

Dedicated
To
My Beloved Parents
And My Wife

DECLARATION

I declare that the thesis entitled “**INNOVATIVE APPROACHES TOWARDS THE SYNTHESIS OF HETEROCYCLIC COMPOUNDS**” has been prepared by me under the guidance of Prof. Pranab Ghosh, Department of Chemistry, University of North Bengal. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

Kumaresh Datta

Kumaresh Datta

Department of Chemistry

University of North Bengal

Darjeeling-734 013

West Bengal

India

Date: 21.06.2024

UNIVERSITY OF NORTH BENGAL

Accredited by NAAC with grade "B++"

Prof. P. Ghosh, FRSC

Department of Chemistry
University of North Bengal
Darjeeling - 734013, India



"সমানো মনো সমিতি সমানো"

Ph: +91 3532776381 (off)

+91 9474441468 (M)

Fax: +91 3532699001

Email: pizy12@yahoo.com

CERTIFICATE

I certify that **Mr. Kumaresh Datta** has prepared the thesis entitled "**INNOVATIVE APPROACHES TOWARDS THE SYNTHESIS OF HETEROCYCLIC COMPOUNDS**", for the award of Ph.D. Degree of the University of North Bengal, under my guidance. He has carried out the research work at the Department of Chemistry, University of North Bengal. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

Prof. Pranab Ghosh

Department of Chemistry
University of North Bengal
Darjeeling - 734013

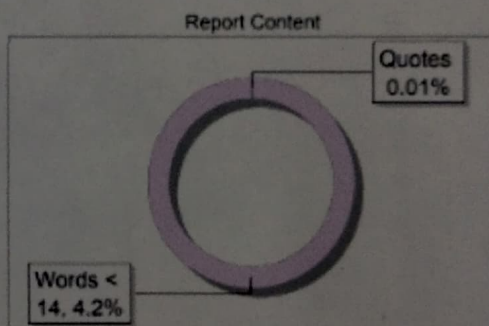
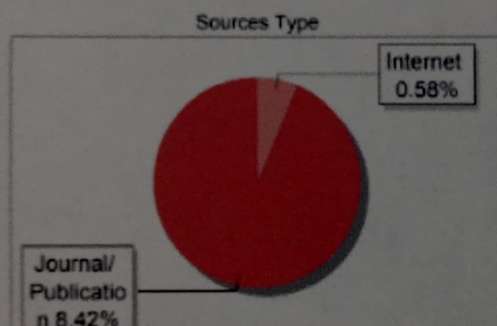
West Bengal, India

Date: 21.06.2024

Professor
Department of Chemistry
University of North Bengal
Darjeeling - 734013, India

Submission Information

Author Name	Kumaresh Datta
Title	INNOVATIVE APPROACHES TOWARDS THE SYNTHESIS OF HETEROCYCLIC COMPOUNDS
Paper/Submission ID	2010657
Submitted by	nbuplg@nbu.ac.in
Submission Date	2024-06-18 11:44:03
Total Pages, Total Words	108, 16554
Document type	Thesis

Result InformationSimilarity **9 %****Exclude Information**

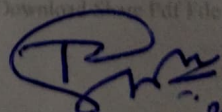
Quotes	Excluded
References/Bibliography	Excluded
Source: Excluded < 14 Words	Excluded
Excluded Source	8 %
Excluded Phrases	Not Excluded

Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
Internet or Web	Yes
Institution Repository	Yes

A Unique QR Code use to View/Download/Share Pdf File

Kumaresh Datta
21.06.2024


21.06.24



Professor
Department of Chemistry
University of North Bengal
Darjeeling - 734013, India

ACKNOWLEDGEMENT

I would like to express my sincere and heartfelt thanks towards all those persons who supported and inspired me to complete this work. Without their active guidance, help, cooperation and encouragement, I would not have been able to complete this work.

First and foremost, I would like to express my deep and sincere gratitude to my honorable supervisor Prof. Pranab Ghosh, Department of Chemistry, University of North Bengal, Darjeeling, for his supervision, valuable guidance, constructive criticisms, insightful suggestions, continuous encouragement and unfailing patience over the years at every stage of my research work.

