C-H Alkoxycarbonylation of Coumarin Derivatives

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By

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DEPARTMENT OF CHEMISTRY

INDIAN INSTITUTE OF TECHNOLOGY INDORE

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A THESIS

Submitted in partial fulfilment

Of the requirements for the award of the degree

Of

Master of Science

by

Shalini Gupta

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being reported in this thesis entitle **"C-H Alkoxycaronylation of Coumarin Derivatives"** in the partial fulfilment of the requirements for the award of the degree of **Master of Science** and submitted in the **Department of Chemistry**, **Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the period from October, 2021 to May, 2022 under the supervision of **Dr. Umesh A. Kshirsagar,** Assistant professor, Department of Chemistry, IIT Indore.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

Shalini Gupta

Shalini Gupta

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

Dr. Umesh A. Kshirsagar

Shalini Gupta has successfully given her M.Sc. Oral Examination held on **25 May 2022.**

Signature of Supervisor of MSc thesis	Convener, DPGC
Dr. Umesh A. Kshirsagar	**Dr. Tushar Kanti Mukherjee**
Date	Date
Signature of PSPC member	Signature of PSPC member
Dr. Tridib Kumar Sharma	**Prof. Sampak Samanta**
Date	Date

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Shalini Gupta

Department of Chemistry

DEDICATE TO MY FAMILY, FRIENDS

AND TEACHERS.....

ABSTRACT

Now a days, different type of diseases like tuberculosis, tumor, inflammatory, cancer and several other diseases are spread all over the world. So, for the controlling these diseases, different type of drugs had made. In the synthesis of these drugs heterocyclic compounds play an important role. In this project, we have done a detailed study on the topic **"C-H Alkoxycarbonylation of Coumarin Derivatives."** We did alkoxycarbonylation of Coumarin heterocyclic compound by the help of Methyl Carbazate which is used as ester source. Coumarins are functionalized by Methyl Carbazate in the presence of oxidant and solvent under Blue LED light at the room temperature via Photocatalysis to give the desired product. Blue Led is ideal towards the green chemistry.

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ACRONYMS

CH_3CN	Acetonitrile
CDC	Cross- Dehydrogenative Coupling
DMSO	Dimethyl Sulfoxide
ESI	Electron Spray Ionization
HRMS	High Resolution Mass Spectrometry
HIV	Human Immune-deficiency Virus
LCMS	Liquid Chromatography Mass Spectrometry
MDR	Multidrug Resistant
ppm	Parts per million
^{1}H NMR	Proton NMR Spectroscopy
^{13}C NMR	^{13}C NMR Spectroscopy
RB	Rose Bengal
SET	Single Electron Transfer
TCI	Tokyo Chemical Industry
XRD	X-ray Diffraction

NOMENCLATURE

δ	chemical shift
°C	degree Celsius
eq	equivalent
h	hour
mmol	millimole
mg	milligram
ml	millilitre
min	minutes
rt	room temperature

Chapter 1

A: INTRODUCTION

Basically, Coumarins and their derivatives are oxygen containing heterocyclic compounds. It belongs to benzopyron family.[1] These are biological and pharmacological active compounds. These are naturally occurring in the biologically active form. They are mainly obtained from the plant's part such as root leaves, flower and fruits. In **1820, Vogel,** first extract it from tonka beans *(Dipteryx odoranta)* plant, which belong to family **Fabaceae**.[1] It is also found in some other medicinal plants such as vanilla grass (*Anthoxanthum odoratum*), sweet clover (*genus Melilotus*), and cassia cinnamon (*Cinnamomum cassia*) in concentrates of Justicia pectoralis, and countless cherry bloom trees and a few species from the **Apiaceae** family.[1] Coumarin is also known as **2H-chromen 2-one.** Its IUPAC name is **chromen 2-one.** Chemically, it belongs to the subset of lactones.[1] Other name of coumarin is 1,2-benzopyrone or o-hydroxycinnamic acid-8-lactone. Most of the coumarin derivates are thermally stable. Calanolides is a naturally occurring coumarin which is obtain from the Calophyllum genus, it has strong anti- HIV activities.[2] The coumarin skeleton is composed of two six-membered rings with lactone carbonyl groups.

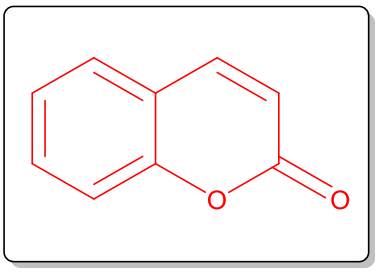


Fig-1- Structure of coumarin skeleton

Natural coumarin divided into 6 fundamental group. These groups are- ***Phenyl Coumarins, Pyrano coumarins (linear type and angular type), simple coumarins, Furanocoumarins, Dihydrofurano Coumarins, and Bicoumarins***.[1] These are shown in figure 2.

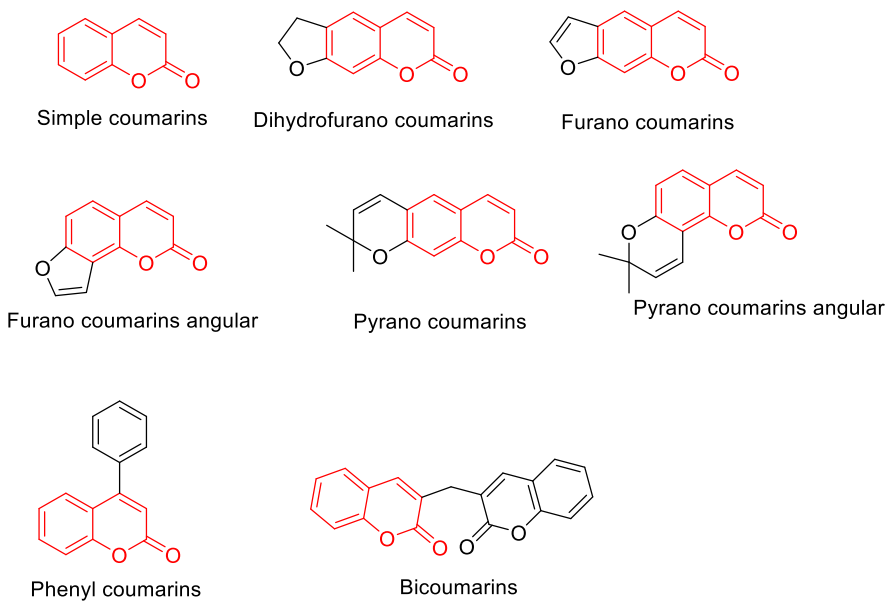


Fig 2: Six fundamental groups of natural coumarins.

Due to their lipophilic nature, Coumarins can bind to their biological counterparts, especially lipophilic binding sites, and are stabilized by strong hydrophobic or π-π stacking interactions with aromatic amino acids, such as Phenylalanine, Tyrosine and Tryptophan.[3]

The synthesis of coumarins and their derivatives can be accomplished in a variety of ways, such as Pechmann condensation,[4] Wittig reaction,[5] Parkin condensation,[6] and Knoevenagel reaction.[7] In all the method, one of the valuable methods are Pechmann condensation,[4] in which a reaction performs between Phenol or phenol derivatives and ethyl acetoacetate in presence of concentrated sulfuric acid.

C-3 functionalization of coumarin mainly take place by cross dehydrogenative coupling (CDC) and C-H activation. In the Cross dehydrogenative coupling reaction new C-C and C-X (X= heteroatom) bond formation takes place.[8]

Coumarin and their derivatives are biologically active. Clinically, they are used as an anti-cancer,[9] anti-bacterial,[10] anti-coagulant,[10] anti-Alzheimer,[10] anti-oxidant, anti-HIV agent,[10] anti-viral, anti-dementia agent.[10] Among the all coumarin derivatives C-3 derivatives of coumarin are more widely spread due to their potential application biological field.

They are also broadly used in agrochemicals, perfumes, insecticides, in food and cosmetics as additive. C-H functionalization have mainly done at C-3 position because C-3 functionalized derivatives are biologically active.

They are use as anti-cancer, anti-tumor, ant anti-bacterial, anti-HIV, anti-oxidant agent. They are also use as Laser dyes, Photosensitizers, Fluorescent indicators, Optical brighteners.

Some C-3 derivatives of coumarin compounds are given below. These are clinically used coumarin derivatives.[11,12]

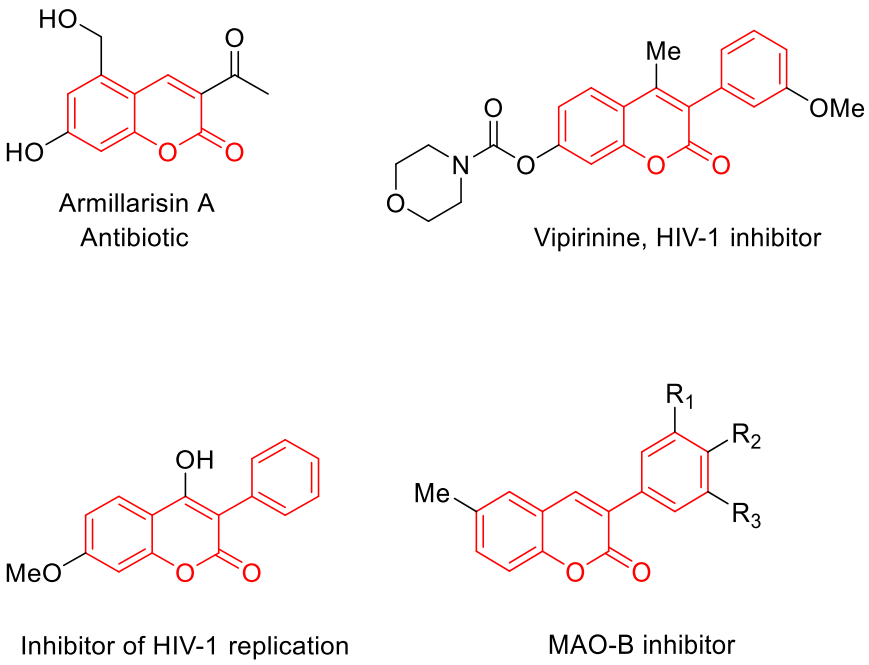


Fig-3- Biologically active C-3 derivatives.[11, 12]

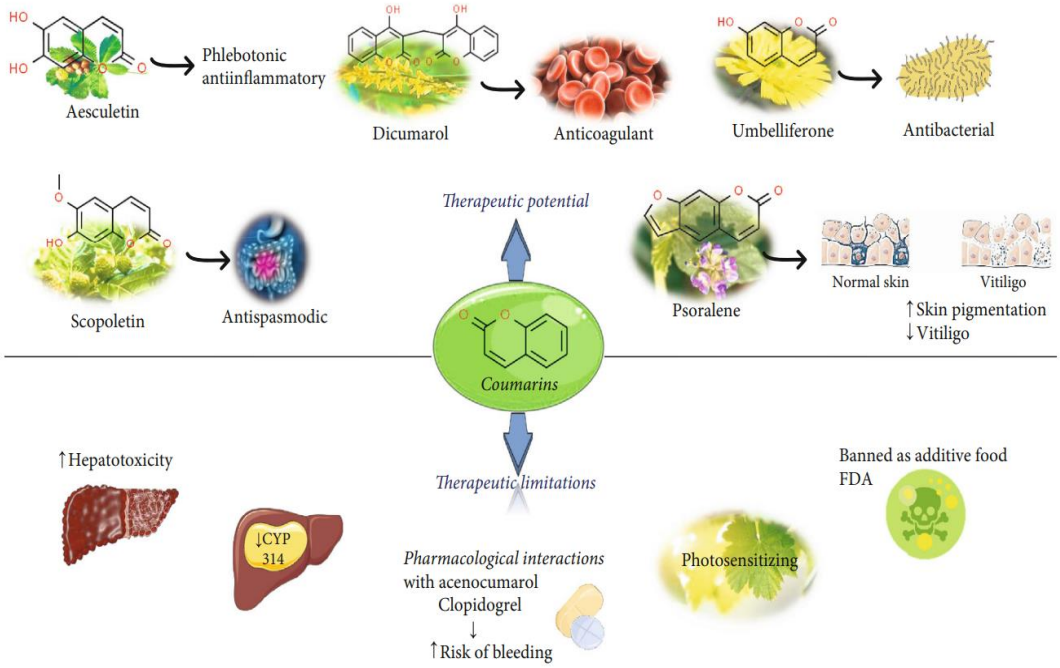


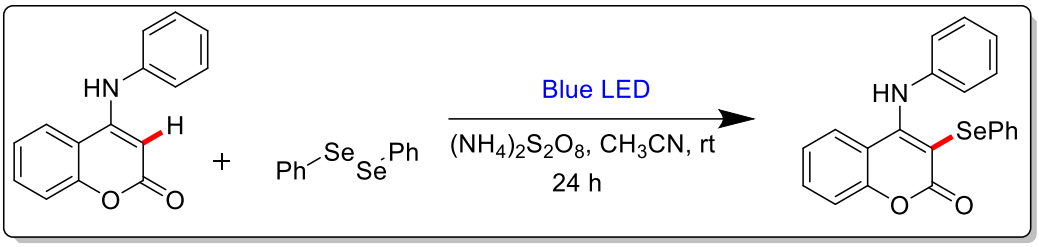
Fig-4- Pharmacological properties of natura coumarin with chemical structure.[13]

B: OBJECTIVE

So far, there are several reports on the functionalization of heterocyclic compounds. The formation of a new C-C bond via C-H bond functionalization has long been regarded as the holy grail of organic synthesis. C-3 functionalization of coumarin have widely interested due to their biological and pharmacological activities. Heterocyclic esters are also the part of biologically active compounds. Hence the motive of this work is to synthesize 3-methoxy carbonyl coumarin which might be useful for the biological and pharmacological field.

