Base-Promoted Reaction of Unsaturated N-Sulfonyl Ketimines with Sulfer Ylides: Access to Cyclopropane and Pyrrole Rings

M.Sc. Thesis

By

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DEPARTMENT OF CHEMISTRY

INDIAN INSTITUTE OF TECHNOLOGY INDORE

JUNE, 2021

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A THESIS

Submitted in partial fulfillment of the
requirements for the award of the degree
of
Master of Science

by
ANKUR

DEPARTMENT OF CHEMISTRY
INDIAN INSTITUTE OF TECHNOLOGY INDORE
JUNE 2021

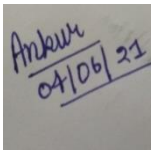
INDIAN INSTITUTE OF TECHNOLOGY

INDORE

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **Base-Promoted Reaction of Unsaturated N-Sulfonyl Ketimines with Sulfer Ylides: Access to Cyclopropane and Pyrrole Rings** in the partial fulfillment 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 time period from July 2020 to June 2021 under the supervision of Dr. Sampak Samanta, Associate Professor, 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.



Signature of the student with date
(Ankur)

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

04.06.2021

Signature of the Supervisor of M.Sc. thesis
(Dr. Sampak Samanta)

Ankur has successfully given his/her M.Sc. Oral Examination held on **<Date of M.Sc. Oral Examination>**.

Signature of Supervisor of MSc thesis
Date: 04.06.2021

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Signature of PSPC Member
Dr. Amrendra Kumar Singh
Date: 8/6/2021

Signature of PSPC Member
Dr. Umesh Achyutrao Kshirsagar
Date:

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to those whose constant support and motivation made it possible to present my research work in the form of a dissertation.

At this moment of acknowledgment, first of all, I would like to say special thanks to my thesis supervisor **Dr. Sampak Samanta** (Associate Professor, Discipline of Chemistry, IIT Indore) for valuable guidance, suggestions, and supervision throughout my research work. Further, I would like to thank my PSPC members **Dr. Amrendra Kumar Singh** and **Dr. Umesh Achyutrao Kshirsagar** for their valuable suggestions and support.

I would like to thank all faculty members, seniors (research scholars), SIC, staff and lab mates of IIT Indore for their help and cooperation during this dissertation work.

I wish to express my special thanks to the lab mates Soumitra Guin, Meher Prakash Rajpoot, S Banu Prakash Goud, Rajni Rajpoot, Shikha Singh Rathor, Ashvani K. Patel at Dr. S.S. Lab, and IIT Indore for their valuable co-operation in the completion of the project.

I want to extend my thanks to my batch mates who were always there and never let me down during these M.Sc. days.

I would like to thank my family members for their constant support.

Abstract

Pyrrole and cyclopropane rings are present ubiquitously in biologically active natural molecules, pharmaceutical and drug molecules etc. So, the establishment of unprecedented tactics for the synthesis of interesting functionalized cyclopropane and pyrrole scaffolds is a pivotal research target for chemists. Towards the above goal, herein we have developed an efficient base-promoted [2+1] and [4+1] cyclization reaction of cyclic 1-azadienes with sulfur ylides. The above Michael-initiated ring closing process affords vital classes of cyclopropane and pyrrole moieties with acceptable chemical yields.

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NOMENCLEATURE

Equiv.	Equivalent
δ	Chemical shift
°C	Degree Celsius
mmol	Millimole
mL	Milliliter
rt	Room temperature

ACRONYMS

DCM	Dichloromethane
$CDCl_3$	Chloroform-D
MeCN	Acetonitrile
CH_3OH	Methanol
EtOAc	Ethyl acetate
NMR	Nuclear magnetic resonance spectroscopy
^{1}H NMR	Proton NMR Spectroscopy
^{13}C NMR	Carbon-13 NMR Spectroscopy
mL	milliliter
ppm	Parts per million

Chapter 1

INTRODUCTION

1.1 Pyrrole:

Heterocyclic compounds are cyclic compounds, containing one or more non-carbon elements for instance sulfur, oxygen, nitrogen etc. Pyrrole is a 5-membereds heterocyclic compound in which one carbon atom is replaced by one nitrogen atom. Pyrrole is a colourless and vaporous liquid. It darkens instantly when it comes in contact with air and polymerizes in the presence of light *[1]*.

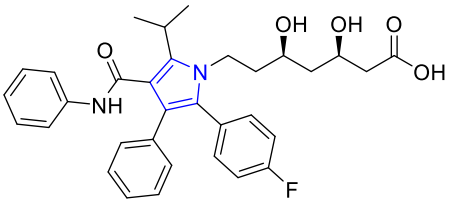
Pyrrole is not a naturally occurring heterocyclic compound, however various of its derivatives are found in a variety of cofactors and natural products. Pyrroles are essential components of many complex macrocyclic rings for example corrin ring in vitamin B12, porphyrins, chlorophyll, and chlorins *[1]*.

Pyrrole ring compounds have various applications in chemistry which include fungicides, antibiotics, anti-inflammatory drugs, cholesterol reducing drugs, anti-tumor agents and many more. Pyrroles have shown a vital role in various catalytic reactions for instance polymerization process, corrosion inhibitor, preservative, solvent of resin, terpenes, in metallurgical process etc. *[2]*.

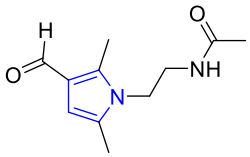
Cyclopropane:

New pathways for the synthesis of substituted cyclopropane are in great demand in organic chemistry. This three-membered ring is ubiquitously present in a wide range of biologically active naturally occuring molecules, pharmaceuticals, agrochemicals etc. *[3]*.

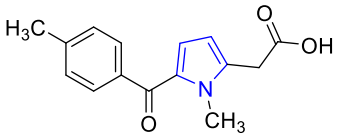
Figure 1: Various marketed drugs containing pyrrole moiety *[4]*.



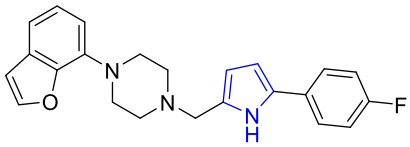
Atorvastatin
For the treatment of
Dyslipidemia



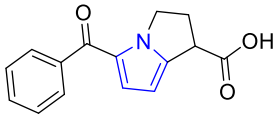
Aloracetam
For the treatment of
Alzheimer's disease



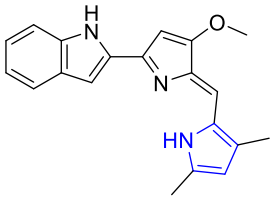
Tolmetin
use primarily to reduce
the pain, swelling,
and stiffness of arthritis



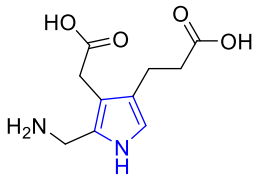
Elopiprazole
Antipsychotic drug
of the phenylpiperazine class



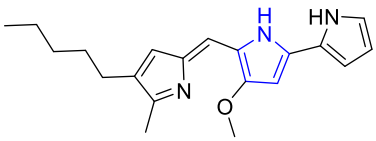
Ketorolac (Toradol)
used to treat eye pain,
and itchiness of
seasonal allergies.



Obatocalx
It is used for treatment
of leukemia, lymphoma,
myelofibrosis and mastocytosis.

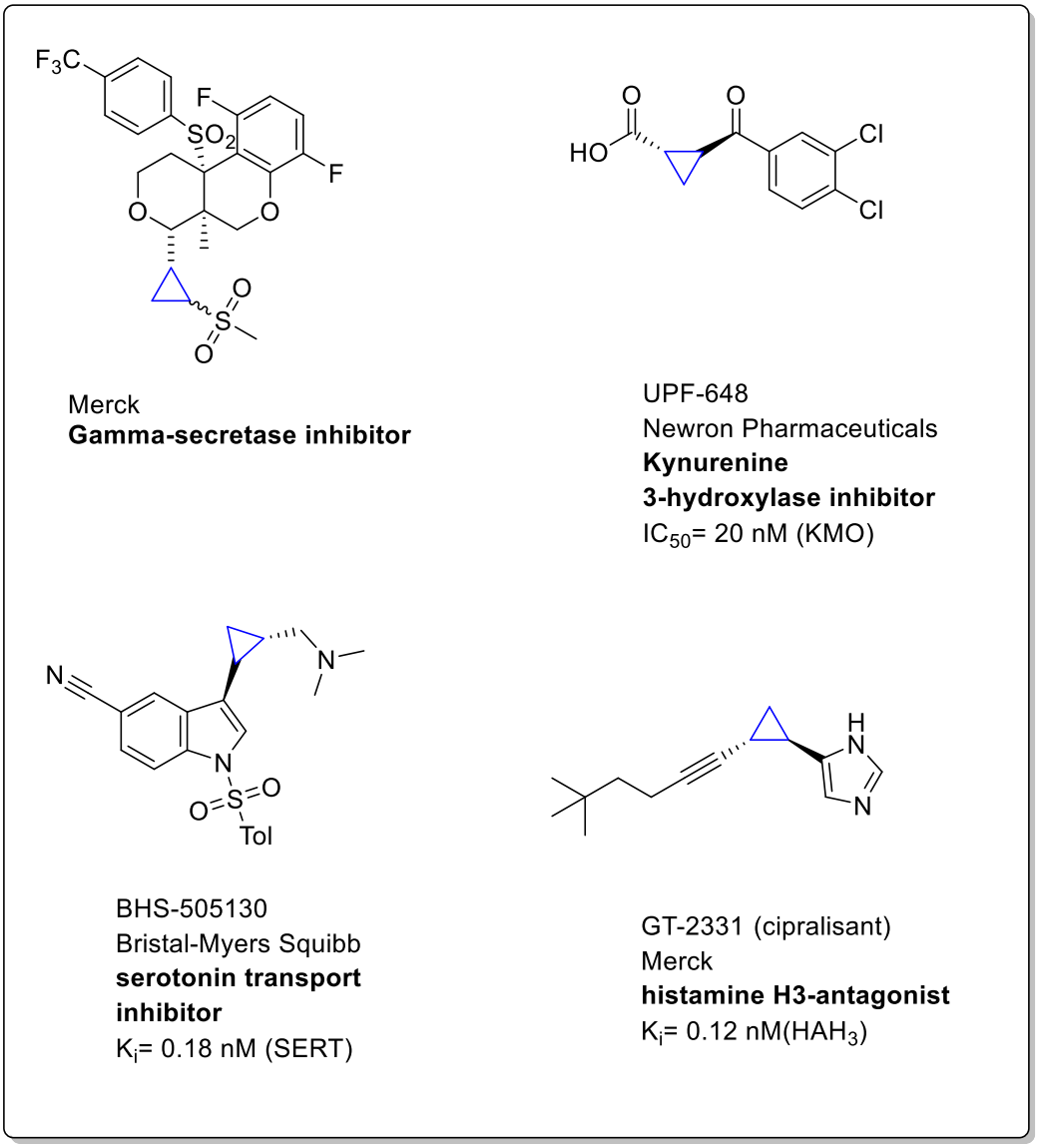


Porphobilinagen
It is an intermediate in
the biosynthesis of porphyrins.