I express my sincere gratitude towards Prof. Bhaskar Biswas, Head, Department of Chemistry, University of North Bengal and all the faculty members, non-teaching staff of the department for their constant support throughout this work.

I am thankful to Dr. Mayukh Deb, Microanalyst, Department of Chemistry and University of North Bengal for his ideas regarding compound characterization.

I would like to express my thanks to the Lab no.107, Dept. of Chemistry, NBU where I have done my research work and also my fellow labmates Rabindra Da, Hridoy Da, Suvodip Da, Passang Da, Puja Di, Tandra Di, Manishita Di, Sourav, Aminul, Sharmistha, Subhankar, Saptadwipa for stimulating discussions, valuable suggestions and cooperation during my experiments and data analysis.

I would like to express my special gratitude to Gyan Da and Bijeta Di for their constant help, support and inspiration throughout my Ph.D. journey. Without them this journey would have been quite difficult for me.

I would like to thank my friends Biswajit, Subhajit, Gautam, Arindam, Kingkar Da, Pranesh Da, Koushik Da and Pronay Da for their enormous help during this journey and lab work.

I convey my special thanks to all my colleagues from Sukanta Mahavidyalaya, Dhupguri, whose cooperation really helped me to complete my Ph.D. journey.

I am extremely grateful to my parents, Mrs. Manju Datta and Mr. Kamalesh Datta for their love, care, understanding, encouragement, belief and sacrifices for educating me. They are my source of energy, motivation and patience. Also I express my thanks to my elder sister Mrs. Piyali Datta for her guidance and active support and also I thank my younger brother Abhishake Datta for his support.

I am extremely thankful to my wife, Mrs. Moupita Sarkar for her sincere, unprecedented cooperation and moral support throughout this work.

Finally despite best of my efforts and sincerity, I might have committed some unintentional errors and mistakes in my thesis. Suggestions and criticisms from learned professors will be thankfully accepted.

Thank you.

Kumaresh Datta
21.06.2024

Kumaresh Datta

PREFACE

A wide range of pharmacologically significant drugs have been designed using heterocyclic molecules. These compounds have a notable impact on the agrochemical sectors as well. In addition, they are regarded as strong building blocks for the synthesis of naturally occurring biologically active substances such as heterocyclic compounds, glycosides, and amino acids.

The methods for creating a wide variety of heterocyclic compounds are described in the current work. This thesis starts with **Chapter I** which deals with a brief review of various approaches towards the synthesis of heterocyclic molecules. **Chapter II** is divided into two sections. **Section A** describes synthesis of tetrazolo[1,2-*a*]pyrimidine and **Section B** provides the preparation of [1,2,4]triazolo[1,5-*a*]pyrimidine assisted by β -cyclodextrin, an environmentally benign supramolecular organocatalyst, under solvent-free condition. **Chapter III** describes synthesis of functionalized diethyl(phenyl(phenylamino)methyl)phosphonate under solvent-free condition, using a green organocatalyst humic acid. **Chapter IV** deals with synthesis of 1,3,4-selenadiazoles from aldehyde, hydrazine and Se powder via one-pot pseudo three-component cascade reaction by using KI as a catalyst and oxidant $K_2S_2O_8$ in DMSO solvent. **Chapter V** describes synthesis of bis-coumarine derivatives using eucalyptol as a green solvent.