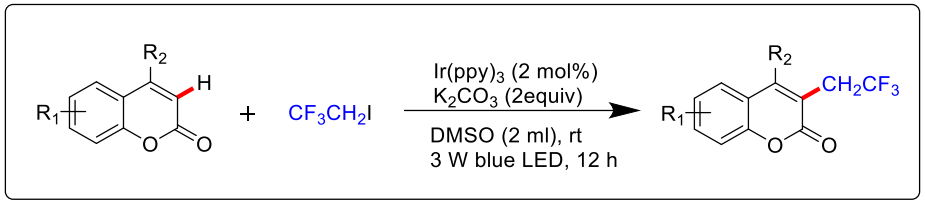
C: LITERATURE SURVEY

From our literature survey we found that, there are several literatures on the topic of C-H activation/ functionalization. Some of which are reported here-



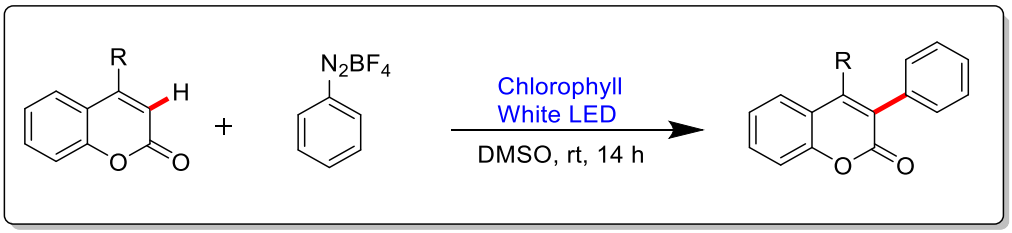
Scheme 1: Metal- and photocatalyst-free selenylation of coumarin derivatives.[14]

The synthesis of organoselenium compound is most important in organic chemistry due to their biological activities. It is use as anti-tumour, anti-oxidant, antiproliferative and RAR agonist. The visible light induced C-3 selenylation of coumarin is shown in scheme 1. In which coumarin react with diselenides in presence of oxidant without any transition-metal catalyst or photocatalyst in acetonitrile solvent and give the product C-3 selenylated coumarin.



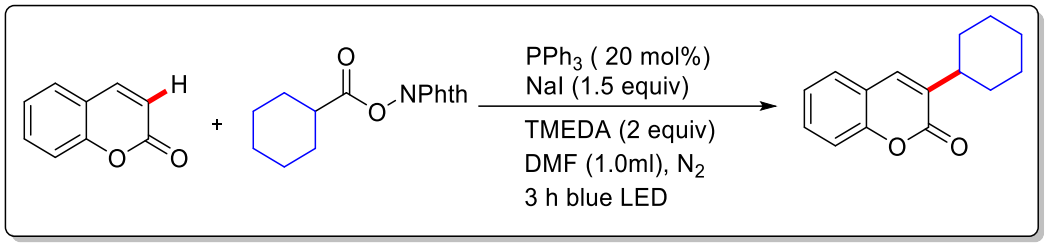
Scheme 2: Direct Csp^2 -H Radical Trifluoroethylation of coumarin.[15]

This is the trifluoroethylation of coumarin, in which coumarin react with a low-cost reagent 1,1,1-Trifluoro-2-iodoethane (CF_3CH_2I) in presence of photocatalyst under visible light and give the product. Here K_2CO_3 use as a base. This reaction goes through the radical pathway, in which CF_3CH_2 radical generate via photo-redox catalyst. The structure of product form in this reaction was confirm by X-ray diffraction (XRD).



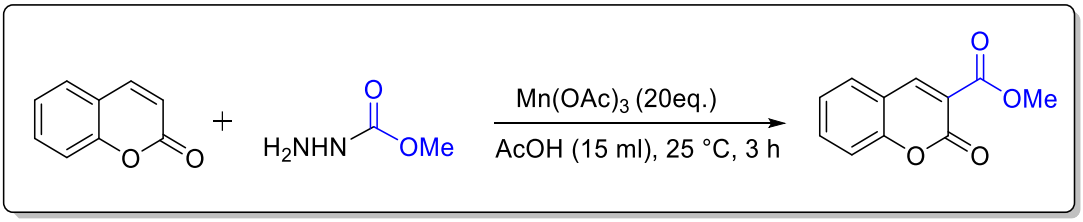
Scheme 3: Regioselective coumarin **C–H** arylation via chlorophyll photosensitizer.[12]

This is arylation of coumarin with diazonium salts in presence of natural pigment chlorophyll. In this reaction chlorophyll is used as an environmentally friendly catalyst a green photosensitizer and. In this reaction, no any metal catalyst is used. The reaction goes through radical pathway at room temperature without any base. This reaction is based on green chemistry due used of visible light and natural green pigment chlorophyll as Source.



Scheme 4: Photocatalytic C-H alkylation of coumarins.[16]

This is the metal and oxidant free C-H alkylation of coumarin via visible light. In this reaction, coumarin react with a good alkyl reagent alkyl N-hydroxy phthalimide ester in presence of base in DMF solvent under blue led light. The reaction time this reaction is 3 hours only. Here TMEDA is used ass base. This reaction also goes through the radical pathway.



Scheme 5: $Mn(OAc)_3$-Mediated Regioselective Radical Alkoxycarbonylation of coumarin.[17]

This is the metal free alkoxycarbonylation of coumarin. In this reaction coumarin react with the methyl carbazate in presence of oxidant $Mn(OAc)_3$ and acetic acid solvent.This reaction under go at 25℃ for 3 hours and give the final product C-3 alkoxycarbonylate coumarin. In this reaction methyl carbazate act as source of alkoxycarbonyl functional group.

Chapter 2

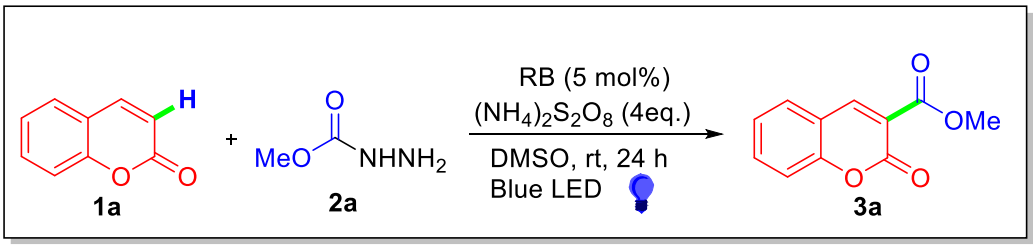
EXPERIMENTAL WORK-

A: Material and instrumentation

All the chemicals were bought from Sigma Aldrich, TCI, Spectrochem and Avra. The mass spectrometry (ESI-MS) was performed using a Bruker MicrOTOF-Q II that used positive-mode electron spray ionization. ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) were recorded in deuterated solvent (D_2O) using Bruker Advance 500.

B: Synthesis of alkoxy carbonylate coumarin

A regioselective Alkoxy carbonylation of Coumarin using Methylcarbazate as ester group and DMSO as solvent source was developed, in which an inexpensive Rose Bengal was used as the Photo-Redox catalyst and Ammonium per oxo- disulfate used as oxidant.



GENERAL PROCEDURE-

REQUIRMENT-

Coumarin	-	0.050g
Methyl carbazate	-	0.123g
Ammonium per oxo disulfate	-	0.312g
Rose Bengal	-	0.0174g
DMSO (Solvent)	-	4 ml

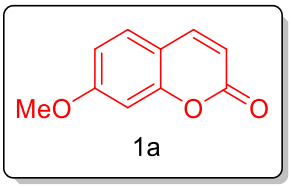
Blue LED at room temperature for 24 h.

In a 25 ml of dry test-tube, a mixture of coumarin (1 eq), methyl carbazate (4 eq), ammonium per oxo-disulfate (4 eq) and rose bengal use as photocatalyst was taken and 4 ml of DMSO used as a solvent. This reaction mixture stirred under the blue LED light for 24 hours at room temperature.

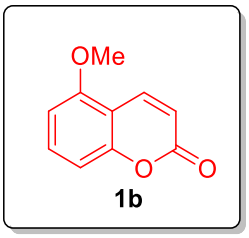
General procedure for synthesis of starting material-

Scheme 5- Synthesis of coumarin derivatives.[18]

Coumarin derivative can be synthesized by using different type of phenol such as 3-methoxy, 4-methoxy ,3-5 dimethoxy, bromo phenol etc. In a 25 ml R.B., adding mixture of phenol derivative, palladium acetate catalyst and solvent TFA and mix it well. Then adding propiolic acid at 0°C then whole reaction mixture was stirred for 42 hours at room temperature.

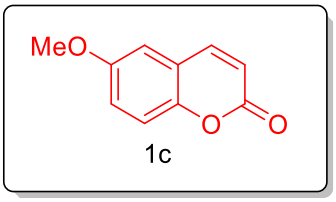


7- Methoxy coumarin (1a): Brown solid, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 9.5 Hz, 1H), 7.35 (d, *J* = 8.6 Hz, 1H), 6.82 (dd, *J* = 8.6, 2.4 Hz, 1H), 6.79 (d, *J* = 2.4 Hz, 1H), 6.23 (d, *J* = 9.5 Hz, 1H), 3.85 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.67, 161.02, 155.74, 143.27, 128.61, 112.90, 112.40, 112.37, 100.68, 55.61. LCMS(ESI): observed m/z for $C_{10}H_9O_3$ $[M+H]^+$=177.0538 calculated m/z = 177.0546.



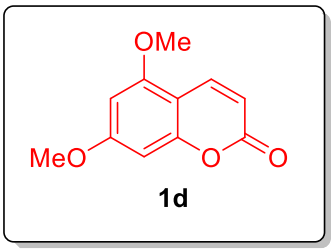
1b

6-Methoxy coumarin (1b): Browm solid, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.08 (d, *J* = 9.7 Hz, 1H), 7.44 (t, *J* = 8.3 Hz, 1H), 6.92 (d, *J* = 8.4 Hz, 1H), 6.71 (d, *J* = 8.2 Hz, 1H), 6.33 (d, *J* = 9.7 Hz, 1H), 3.93 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.35, 156.55, 155.53, 138.93, 132.72, 114.97, 110.02, 109.62, 105.50, 56.40. LCMS (ESI) observed m/z for $C_{10}H_9O_3$ $[M+H]^+$ = 177.0542 calculated m/z = 177.0546



1c

6-Methoxy coumarin (1c): Yellow solid, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 9.5 Hz, 1H), 7.24 (s, 1H), 7.10 (dd, *J* = 9.1, 2.9 Hz, 1H), 6.91 (d, *J* = 2.9 Hz, 1H), 6.42 (d, *J* = 9.5 Hz, 1H), 3.84 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.02, 155.96, 148.29, 143.19, 119.37, 119.03, 117.75, 116.89, 109.87, 55.70. LCMS (ESI) observed m/z for $C_{10}H_9O_3$ $[M+H]^+$ = 177.0538 calculated m/z = 177.0546



1d

5-7 Dimethoxy coumarin (1d): White solid, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.95 (d, *J* = 9.6 Hz, 1H), 6.39 (d, *J* = 2.2 Hz, 1H), 6.26 (d, *J* = 2.2 Hz, 1H), 6.14 (d, *J* = 9.7 Hz, 1H), 3.86 (d, *J* = 18.1 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.58, 161.49, 156.83, 156.64, 138.67, 110.73, 103.86, 94.68, 92.66, 55.80, 55.66. LCMS (ESI) observed m/z for $C_{11}H_{10}O_4Na$ $[M+Na]^+$ = 229.0475 calculated m/z = 177.0471

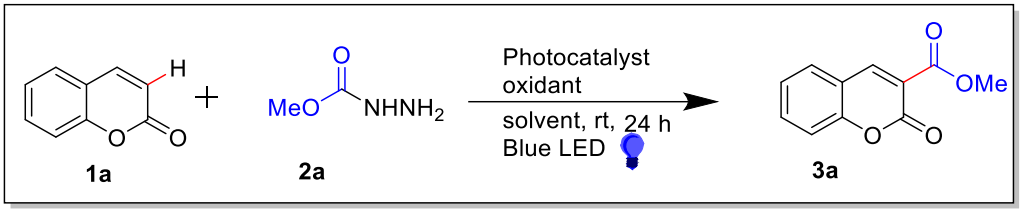
Chapter-3

A: RESULTS AND DISCUSSION

Here discussing about the synthesis of 3-methoxy carbonyl coumarin by using coumarin as starting material, methyl carbazate is use as a source of methoxy carbonyl and using different photocatalyst, oxidant and solvent for better yield of product i.e., 3-methoxy carbonyl coumarin.