Prodigiosin
It possesses antibacterial, antifungal,
antiprotozoal, antimalarial, immune suppressive
and anticancer properties.

Figure 2: Various marketed drugs containing cyclopropane moiety *[5]*.

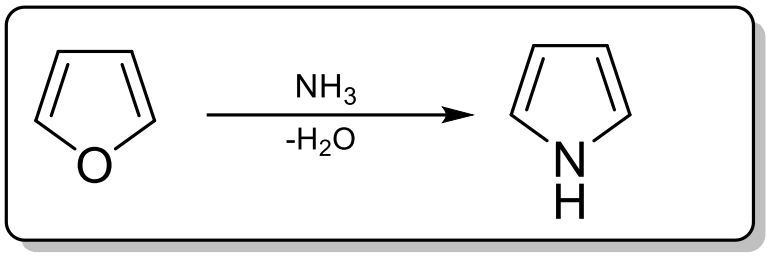


1.2 Review Work:

1.2.1 Classical methods for the synthesis and functionalization of pyrrole:

Industrial preparation

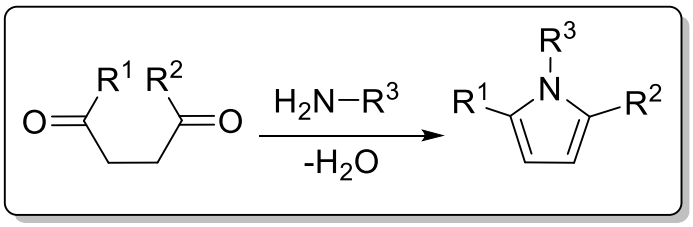
In industry, pyrrole is synthesized by reaction between furan and ammonia in the company of solid acid catalyst for instance Al_2O_3 and SiO_2 *[4]*.



Scheme 1: Industrial preparation of pyrrole

Paal-Knorr synthesis of pyrrole

Paal-Knoor synthesis of pyrrole is a very successful one-pot strategy which produces pyrroles via a reaction between 1,4-dicarbonyl compounds and primary amines or ammonia to synthesis substituted pyrroles. This reaction happens in the presence of protic or Lewis acidic (weak acidic condition), with a primary amine *[4]*.



Scheme 2: Paal-Knorr pyrrole synthesis

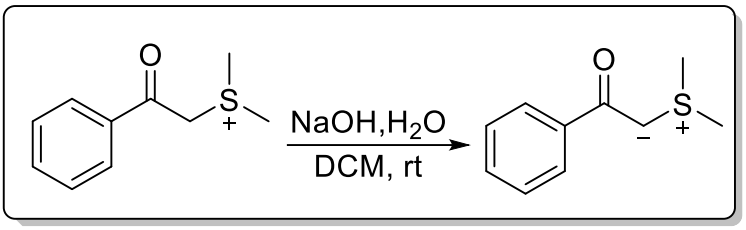
The need of greener approach towards the synthesis of new functionalized pyrrole skeletons. The rampant utilization of Paal-Knoor strategy started in 1990s. Amarnath *et al.* discovered the mechanism of the Paal-Knoor reaction in which a

1,4-dicarbonyl molecule reacts with ammonia or a primary amine to generate pyrrole in the early 1990s *[6]*.

1.2.2 New approach towards the synthesis of [2+1] or [4+1] cycloaddition reaction:

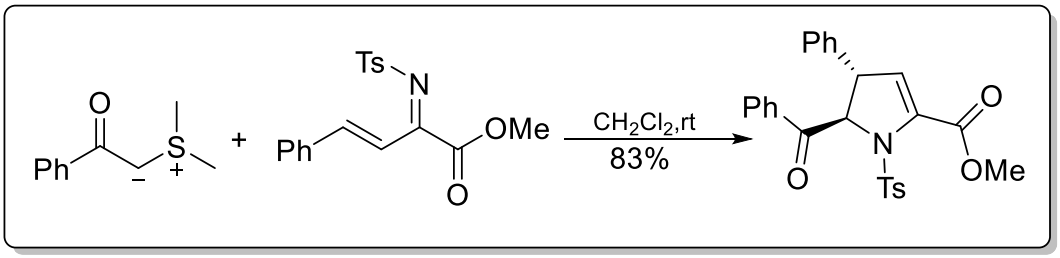
Sulfonium ylide

Sulphonium ylides are those compounds in which a negative charge carrying carbon atom is bonded directly to a positively charged sulfur atom.



Scheme 3: Synthesis of sulfonium ylide *[7]*

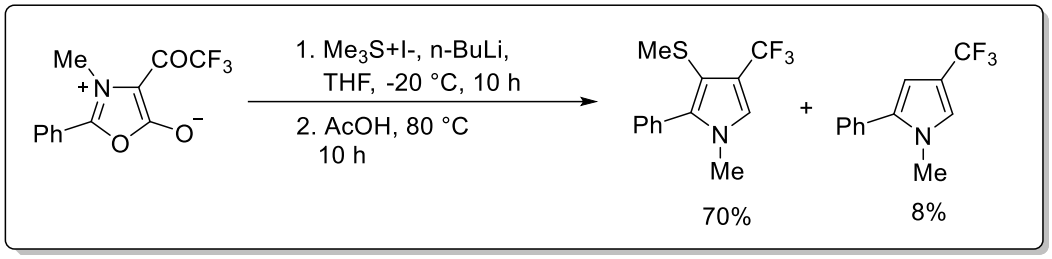
A simple approach for producing functionalized 2,3-dihydro-1H-pyrroles was developed via a formal [4+1] cycloaddition of 1-aza-1,3-diene with a benzoyl substituted sulfonium ylide at room temperature. The current method delivers high yield with excellent diastereoselectivities *[8]*.



Scheme 4: Synthesis of 2,3-dihydropyrrole

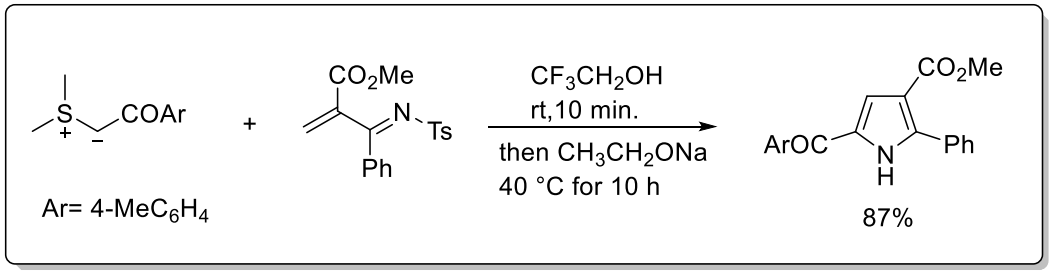
In 2012, Ryosku Saijo and Masami Kawase reported the one-pot two-step sequential-reaction between mesoionic oxazoles and sulfur ylide. Interestingly, a mixture of 4-trifluoromethyl-1-methyl-3-methylthio-2-phenylpyrrole and 4-

trifluoromethyl-1-methyl-2-phenylpyrrole were achieved in 70% and 8% yields, respectively *[9]*.



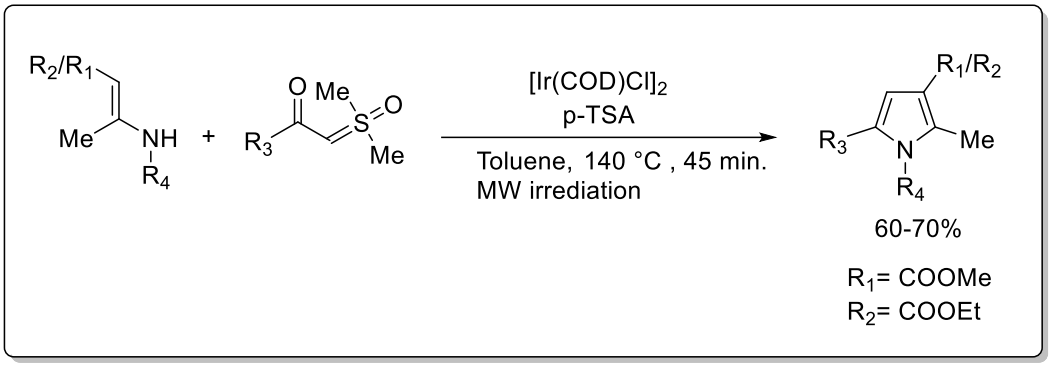
Scheme 5: Reaction of mesoionic oxazole with S-ylide

Bei-Yi Cheng *et al.* synthesised polysubstituted pyrroles in 2017 using a formal [4+1] cycloaddition reaction, E1cb elimination, sulphur ylide aromatization, and -unsaturated imine aromatization sequence. Several examples of polysubstituted pyrroles were reported in excellent yield *[10]*.