LIST OF TABLES

Table No.	Title	Page No.
Table II.A.1.	Optimization of reaction conditions ^a	21
Table II.A.2.	Synthesis of functionalized tetrazolo[1,2- <i>a</i>]pyrimidine derivatives ^a	22
Table II.A.3.	Synthesis of tetrazolo[1,2- <i>a</i>]pyrimidine derivatives from various active methylene compounds ^a	23
Table II.B.1.	Optimisation of reaction conditions ^a	38
Table II.B.2.	Synthesis of diversified [1,2,4]triazolo[1,5- <i>a</i>]pyrimidine derivatives ^a	39
Table III.1.	Optimization of reaction conditions ^a	55
Table III.2.	Synthesis of functionalized diethyl(phenyl(phenylamino)methyl) phosphonate derivatives ^a from functionaziled aldehyde	57
Table III.3.	Synthesis of functionalized diethyl (phenyl(phenylamino)methyl) phosphonate derivatives ^a from functionalized amines	58
Table IV.1.	Optimization of reaction conditions ^a	83
Table IV.2.	Synthesis of functionalized 2,5-diphenyl-1,3,4-selenadiazole derivatives ^a from functionalized aldehydes	85
Table IV.3.	Result of control experiment ^a	86
Table V.1.	Optimization of reaction conditions ^a	101
Table V.2.	Synthesis of functionalized bis-coumarin derivatives ^a	103

LIST OF SCHEMES

Scheme No.	Title	Page No.
Scheme I.1.	Synthesis of the derivative of 2,4,6-triphenyl-1,3,5-triazine	4
Scheme I.2.	One-pot three-component synthesis of 2,4,6-triarylpyridines	4
Scheme I.3.	Copper catalyzed aerobic synthesis of 2,4,5-trisubstituted imidazoles	5
Scheme I.4.	Synthesis of functionalized tetrazolo[1,2- <i>a</i>]pyrimidine derivatives	5
Scheme I.5.	Synthesis of quinoxaline from 2-iodobenzoic acid using organo Cu(II) Catalyst	5
Scheme I.6.	Cu (I) catalyzed synthesis of 4(3 <i>H</i>)-quinazolinone	6
Scheme I.7.	Synthesis of 5-substituted 1 <i>H</i> - tetrazole	6
Scheme I.8.	Synthesis of 2-substituted benzimidazoles	6
Scheme I.9.	One pot metal-free synthesis of quinoxalines from 2-nitroaniline	6
Scheme I.10.	Synthesis of the functionalized 2-substituted-2,3-dihydroquinazolin- 4(1 <i>H</i>)-one derivative	7
Scheme I.11.	Synthesis of pyrimido[4,5- <i>b</i>]quinolinone-2,4-diones	7
Scheme I.12.	Synthesis of substituted 5-oxo-1,4,5,6,7,8-hexahydroquinoline derivatives	8
Scheme I.13.	Synthesis of 1,2,4-triazole derivative	8
Scheme I.14.	Preparation of 2-amino-3-cyanopyridine	8
Scheme I.15.	Synthesis of functionalized pyrrolidine-2-ones	9
Scheme I.16.	Synthesis of functionalized <i>N</i> -amino-3-cyano-2-pyridone	9
Scheme I.17.	Copper catalyzed synthesis of substituted pyrazoles at room temperature	9
Scheme I.18.	Synthesis of 2 <i>H</i> -indazole derivatives catalysed by Cu ₂ O-Np	10
Scheme I.19.	Synthesis of benzoxazoles in ethanol at room temperature	10
Scheme I.20.	Sulfonated graphene oxide catalyzed synthesis of pyrano[2,3- <i>c</i>] pyrazole	10
Scheme I.21.	Synthesis of 2-amino-4 <i>H</i> -chromen-4-yl phosphonate derivatives using β-cyclodextrin	11

