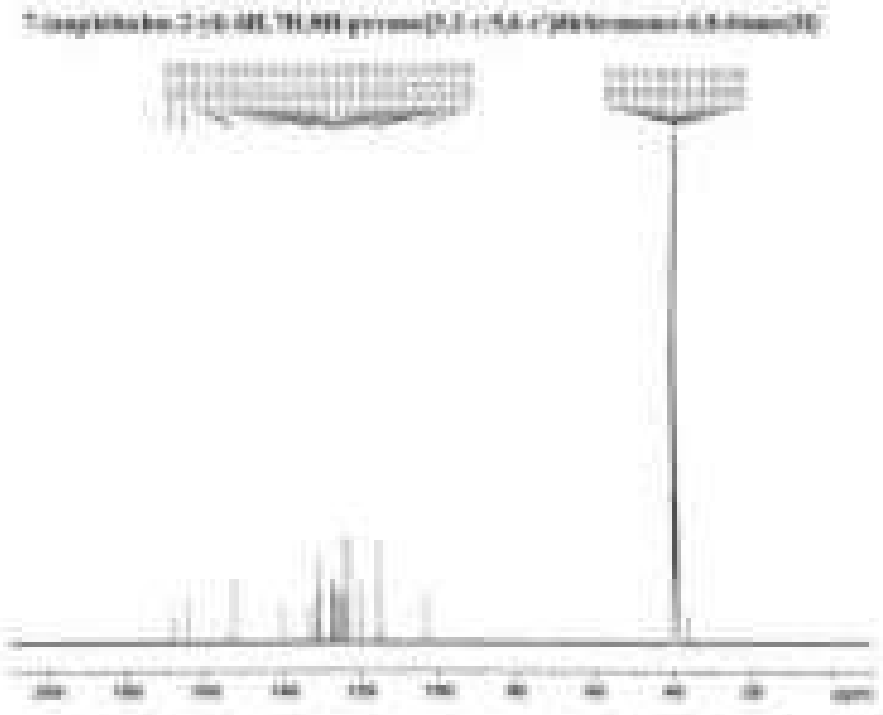


Figure III.35-^{13}C-NMR of compound 3l

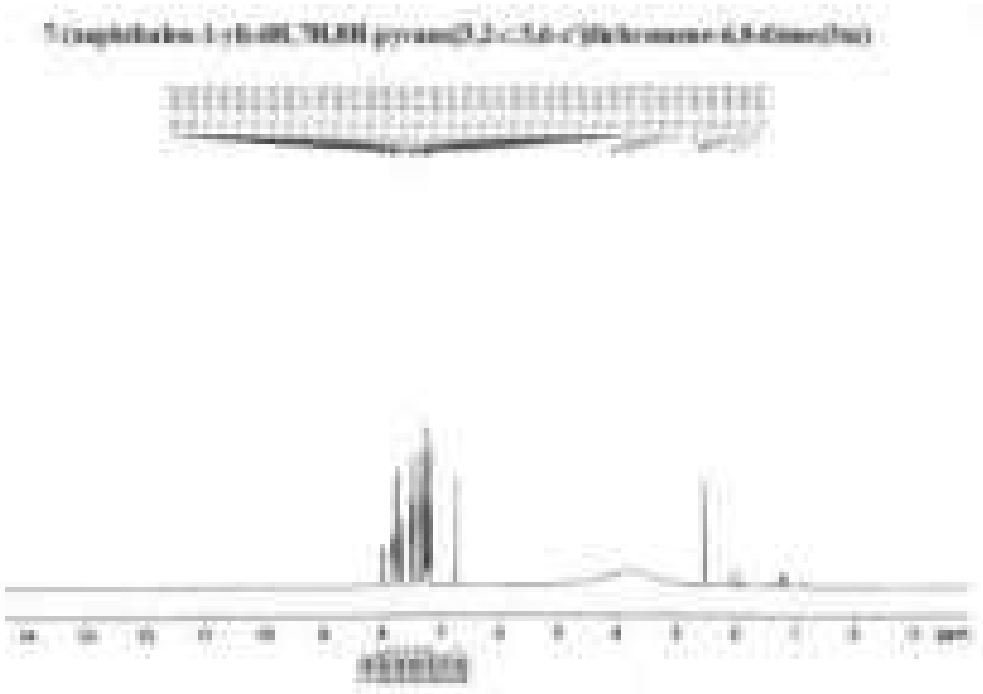


Figure III.36-^{1}H-NMR of compound 3m

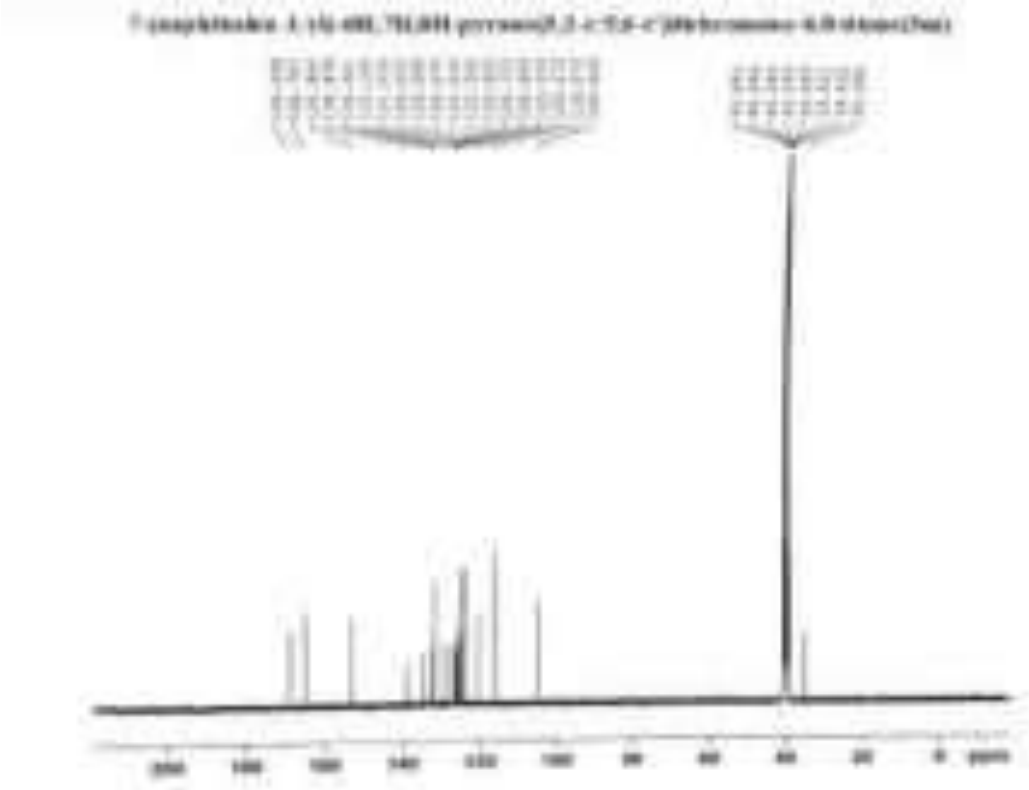


Figure III.37-^{13}C-NMR of compound 3m

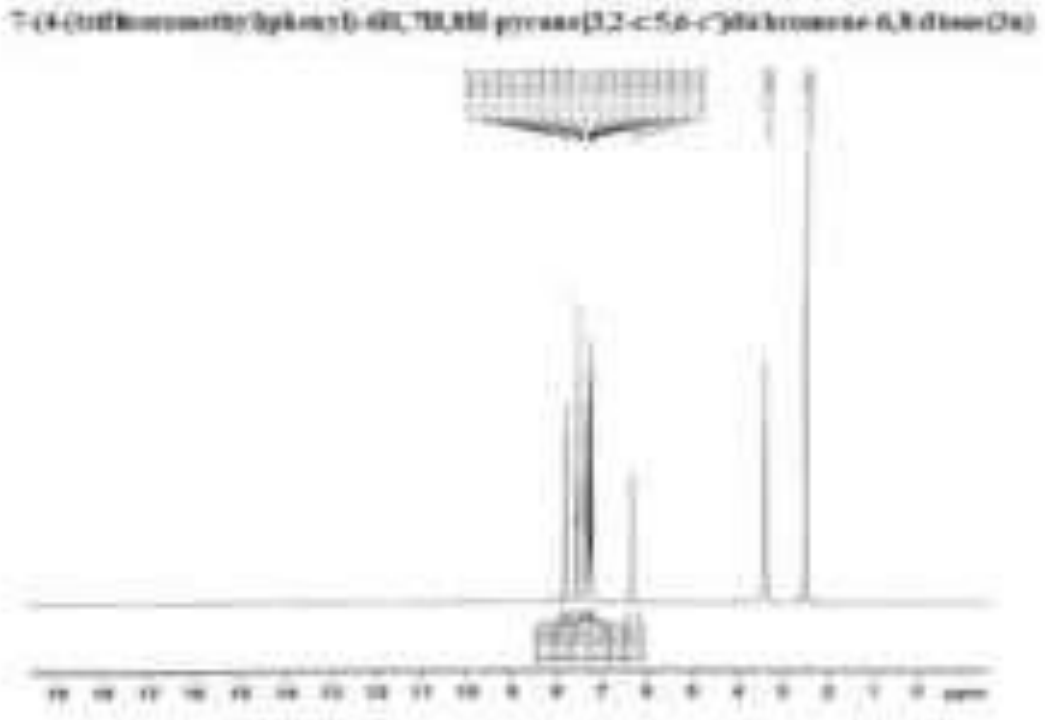


Figure III.38-^{1}H-NMR of compound 3n

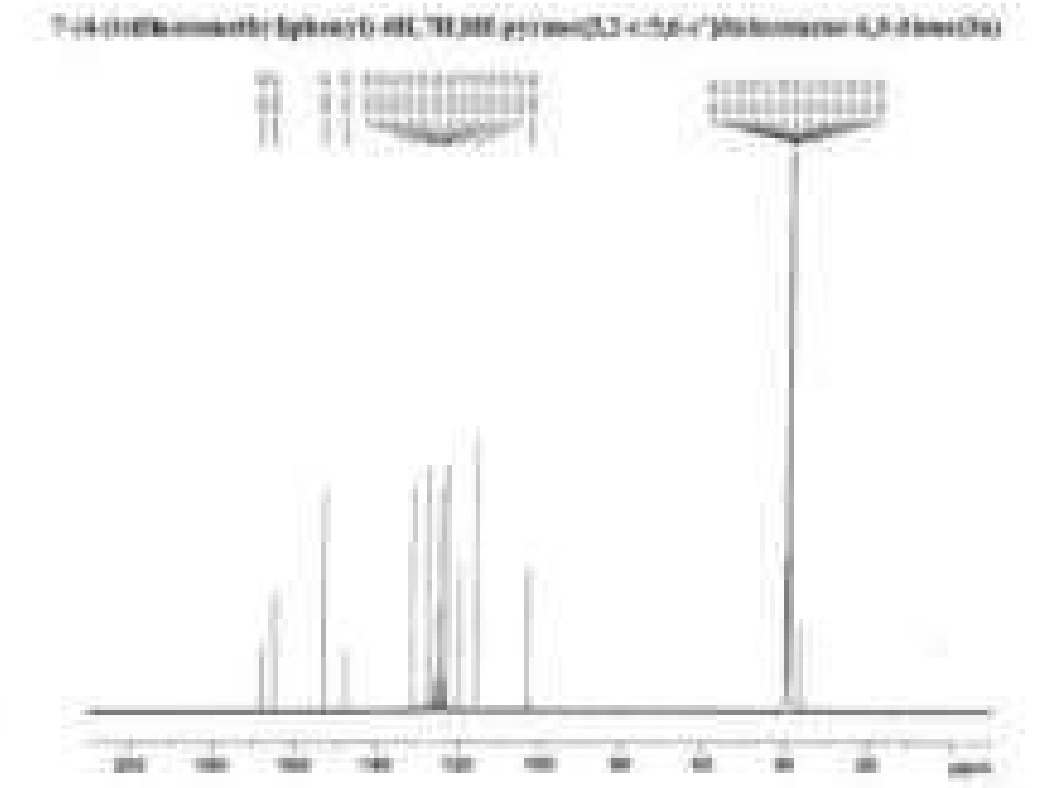