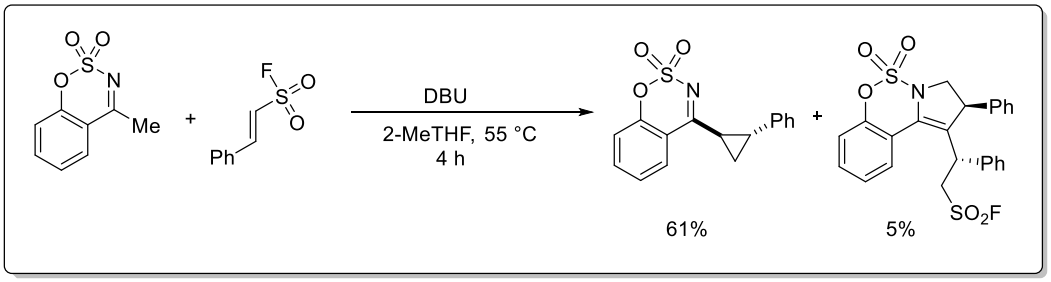
Scheme 6: Synthesis of polysubstituted pyrrole by αβ-unsaturated imines

In 2017, Jankiram Vaitla *et al.* reported a novel approach in order to produce substituted pyrroles by utilizing enamines and sulfoxonium ylide catalyzed by iridium complex at 140 °C irradiated by Microwave. The desired products were obtained in 60-70% yields after 45 min. *[11]*.



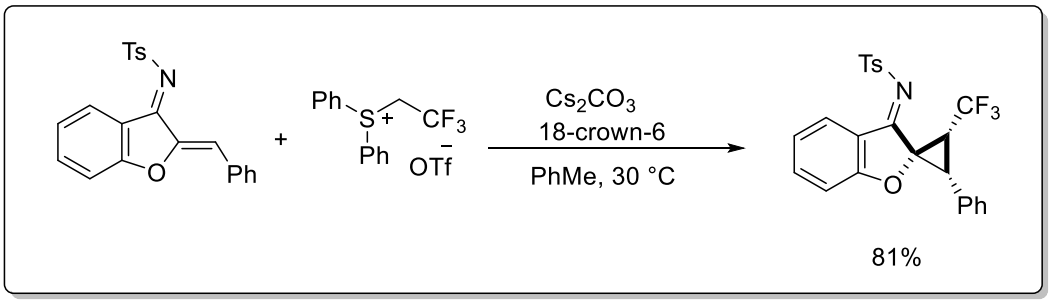
Scheme 7: Transition metal-catalyzed synthesis of pyrroles

In 2019, Dr. Sampak Samanta *et al.* reported [2+1] cycloaddition reaction in between N-sulfonyl ketimine and vinyl sulfonyl-fluoride with trace amount of [4+1] cycloaddition product. The desired products were obtained in 61% yield after 4 h *[12]*.



Scheme 8: β-substituted ethenesulfonyl fluoride as 1,2-bielectrophiles

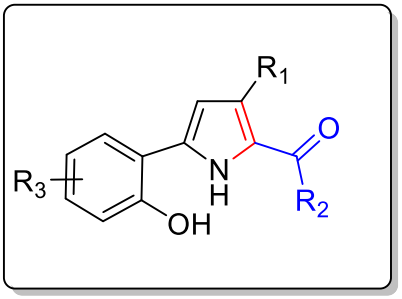
In 2019, Chen *et al.* developed a synthetic method to access the spiro trifluoromethyl cyclopropanes. Several derivatives were synthesized in good yields via base-promoted Michael-initiated ring closing reaction of sulfur ylide with 1-azadienes *[13]*.



Scheme 9: Synthesis of spiro cyclopropane

1.3 Objective of the Present Work:

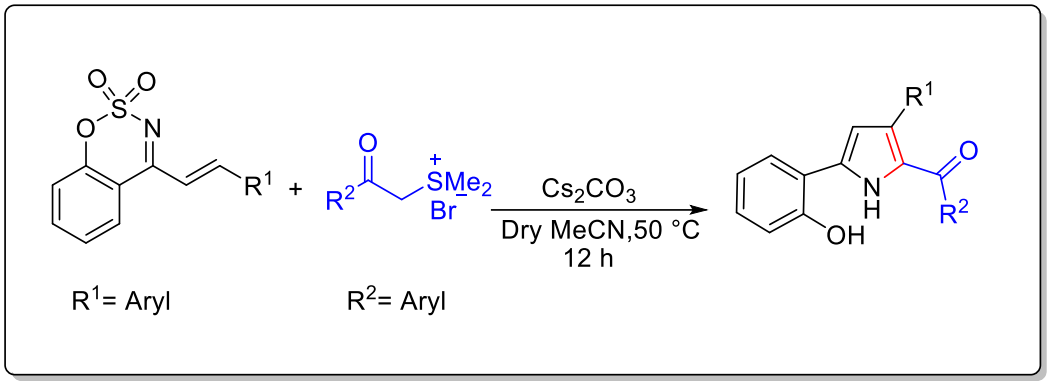
As can be seen that there are many routes available to synthesize pyrrole and cyclopropane rings with good to high yields. However, several methods are linked with many practical difficulties such as drastic reaction conditions, poor substrate scope, high temperature etc. which makes the methods less practical utility. Moreover, there is no such method established for the synthesis of substituted pyrroles and cyclopropanes involving αβ-unsaturated cyclic N-sulfonyl ketimines as carbonucleophiles. Therefore, it is great idea to develop an alternative method for their effective access.



Our target

1.4 Present work:

To our synthetic exercise, we performed a reaction at 50 °C between (*E*)-4-(2,5-dimethoxystyryl) benzo[*e*][1,2,3]oxathiazine 2,2-dioxide and dimethyl(2-oxo-2-phenylethyl)sulfonium bromide in the company of cesium carbonate in dry MeCN as solvent. Then after 12 h, the derivative was isolated.



Scheme 10: Synthesis of substituted pyrrole ring

Chapter 2

EXPERIMENTAL SECTION

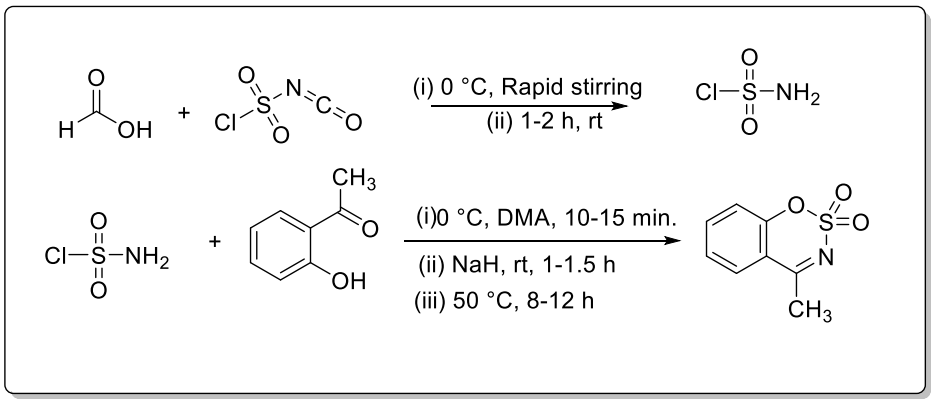
2.1 Material and instrumentation

Some of the starting materials were synthesized in the laboratory and one chemical that is phenacyl bromide was ordered from S.K. Traders. All synthetic reactions were carried out under air and weather reaction completed or not, confirmed by TLC using Merck 60 F_{254} pre coated silica gel plate (0.25 mm thickness). Then that TLC was monitored under UV chamber. After completing the reaction, work up was done using separating funnel by water and DCM. Solvent was evaporated rotatory evaporator and slurry was prepared. Silica gel (100-200 mesh) was used for column chromatography. In $CDCl_3$, NMR spectra were acquired using a Bruker 400 spectrometer at 400 MHz for ^1H NMR and 100 MHz for ^{13}C NMR. Data for ^1H NMR Chemical Shifts is presented in delta (δ) units, expressed in parts per million (ppm) downfield from tetramethylsilane (TMS), with $CDCl_3$, 7.26 ppm as an internal reference. Chemical shifts in ^{13}C NMR are measured in delta (δ) units. Compounds were named by using Chem draw Ultra 12.0 and NMR data processed by MestReNova.

2.2 General procedure for synthesis of precursors

2.2.1 General procedure for synthesis of 4-methylbenzo[*e*][1,2,3]oxathiazine 2,2-dioxide:

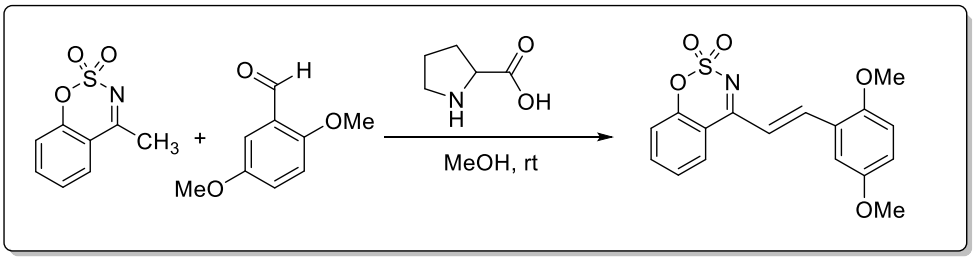
Firstly, anhydrous formic acid (20 mmol, 0.75 mL) was taken in a 250 mL round bottom flask of two neck and a balloon was put on one of the two necks. After that neat chlorosulfonyl isocynate (20 mmol, 1.74 mL) added to the flask at 0 °C with rapid stirring on the stirrer. The ice bath was then withdrawn, and the reaction mixture was left to stir for 1-2 hours. Once the sulfamoyl chloride was obtained, 2-hydroxyacetophenone (10 mmol, 1.20 mL) and DMA (15 mL) was added into it at 0 °C. Removed the mixture from the ice bath and stirred it for 10-15 minutes. After that sodium hydride (480 mg, 12 mmol) was added to the mixture and let it stir for 30 minutes at room temperature. Another portion of sodium hydride (480 mg, 12 mmol) was added and left the stirring for 1-1.5 h. Then put the reaction mixture for 8-12 h at 50 °C heating with stirring. After that reaction was quenched by adding ice to the reaction mixture and work up was done with ethyl acetate. After evaporating solvent, we left with white solid *[14]*.