Scheme I.22.	Synthesis of 2,5-disubstituted oxazoles	11
Scheme I.23.	Synthesis of ArSe-substituted chromone derivatives	11
Scheme I.24.	One-pot synthesis of 3,5-disubstituted 1,2,4-oxadiazoles using potassium fluoride	12
Scheme I.25.	Glycerol assisted one-pot pseudo five-component synthesis of 4 <i>H</i> -thiopyran	12
Scheme I.26.	Synthesis of substituted benzothiazoles	12
Scheme I.27.	Synthesis of 1,4-benzothiazines	13
Scheme I.28.	One-pot synthesis of 3,5-disubstituted 1,3,4-thiadiazole from dithioesters	13
Scheme I.29.	PEG-600 mediated synthesis of 2-aminothiophene derivatives	13
Scheme I.30.	Synthesis of 1,4-Oxathiane 4,4-Dioxide	14
Scheme I.31.	Synthesis of 4 <i>H</i> -benzo[4,5]thiazolo[3,2- <i>a</i>]pyrimidine	14
Scheme I.32.	Synthesis of 2-alkyl-1,2-benzisoselenazol-3(2 <i>H</i>)-ones	14
Scheme I.33.	Synthesis of 1,3,4-selenadiazoles derivative	15
Scheme I.34.	Copper catalyzed synthesis of imidazo[1,2- <i>a</i>]pyridines	15
Scheme I.35.	Synthesis of 2-Arylbenzoselenazoles	15
Scheme II.A.1.	Synthesis of ethyl 5-methyl-7-phenyl-4,7-dihydrotetrazolo[1,5- <i>a</i>]pyrimidine-6-carboxylate	18
Scheme II.A.2.	Synthesis of 5-methyl-7-aryl-4,7-dihydrotetrazolo[1,5- <i>a</i>]pyrimidine-6-carboxylic esters	18
Scheme II.A.3.	Synthesis of 5,7-Diaryl-4,7-dihydrotetrazolo[1,5- <i>a</i>]pyrimidines	19
Scheme II.A.4.	Catalytic synthesis of tetrazolopyrimidine derivatives	19
Scheme II.A.5.	Synthesis of tetrazolo[1,5- <i>a</i>]pyrimidine derivatives	19
Scheme II.A.6.	Synthesis of diethyl 6-aryl-3,6-dihydrotetrazolo- [1,5- <i>a</i>]pyrimidine-4,5-dicarboxylates	20
Scheme II.A.7.	Synthesis of 5,7-diaryl-4,7-dihydrotetrazolo[1,5- <i>a</i>]pyrimidines	20
Scheme II.A.8.	Synthesis of tetrazolo[1,5- <i>a</i>]pyrimidine	20
Scheme II.A.9.	β -Cyclodextrin assisted synthesis of tetrazolo[1,2- <i>a</i>]pyrimidine	21
Scheme II.A.10.	Probable mechanism for formation of tetrazolo[1,2- <i>a</i>]pyrimidine	25

Scheme II.B.1.	Synthesis of [1,2,4]triazolo[1,5- <i>a</i>]pyrimidines	33
Scheme II.B.2.	Synthesis of [1,2,4]triazolo[1,5- <i>a</i>]pyrimidine-6-carboxylic acid ethyl ester	34
Scheme II.B.3.	Synthesis of dihydro-1,2,4-triazolo[1,5- <i>a</i>]pyrimidines	34
Scheme II.B.4.	Synthesis of 4,7-dihydro[1,2,4]triazolo[1,5- <i>a</i>]pyrimidine	34
Scheme II.B.5.	Synthesis of 1,2,4-triazolo pyrimidine	34
Scheme II.B.6.	One-pot four-component synthesis of 2-amino-4,6-diphenyl nicotinonitriles	35
Scheme II.B.7.	Synthesis of functionalized pyrrolidine-2-ones	36
Scheme II.B.8.	Humic acid assisted synthesis of functionalized diethyl (phenyl(phenylamino)methyl)phosphonate	36
Scheme II.B.9.	Synthesis of 1 <i>H</i> -pyrazolo[1,2- <i>b</i>]phthalazine-5,10 diones	37
Scheme II.B.10.	β -Cyclodextrin assisted synthesis of [1,2,4]triazolo[1,5- <i>a</i>]pyrimidine	37
Scheme II.B.11.	Probable mechanism for formation of [1,2,4]triazolo[1,5- <i>a</i>]pyrimidine	40
Scheme III.1.	Synthesis of α -aminophosphonates	48
Scheme III.2.	Synthesis of α -aminophosphonates catalyzed by NbCl ₅	48
Scheme III.3.	Synthesis of α -aminophosphonates catalyzed by TiO ₂	48
Scheme III.4.	Synthesis of α -aminophosphonates catalyzed by Fe ₃ O ₄ @SiO ₂ -2mim SO ₃ H	49
Scheme III.5.	Synthesis of α -aminophosphonates catalyzed by hydrophobic γ -Fe ₂ O ₃ -cu-complex	49
Scheme III.6.	Synthesis of α -aminophosphonates catalyzed by MgFe ₂ O ₄ catalyst	49
Scheme III.7.	Synthesis of α -aminophosphonates	49
Scheme III.8.	Synthesis of α -aminophosphonates	50
Scheme III. 9.	Synthesis of α -aminophosphonates	50
Scheme III.10.	Synthesis of α -aminophosphonates	50
Scheme III.11.	Synthesis of α -aminophosphonate derivatives	50
Scheme III.12.	Synthesis of α -aminophosphonate derivatives	51
Scheme III.13.	Synthesis of diethyl (phenyl(phenylamino)methyl)phosphonate	51
Scheme III.14.	Synthesis of diphenyl (phenyl(phenylamino)methyl)phosphonate	51
Scheme III.15.	Synthesis of α -aminophosphonates derivatives	52