Figure III.39-^{13}C-NMR of compound 3n

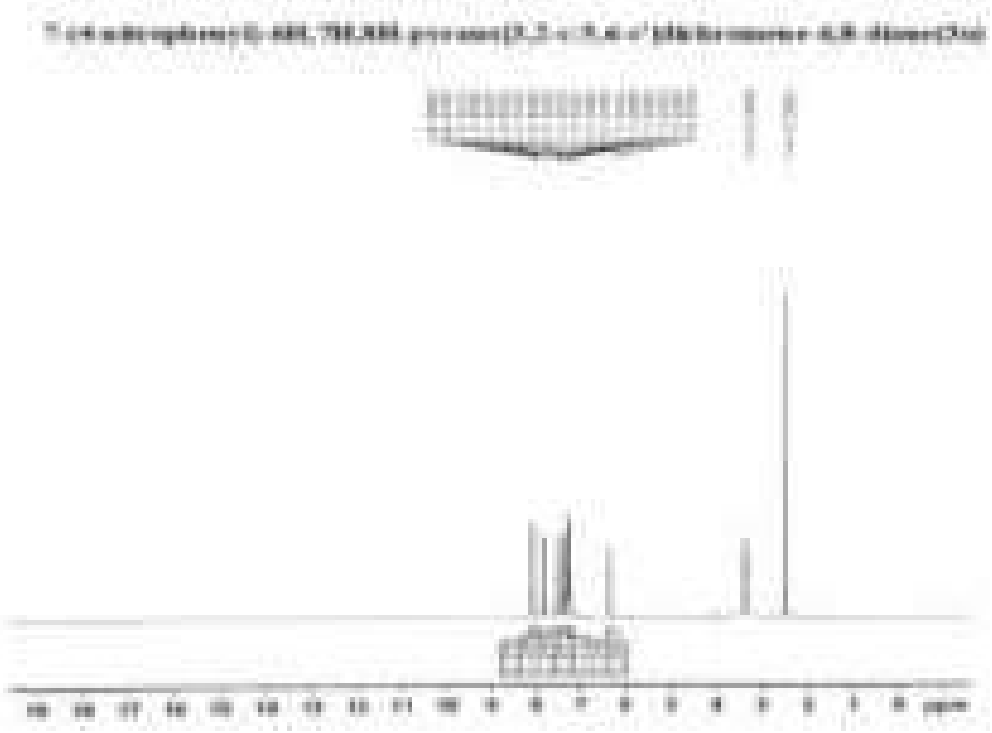


Figure III.40-^{1}H-NMR of compound 3o

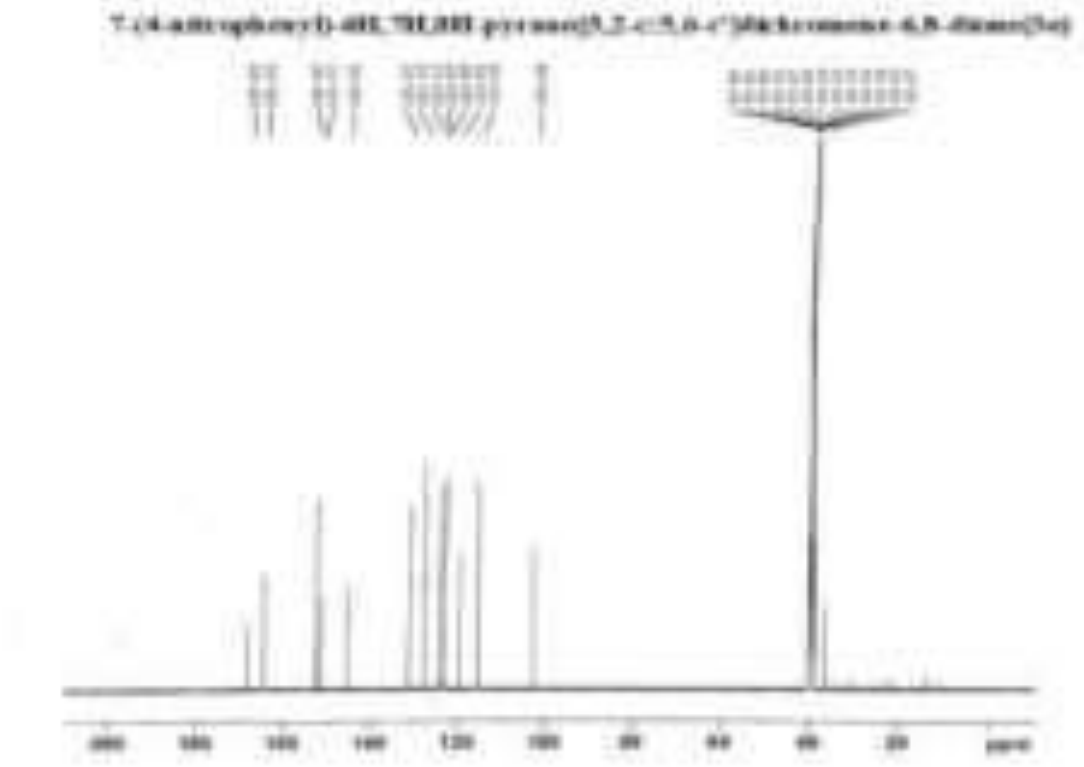


Figure III.41-^{13}C-NMR of compound 3o

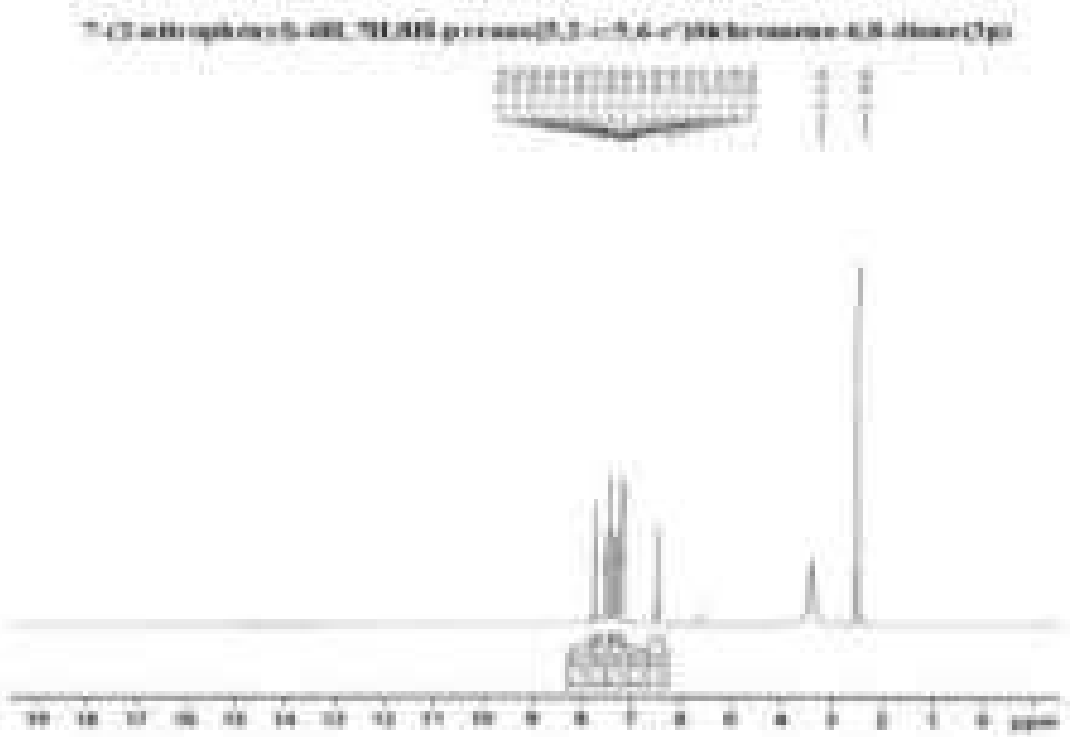


Figure III.42-^{1}H-NMR of compound 3p

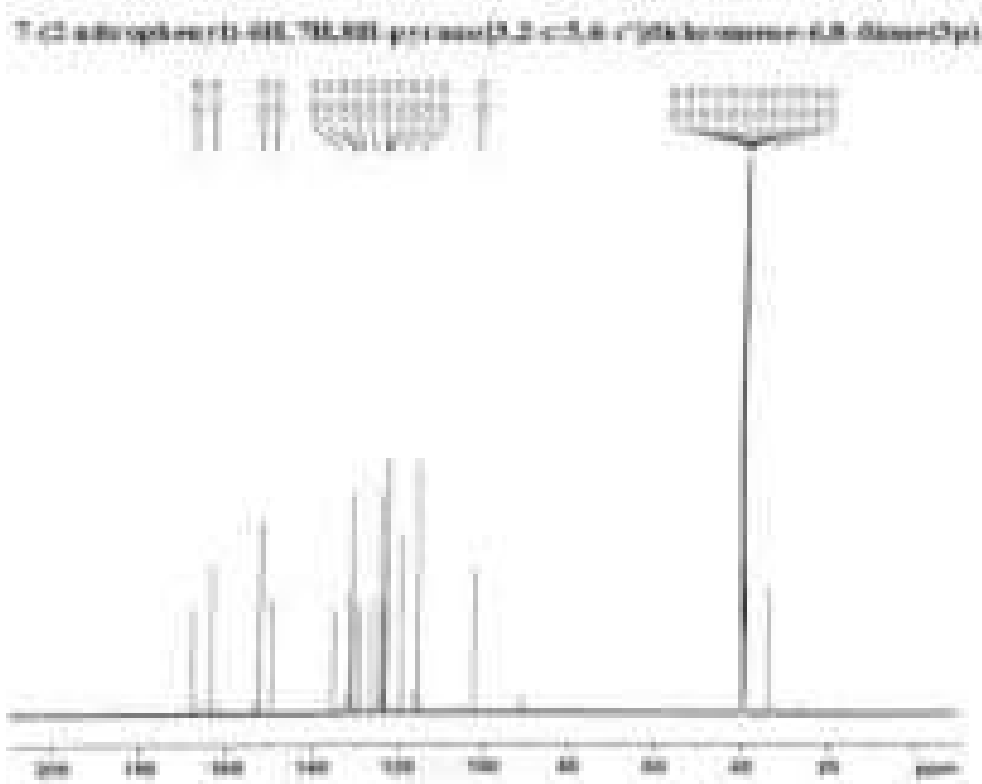
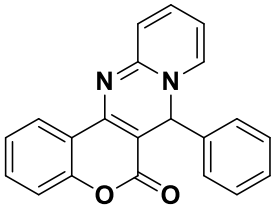


