GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

REVISED MINUTES

of the 5th Meeting of the Standing Committee of

X ACADEMIC COUNCIL

Day & Date

Tuesday, 14th February, 2023 & Thursday, 23rd February, 2023

Time

10.00 a.m.

Venue
Council Hall,
Administrative Block
Goa University

Prof. Sunder N. Dhuri, Director, Directorate of Internal Quality Assurance, Goa University sought leave of absence for the meeting held on 14.02.2023.

The Adjourned meeting of the Standing Committee of the Academic Council was held on 23.02.2023 at 2.30 p.m. Prof. Koshy Tharakan, Dean, School of Sanskrit, Philosophy & Indic Studies, Goa University, Prof. K. S. Priolkar, Dean, School of Physical and Applied Sciences, Goa University, Prof. Filipe Rodrigues e Melo, Principal, Sant Sohirobanath Ambiye Govt. College of Arts & Commerce, Virnoda, Pernem, Prof. K. S. Priolkar, Dean, School of Physical and Applied Sciences, Goa University, Prof. Aparajita Gangopadhyay, Dean, School of International and Area Studies, Goa University sought leave of absence for the meeting.

The Chairperson (Vice-Chancellor) welcomed the members to the fifth meeting of the Standing Committee of the X Academic Council and in particular to all the Deans of the Faculties and Schools who were attending the meeting as special invitees.

The Chairperson (Vice-Chancellor) informed the House that due to the implementation of the New Education Policy 2020 for the Post Graduate General Education Programmes offered at the University Campus and Affiliated Colleges, the agenda for the meeting was rather large and therefore requested the members to discuss only Semester III and Semester IV.

The Chairperson (Vice-Chancellor) also informed that as the agenda for the meeting was large, agenda items pertaining to Board of Studies and Affiliation Inquiry Committee required to be deliberated upon, if required the meeting would be adjourned and reconvened.

The meeting was adjourned and reconvened on 23.02.2023 at 2.30 p.m.

Thereafter, the agenda was taken up for discussion.

D	**DISCCUSSION**
D 3	**BOARDS OF STUDIES**
D 3.1	**Minutes of the Board of Studies in Chemistry (PG) meeting held on 27.10.2022.** The Standing Committee of the Academic Council approved the minutes of the Board of Studies in Chemistry (PG) meeting held on 27.10.2022. **(Action: Assistant Registrar Academic-PG)**
D 3.2	**Minutes of the Board of Studies in Women's Studies meeting held by circulation.** The Standing Committee of the Academic Council approved the minutes of the Board of Studies in Women's Studies meeting held by circulation with the following suggestions: 1. Uniform format for References/Readings to be followed. 2. Under Research Methodology for PhD in Women's Studies, Sensitive Analysis to be added under content of Module 2. **(Action: Assistant Registrar Academic-PG)**

Std. Com. X AC-5
14.02.2023

GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

F I N A L A G E N D A

For the 5th Meeting of the Standing Committee of

X ACADEMIC COUNCIL

Day & Date

Tuesday, 14th February, 2023

Time

10.00 a.m.

Venue
Conference Hall
Administrative Block
Goa University

Std. Com. X AC-5
14.02.2023

Fifth meeting of the Standing Committee of the X Academic Council

Date: 14.02.2023

Time: 10.00 a.m.

Venue: Conference Hall, Administrative Block, Goa University

D	**DISCUSSIONS**
D 3	**BOARDS OF STUDIES**
D 3.1	**Minutes of the Board of Studies in Chemistry (PG) meeting held on 27.10.2022.** **Part A.** i. Recommendations regarding courses of study in the subject or group of subjects at the undergraduate level: **NIL** ii. Recommendations regarding courses of study in the subject or group of subjects at the postgraduate level: (Detailed minutes of the BOS meeting may please be seen). **1. Approval of SEM-III & IV syllabus of 80-credit M.Sc. Chemistry course designed as per NEP applicable from AY 2023-24** After due deliberations and incorporating the suggestions made by the members, the BOS unanimously resolved to approve the draft syllabus of semester III and IV of all four branches (Organic, Inorganic, Physical and Analytical) of M.Sc. Chemistry program based on NEP. The approved syllabus of SEM. III & IV of all four branches of M.Sc. Chemistry program is attached as **Annexure I (Refer page No. 1).** **Approval of SEM III & IV syllabus of 80 credit Pharmaceutical Chemistry under NEP-2020 applicable from AY 2023-24** After due deliberations and incorporating the suggestions made by the members, the BOS unanimously resolved to approve the draft syllabus of semester III and IV of M.Sc. Pharmaceutical Chemistry program based on NEP-2020. The approved syllabus of SEM. III & IV of M.Sc. Pharmaceutical Chemistry program is attached as **Annexure II (Refer page No. 94).** **Approval of syllabus for the Ph.D. Coursework paper in Research Methodology, (Paper-I; 4 Credits) for Research Scholars** After due deliberations and incorporating the suggestions made by the members, the BOS unanimously resolved to approve the draft syllabus of 4 credit Paper-I titled "Research methodology" for the Ph.D. Coursework for research scholars in Chemistry. The BOS approved syllabus of Ph.D. coursework in Research Methodology is attached as **Annexure III (Refer page No. 123)**. **Part B** i. Scheme of Examinations at undergraduate level: **NIL** ii. Panel of examiners for different examinations at the undergraduate level: **NIL** iii. Scheme of Examinations at postgraduate level: **NIL**