B: OPTIMIZATION OF REACTION

In optimization of reaction, coumarin react with methyl carbazate in presence of photocatalyst, oxidant and solvent at room temperature under blue led light. By changing the reaction condition yield of product also effected.



When, Rose Bengal is use as photocatalyst (5mol%) with oxidant $Na_2S_2O_8$ and solvent MeOH the yield of product was 38%. By changing the solvent from MeOH to DCM, DMF and ACN then yields of product change, in case of DCM yield of product is 52% and in others solvent reaction did not proceed.

So again, changing the oxidant remaining all the condition same then the yield of product also effected as shown in table. In case of $K_2S_2O_8$ oxidant with DMSO solvent the yield of product is 55%.

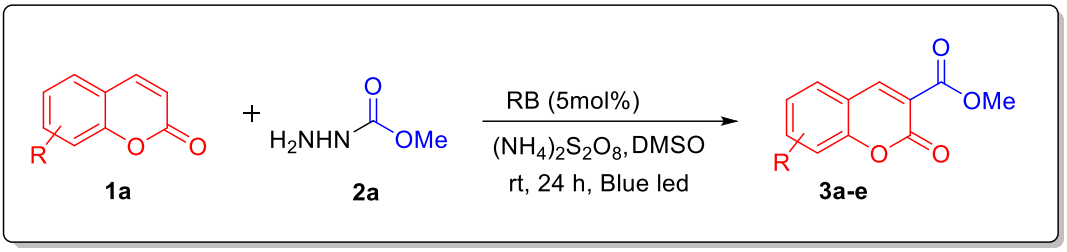
By changing the catalyst and their amount then yield of product change, when catalyst RB was used 5mol% with $Na_2S_2O_8$ oxidant and DMSO solvent then the yield was increases as shown in entry 8.

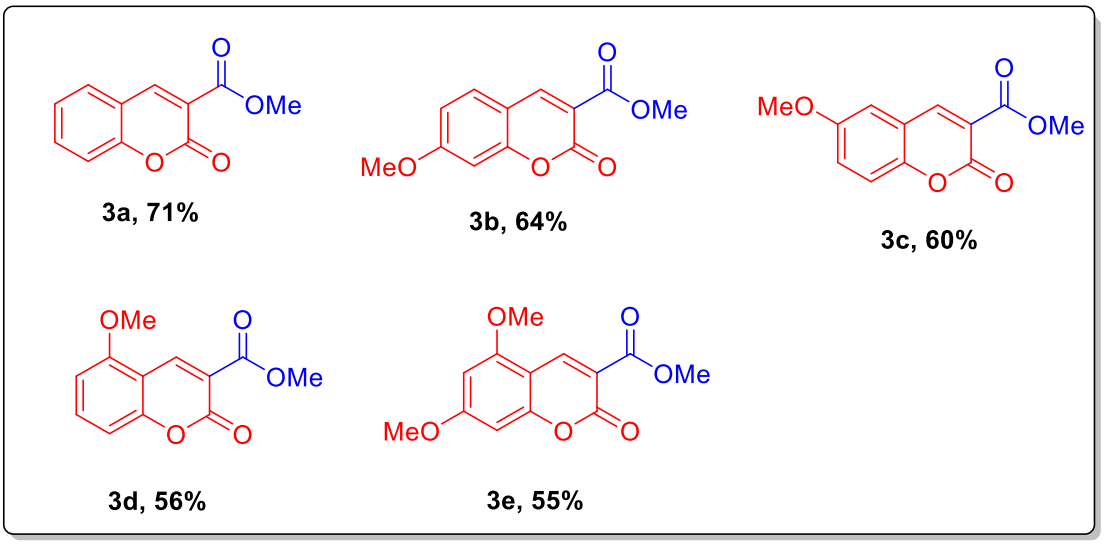
Thus, the best reaction condition for highest yield was, by using Rose Bengal (5mol%), oxidant $Na_2S_2O_8$ (4eq), and DMSO as a solvent and yield of product is 71%.

Table 1- Optimization of Reaction Condition

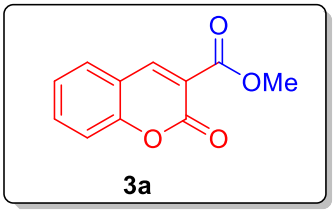
Sr. No.	1a	2a	P.C. (mol%)	Oxidant (eq)	Solvent (ml)	Time	Yield
1	1	4	Rose Bengal (5)	$(NH_4)_2S_2O_8$(4)	MeOH (2ml)	24 h	38%
2	1	4	Rose Bengal (5)	$(NH_4)_2S_2O_8$(4)	DCM (2ml)	24 h	52%
3	1	4	Rose Bengal (5)	$(NH_4)_2S_2O_8$(4)	DMF (2ml)	24 h	NR
4	1	4	Rose Bengal (5)	$(NH_4)_2S_2O_8$(4)	ACN (2ml)	24 h	NR
5	1	4	Rose Bengal (5)	$K_2S_2O_8$	DMSO	24 h	55%
6	1	4	Rose Bengal (5)	TBHP (4)	DMSO (2ml)	24 h	NR
7	1	4	Rose Bengal (5)	O_2 balloon	DMSO(2ml)	24 h	trace
8	**1**	**4**	**Rose Bengal (5)**	**$(NH_4)_2S_2O_8$(4)**	**DMSO (2ml)**	**24 h**	**71%**
9	1	4	Rhodamine (5)	$(NH_4)_2S_2O_8$(4)	DMSO (2ml)	24 h	trace
10	1	4	Methyleneblue (5)	$(NH_4)_2S_2O_8$(4)	DMSO (2ml)	24 h	30%
11	1	4	Acridine red (5)	$(NH_4)_2S_2O_8$(4)	DMSO (2ml)	24 h	trace
12	1	4	Eosin Y (5)	$(NH_4)_2S_2O_8$(4)	DMSO (2ml)	24 h	49%
13	1	4	Rose Bengal (10)	$(NH_4)_2S_2O_8$(4)	DMSO (2ml)	24 h	69%
14	1	3	Rose Bengal (5)	$(NH_4)_2S_2O_8$(3)	DMSO (2ml)	24 h	60%
15	1	3	Rose Bengal (5)	$(NH_4)_2S_2O_8$(4)	DMSO (2ml)	24 h	64%

Substrate Scope of Coumarin-

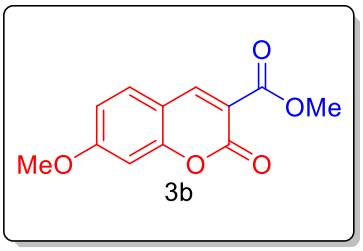




^{1}H, ^{13}C and HRMS of (3a-3e)

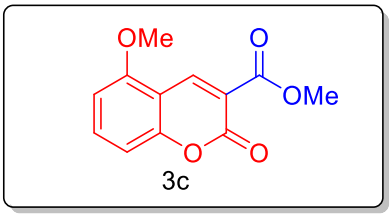


Methyl 2-oxo-2H-chromene-3-carboxylate (3a): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.57 (s, 1H), 7.74 – 7.54 (m, 2H), 7.47 – 7.31 (m, 2H), 3.96 (s, 3H), ^{13}C NMR (125 MHz, $CDCl_3$) δ163.6, 156.6, 155.1, 149.0, 134.4, 129.4, 124.8, 117.9, 117.7, 116.7, 52.8. HRMS: observed m/z for $C_{11}H_8O_4Na$ $[M+Na]^+$ = 227.0325, calculated m/z = 227.0325.



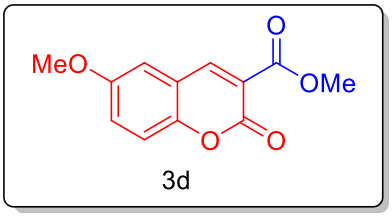
3b

Methyl 7-methoxy-2-oxo-2H-chromene-3-carboxylate (3b): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.54 (s, 1H), 7.50 (d, *J* = 8.7 Hz, 1H), 6.89 (dd, *J* = 8.7, 2.4 Hz, 1H), 6.82 (d, *J* = 2.4 Hz, 1H), 3.94 (s, 3H), 3.90 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.42, 164.30, 157.81, 157.30, 149.65, 130.93, 128.69, 113.90, 111.78, 100.51, 56.17, 52.88. HRMS observed m/z for $C_{12}H_{10}O_5Na$ $[M+Na]^+$ = 257.0432 calculated m/z = 257.0420



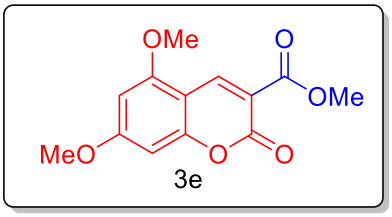
3c

Methyl 5-methoxy-2-oxo-2H-chromene-3-carboxylate (3c): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.93 (s, 1H), 7.55 (t, *J* = 8.3 Hz, 1H), 6.91 (d, *J* = 8.4 Hz, 1H), 6.72 (d, *J* = 8.3 Hz, 1H), 3.96 (s, 3H), 3.94 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.30, 157.84, 157.29, 156.61, 145.06, 135.83, 115.89, 109.36, 109.24, 105.71, 56.59, 53.14. HRMS observed m/z for $C_{12}H_{10}O_5Na$ $[M+Na]^+$ = 257.0435 calculated m/z = 257.0420



3d

Methyl 6-methoxy-2-oxo-2H-chromene-3-carboxylate (3d): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.50 (s, 1H), 7.28 (d, *J* = 9.2 Hz, 1H), 7.22 (dd, *J* = 9.1, 2.9 Hz, 1H), 7.00 (d, *J* = 2.9 Hz, 1H), 3.94 (s, 3H), 3.85 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 163.72, 156.77, 156.23, 149.72, 148.76, 122.63, 118.11, 118.02, 117.77, 110.63, 55.79, 52.75. HRMS observed m/z for $C_{12}H_{10}O_5Na$ $[M+Na]^+$ = 257.0428 calculated m/z = 257.0420



3e

Methyl 5,7-dimethoxy-2-oxo-2H-chromene-3-carboxylate (3e): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.85 (s, 1H), 6.41 (s, 1H), 6.27 (s, 1H), 3.92 (d, *J* = 1.6 Hz, 6H), 3.88 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.93, 164.71, 158.89, 158.86, 157.87, 145.51, 111.70, 104.05, 95.50, 93.00, 56.54, 56.45, 52.94. HRMS observed m/z for $C_{13}H_{12}O_6Na$ $[M+Na]^+$ = 287.0525 calculated m/z =287.0526

C: PLAUSIBLE MECHANISM-

The reaction mechanism goes through the radical pathway. In which methoxy carbonyl radical generate. First of all, photocatalyst under goes excited state by the irradiation of visible light, and then by the help of oxidant methoxy carbonyl radical [B] form through the single electron transfer (SET) and remove the N_2 gas. This methoxy carbonyl radical attack on the C-3 position of coumarin [1] and generate radical intermediate [C], then it under goes single electron transfer to intermediate [D], which undergo aromatization by the removal of H^+ and give final product.