Figure III.43-^{13}C-NMR of compound 3p

III.8.A.12.g Spectral data of the compounds mentioned in scheme III.20

7-phenyl-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4a)



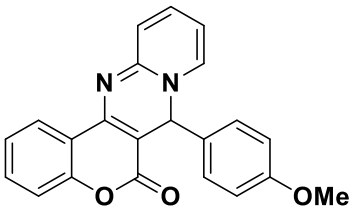
^{1}H-NMR(500MHz,DMSO-d_6)

δ(ppm)6.31(s,1H),6.81-6.83(m,1H),6.94-7.08(m,1H),7.12-7.15(m,1H),7.17-7.27(m,4H),
7.48-7.52(m,2H),7.83-7.92(m,4H).

^{13}C-NMR(500MHz,DMSO-d_6)

δ(ppm)36.06,103.34,112.01,113.01,115.36,119.86,122.79,124.04,124.71,126.57,127.60,130.81,136.58,142.24,143.57,152.42,154.13,164.61,167.71.

7-(4-methoxyphenyl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4b)



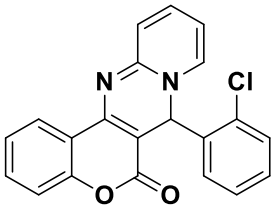
^{1}H-NMR(500MHz,DMSO-d_6)

δ(ppm)3.68(s,3H),6.21(s,1H),6.74(d,2H),6.99(d,2H),7.20-7.26(m,3H),7.48-7.51(m,2H),7.80(d, 1H),7.82(d,2H).

^{13}C-NMR(500MHz,DMSO-d_6)

δ(ppm)35.25,54.76,103.56,111.71,113.00,114.40,115.31,119.88,122.71,123.98,127.49,130.70,131.69,134.00,139.40,141.85,152.38,155.53,156.67,164.45,167.51.

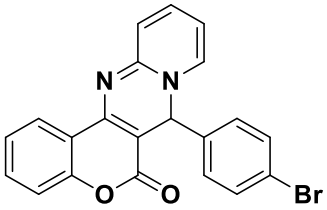
7-(2-chlorophenyl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4c)



^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)6.10(s,1H),6.82(m.1H),6.96(d,1H)7.11-7.25(m,5H),7.42(dd,1H),7.47-7.50(m,2H),7.81-7.92(m,3H).

^{13}C-NMR(500MHz,DMSO-d_6)
δ(ppm)36.02,102.68,112.02,113.14,115.34,119.81,122.80,123.95,125.87,126.93,129.23,130.27,130.72,132.60,136.26,140.29,143.78,152.31,153.96,163.82,167.63.

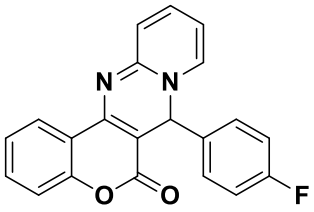
7-(4-bromophenyl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4d)



^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)6.24(s,1H),6.80-6.83(m,1H),6.94(d,1H),7.05-7.07(dd,1H),7.21-7.27(m,3H),7.33-7.36(m,1H),7.49-7.52(m,1H),7.81-7.92(m,4H).

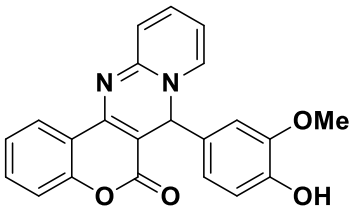
^{13}C-NMR(500MHz,DMSO-d_6)
δ(ppm)35.76,102.98,111.99,112.94,115.39,117.70,119.73,122.83,124.03,128.92,130.43,130.92,136.70,141.85,143.50,152.42,154.18,164.39,167.69.

7-(4-fluorophenyl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4e)



^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)6.27(s,1H),6.79-82(m,1H),6.92(d,1H),6.93-7.00(m,2H),7.11-7.14(m,1H),7.21-7.27(m,3H),7.49-7.52(m,1H),7.82-7.92(m,3H).
^{13}C-NMR(500MHz,DMSO-d_6)
δ(ppm)35.51,103.31,111.99,112.78,114.08,114.25,115.38,119.80,122.82,124.04,128.21,128.27,130.88,137.06,138.13,138.15,143.28,152.42,154.37,159.10,161.00,164.47,167.70.

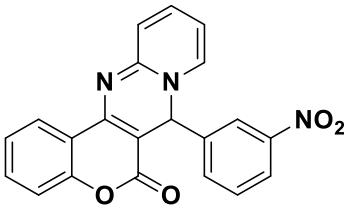
7-(4-hydroxy-3-methoxyphenyl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4f)



^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)3.54(s,3H),6.19(s,1H),6.52-6.54(m,1H),6.58(d,1H),6.82(s,1H),6.94(d,1H),
7.21-7.25(m,3H),7.47-7.51(m,1H),7.82-7.87(m,3H),8.53(broad s,1H).

^{13}C-NMR(500MHz,DMSO-d_6)
δ(ppm)35.56,55.59,103.72,111.68,112.04,112.98,114.81,115.33,119.20,119.93,122.
76,124.00,130.70,133.09,136.68,143.56,144.00,146.89,152.37,154.18,164.55,167.61
.

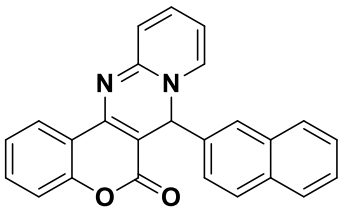
7-(3-nitrophenyl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4g)



^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)6.40(s,1H),6.81-6.83(m,1H),6.94(d,1H),7.23-7.30(m,2H),7.49-7.61(m,3H),
7.59-7.61(m,1H),7.83-7.94(m,4H),7.99-8.01(m,1H).

^{13}C-NMR(500MHz,DMSO-d_6)
δ(ppm)36.19,102.57,111.99,113.02,115.52,119.59,120.25,121.00,123.00,124.11,129
.28,131.17,133.74,136.55,143.58,145.05,147.68,152.48,154.12,164.37,167.94.

7-(naphthalen-2-yl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4h)



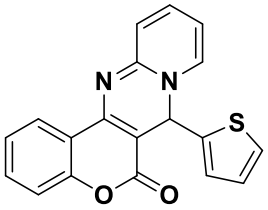
^{1}H-NMR(500MHz,DMSO-d_6)
δ(ppm)6.46(s,1H),6.76-6.79(m,1H),6.90(d,1H),7.23-7.32(m,1H),7.29-7.32(m,2H),

7.36-7.40(m,1H),7.51-7.54(m,2H),7.59(s,1H),7.70-7.72(dd,2H),7.78-7.85(m,3H),7.90(d,1H).

^{13}C-NMR(500MHz,DMSO-d_6)

δ(ppm)36.46,103.31,111.97,112.54,115.44,119.89,122.85,124.09,124.67,125.45,126.22,127.03,127.06,127.35,130.88,131.30,132.94,137.55,140.05,142.96,152.48,154.61,164.60,167.89.

7-(thiophen-2-yl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4i)



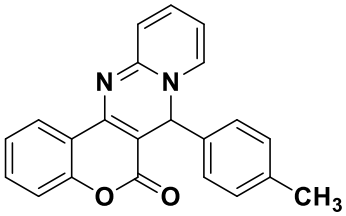
^{1}H-NMR(500MHz,DMSO-d_6)

δ(ppm)6.44(s,1H),6.60-6.61(m,1H),6.79-6.84(m,1H),6.95(d,1H),7.13-7.14(m,1H),7.22-7.26(m,3H),7.49-7.52(m,1H),7.85-7.91(m,3H).

^{13}C-NMR(500MHz,DMSO-d_6)

δ(ppm)32.84,103.64,112.01,113.08,115.40,119.79,122.54,122.86,122.93,124.13,126.02,130.99,136.41,143.69,147.99,152.39,154.04,164.05,167.86.

7-(p-tolyl)-6*H*,7*H*-chromeno[4,3-*d*]pyrido[1,2-*a*]pyrimidin-6-one(4j)



^{1}H-NMR(500MHz,DMSO-d_6)

δ(ppm)2.21(s,3H),6.21(s,1H),6.78-6.80(m,1H),6.88(d,1H),6.94-6.98(m,3H),7.20-7.25(m,3H),7.47-7.51(m,1H),7.79-7.84(m,2H),7.91-7.92(m,1H).

^{13}C-NMR(500MHz,DMSO-d_6)

δ(ppm)20.39,35.65,103.42,111.96,112.34,115.30,119.87,122.70,123.98,126.46,128.15,130.70,133.32,137.97,139.14,142.76,152.38,154.80,164.42,167.50.