Scheme 11: Synthesis of 4-methylbenzo[e][1,2,3]oxathiazine 2,2-dioxide

2.2.2 Synthesis of *(E)*-4-(2,5-dimethoxystyryl) benzo[*e*][1,2,3]oxathiazine 2,2-dioxide:

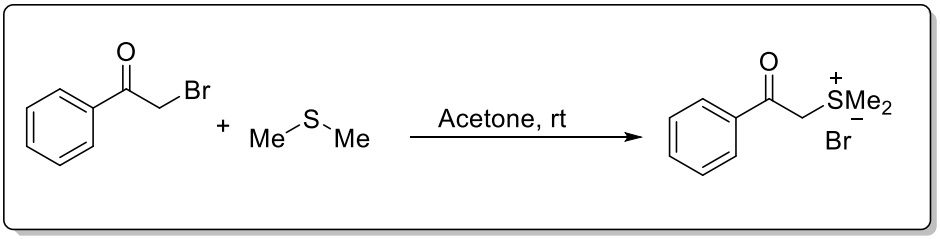
We took 50 mL one neck round bottom flask and added 2,5-dimethoxybenzaldehyde (1.522 mmol, 252.65 mg), L-Proline (0.203 mmol, 23.34 mg) and 1.5 mL of methanol into it. Then left the reaction concoction for stirring at room temperature for 5-10 minutes. After that we added 4-methylbenzo[*e*][1,2,3]oxathiazine 2,2-dioxide (1.015 mmol, 200 mg) to the reaction concoction and left it for stirring. After 12 h, We got precipitate and washed them with hexane to discard extra substrate if any.



Scheme 12: Synthesis of *(E)*-4-(2,5-dimethoxystyryl) benzo*[e]*[1,2,3]oxathiazine 2,2-dioxide

2.2.3 Synthesis of dimethyl(2-oxo-2-phenylethyl)sulfonium bromide:

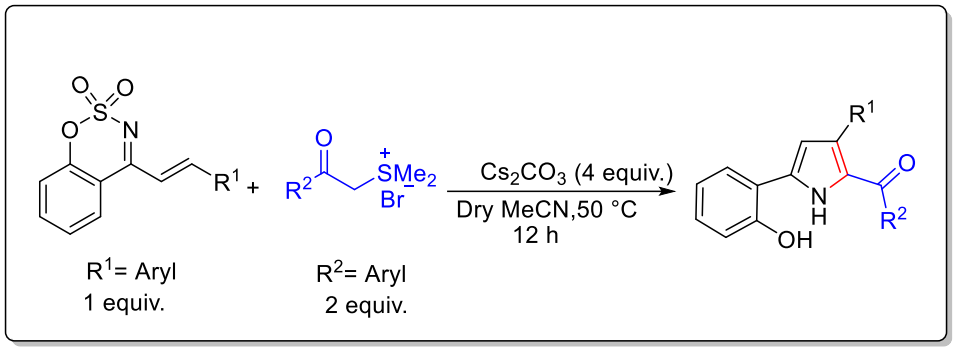
We took a 25 mL round bottom flask and added phenacylbromide (5 mmol, 995 mg) into it. Then we added 10 mL of acetone followed by 310 mg of dimethylsulfide (5 mmol, 310 mg). After that put the reaction on stirrer. After 4 h, we washed obtained precipitate with acetone *[15]*.



Scheme 13: Synthesis of dimethyl(2-oxo-2-phenylethyl)sulfonium bromide

2.3 General procedure for the synthesis of (2-(2,5-dimethoxyphenyl)-5-(2-hydroxyphenyl)-1*H*-pyrrol-3-yl)(phenyl)methanone:

In a reaction tube, we added (*E*)-4-(2,5-dimethoxystyryl) benzo[*e*][1,2,3]oxathiazine 2,2-dioxide (0.289 mmol, 100 mg) and dimethyl(2-oxo-2-phenylethyl)sulfonium bromide (0.579 mmol, 150.54 mg) and dissolved them in dry MeCN (1 mL) by on stirrer at 50 °C. After that we added cesium carbonate (1.156 mmol, 375.7 mg) and let the reaction run for 12 h. When 12 h passed, we corroborated the completion of reaction by visualizing TLC in UV chamber. After confirmation, work up was done in water and DCM (3×10 mL). Desired product that was in DCM extracted in a 100 mL conical flask and dried over sodium sulphate. After some time, DCM was evaporated by rotatory evaporator and slurry was prepared. To obtain pure desired product, column chromatography was done using 100-200 mesh silica. The column was done by 1% ethyl acetate and hexane solution as eluent. The product was characterized by its spectroscopic data (^{1}H NMR). By confirming the formation of desired product, we started to optimize the reaction condition for better yield.

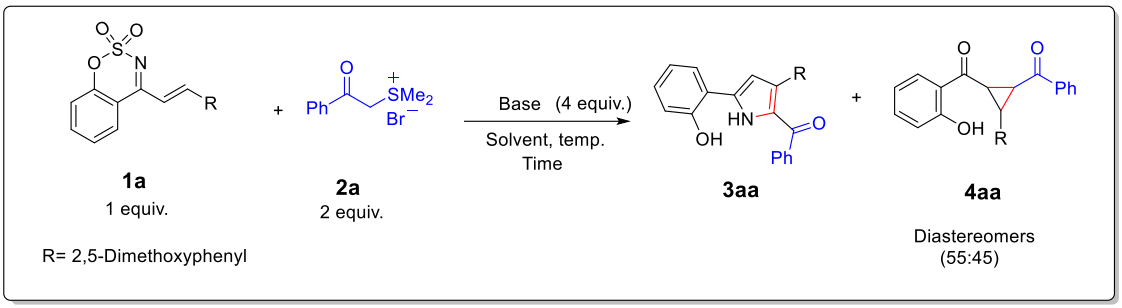


Scheme 14: Synthesis of substituted pyrrole ring and its derivatives

Chapter 3

RESULTS AND DISCUSSION

3.3 Table 1: Optimization of reaction conditions[a]

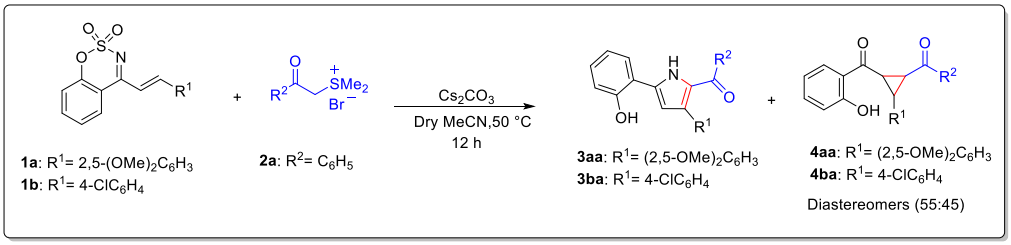


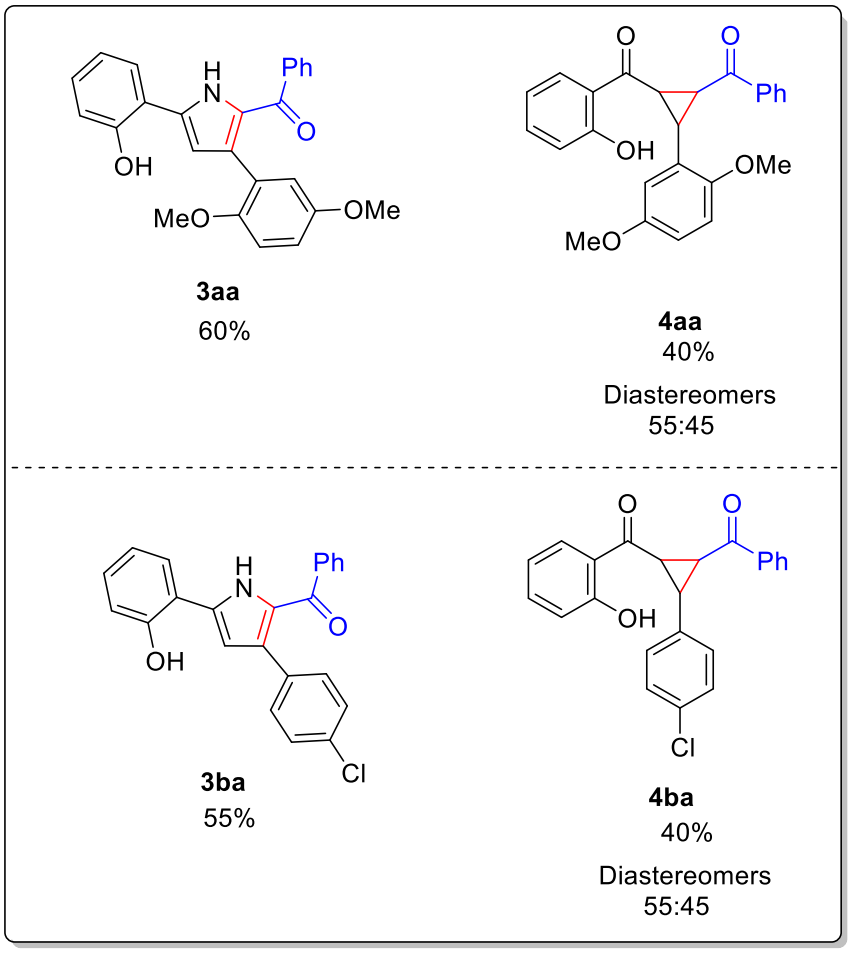
Entry	Solvent	Base	Temperature	Time	Yield (%) (3aa)	Yield[b](%) (4aa)
1	**Dry MeCN**	**Cs_2CO_3**	**50 °C**	**8 h**	**60**	**40**
2	Dry MeCN	DBU	50 °C	8 h	NR	NR
3	Dry MeCN	DABCO	50 °C	8 h	NR	NR
4	Dry MeCN	NaOH	50 °C	8 h	NR	NR
5	Dry MeCN	K_2CO_3	50 °C	8 h	NR	NR
6	Dry MeCN	KOH	50 °C	8 h	NR	NR
7	Dry MeCN	Et_3N	50 °C	8 h	NR	NR

[a]**Reaction condition:** All reactions were performed with **1a** (0.0579 mmol), **2a** (0.1159 mmol) and **base** (0.2316 mmol, 4 equiv.) at 50 °C in dry MeCN. [b]Isolated yield after column chromatography.