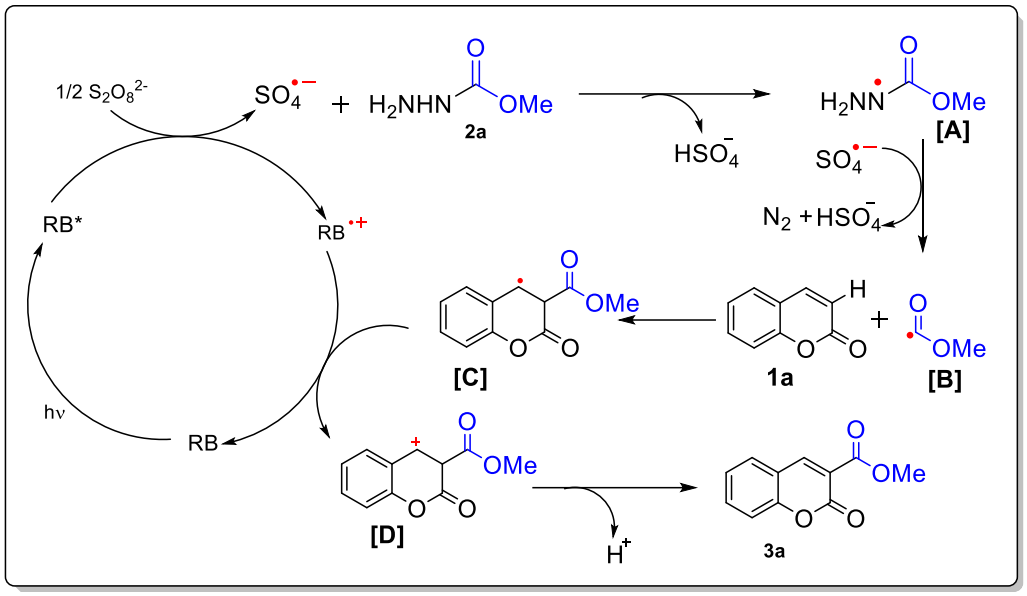
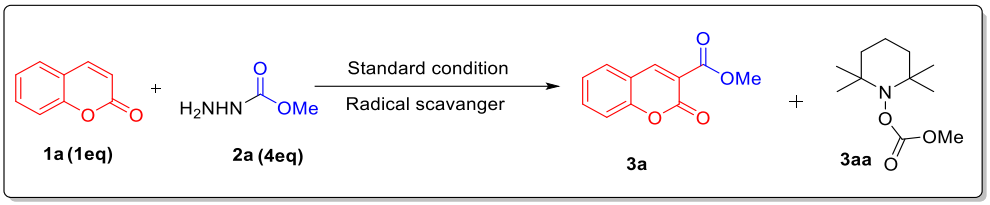
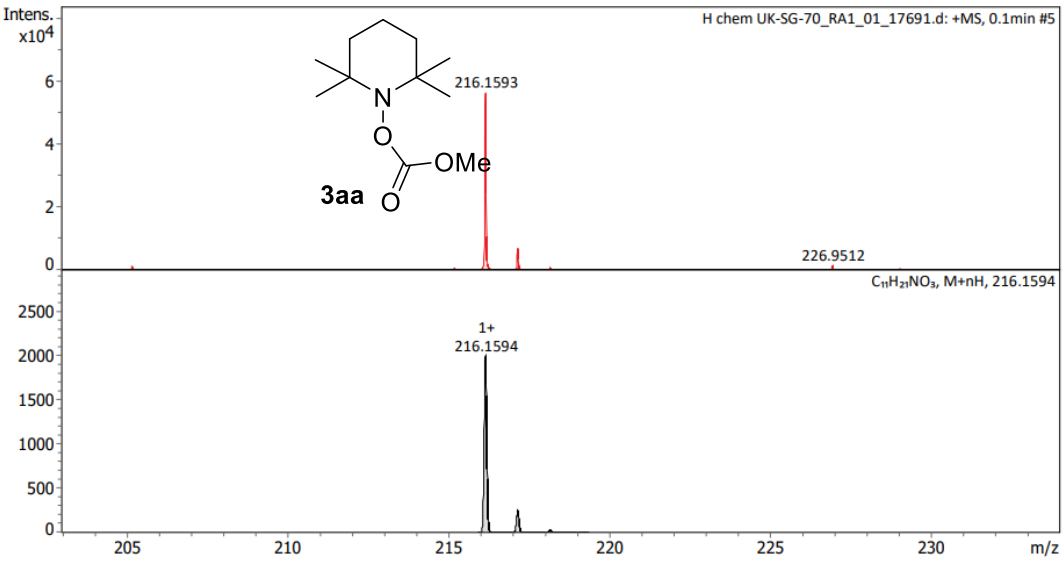


Fig 5- Plausible mechanism of reaction

D: CONTROL EXPERIMENT-



Sr. No.	Radical scavenger	eq.	3a	3aa
1	TEMPO	3	16%	-
2	TEMPO	4	trace	-
3	TEMPO	5	-	3aa, HRMS



Chapter -4

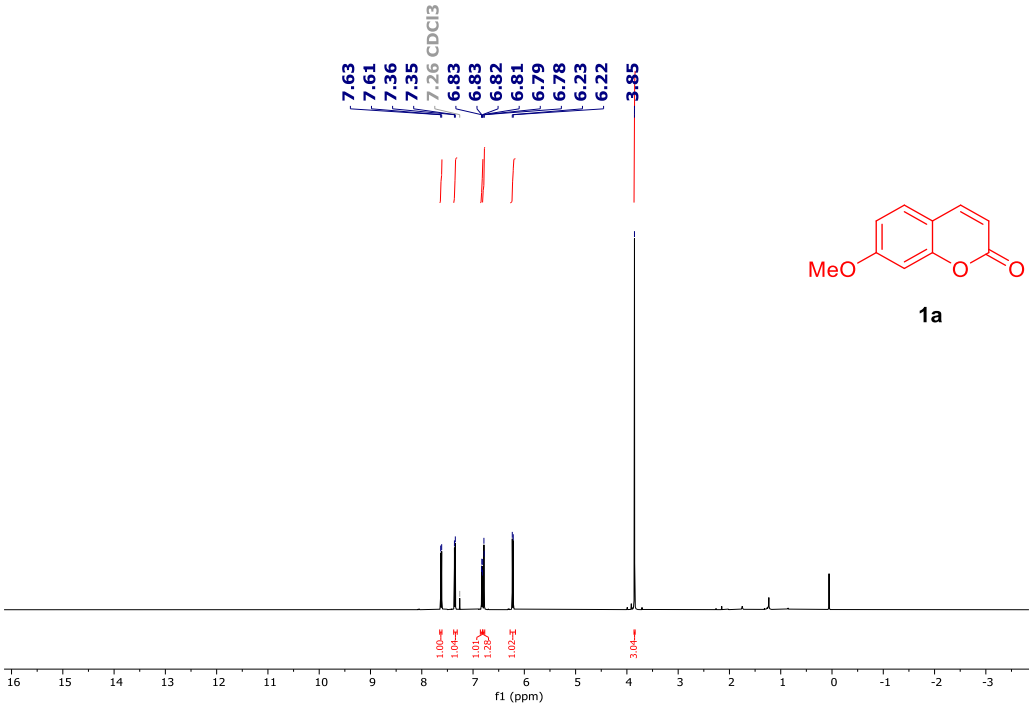
CONCLUSION

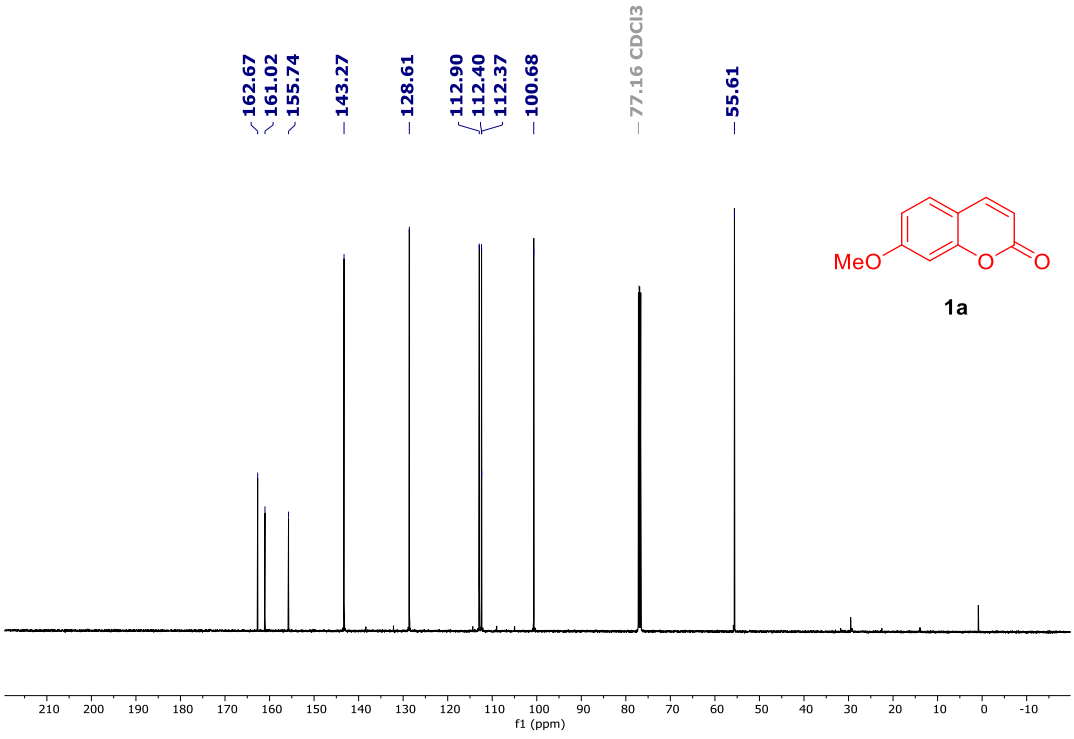
In conclusion, we have synthesized the 3- alkoxy carbonyl coumarin under the visible blue led light. Here, methyl carbazate is use as source of ester group. Now a days, visible light induced reaction aroused more and more attention due to their mild and eco-friendly nature. C-3 position is active site for C-H of functionalization coumarin. The reaction mechanism involves generation of C-H radical on heterocyclic 6 membered ring of coumarin by the help of ester functional group which is generated from methyl carbazate. C-3 derivatives of the coumarin have many medicinal benefits and future scope in organic chemistry.

APPENDIX-

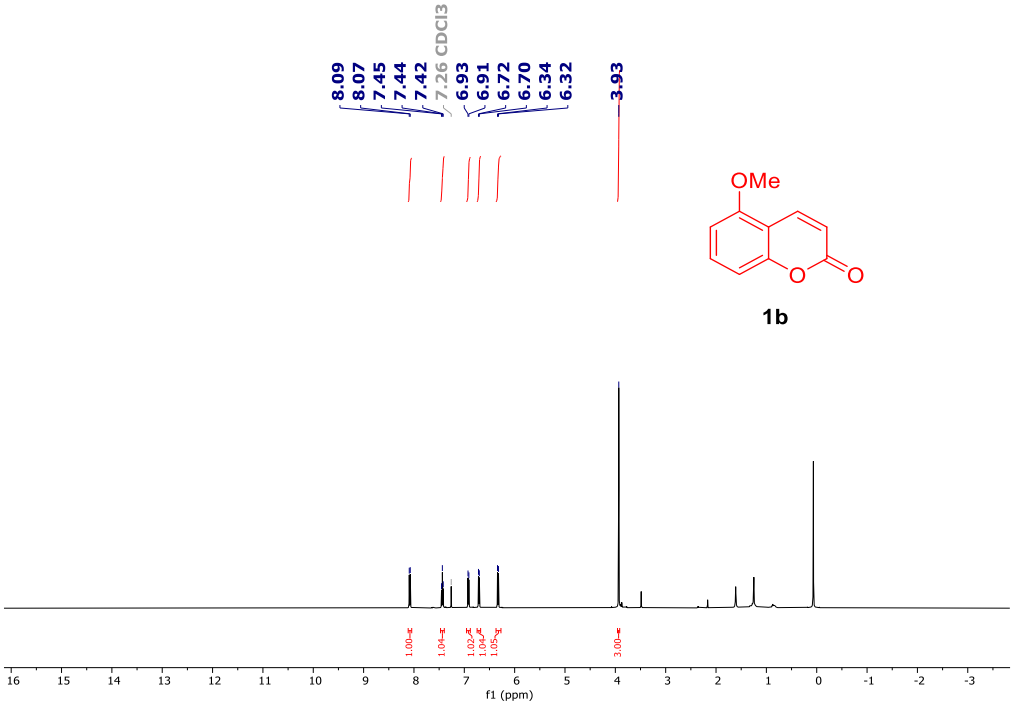
^{1}H and ^{13}C NMR of starting material –