III.8.A.12.h Sanned copies of compounds mentioned in scheme III.20

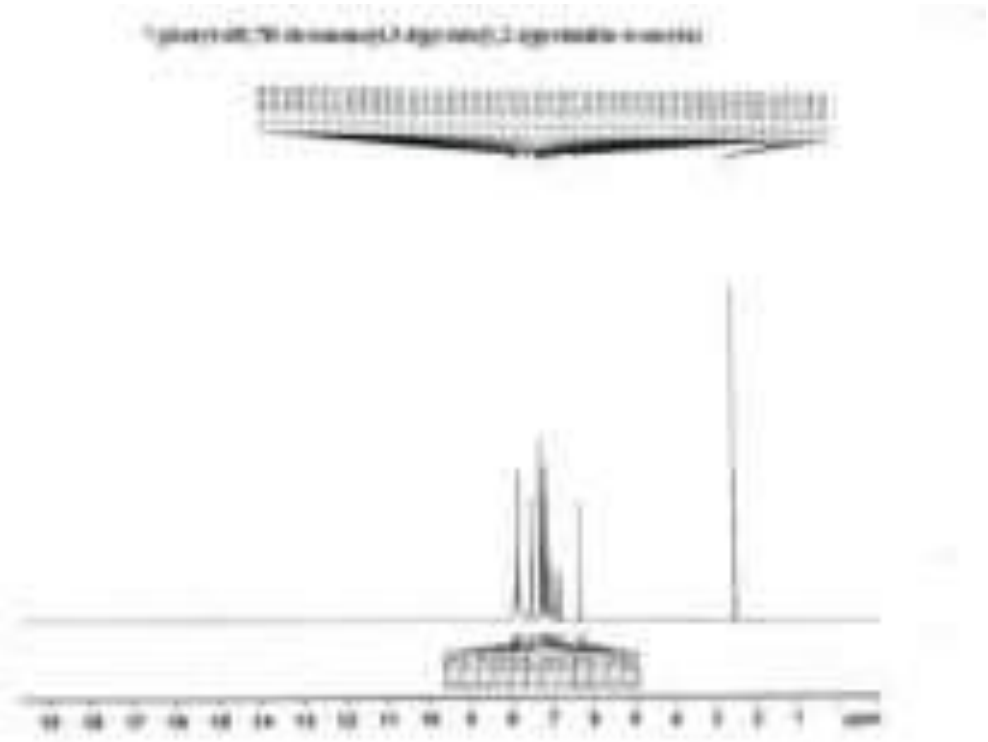


Figure III.44-^{1}H-NMR of compound 4a

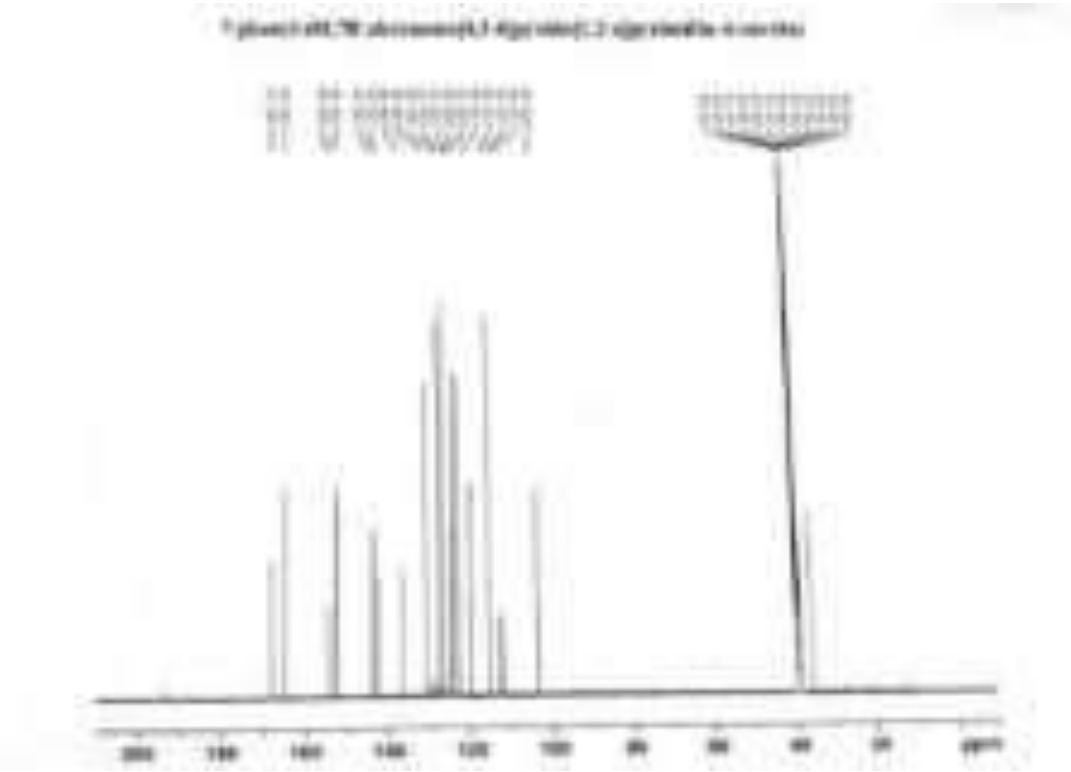


Figure III.45-^{13}C-NMR of compound 4a

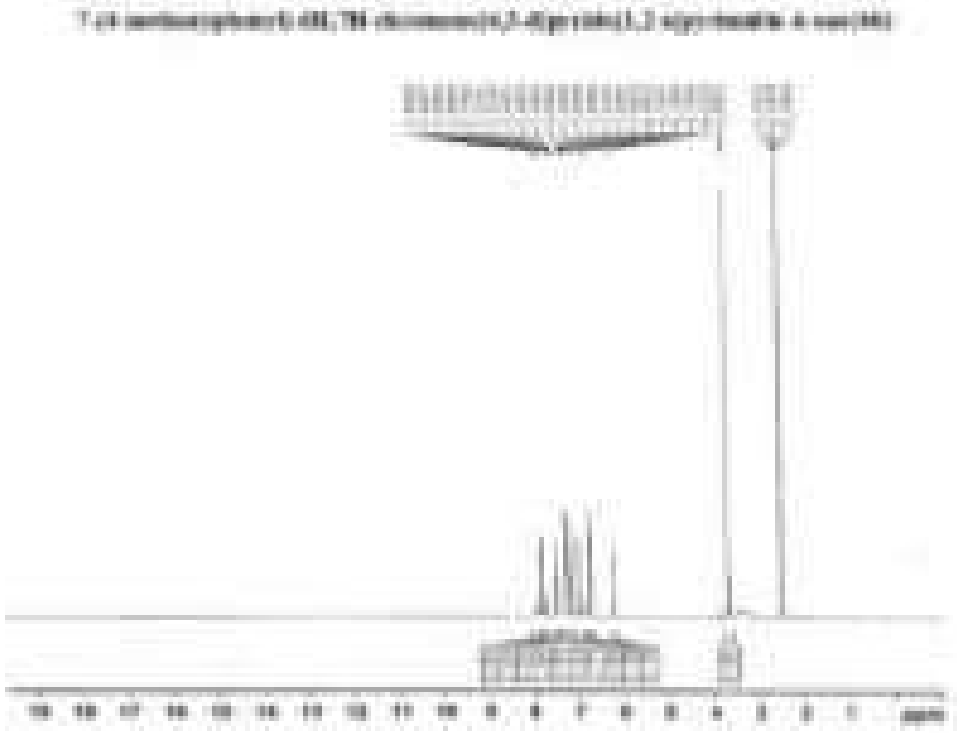


Figure III.46-^{1}H-NMR of compound 4b

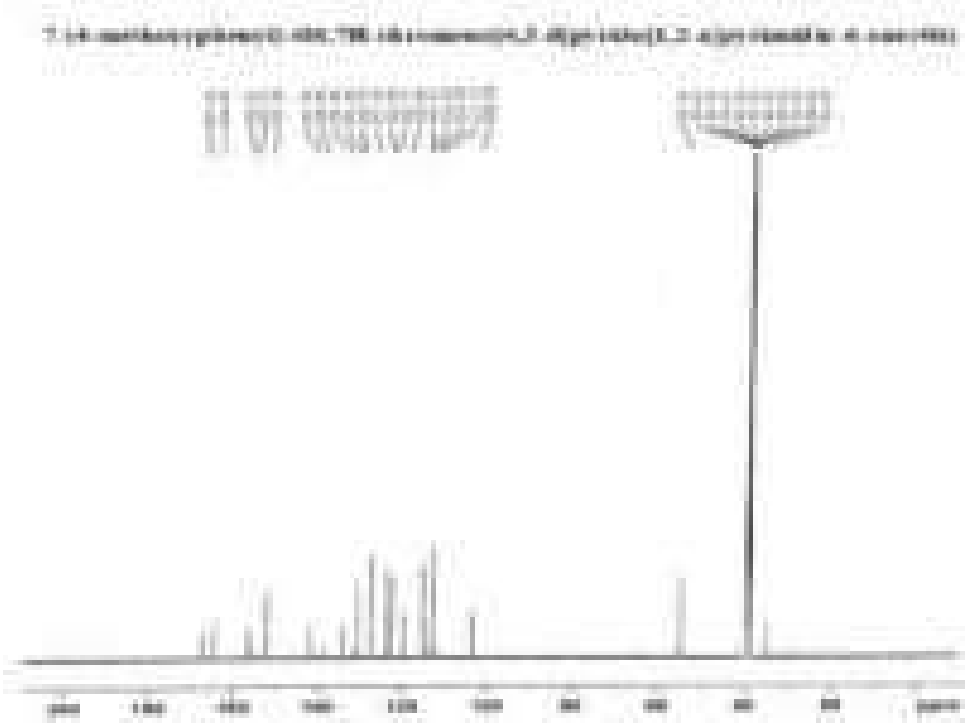


Figure III.47-^{13}C-NMR of compound 4b

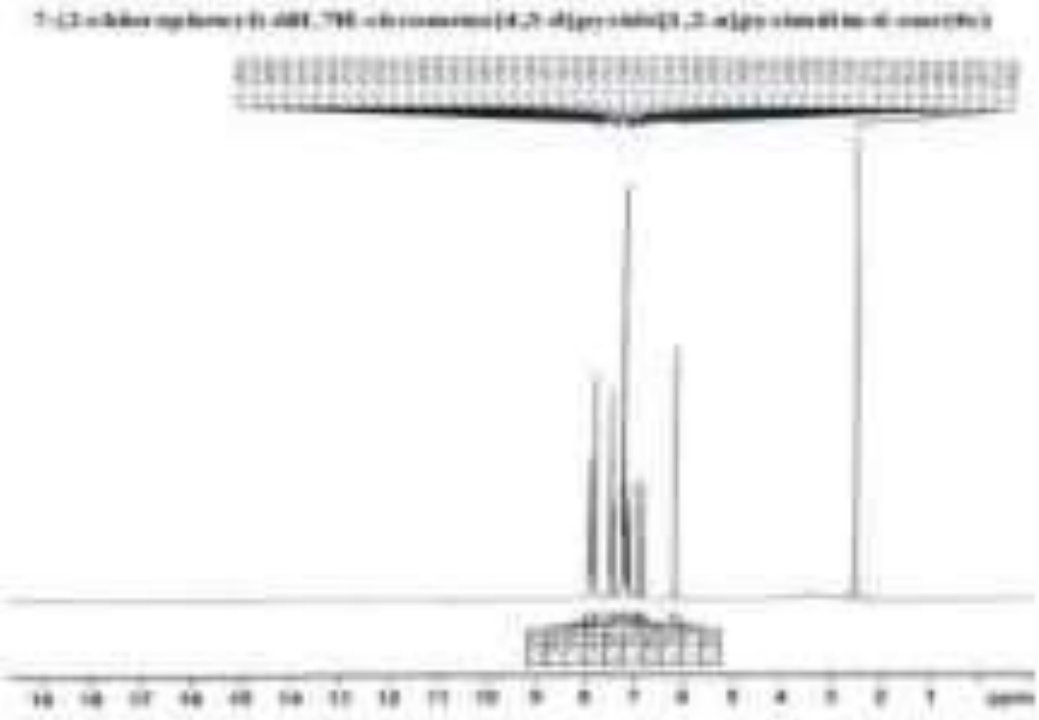


Figure III.48-^{1}H-NMR of compound 4c

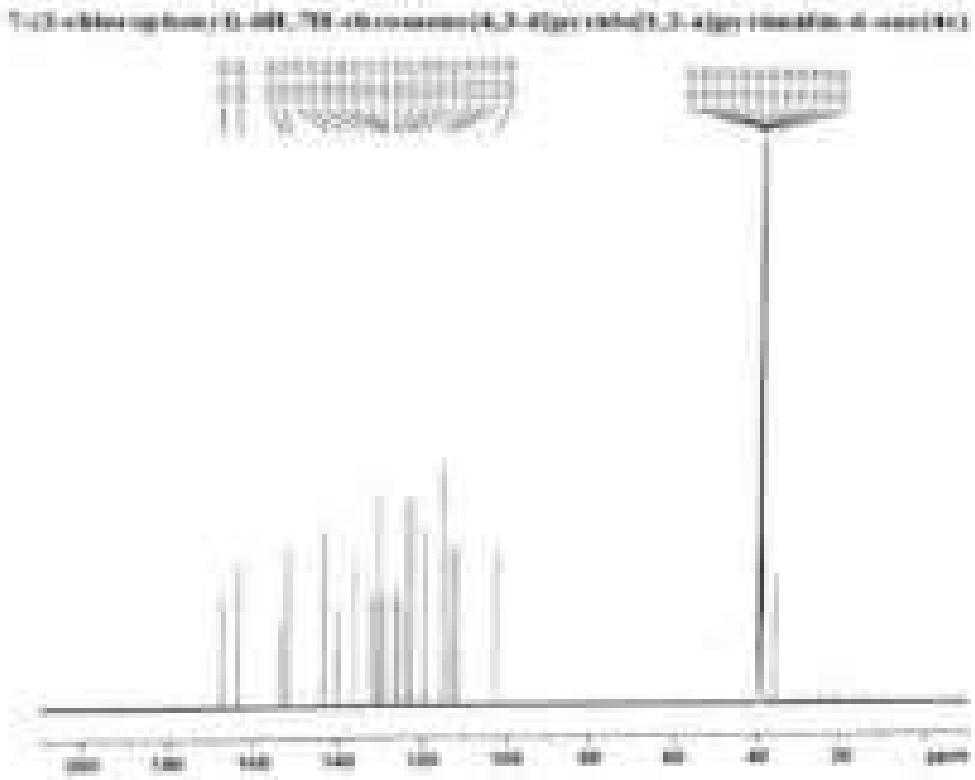


Figure III.49-^{13}C-NMR of compound 4c

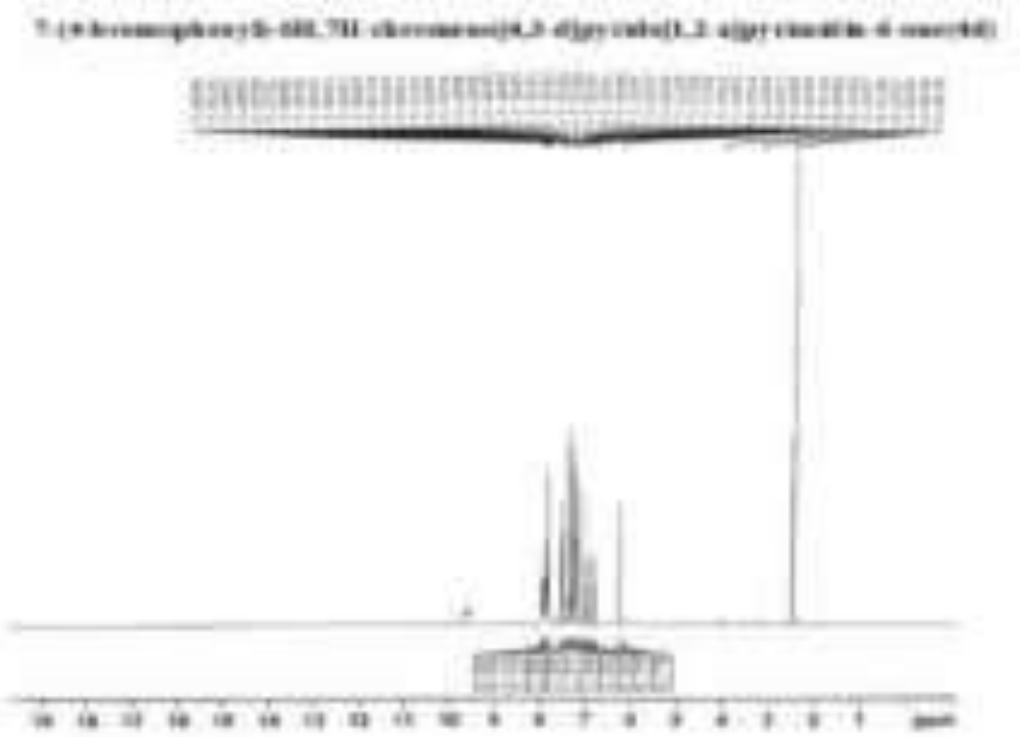


Figure III.50-^{1}H-NMR of compound 4d

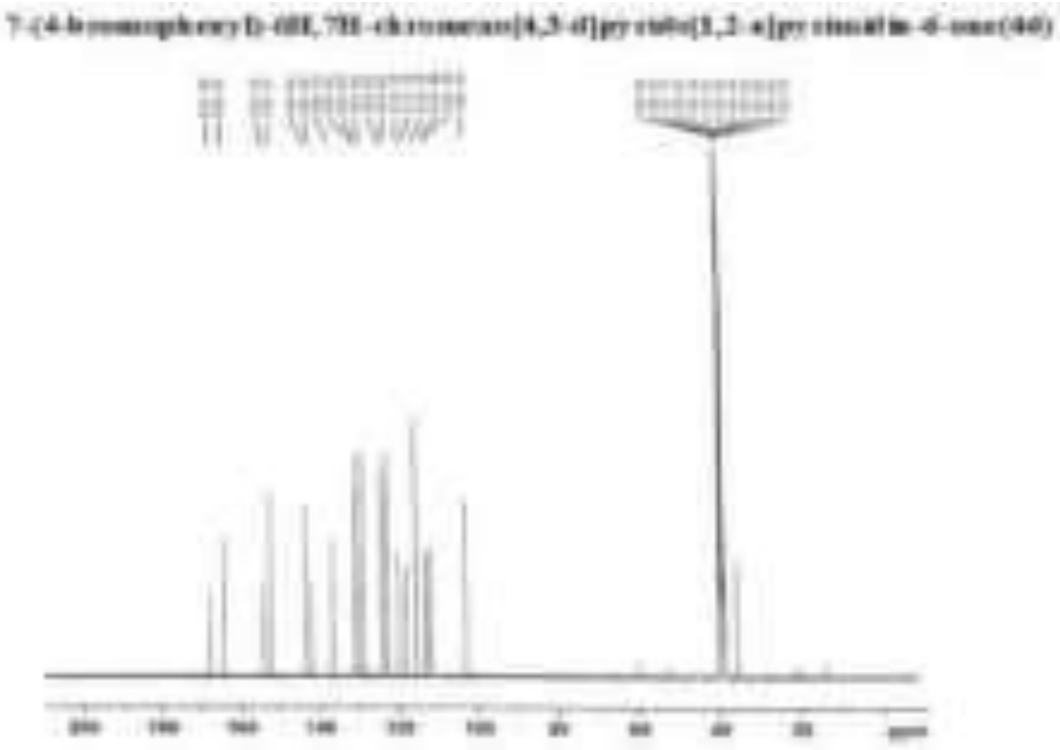