We observed that the above reaction proceeded only in the presence of cesium carbonate with 60% yield of **3aa** and 40% yield of **4aa**. Besides, substituted cyclopropane ring was obtained in diastereomeric ratio of 55:45.

3.2 Scheme 15: Synthesis of substituted pyrrole and cyclopropane derivatives:

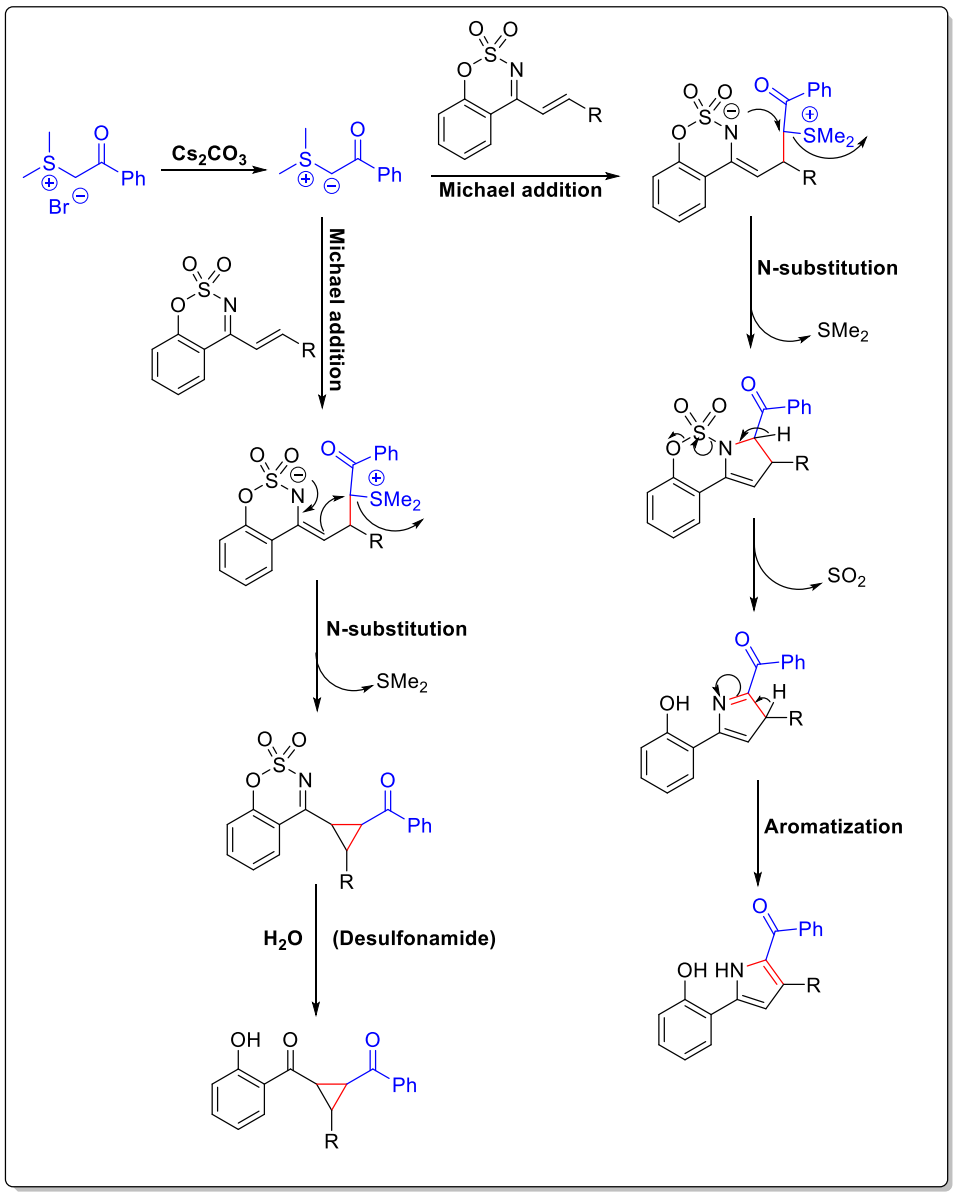




we performed a reaction between unsaturated N-sulfonyl ketimine (1equiv., 100 mg) and sulfonium salt (2 equiv.) by taking cesium carbonate (4 equiv.) as base in dry acetonitrile at 50 °C. TLC was used to osbserve the

reaction. When the reaction has completed, we separate the desired spot using column chromatography to give the pure products which are characterized by NMR that the isolated products were a polysubstituted pyrrole **3aa** and cyclopropane ring **4aa**.

3.3 Plausible mechanism of the reaction:



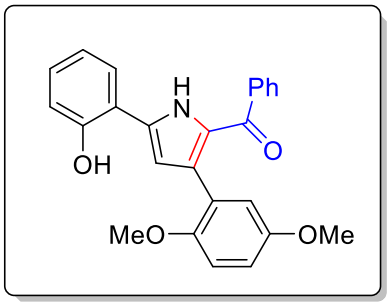
Scheme 15: A plausible mechanism of the reaction

A reaction between sulfonium salt and cesium carbonate produces sulfur ylide in situ at first. The Michael addition reaction between this sulfur ylide and unsaturated N-sulfonyl ketimine produces a zwitterion intermediate. The required product was then generated through N-substitution, elimination, and aromatization.

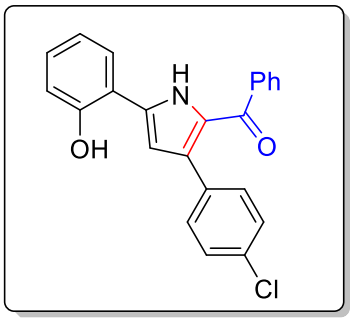
This [4+1] cycloaddition process competes with the [2+1] cycloaddition process (Corey-Chaykovsky reaction), which results in the formation of substituted cyclopropane ring.

Data of all the synthesized compounds:

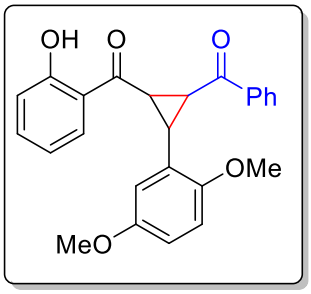
(3-(2,5-Dimethoxyphenyl)-5-(2-hydroxyphenoyl)-1*H*-pyrrol-2-yl)(phenyl)methanone (3aa): Yellow colour solid; R_f = 0.84 (EtOAc:Hexane = 1:5); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 12.17 (s, 1H), 7.75 (d, *J* = 7.3 Hz, 2H), 7.59 (d, *J* = 7.9 Hz, 1H), 7.39 (d, *J* = 7.4 Hz, 5H), 7.02 – 6.94 (m, 2H), 6.84 (d, *J* = 8.9 Hz, 1H), 6.66 (m, *J* = 8.7 Hz, 2H), 3.85 (s, 3H), 3.34 (s, 3H) ppm.



(3-(4-Chlorophenyl)-5-(2-hydroxyphenoyl)-1*H*-pyrrol-2-yl)(phenyl)methanone (3ba): Yellow colour solid; R_f = 0.90 (EtOAc:Hexane = 1:5); **^{1}H NMR (500 MHz, $CDCl_3$) δ** 12.07 (s, 1H), 7.76 (d, *J* = 7.7 Hz, 2H), 7.69 (d, *J* = 8.1 Hz, 3H), 7.52 – 7.42 (m, 3H), 7.38 – 7.31 (m, 3H), 7.07 (d, *J* = 8.5 Hz, 1H), 6.91 (s, 1H), 6.81 (m, 1H) ppm.



(2-Benzoyl-3-(2,5-dimethoxyphenyl)cyclopropyl)(2-hydroxyphenyl)methanone (4aa): White colour solid; R_f = 0.66; (EtOAc:Hexane = 1:5); **^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer)** 12.32 (s, 1H), 8.18 (d, *J* = 8.0 Hz, 1H), 8.05 (d, *J* = 7.7 Hz, 1H), 7.56 – 7.43 (m, 5H), 7.02 (d, *J* = 8.9 Hz, 2H), 6.80 (d, *J* = 3.1 Hz, 1H), 6.70 (dd, *J* = 8.8, 3.2 Hz, 1H), 6.61 (d, *J* = 9.1 Hz, 1H), 4.11 (d, *J* = 5.6 Hz, 1H), 3.89 – 3.82 (m, 1H), 3.72 (s, 3H), 3.49 (m, 1H), 3.43 (s, 3H) ppm.



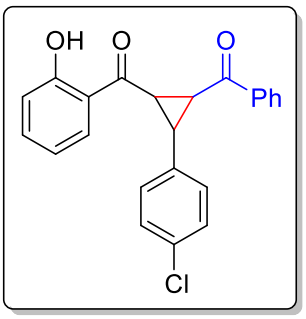
^{13}C NMR (100 MHz, $CDCl_3$) δ (major isomer) 202.47, 193.52, 162.51, 153.10, 152.21, 137.49, 136.79, 132.97, 130.56, 128.81, 128.48, 128.41,

123.67, 119.82, 119.32, 118.48, 116.87, 112.56, 110.67, 110.59, 55.65, 55.07, 36.37, 34.20, 29.70, 22.71, 14.14 ppm.