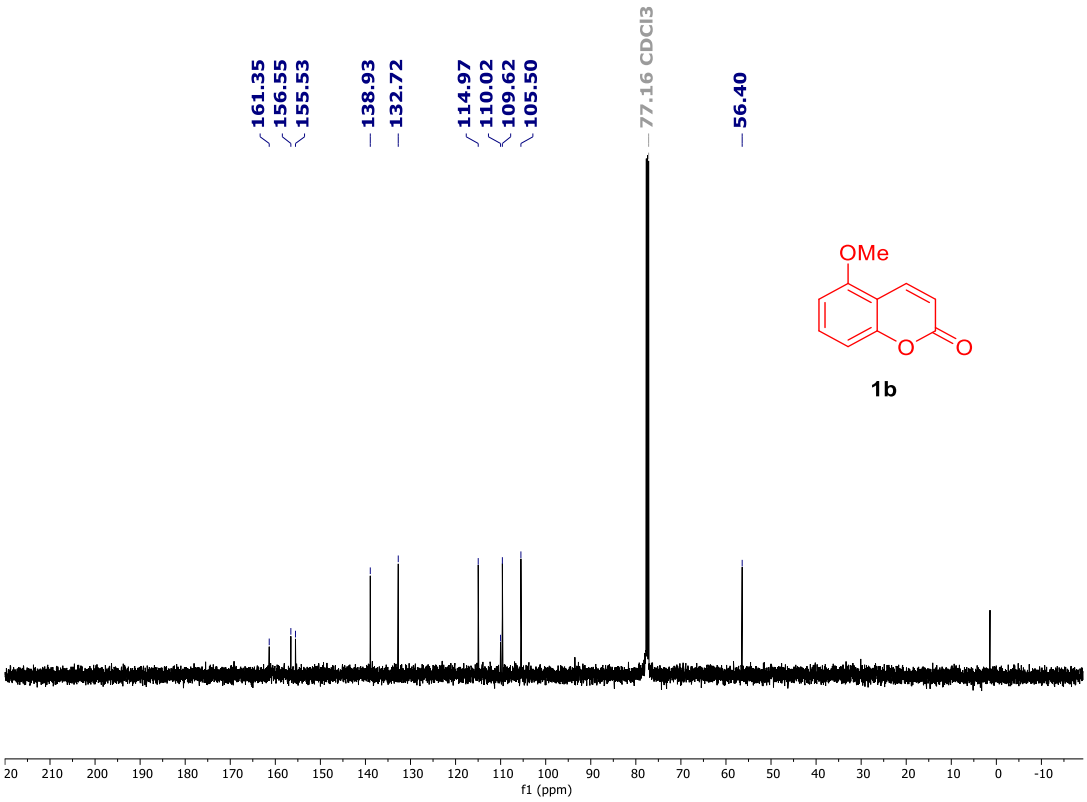
7- Methoxy Coumarin-



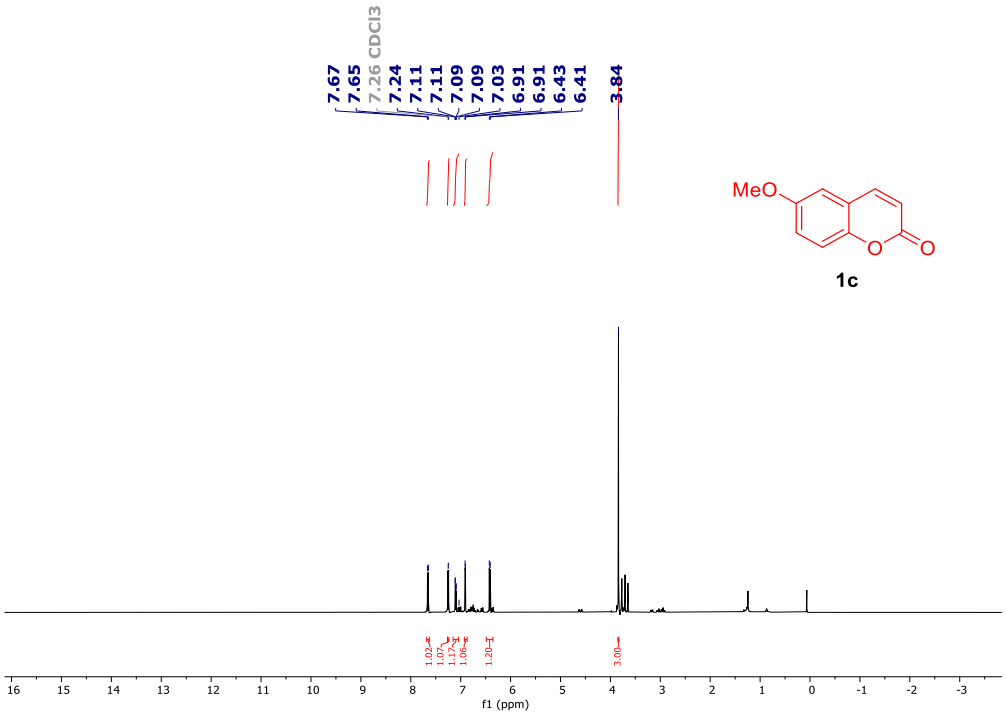


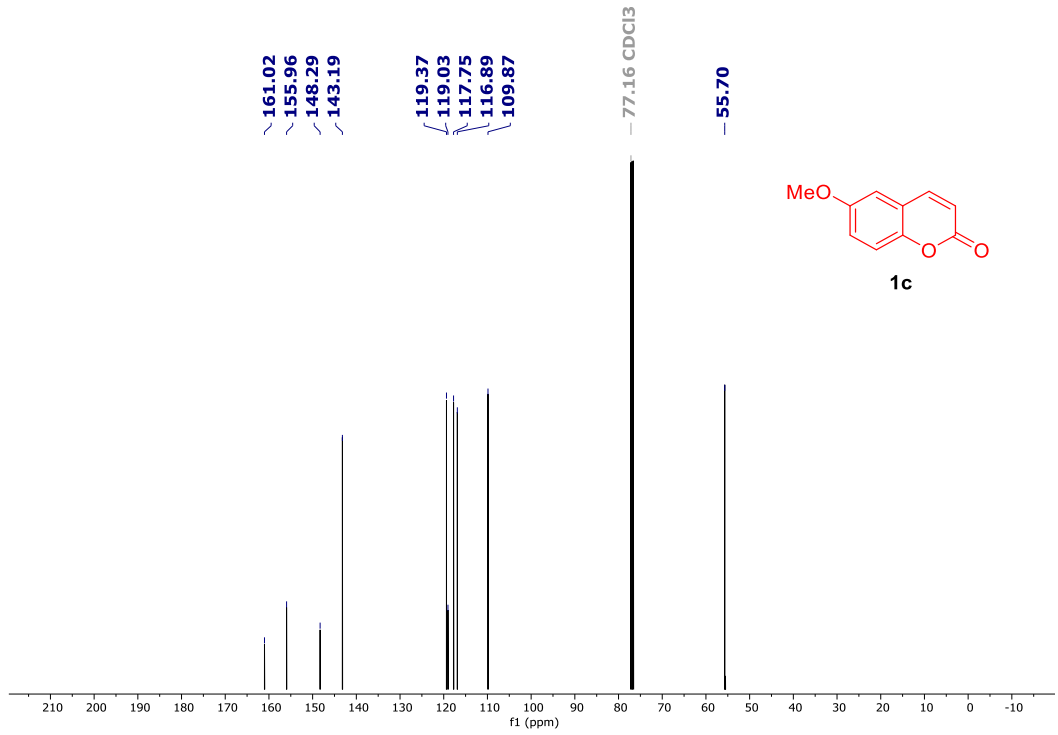
5-Methoxy Coumarin-



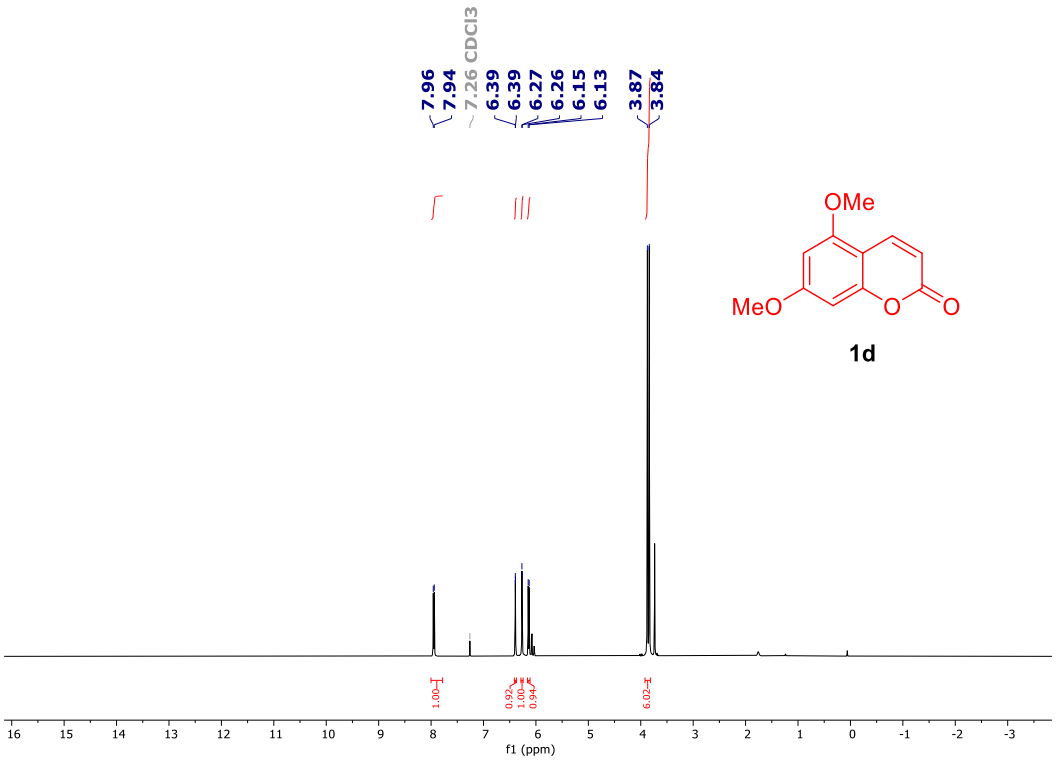


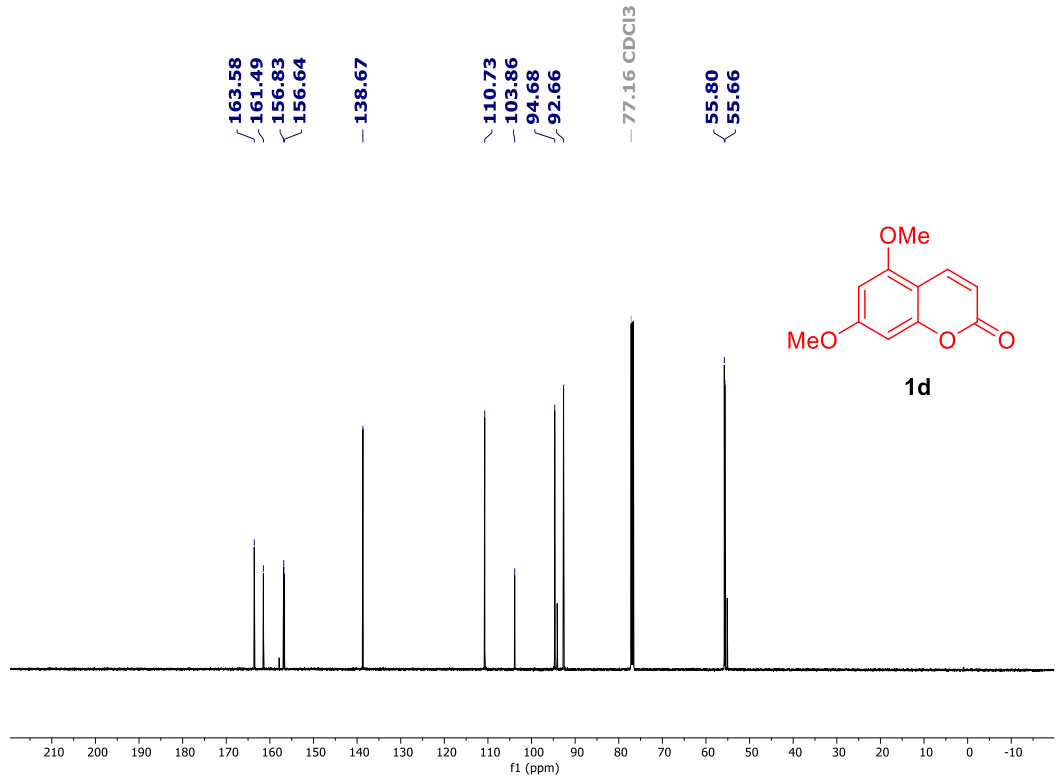
6- Methoxy Coumarin-





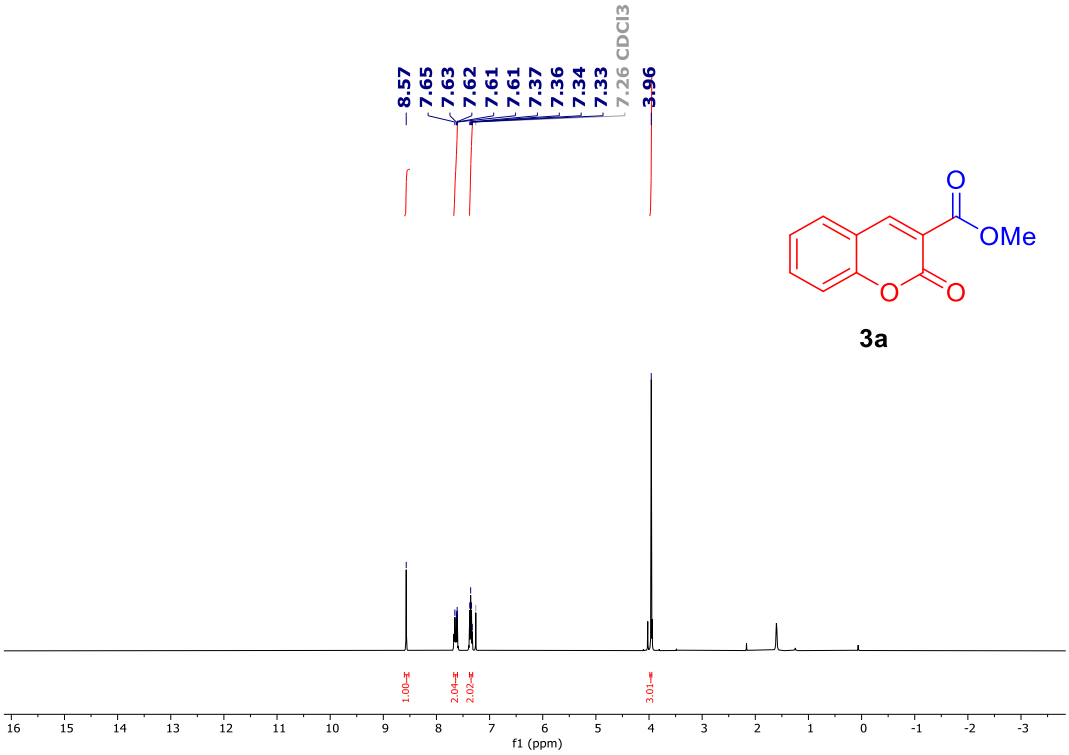
5-7 Dimethoxy coumarin-