Figure III.51-^{13}C-NMR of compound 4d

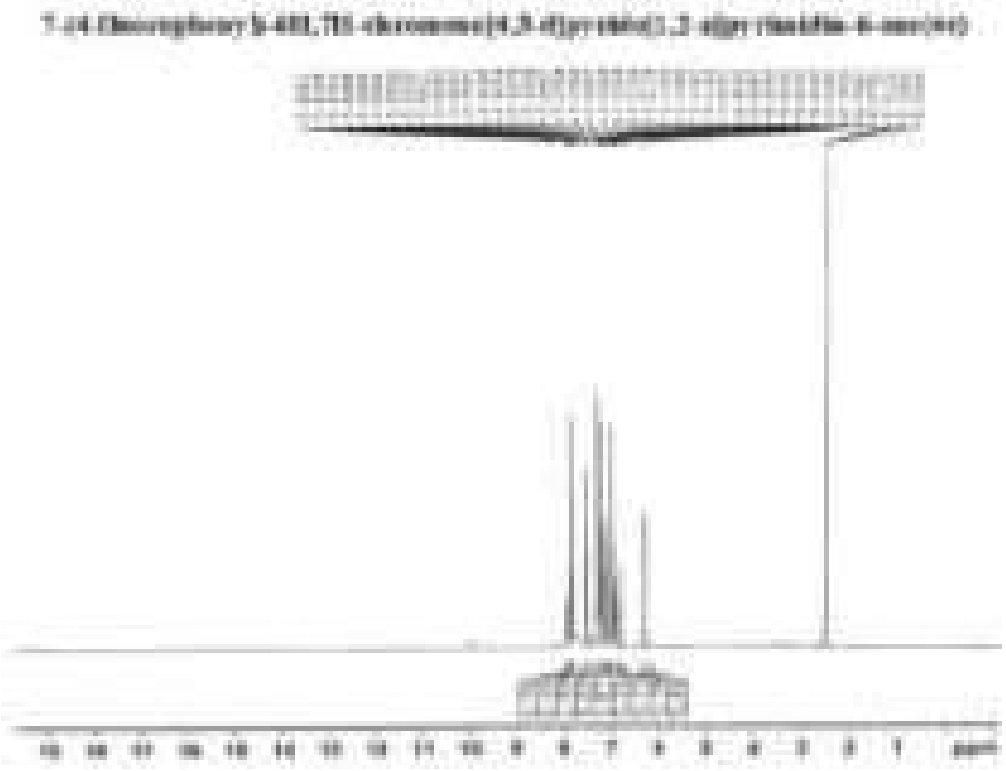


Figure III.52-^{1}H-NMR of compound 4e

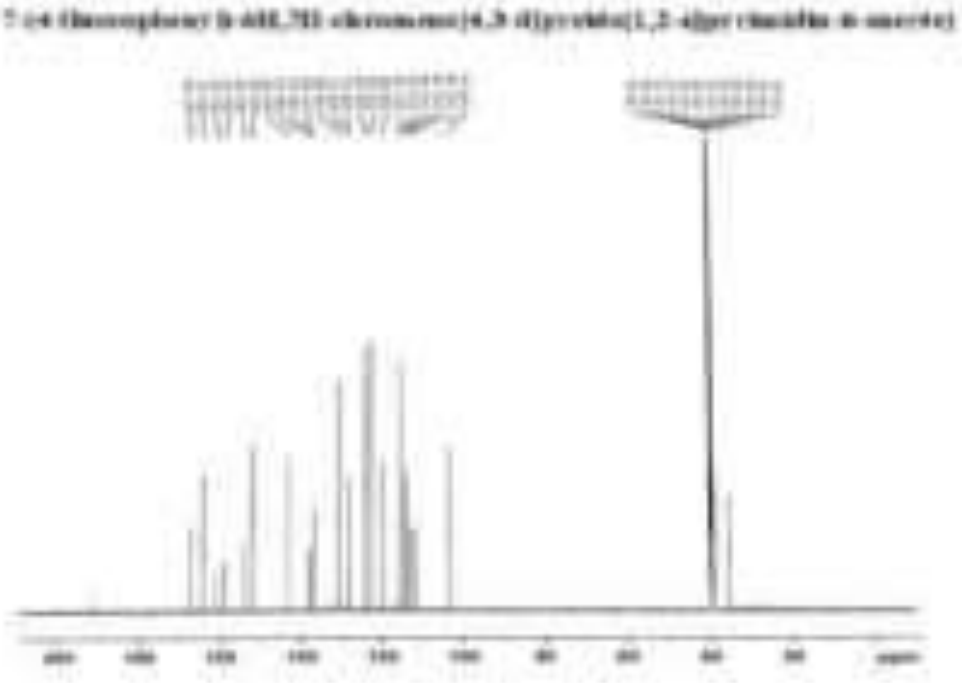


Figure III.53-^{13}C-NMR of compound 4e

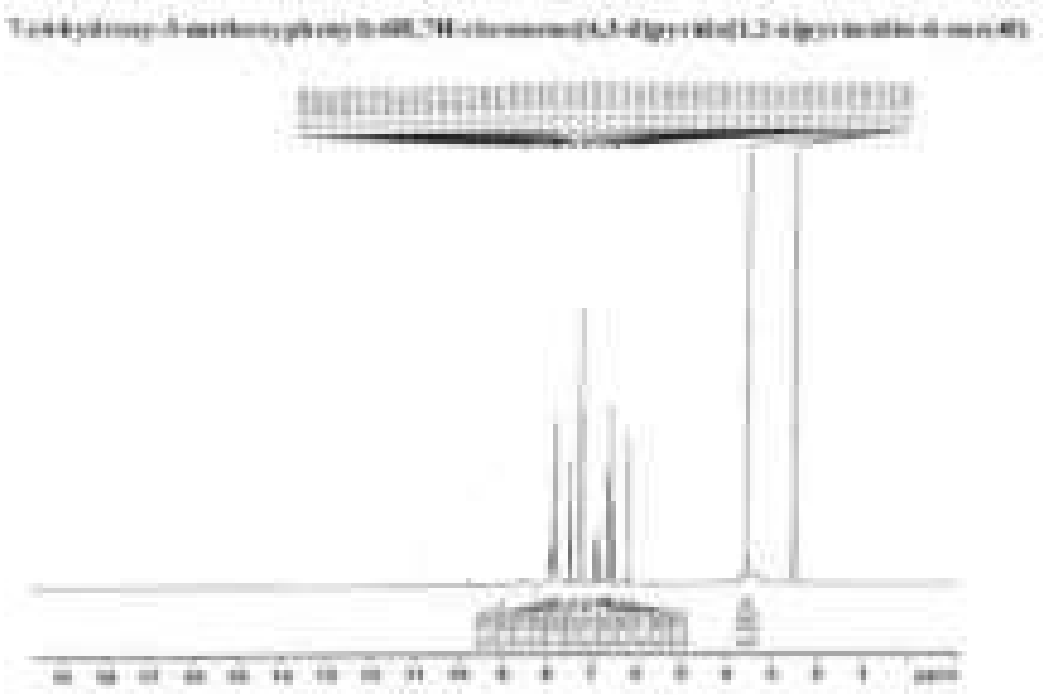


Figure III.54-^{1}H-NMR of compound 4f

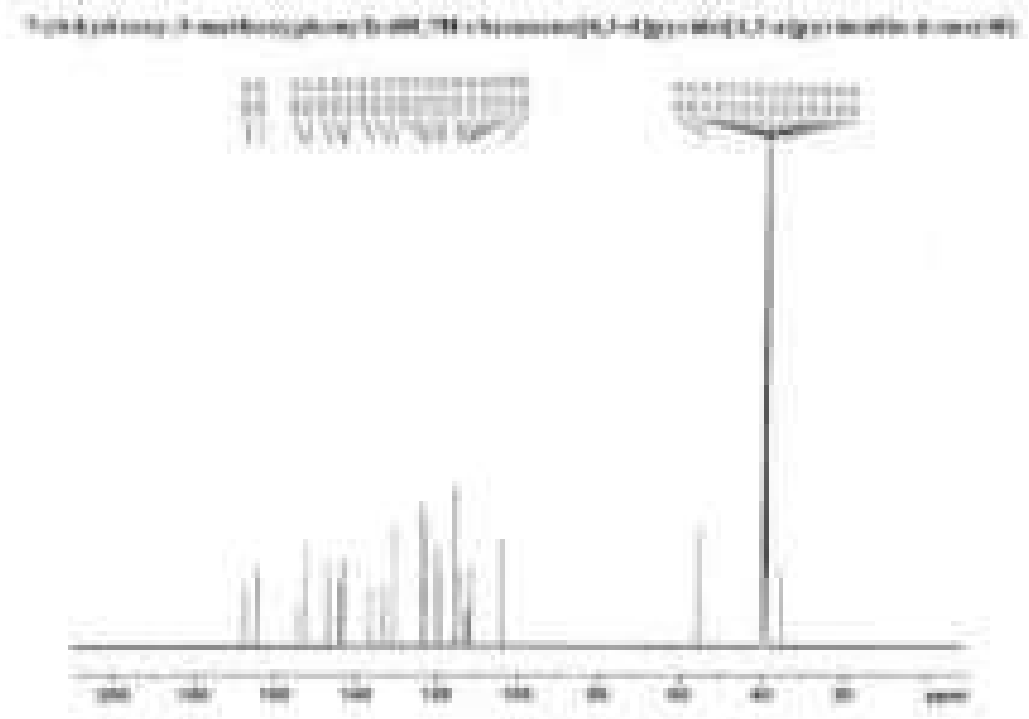


Figure III.55-^{13}C-NMR of compound 4f

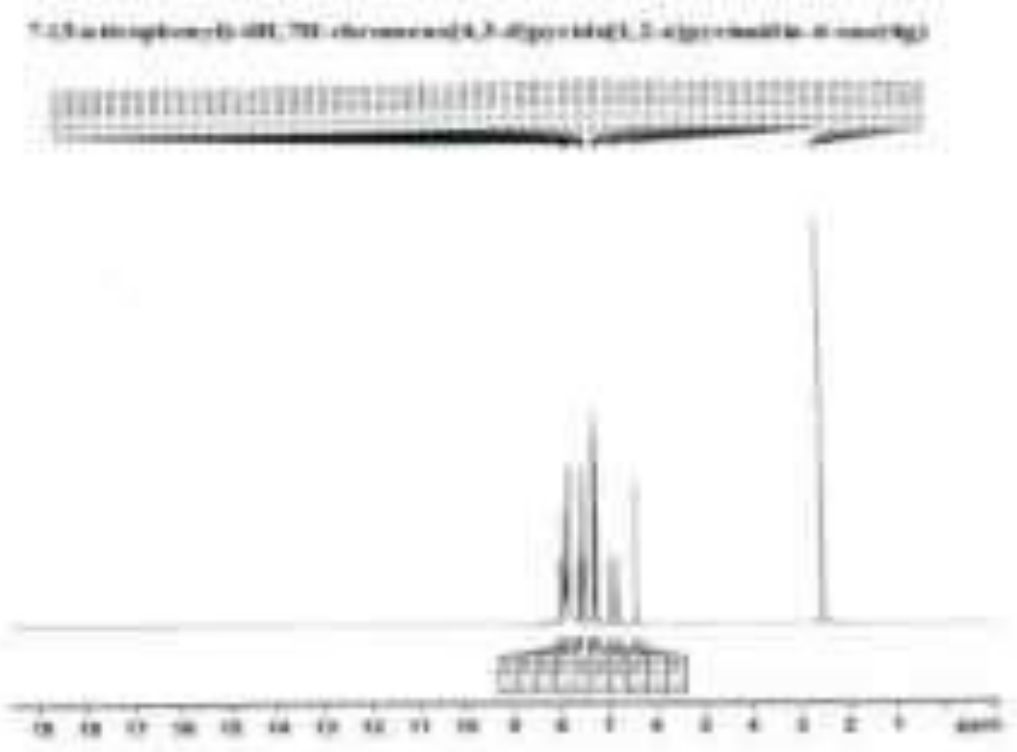


Figure III.56-^{1}H-NMR of compound 4g

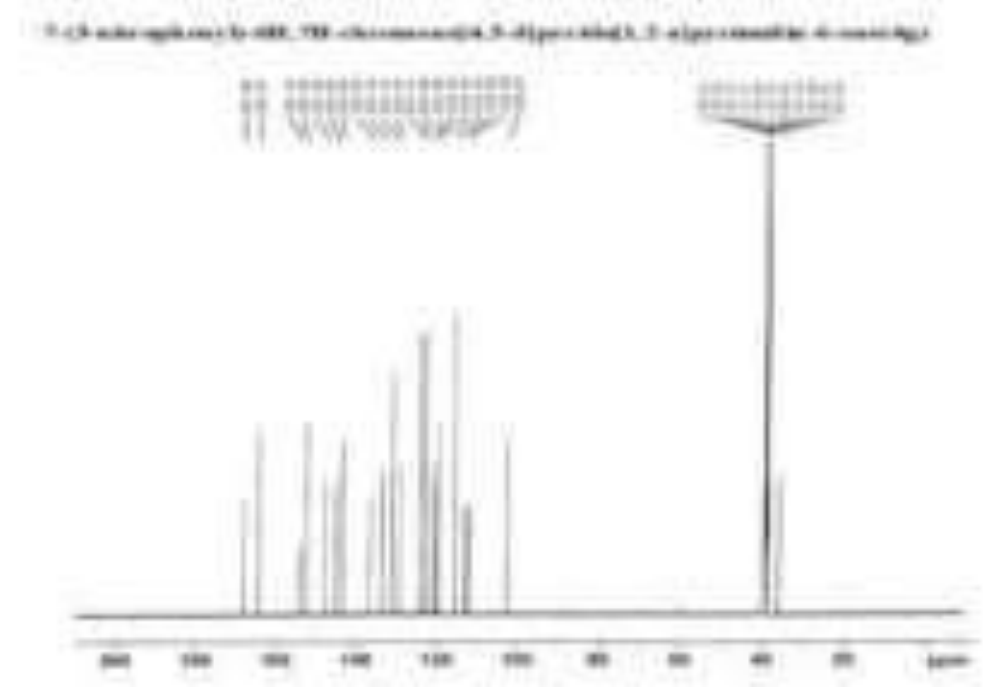


Figure III.57-^{13}C-NMR of compound 4g

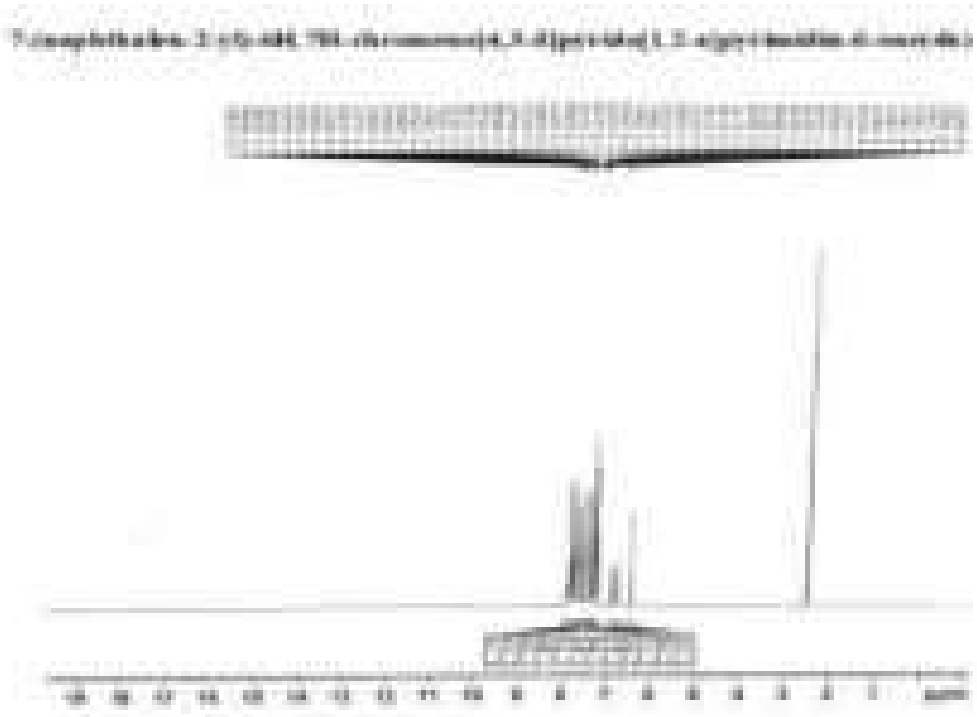


Figure III.58-^{1}H-NMR of compound 4h

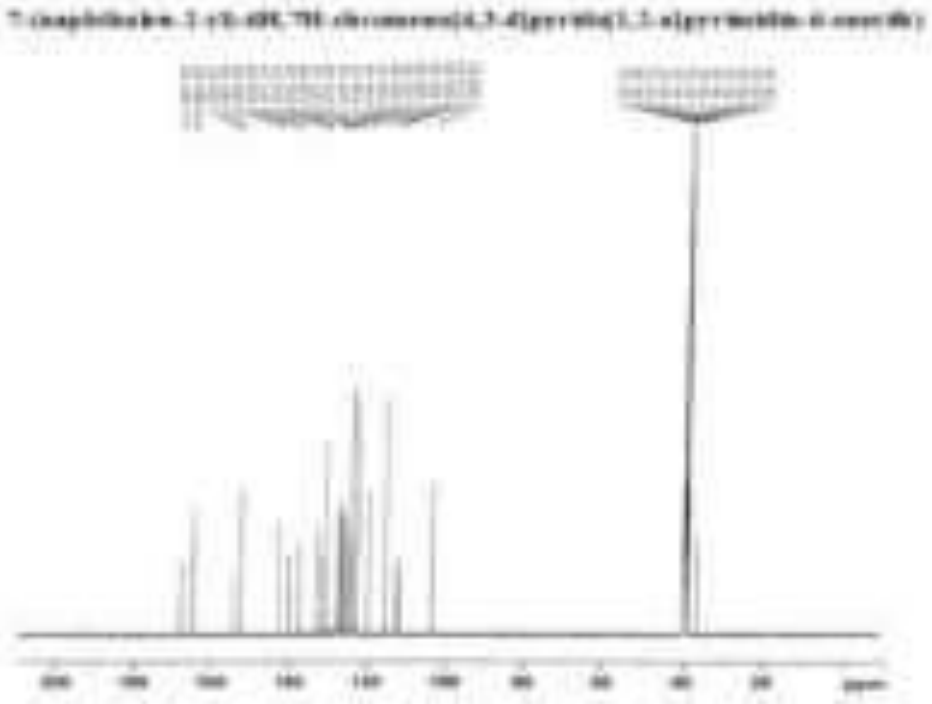