^{1}H NMR (400 MHz, $CDCl_3$); R_f = 0.70 (EtOAc:Hexane = 1:5); **δ (minor isomer)** 11.90 (d, *J* = 11.5 Hz, 1H), 8.17 (s, 1H), 7.54 (m, 5H), 6.96 (dt, *J* = 25.5, 7.7 Hz, 2H), 6.82 (d, *J* = 3.1 Hz, 1H), 6.72 (d, *J* = 9.0 Hz, 1H), 6.63 (d, *J* = 9.1 Hz, 1H), 4.15 – 4.07 (m, 1H), 3.84 (dd, *J* = 9.9, 4.8 Hz, 2H), 3.74 (d, *J* = 9.6 Hz, 3H), 3.48 (dd, *J* = 10.1, 6.4 Hz, 1H), 3.42 (d, *J* = 8.7 Hz, 3H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ (minor isomer) 199.15, 197.22, 161.95, 153.10, 152.29, 137.08, 136.10, 133.59, 130.78, 128.83, 128.46, 123.72, 120.31, 118.94, 118.12, 116.90, 112.50, 110.68, 55.67, 55.05, 35.47, 34.46, 31.94, 31.45, 30.13, 29.72, 29.38, 22.71, 14.13 ppm.

(2-Benzoyl-3-(4-chlorophenyl)cyclopropyl)(2-hydroxyphenyl)methanone (4ba): White colour solid; R_f = 0.81 (EtOAc:Hexane = 1:5); **^{1}H NMR (500 MHz, $CDCl_3$) δ (major isomer)** 12.20 (s, 1H), 8.14 (d, *J* = 8.0 Hz, 1H), 7.98 (d, *J* = 7.6 Hz, 2H), 7.60 – 7.52 (m, 2H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.18 (q, *J* = 8.4 Hz, 4H), 7.01 (t, *J* = 9.0 Hz, 2H), 4.20 (t, *J* = 5.5 Hz, 1H), 3.80 (dd, *J* = 10.0, 4.8 Hz, 1H), 3.54 (dd, *J* = 10.0, 6.1 Hz, 1H) ppm.



^{13}C NMR (125 MHz, $CDCl_3$) δ (major isomer) 201.79, 193.18, 162.55, 137.22, 137.05, 133.59, 133.33, 132.57, 130.41, 130.09, 128.79, 128.56, 128.33, 119.66, 119.46, 118.59, 37.20, 37.04, 31.95, 29.73, 29.23, 22.72, 14.16 ppm.

^{1}H NMR (500 MHz, $CDCl_3$); R_f = 0.76 (EtOAc:Hexane = 1:5); **δ (minor isomer)** 11.84 (s, 1H), 8.14 (d, *J* = 7.7 Hz, 2H), 8.04 (dd, *J* = 8.1, 1.6 Hz, 1H), 7.65 (t, *J* = 7.4 Hz, 1H), 7.55 (t, *J* = 7.6 Hz, 2H), 7.51 – 7.45 (m, 1H),

7.23 – 7.14 (m, 4H), 6.99 – 6.91 (m, 2H), 4.21 (t, *J* = 5.5 Hz, 1H), 3.77 (dd, *J* = 10.0, 4.9 Hz, 1H), 3.53 (dd, *J* = 10.0, 6.2 Hz, 1H) ppm.

^{13}C NMR (125 MHz, $CDCl_3$) δ (minor isomer) 198.65, 196.70, 162.26, 136.83, 136.79, 133.83, 133.38, 132.51, 130.20, 130.09, 128.92, 128.59, 128.46, 120.24, 119.32, 118.51, 37.34, 36.37, 31.95, 29.72, 29.68, 29.51, 29.38, 22.71, 14.14 ppm.

Chapter 4

CONCLUSION

In this work, we have synthesized polysubstituted pyrroles and cyclopropanes by using base promoted [2+1] and [4+1] cyclization of αβ-unsaturated N-sulfonyl ketimines with sulfur ylides. In future, the functional group tolerance and substrate scope of this methodology will be will be thoroughly examined. We hope that current method will find a potential application in organic synthesis.