iv. Panel of examiners for different examinations at post-graduate level: **NIL**

Part C

i. Recommendations regarding preparation and publication of selection of reading material in the subject or group of subjects and the names of the persons recommended for appointment to make the selection: **NIL**

Part D

i) Recommendations regarding general academic requirements in the Departments of University or affiliated colleges:**NIL**

ii) Recommendations of the Academic Audit Committee and status thereof: **NIL**

Part E.

i. Recommendations of the text books for the course of study at undergraduate level: **NIL**

ii. Recommendations of the text books for the course of study at post graduate level: **NIL**

Part F.

Important points for consideration/approval of Academic Council

i. The important points/recommendations of BoS that require consideration/approval of Academic Council as mentioned below
   a) **PART-A (ii)**

ii. The declaration by the Chairperson:
   Hereby, it is declared that the minutes were readout by the Chairperson at the meeting itself.

Date: 27.10.2022 Sd/-
Place: Taleigao Plateau Prof. V. M. S. Verenkar
Signature of the Chairperson

Part G.

The Remarks of the Dean of the Faculty

i. The minutes are in order.

ii. The following important points / recommendations of BOS may be considered / approved by the Academic Council.
   Attention of the Academic Council is drawn to item Nos. PART-A (ii)

iii. May be recommended for approval of Academic Council.

iv. Special remarks if any: NIL

Date: 27.10.2022 Sd/-
Place: Taleigao Plateau Prof. V. M. S. Verenkar
Dean, School of Chemical Sciences

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D 3.2	**Minutes of the Board of Studies in Women's Studies meeting held by circulation.** The Academic Council may recall that in its meeting held on 19.09.2022 the minutes of the Board of Studies in Women's Studies meeting held by circulation were approved with the following suggestions : 1) The Credits for the Research Methodology Course to be increased to 4 Credits (60 hours).

D 3.1 Minutes of the Board of Studies in Chemistry (PG) meeting held on 27.10.2022.

Annexure I

M.Sc. Organic/Inorganic/Analytical/Physical Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV) based on NEP 2020

SEM III & IV			
		Research Specific Elective (RSE) Courses	
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHOR-511**	Practical Course in Organic Chemistry-III	4
2.	**CHOR-512**	Practical Course in Organic Chemistry-IV	4
3.	**CHOR-513**	Retrosynthesis and Heterocyclic Chemistry	4
4.	**CHOR-514**	Chemistry of Natural Products	4
5.	**CHIR-511**	Practical Course in Inorganic Chemistry-III	4
6.	**CHIR-512**	Practical Course in Inorganic Chemistry-IV	4
7.	**CHIR-513**	Principles and applications in catalysis	4
8.	**CHIR-514**	Topics in Inorganic Chemistry	4
9.	**CHAR-511**	Practical Course in Analytical Chemistry-III	4
10.	**CHAR-512**	Practical Course in Analytical Chemistry-IV	4
11.	**CHAR-513**	Advanced Mass Spectrometry	4
12.	**CHAR-514**	Selected Topics in Analytical Chemistry	4
13.	**CHPR-511**	Practical Course in Physical Chemistry-III	4
14.	**CHPR-512**	Practical Course in Physical Chemistry-IV	4
15.	**CHPR-513**	Heterogeneous Catalysis: Fundamentals and Applications	4
16.	**CHPR-514**	Applied Electrochemistry	4
17.	**CHCR-511**	Research Methodology and instrumental techniques-I	4
18.	**CHCR-512**	Research Methodology and instrumental techniques-II	4
19.	**CHCD-511**	Discipline Specific Dissertation	16
		Generic Elective (GE) Courses	
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHOG-511**	Polymer Chemistry: Concepts, Synthesis and Processing of Polymers	4
2.	**CHOG-512**	Concepts in Medicinal Chemistry	4
3.	**CHOG-513**	Concepts in Green Chemistry	4
4.	**CHOG-514**	Chemistry of Life	4
5.	**CHOG-515**	Organometallic Chemistry and Rearrangement Reactions	4
6.	**CHIG-511**	Bioinorganic Chemistry	4
7.	**CHIG-512**	Chemistry of p-block elements & their compounds	4