Figure III.59-^{13}C-NMR of compound 4h

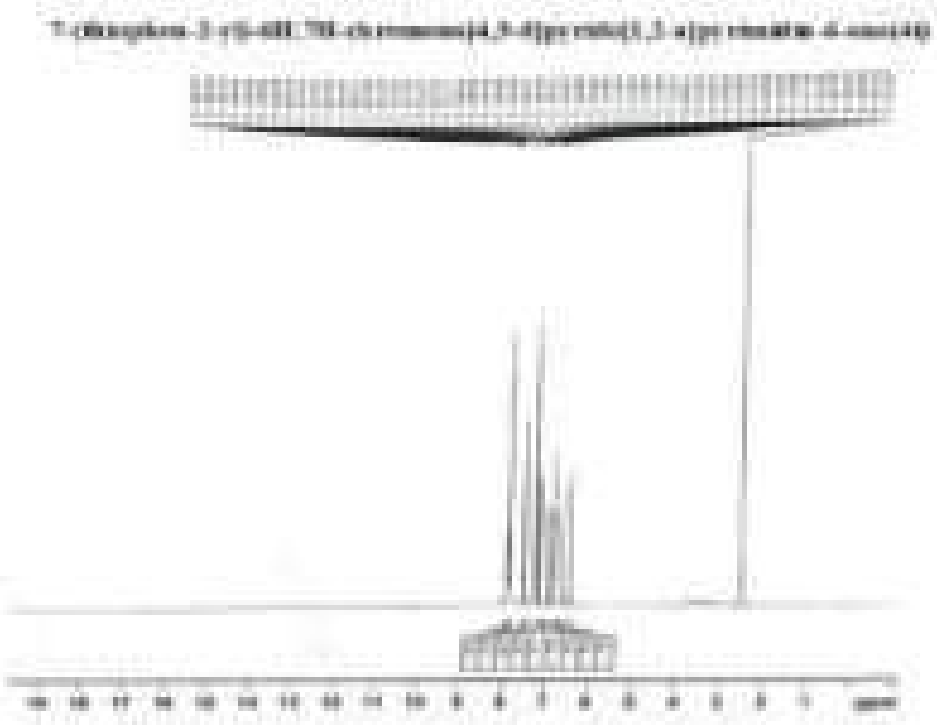


Figure III.60-^{1}H-NMR of compound 4i

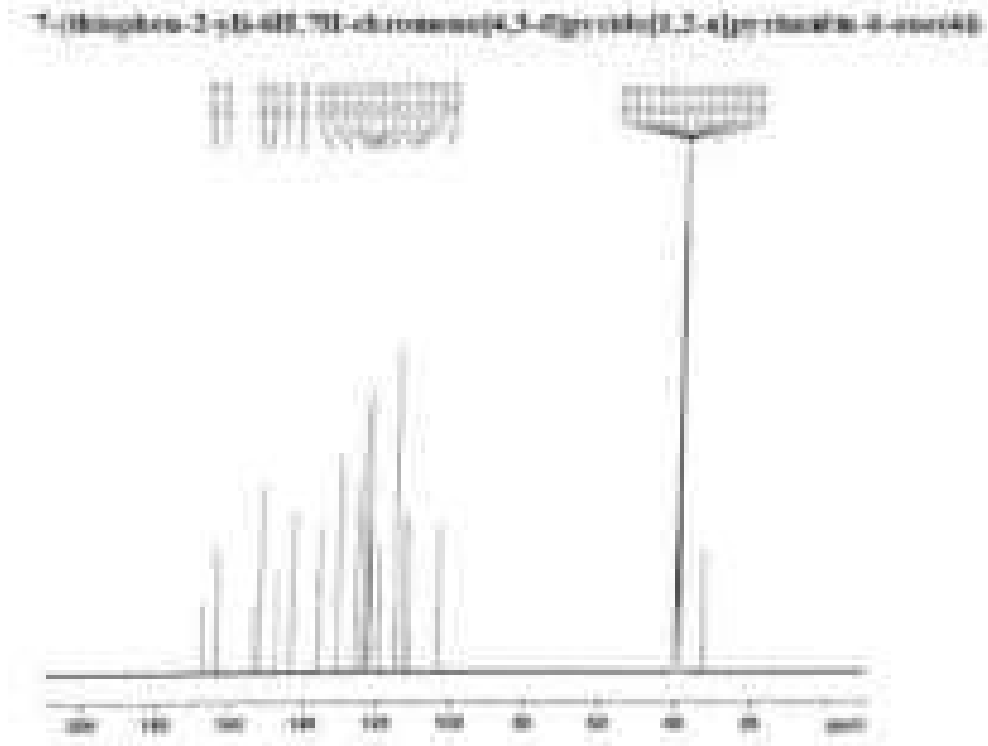


Figure III.61-^{13}C-NMR of compound 4i

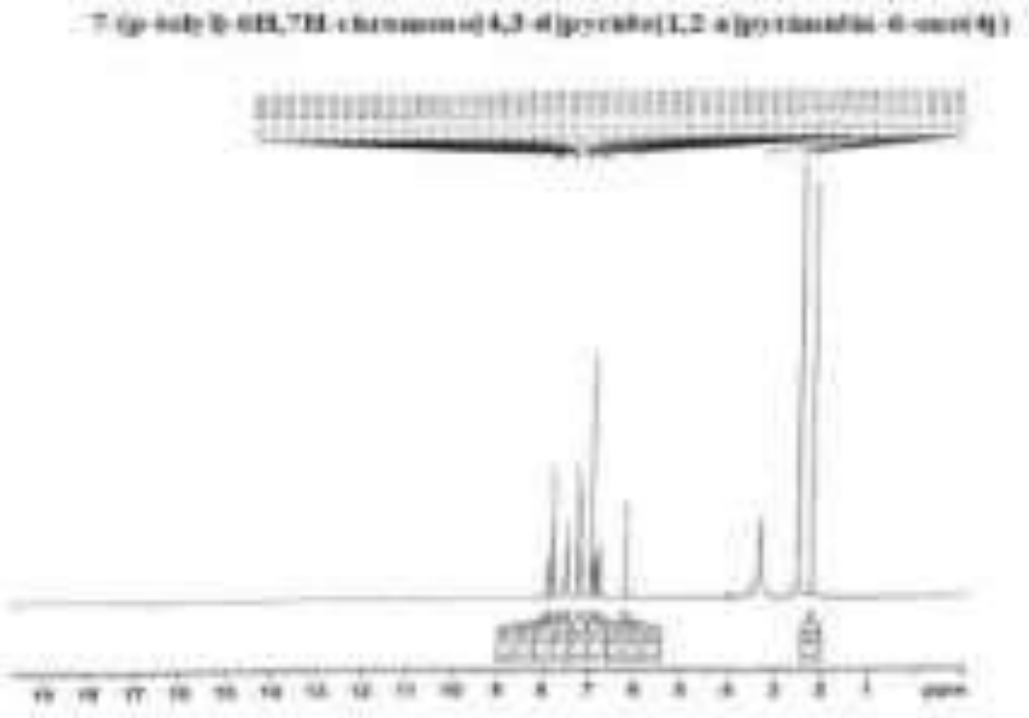


Figure III.62-^{1}H-NMR of compound 4j

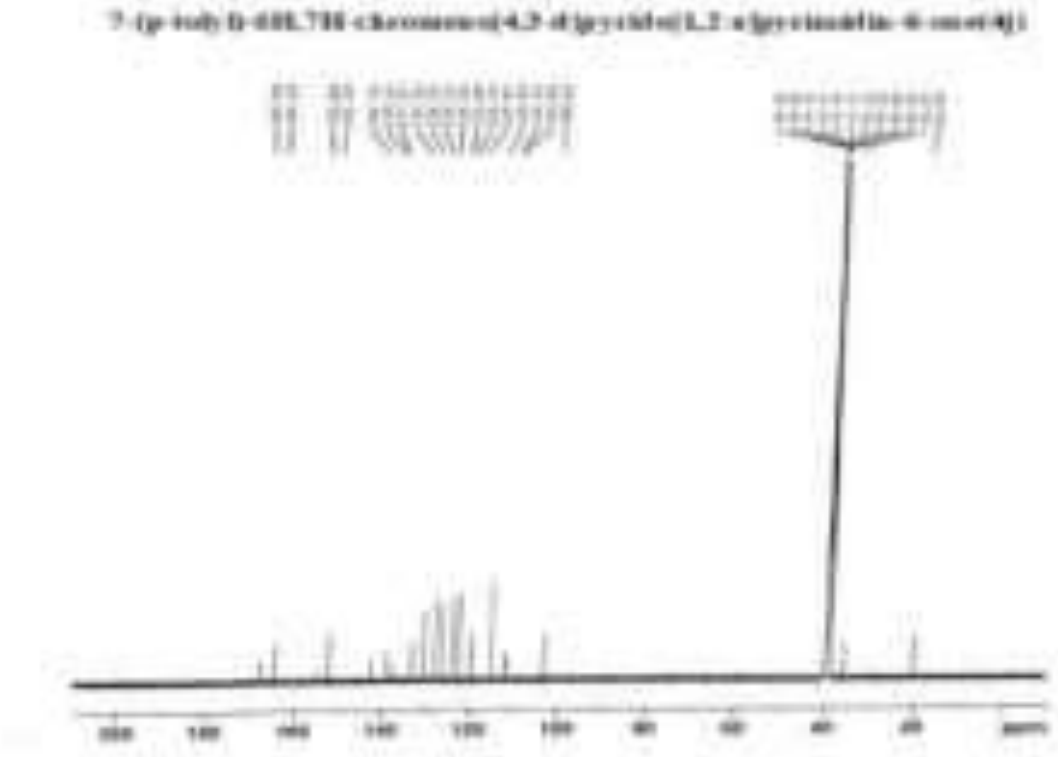


Figure III.63-^{13}C-NMR of compound 4j

III.7.A.12.i EDX data of sulphonated rice husk (SRH) and rice husk(RH)

EDX data of SRH and RH respectively are given below-

Project 1

1/21/2019 2:26:03 PM

Spectrum processing :

Peaks possibly omitted : 8.043, 8.626 keV

Processing option : All elements analyzed (Normalised)

Number of iterations = 6

Standard :