APPENDIX A

^{1}H NMR and ^{13}C NMR spectra

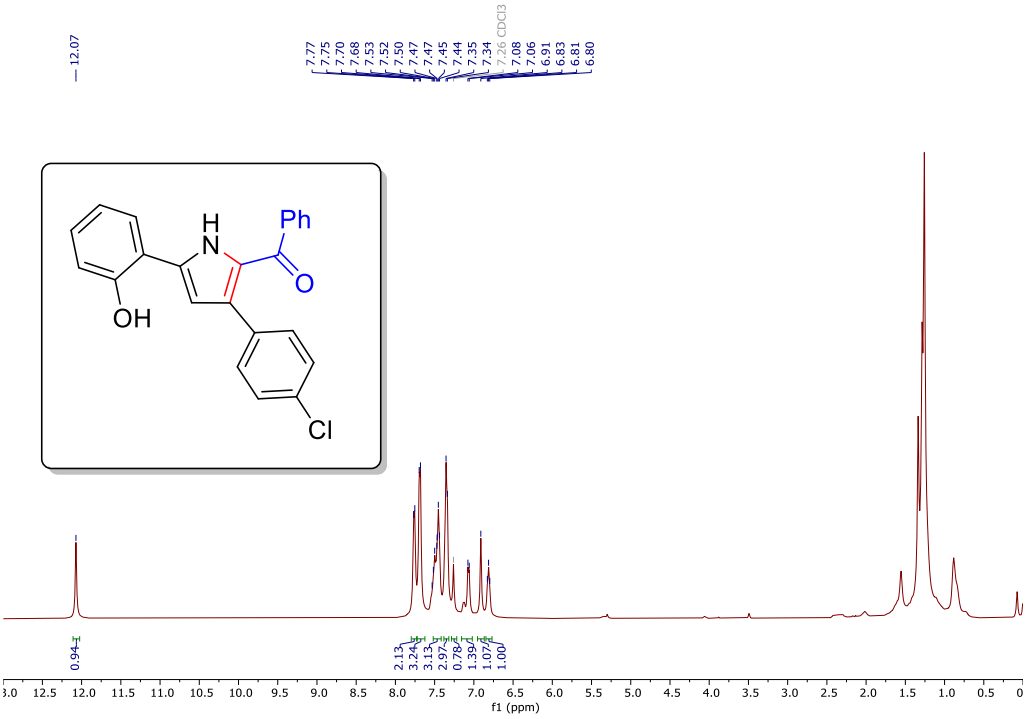


Figure 3: ^{1}H NMR spectra of **3ba** in $CDCl_3$

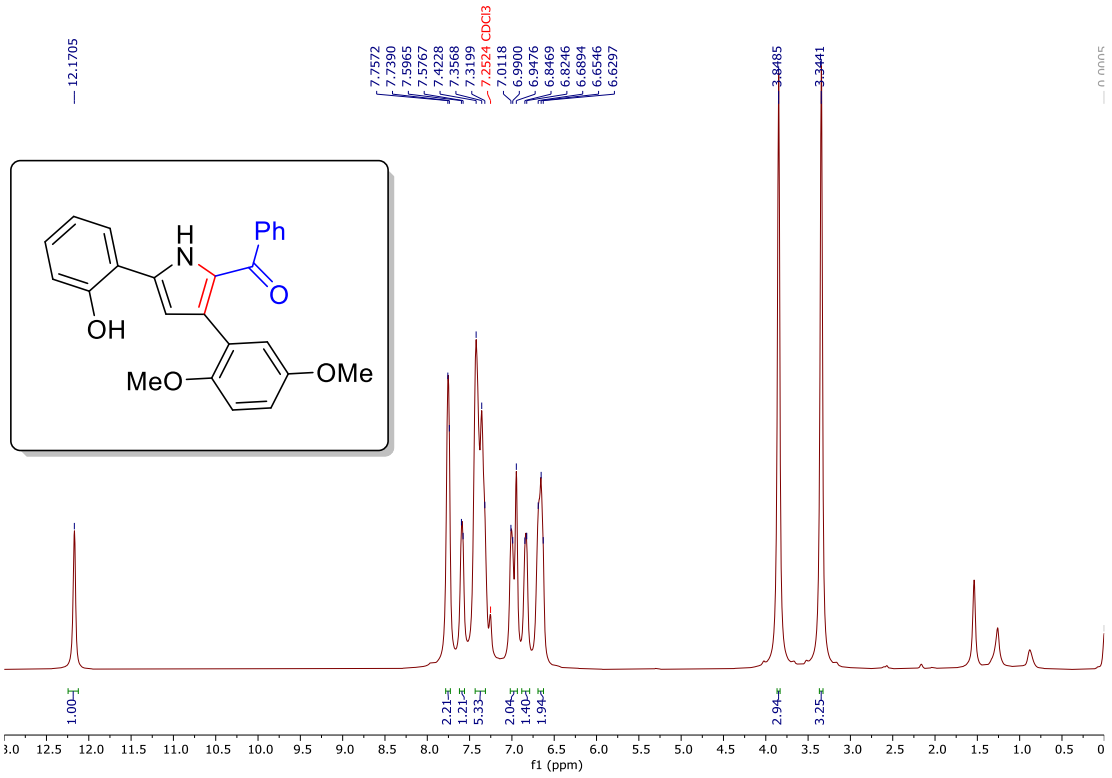


Figure 4: ^{1}H NMR spectra of **3aa** in $CDCl_3$

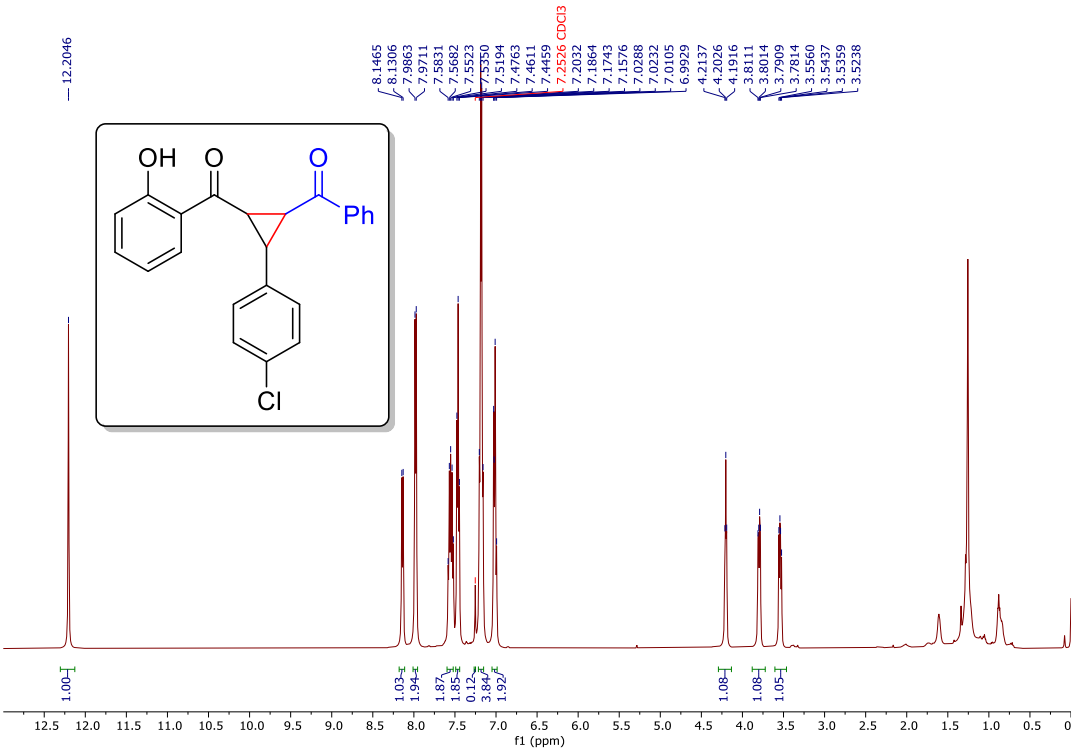


Figure 5: ^{1}H NMR spectra of **4ba** (major isomer) in $CDCl_3$

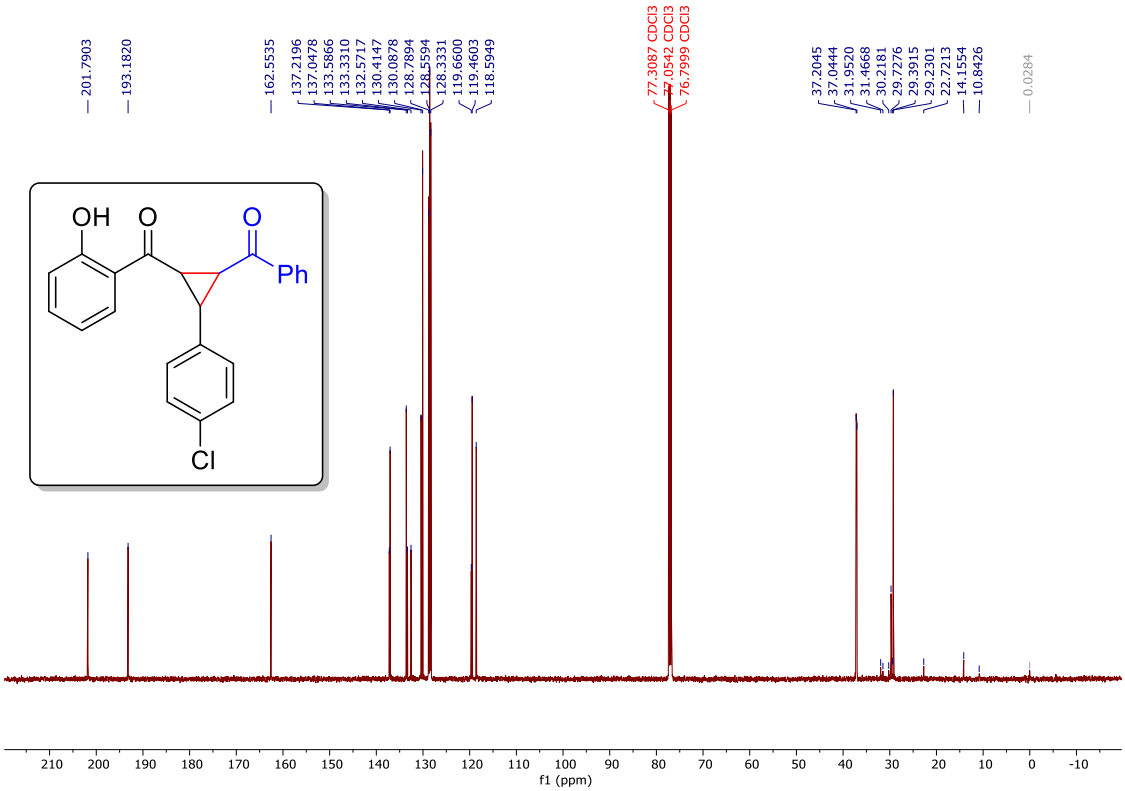


Figure 6: ^{13}C NMR spectra of **4ba** (major isomer) in $CDCl_3$

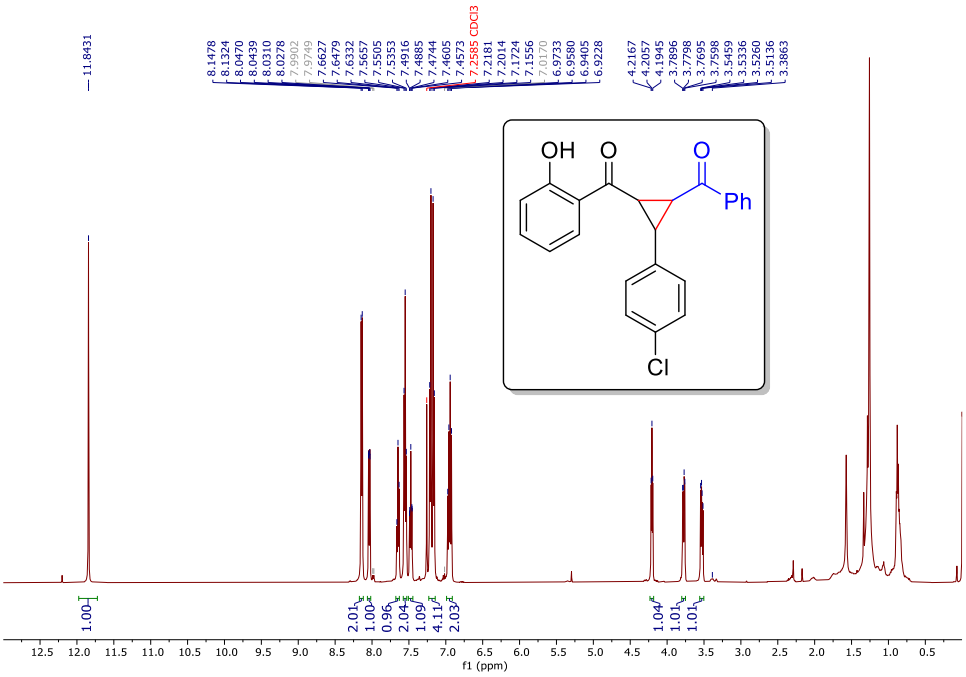


Figure 7: ^{1}H NMR spectra of **4ba** (minor isomer) in $CDCl_3$