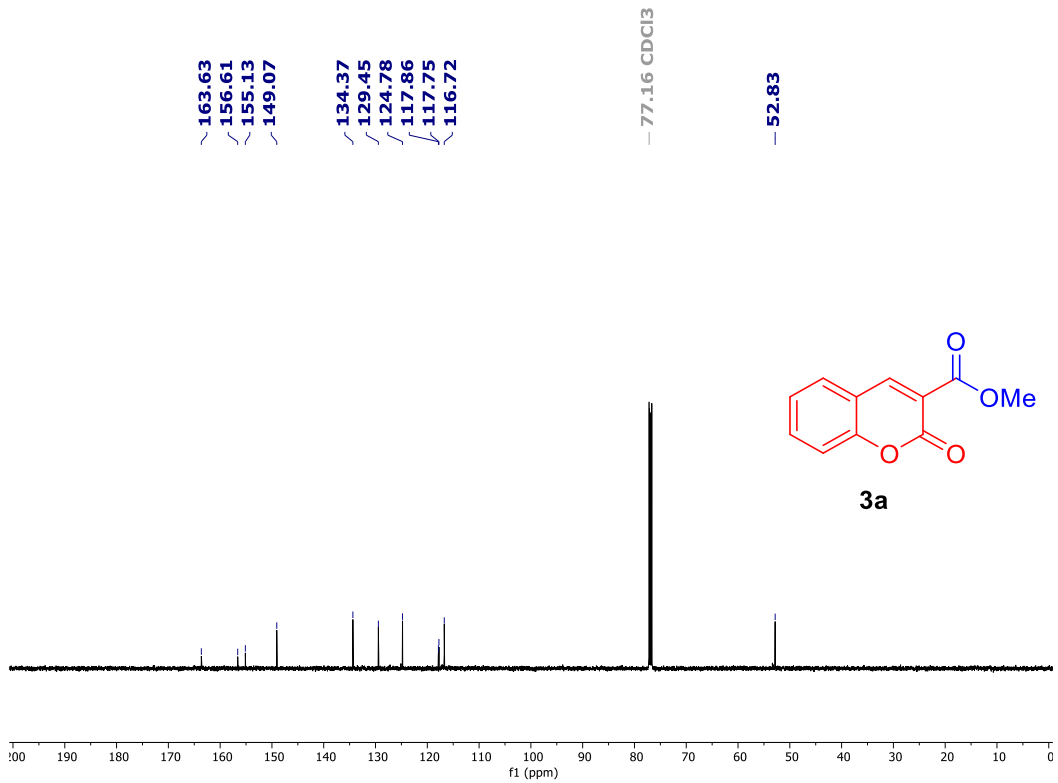


^{1}H, ^{13}C NMR and HRMS of the compounds-

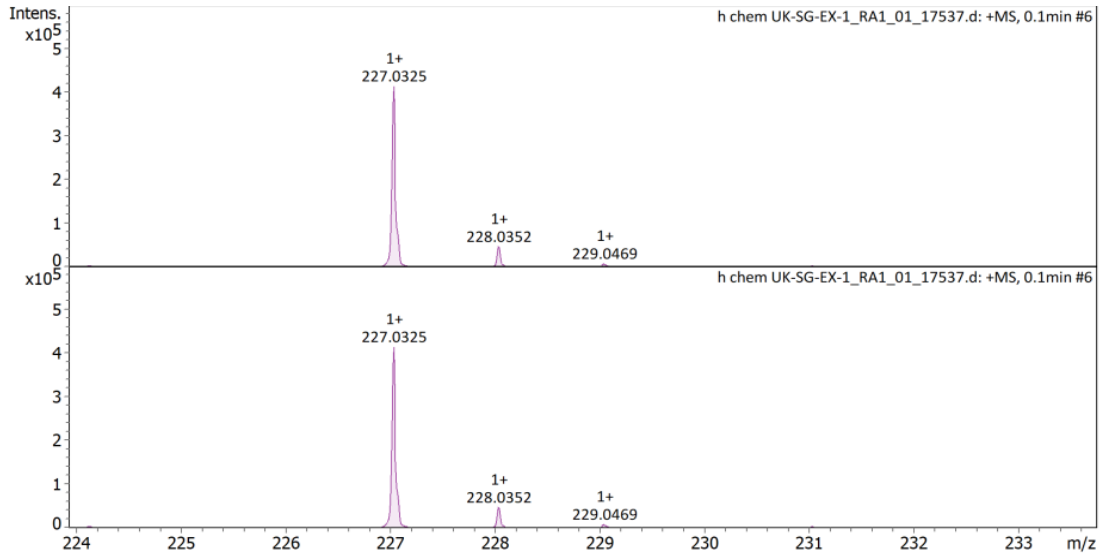
methyl 2-oxo-2H-chromene-3-carboxylate



3a

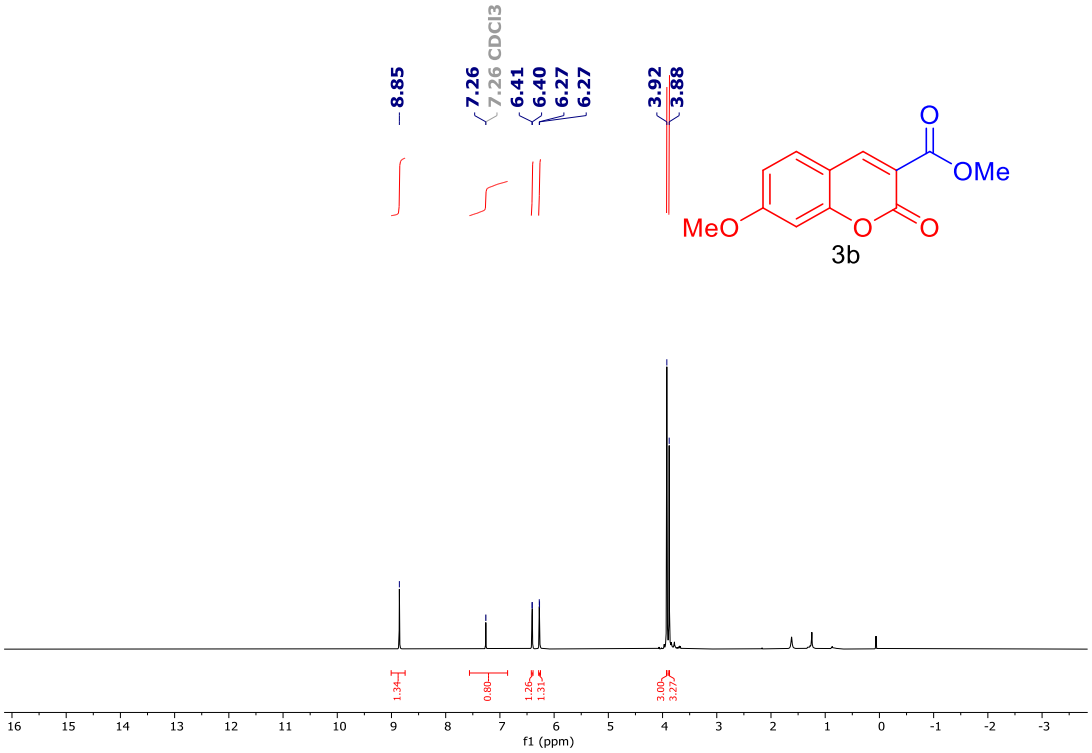


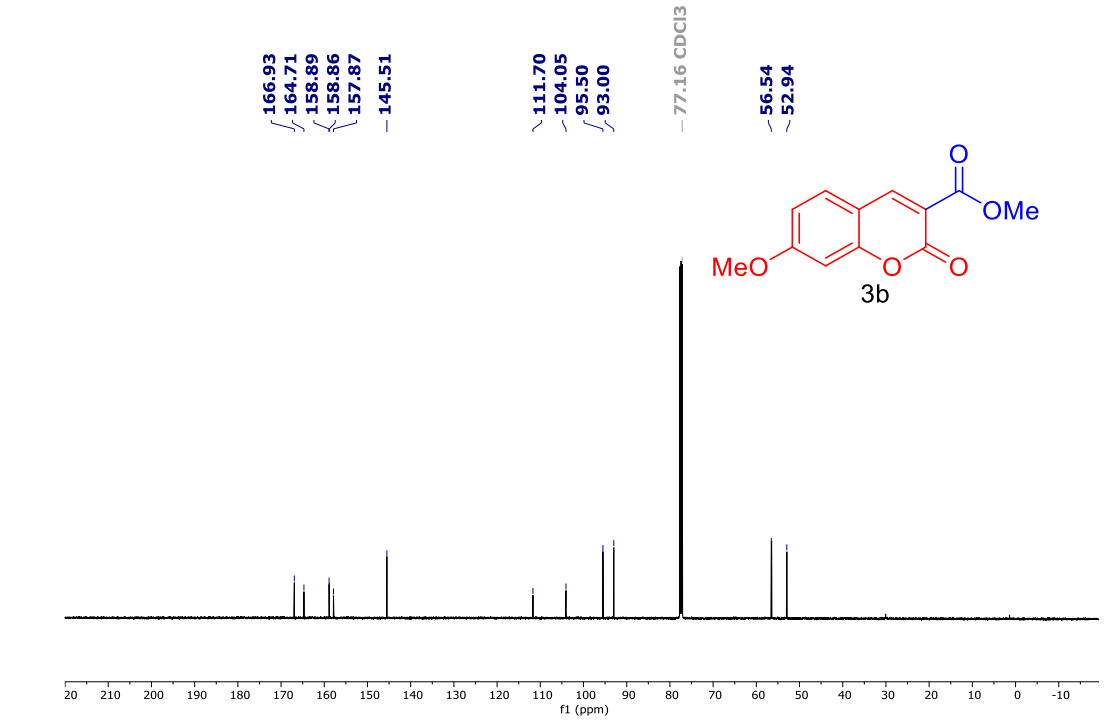
3a

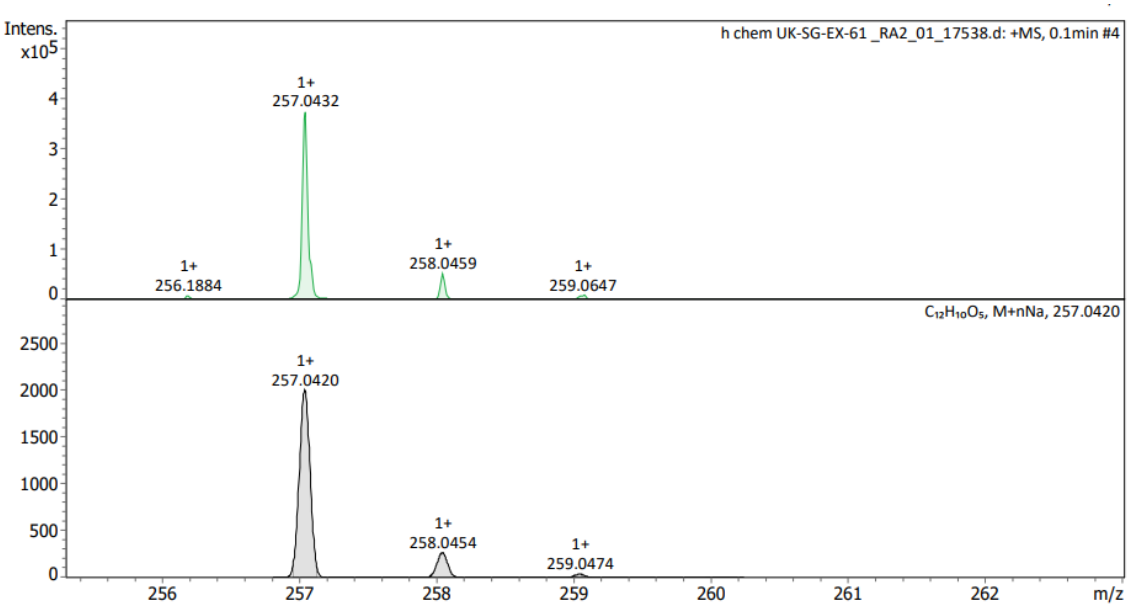


HRMS of compound 3a

Methyl 7-methoxy-2-oxo-2H-chromene-3-carboxylate-