C CaCO3 1-Jun-1999 12:00 AM

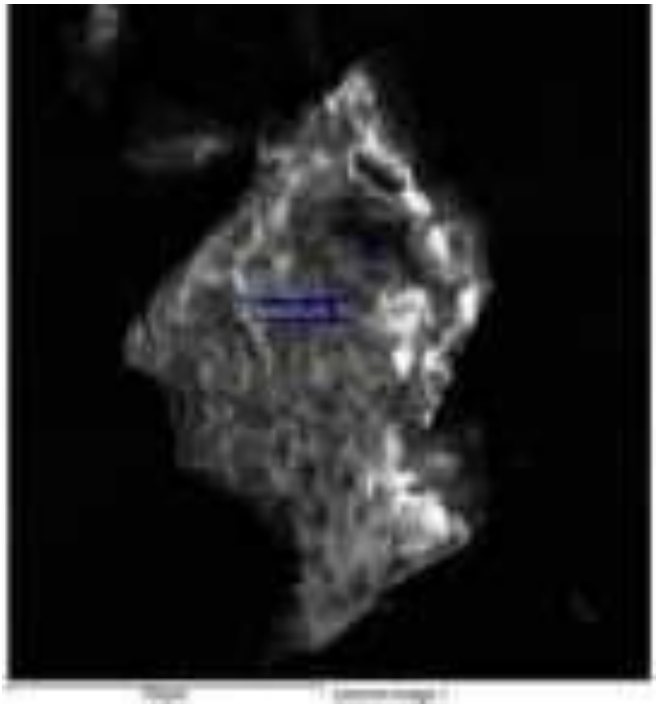
O SiO2 1-Jun-1999 12:00 AM

Si SiO2 1-Jun-1999 12:00 AM

S FeS2 1-Jun-1999 12:00 AM

Cl KCl 1-Jun-1999 12:00 AM

K MAD-10 Feldspar 1-Jun-1999 12:00 AM



Element	App Conc.	Intensity Corrn.	Weight%	Weight% Sigma	Atomic%
C K	71.39	0.4111	57.29	0.88	68.73
O K	24.20	0.3287	24.30	0.70	21.88
Si K	50.69	0.9435	17.73	0.37	9.09

Comment:sourav

S K	0.96	0.7957	0.40	0.04	0.18
Cl K	0.40	0.7250	0.18	0.03	0.07
K K	0.30	0.9905	0.10	0.03	0.04

Totals	100.00

Project 1

1/21/2019 2:13:48 PM

Spectrum processing :

Peaks possibly omitted : 8.036, 8.640, 8.905 keV

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