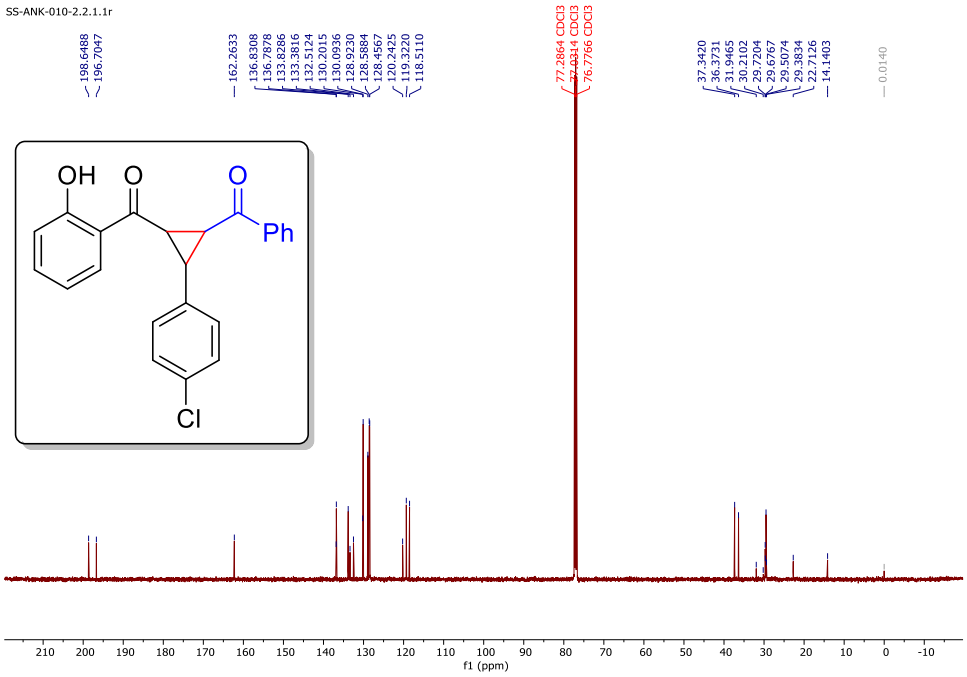


Figure 8: ^{13}C NMR spectra of **4ba** (minor isomer) in $CDCl_3$

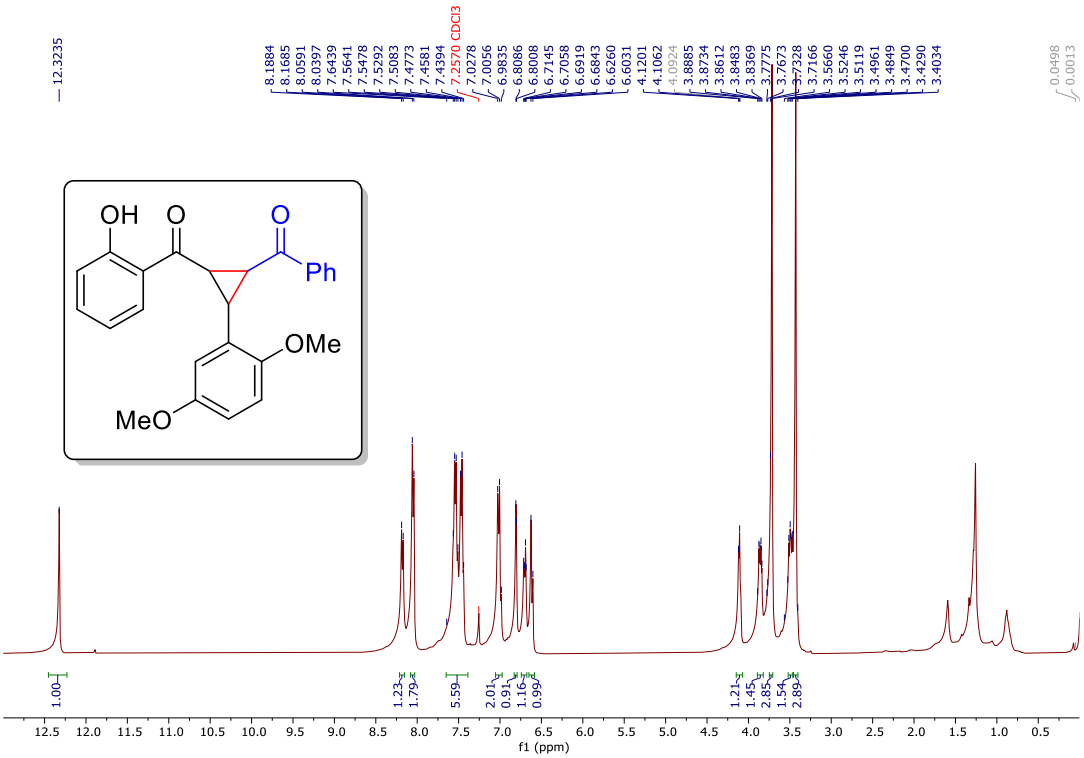


Figure 9: ^{1}H NMR spectra of **4aa** (major isomer) in $CDCl_3$

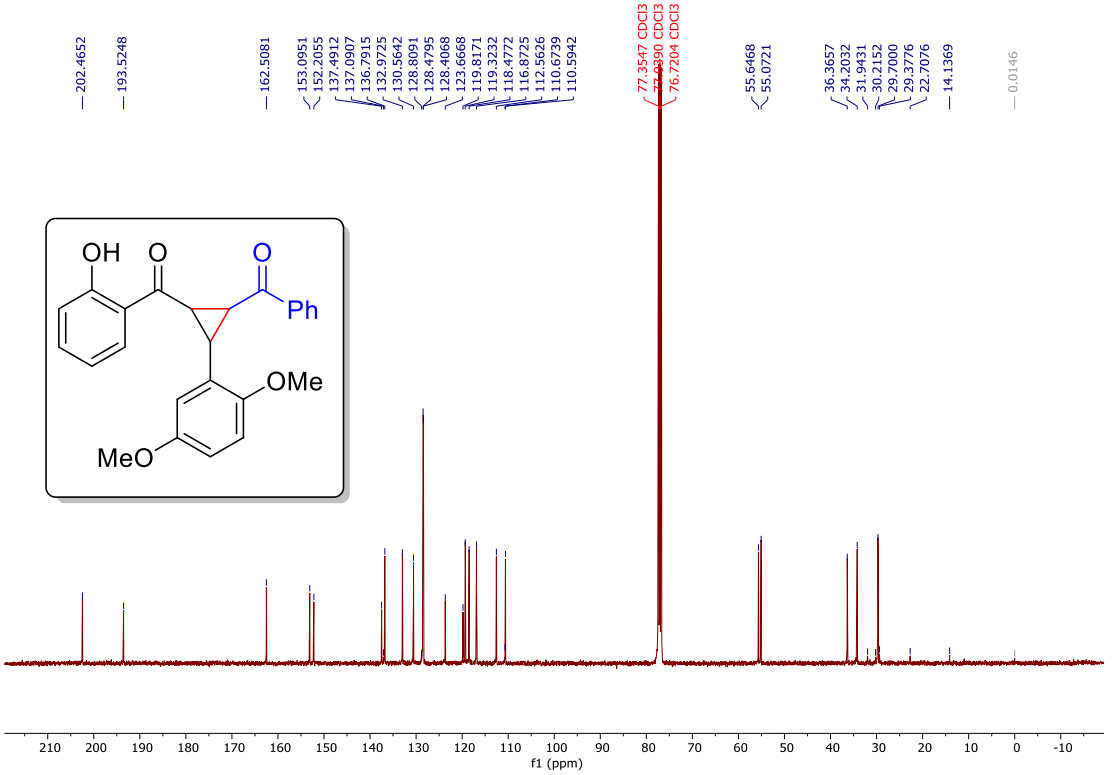


Figure 10: ^{13}C NMR spectra of **4aa** (major isomer) in $CDCl_3$

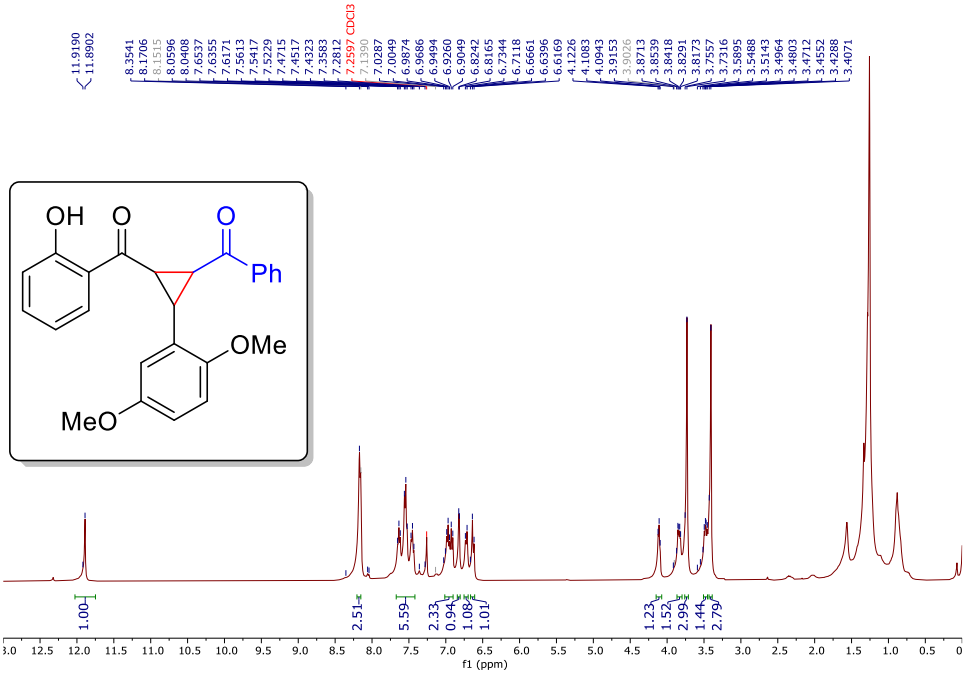


Figure 11: ^{1}H NMR spectra of **4aa** (minor isomer) in $CDCl_3$

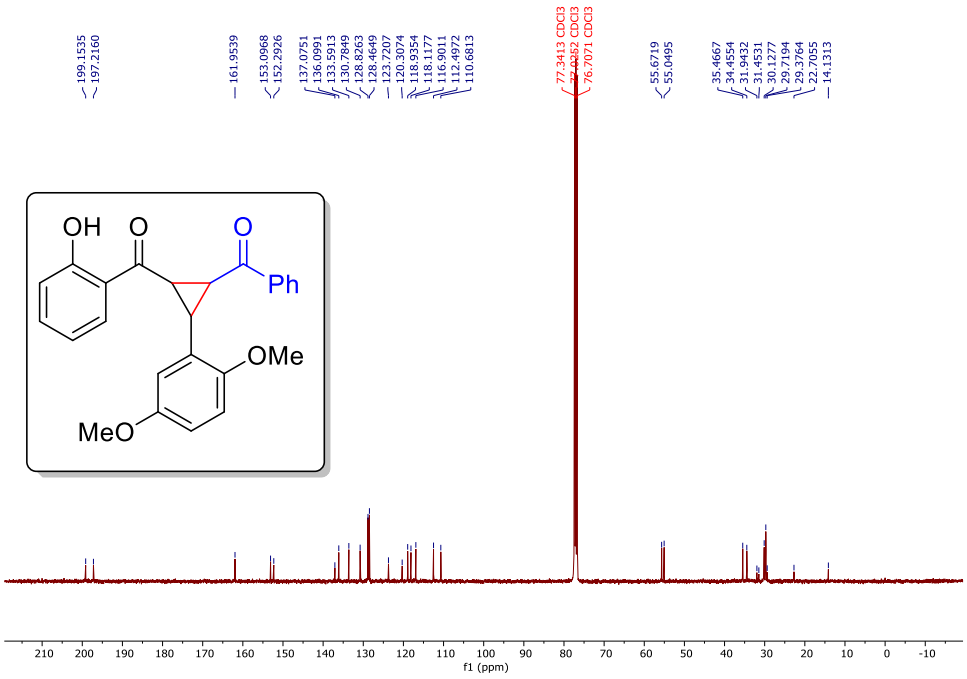


Figure 12: ^{13}C NMR spectra of **4aa** (minor isomer) in $CDCl_3$

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