8.	**CHIG-513**	Environmental Chemistry	4
9.	**CHIG-514**	Inorganic Chemistry: Industrial Perspective	4
10.	**CHAG-511**	Fundamentals of Crystallography	4
11.	**CHAG-512**	Advanced NMR and combined Spectroscopy	4
12.	**CHAG-513**	Bioanalytical Techniques	4
13.	**CHAG-514**	Calibration and Validation in Analytical Chemistry	4
14.	**CHPG-511**	Solid State Chemistry: Concepts and Applications	4
15.	**CHPG-512**	Nanoscience: Concepts and Applications	4
16.	**CHPG-513**	Physical aspects of Polymer Chemistry	4
17.	**CHPG-514**	Colloids and Surface Chemistry	4
		Dissertation	
1.	**CHCD-511**	Discipline Specific Dissertation	16

M.Sc. Organic Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III (Organic Chemistry)			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHOR-511**	Practical Course in Organic Chemistry-III	4
2.	**CHOR-512**	Practical Course in Organic Chemistry-IV	4
3.	**CHCR-511**	Research methodology and instrumental techniques-I	4
4.	**CHCR-512**	Research methodology and instrumental techniques-II	
5.	**CHOG-511**	Polymer Chemistry: Concepts, Synthesis and Processing of Polymers	4
6.	**CHOG-512**	Concepts in Medicinal Chemistry	4
7.	**CHOG-513**	Concepts in Green Chemistry	4
8.	**CHOG-514**	Chemistry of Life	4
9.	**CHOG-515**	Organometallic Chemistry and Rearrangement Reactions	4
SEM IV (Organic Chemistry)			
1.	**CHOR-513**	Retrosynthesis and Heterocyclic Chemistry	4
2.	**CHOR-514**	Chemistry of Natural Products	4
3.	**CHCD-511**	Discipline Specific Dissertation	16

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Programme: **M. Sc. Part-II (Organic Chemistry)**
Course Code: **CHOR-511**
Title of the Course: **Practical Course in Organic Chemistry-III**
Number of Credits: **04** Total Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course	Should have studied organic chemistry practical course at M.Sc. Part-I.
Course Objective:	1. To translate certain theoretical concepts learnt earlier into experimental knowledge

	2. To provide hands-on experience of laboratory techniques required for organic syntheses, organic mixture separations and purification.
Course Outcome:	1. Students will be in a position to perform separation of organic components based on chemical nature, solubility and boiling points. 2. Students will be in a position to understand stoichiometric requirements in organic syntheses. 3. Students will be able to monitor progress of reaction by chromatographic techniques. 4. Students will be able to carry out purification of reaction products by column chromatography.

Content	*Hours*
1. Organic ternary mixture separation (*Minimum 10 experiments of 6h each*) Three component mixture separation based upon differences in the physical and the chemical properties of the components. Elemental and functional group analysis, determination of physical constant and derivative preparation-its recrystallization and melting point/boiling point of any one compound.	60
2. **Organic synthesis (Any Six)** a. Benzophenone oxime to benzanilide (Beckmann rearrangement) b. Benzil to hydrobenzoin ($NaBH_4$ reduction) c. Diels - Alder reaction of anthracene and maleic anhydride using microwave irradiation d. Friedel- Crafts acylation of anisole e. 2-methyl benzimidazole from *o*-phenylene diamine f. Dicoumarol from coumarin derivative g. Halogenation using NBS: preparation of 9-bromoanthracene (or benzylic bromides) h. Resolution of racemic phenyl ethylamine using tartaric acid i. Ferric chloride oxidative coupling of 2-naphthol to [1,1'-binaphthalene]-2,2'-diol] j. Dimedone from mesityl oxide (Dieckmann condensation) k. $KMnO_4$ oxidation of toluene assisted by microwave l. 2-phenylindole from acetophenone (Fisher indole synthesis)	36
3. Polarimetry and column chromatography (*Any 4 experiments of 6h from '**sections a and b**'*) **a. Enantiomeric excess by Polarimetry** Determination of optical rotation and enantiomeric excess of enantiomers and unknown mixtures of: i. Amino acids ii. Drugs iii. Carbohydrates iv. Other readily available chiral compounds **b. Purification of organic compounds by column chromatography** i. Mixture of ortho and para nitrophenols ii. Mixture of benzil and benzoin iii. Mixture of acetophenone and benzylideneacetophenone	24