C CaCO3 1-Jun-1999 12:00 AM

O SiO2 1-Jun-1999 12:00 AM

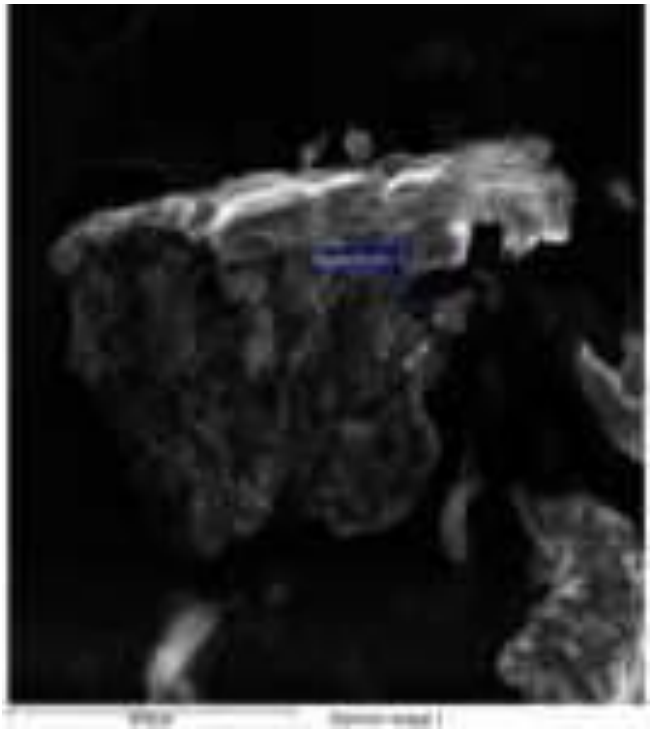
Mg MgO 1-Jun-1999 12:00 AM

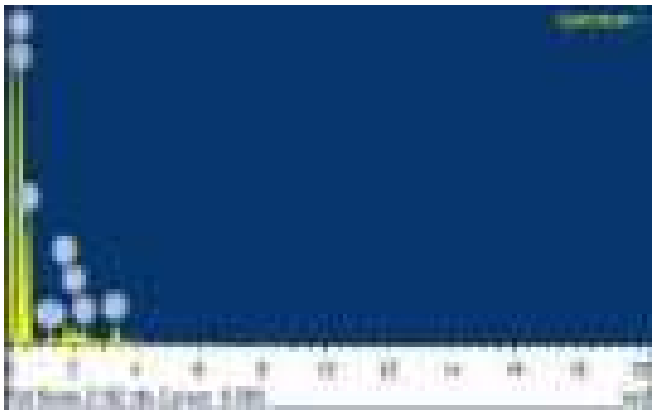
Si SiO2 1-Jun-1999 12:00 AM

P GaP 1-Jun-1999 12:00 AM

S FeS2 1-Jun-1999 12:00 AM

K MAD-10 Feldspar 1-Jun-1999 12:00 AM





Element	App Conc.	Intensity Corrn.	Weight%	Weight% Sigma	Atomic%
C K	122.06	1.0292	55.96	0.82	63.40
O K	34.95	0.3931	41.95	0.81	35.68
Mg K	0.42	0.6145	0.32	0.05	0.18
Si K	0.87	0.8459	0.48	0.04	0.23

Comment:sourav

P K	0.92	1.2546	0.35	0.05	0.15
S K	0.69	0.9358	0.35	0.04	0.15
K K	1.32	1.0579	0.59	0.04	0.20
Totals			100.00		

III.9 References

References are given in BIBLIOGRAPHY under Chapter III.