Scheme III.16.	CAN-catalyzed synthesis of α -aminophosphonates	52
Scheme III.17.	Synthesis of α -aminophosphonates	52
Scheme III.18.	Synthesis of some diversified bis(indolyl)methane from diverse array of aldehydes	53
Scheme III.19.	Synthesis of benzothiazole derivative	53
Scheme III.20.	Synthesis of functionalized tetrazolo[1,2- <i>a</i>]pyrimidine derivatives	54
Scheme III.21.	Synthesis of 1,4-benzothiazines using graphene oxide	54
Scheme III.22.	Humic acid assisted synthesis of functionalized diethyl(phenyl(phenylamino)methyl)phosphonate	54
Scheme III.23.	Possible mechanism for diethyl(phenyl(phenylamino)methyl) phosphonate derivatives assisted by humic acid	60
Scheme IV.1.	Synthesis of 2,5-diamino-1, 3,4-selenadiazol derivative	77
Scheme IV.2.	Synthesis of 2,5-diaryl -1,3,4-selenodiazoles	78
Scheme IV.3.	Synthesis of 2,5-disubstituted 1,3,4-selenadiazoles	78
Scheme IV.4.	Synthesis of 2-amino 1,3,4-selenadiazoles	78
Scheme IV.5.	Synthesis of 1,3,4-selenadiazoles	79
Scheme IV.6.	Synthesis of isoxazole-5(4 <i>H</i>)-one derivative	79
Scheme IV.7.	Synthesis of 1,5-fused 1,2,4-triazoles derivative	79
Scheme IV.8.	Synthesis of isatins derivatives	80
Scheme IV.9.	Synthesis of 2-arylbenzo[<i>d</i>]imidazo[2,1- <i>b</i>] thiazole derivatives	80
Scheme IV.10.	Synthesis of 2-methyl-7-phenyl-3-(phenylthio) pyrazolo[1,5- <i>a</i>] pyrimidine	80
Scheme IV.11.	Synthesis of α -phenylseleno carbonyl compounds	81
Scheme IV.12.	Synthesis of 5-substituted indole chromeno[2,3]-bipyridines	81
Scheme IV.13.	Synthesis of 2-amino-3-cyanopyridine	81
Scheme IV.14.	Synthesis of 3,4,6,7- tetrahydro-3,3-dimethyl-9-phenyl-2 <i>H</i> -xanthene 1,8(5 <i>H</i> ,9 <i>H</i>)-diones	82
Scheme IV.15.	Synthesis of 3-amino alkylated indoles	82
Scheme IV.16.	One-pot three-component synthesis of 1,3,4-selenathiazoles	82
Scheme IV.17.	Possible mechanism for 2,5- diphenyl-1,3,4-selenadiazole derivatives	87