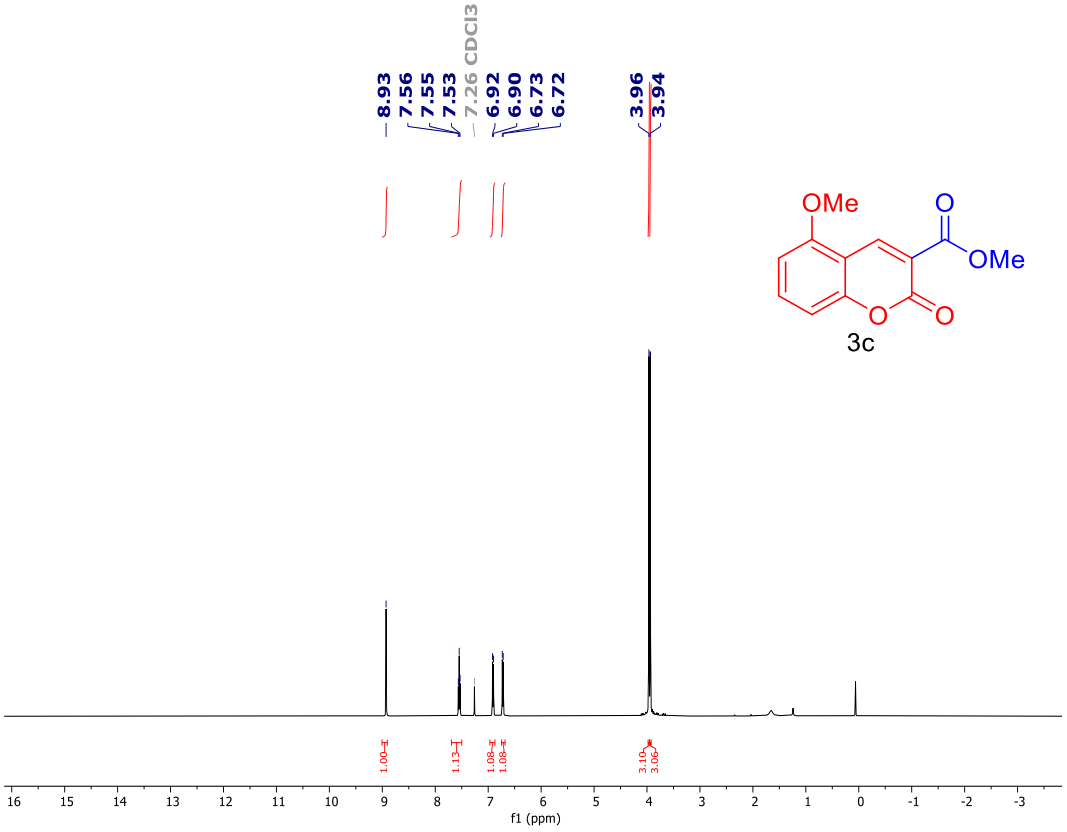


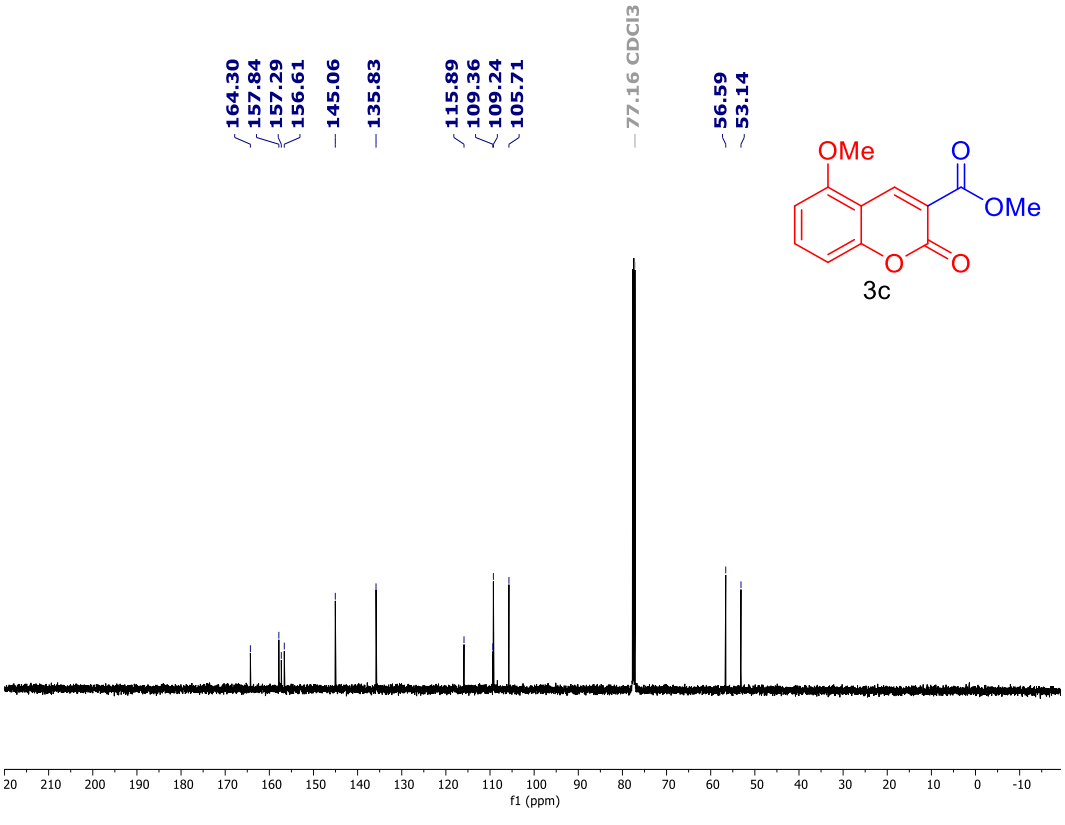


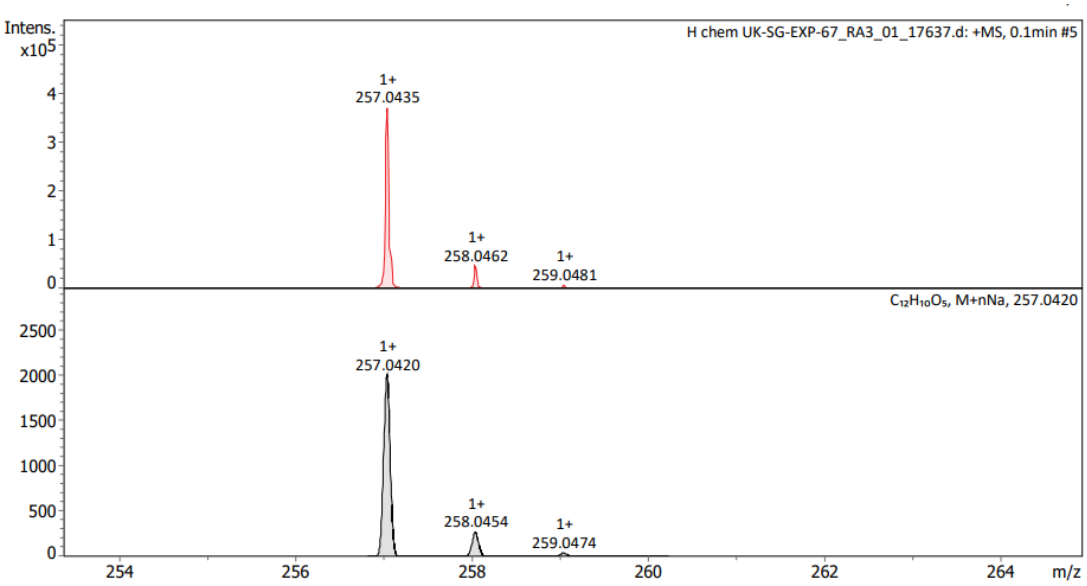


HRMS of Compound 3b

Methyl 5-methoxy-2-oxo-2H-chromene-3-carboxylate

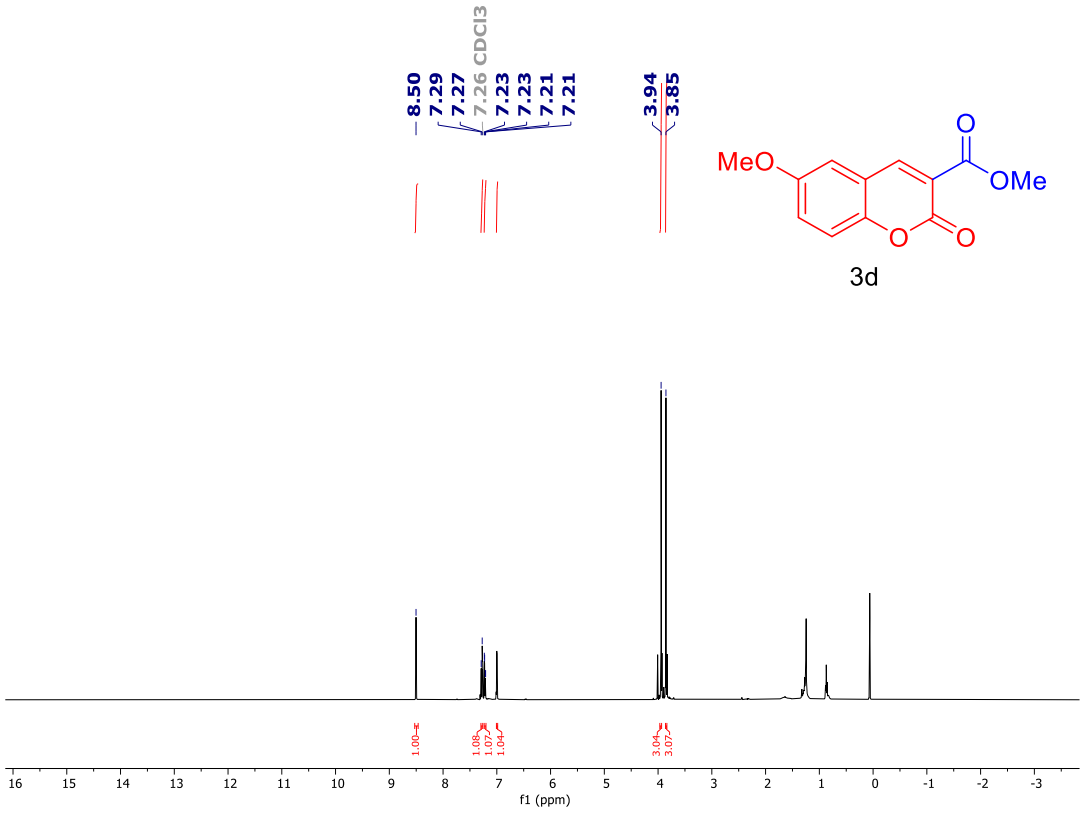


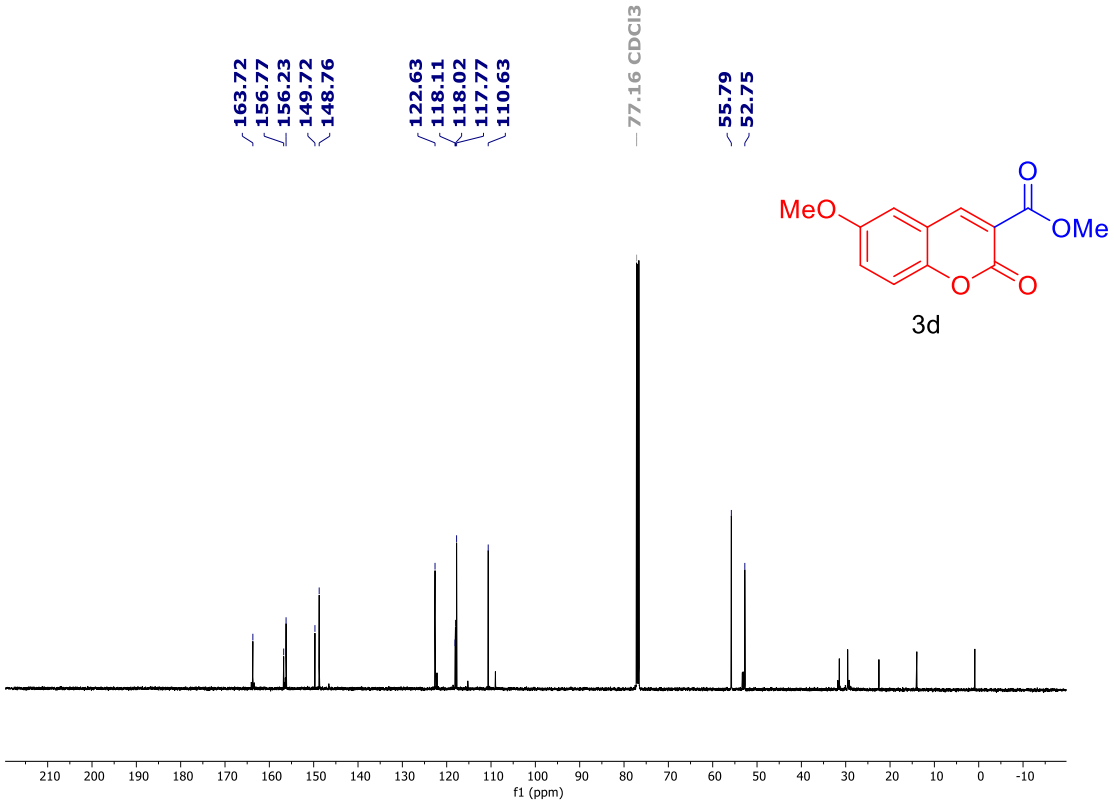


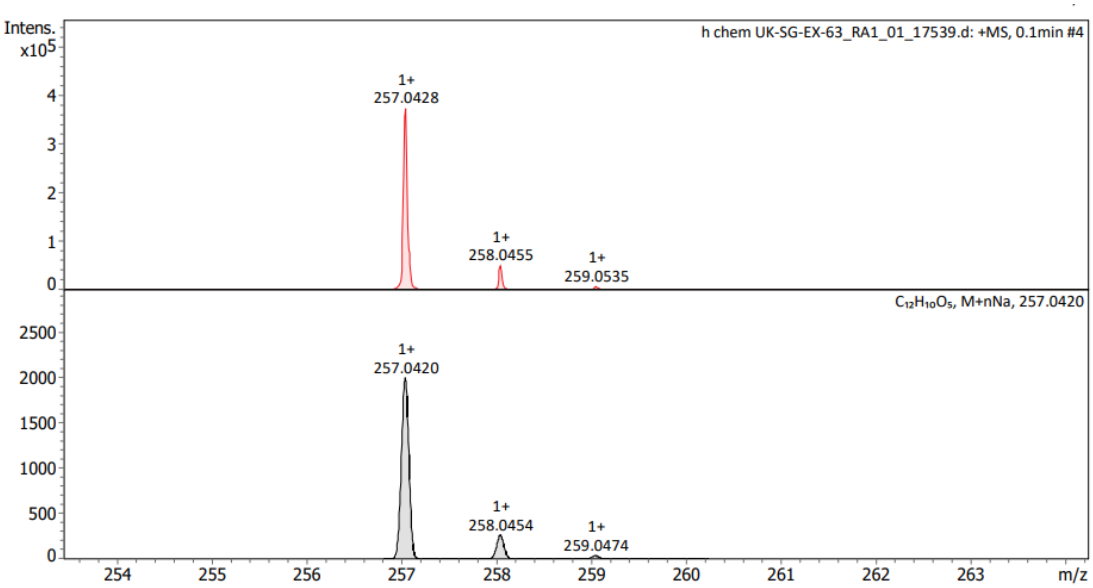