Scheme V.1.	Synthesis of the derivative of bis-coumarine	96
Scheme V.2.	Synthesis of the derivative of bis-coumarine	96
Scheme V.3.	Synthesis of the derivative of bis-coumarine	96
Scheme V.4.	Synthesis of bis-coumarine derivative	96
Scheme V.5.	Synthesis of bis-coumarine derivative	97
Scheme V.6.	Synthesis of bis-coumarine derivative	97
Scheme V.7.	Synthesis of bis-coumarine derivative	97
Scheme V.8.	Synthesis of bis-coumarine derivative	98
Scheme V.9.	Synthesis of bis-coumarine derivative	98
Scheme V.10.	Synthesis of bis-coumarine derivative	98
Scheme V.11.	Synthesis of bis-coumarine derivative	98
Scheme V.12.	Synthesis of bis-coumarine derivative	99
Scheme V.13.	Synthesis of bis-coumarine derivative	99
Scheme V.14.	Synthesis of bis-coumarine derivative	99
Scheme V.15.	Synthesis of bis-coumarine	100
Scheme V.16.	Synthesis of 2,3 dihydro quinazoline-4(1 <i>H</i>)-one derivatives	100
Scheme V.17.	Synthesis of tert-indolylmethane amine derivatives	100
Scheme V.18.	Synthesis of 2-amino-4-phenyl-6-(pyrrolidin-1-yl)pyridine-3,5-dicarbonitrile	101

LIST OF FIGURES

Figure No.	Title	Page No.
Figure I.1.	Some known heterocyclic skeleton	2
Figure I.2.	Biologically active molecules having heterocyclic moiety	3
Figure II.A.1.	Some biologically potent molecule with tetrazolo skeleton	17
Figure II.A.2.	Scanned copy of ¹ H NMR spectra of the ethyl 5-methyl-7-(3-nitrophenyl)-4,7-dihydrotetrazolo[1,5- <i>a</i>]pyrimidine-6-carboxylate	30
Figure II.A.3.	Scanned copy of ¹³ C NMR spectra of the ethyl 5-methyl-7-(3-nitrophenyl)-4,7-dihydrotetrazolo[1,5- <i>a</i>]pyrimidine-6-carboxylate	31
Figure II.B.1.	Some biologically potent molecules	33
Figure II.B.2.	Scanned copy of ¹ H spectra of the ethyl 5-methyl-7-(3-nitrophenyl)-4,7-dihydro-[1,2,4]triazolo[1,5- <i>a</i>]pyrimidine-6-carboxylate	44
Figure II.B.3.	Scanned copy of ¹³ C spectra of the ethyl 5-methyl-7-(3-nitrophenyl)-4,7-dihydro-[1,2,4]triazolo[1,5- <i>a</i>]pyrimidine-6-carboxylate	45
Figure III.1.	Biologically active molecules with α -amino phosphonates skeleton	47
Figure III.2.	Scanned copy of ¹ H NMR spectra of diethyl((3-fluorophenyl)(phenylamino)methyl)phosphonate	71
Figure III.3.	Scanned copy of ¹³ C NMR spectra of diethyl((3-fluorophenyl)(phenylamino)methyl)phosphonate	72
Figure III.4.	Scanned copy of ¹⁹ F NMR spectra of diethyl((3-fluorophenyl)(phenylamino)methyl)phosphonate	73
Figure III.5.	Scanned copy of ³¹ P NMR spectra of diethyl((3-fluorophenyl)(phenylamino)methyl)phosphonate	74
Figure IV.1.	Scanned copy of ¹ H NMR spectra of the 2,5-bis(4-nitrophenyl)-1,3,4-Selenadiazole	92
Figure IV.2.	Scanned copy of ¹³ C NMR spectra of the 2,5-bis(4-nitrophenyl)-1,3,4-Selenadiazole	93