HRMS of compound 3c

Methyl 6-methoxy-2-oxo-2H-chromene-3-carboxylate

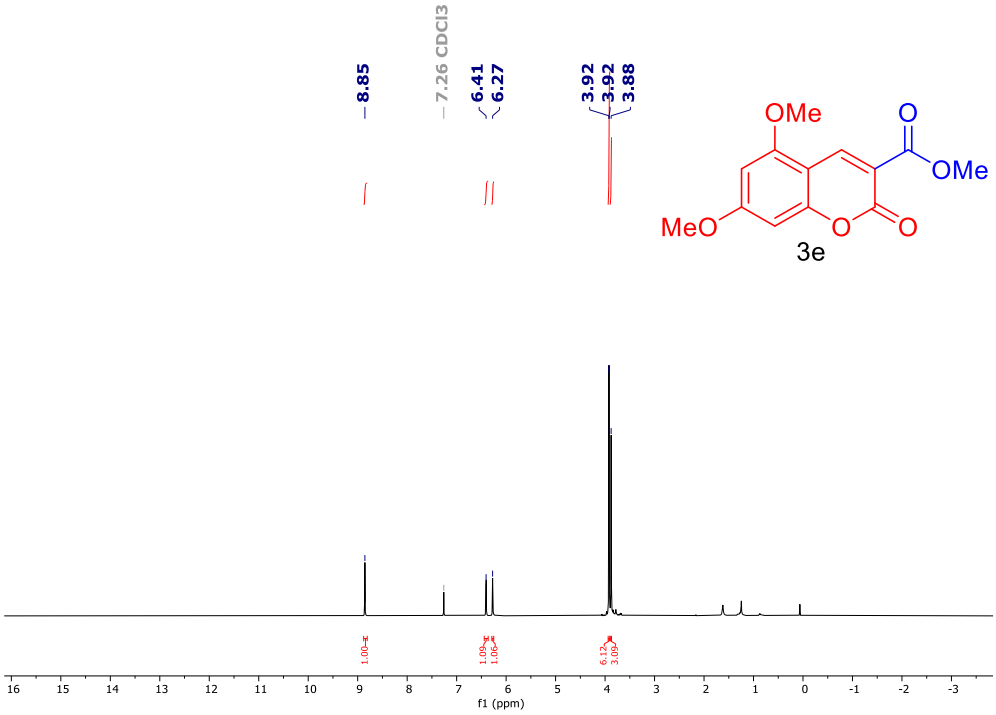


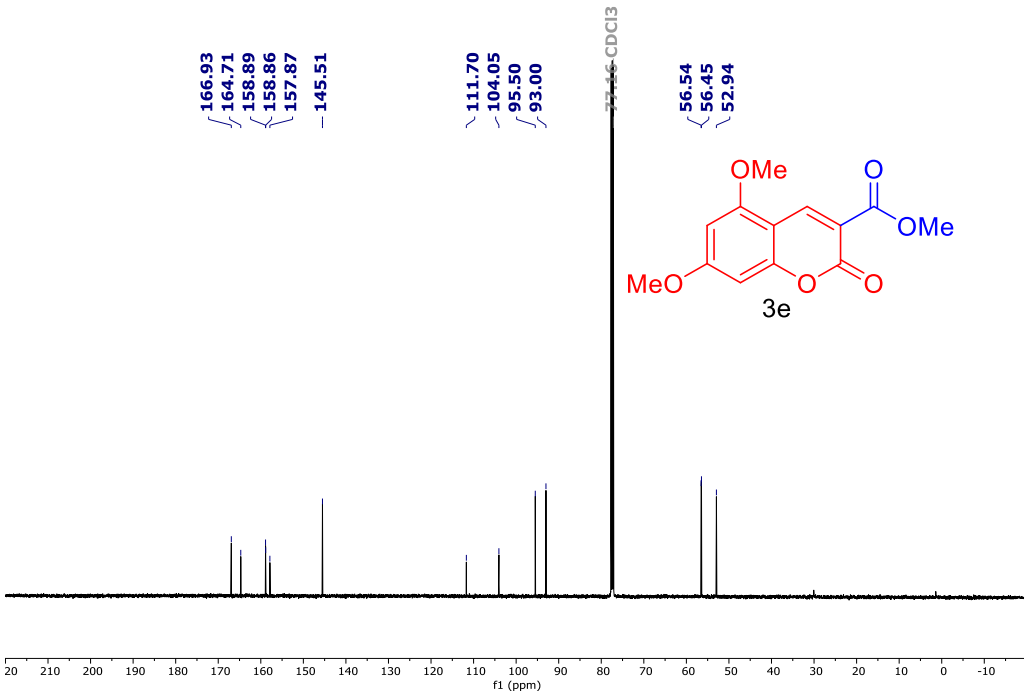


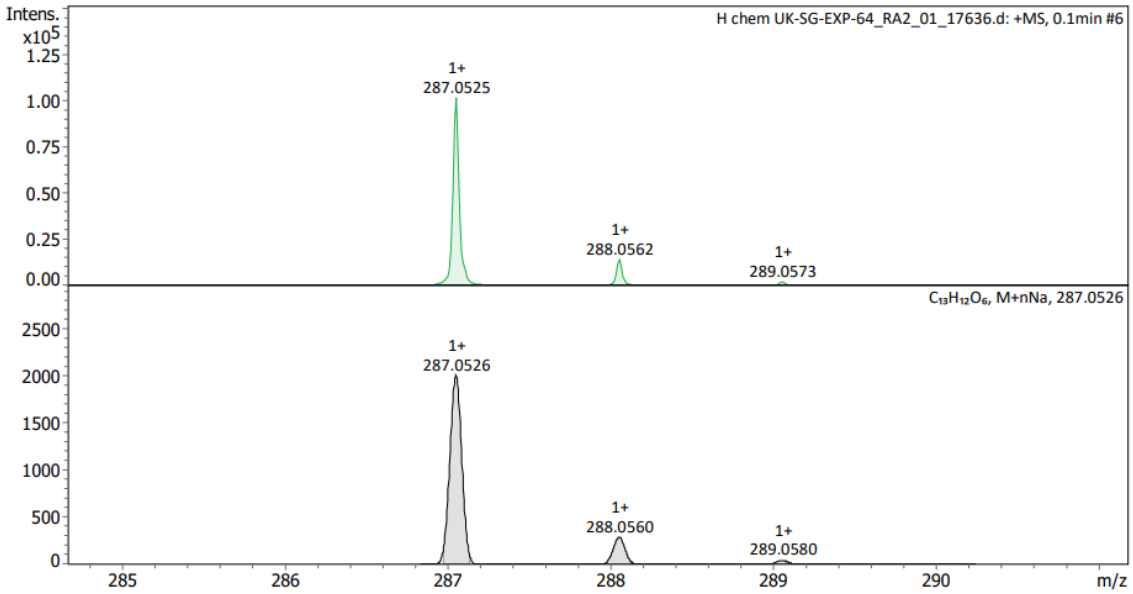


HRMS of compound 3d

Methyl 5,7-dimethoxy-2-oxo-2H-chromene-3-carboxylate-







HRMS of COMPOUND 3e

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