- Figure V.1. Scanned copy of ^1H NMR spectra of 3,3'-((4-methoxyphenyl)methylene)bis(4-hydroxy-2*H*-chromen-2-one) 107
- Figure V.2. Scanned copy of ^{13}C NMR spectra of 3,3'-((4-methoxyphenyl)methylene)bis(4-hydroxy-2*H*-chromen-2-one) 108

LIST OF APPENDICES

APPENDIX A

List of Research Publications

APPENDIX B

Oral Presentations

APPENDIX A

List of Research Publications

1. KI mediated one-pot cascade reaction for synthesis of 1,3,4-selenadiazoles, **Kumaresh Datta**, Bijeta Mitra, Gyan Chandra Pariyar and Pranab Ghosh*, *RSC Adv.*, 2024, 14, 15449-15454.
2. Humic Acid: A Green-Catalyst-Mediated Solvent-Free Synthesis of Functionalized Diethyl(phenyl(phenylamino)methyl)phosphonate, **Kumaresh Datta**, Bijeta Mitra and Pranab Ghosh*, *ChemistrySelect*, 2023, 8, e202301255.
3. One-pot Three-component Solvent-free Tandem Annulations for Synthesis of Tetrazolo[1,2-a]pyrimidine and [1,2,4]triazolo[1,5-a]pyrimidine, **Kumaresh Datta**, Bijeta Mitra, Biswajit Shil Sharma and Pranab Ghosh*, *ChemistrySelect*, 2022, 7, e202103602.
4. Eucalyptol mediated synthesis of Bis-Coumarine, **Kumaresh Datta**, Bijeta Mitra and Pranab Ghosh* (Manuscript under preparation).

APPENDIX B

Oral Presentation

1. “Glycerol mediated catalyst-free synthesis of thioamide from aldehyde”, **Kumaresh Datta** and Pranab Ghosh* in the International web seminar on “Modern Trends in Humanities, Science & Technology and Social Science for Sustainable Development” organized by A. P. C. Roy Govt. College, Himachal Vihar, Matigara, Siliguri-734010, West Bengal, India in collaboration with UGC-Human Resource Development Centre, University of North Bengal, Darjeeling, West Bengal, India held on September 23- September 24, 2021.
2. “Innovative approach for one-pot three-component synthesis of benzo[4,5]tetrazolo[1,2-a]pyrimidine and [1,2,4]triazolo[1,5-a]pyrimidine”, **Kumaresh Datta** and Pranab Ghosh* in the International webinar on “Recent Advances in Condensed Matter and Materials Science” organized by DEPARTMENT OF CHEMISTRY AND PHYSICS, COOCHBEHAR PANCHANAN BARMA UNIVERSITY, COOCH BEHAR-736101 on August 12 –August 14, 2021.

ABBREVIATION

AcOH	Acetic acid
Acac	Acetylacetonate
aq.	Aqueous
br	Broad
CAN	Ceric ammonium nitrate
CD	Cyclodextrin
Cy	Cyclohexyl
cm	centimeter
CDCl ₃	Deuterated chloroform
DMF	<i>N, N</i> -Dimethylformamide
DMSO	Dimethyl sulfoxide
d	Doublet
DABCO	(1,4-diazabicyclo[2.2.2]octane)
DCM	1,2-Dichloromethane
EtOH	Ethanol
Equiv.	Equivalent
g	gram/grams
GO	Graphene oxide
h	hour/hours
HRMS	High-resolution mass spectroscopy
IL	Ionic liquid
m	Multiplet
min	minute/minutes
mol%	mole percent
mmol	millimole
mL	milliliter
mp	Melting point
MW	Microwave
NMR	Nuclear magnetic resonance

NBS	<i>N</i> -Bromosuccinimide
°C	Degree Celsius
PEG	Polyethylene glycol
Phen	Phenyl
rt	room temperature
RGO	Reduced graphene oxide
s	Singlet
SGO	Sulphonated graphene oxide
t	triplet
TEMPO	(2,2,6,6-Tetramethylpiperidine-1-yl)oxyl
TLC	Thin-layer chromatography
THF	Tetrahydrofuran
TMS	Trimethylsilane