iv. Mixture of benzophenone and benzanilide v. Other chiral natural product mixtures	
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.
References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall, 2011. 2. N. K. Vishnoi, *Advanced Practical Organic Chemistry, South Asia Books,* 2010. 3. K. Tanaka, *Solvent-free Organic Synthesis,* 2nd Ed., Wiley-VCH, 2009. 4. L. F. Fieser, K. L. Williamson, *Organic Experiments*, 7th Ed., D. C. Heath, 1992. 5. K. L. Williamson, K. M. Masters, *Macroscale and Microscale Organic Experiments*, 6th Ed., Cengage Learning, 2010. 6. R. K. Bansal, *Laboratory Manual in Organic Chemistry*, 5th Ed. New Age International, 2016. 7. S. Delvin, *Green Chemistry*, Sarup & Sons, 2005. 8. O. R. Rodig, C. E. Bell Jr., A. K. Clark, *Organic Chemistry Laboratory Standard and Microscale Experiments*, 3rd Ed., Saunders College Publishing, 2009. 9. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014. 10. G. J. Shugar, J. T. Ballinger, *Chemical Technicians Ready Reference Handbook*, McGraw-Hill, Inc. 1996. 11. D. P. Shoemaker, *Experimental Physical Chemistry*, McGraw-Hill, 1989.

Programme: **M. Sc. Part-II (Organic Chemistry)**
Course Code: **CHOR-512**
Title of the Course: **Practical Course in Organic Chemistry-IV**
Number of Credits: **04** Total Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course	Should have studied organic chemistry practical course at M.Sc. Part-I.
Course Objective:	1. To translate certain theoretical concepts learnt earlier into experimental knowledge 2. To provide hands on experience of laboratory techniques required for organic syntheses and organic mixture separations.
Course Outcome	1. Students will be in a position to adopt Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 2. Students will be in a position to understand and calculate stoichiometric requirements during organic syntheses.

	3. Students will be in a position to perform separation of organic components based on chemical nature, solubility and boiling points.	
Content		*Hours*
1. Organic ternary mixture separation and identification (Minimum 14 experiments of 6h each) Three component mixture separation based upon differences in the physical and the chemical properties of the components. Elemental and functional group analysis and determination of physical constants of the individual compounds. Derivative preparation, its recrystallization and m. p. of each component and characterization of each component and its derivative by m. p. comparison.		84
2. Organic synthesis (Any Six) a. 1,2,3,4 - tetrahydrocarbazole from cyclohexanone (Fischer indole synthesis). b. Resolution of racemic phenylethylamine using tartaric acid. c. Trans - Stilbene by Wittig reaction. d. Enamine alkylation: 2-methyl cyclohexanone pyrrolidine enamine with CH_3I. e. Chlorobenzylidene rhodanine (Perkin reaction). f. Diels-Alder reaction of anthracene and maleic anhydride using microwave irradiation. Oxidation of a primary / secondary alcohol to carbonyl compound by polymer supported chromic acid (Amberlyst A-26, chromate form). g. Phenytoin from benzil and urea. h. Isoborneol from camphor ($NaBH_4$ reduction) i. 3 -Methyl -2-phenyl-2-butanol from 2-bromopropane and acetophenone j. Triphenyl carbinol from benzophenone or ethyl benzoate (Grignard reaction). k. Benzidine from hydrazobenzene (benzidine rearrangement). l. Methyl orange/red from sulphanilic acid/anthranilic acid (diazotization). m. Reduction of Nitrobenzene to aniline by Sn/HCl. n. LAH reduction of Anthranilic acid. o. Norborneol to norcarnphor using chromium trioxide/sulfuric acid p. Benzhydrol from benzaldehyde (Grignard reaction) q. Diethyl 4-butyl malonate by malonic ester condensation		36
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall, 2011. 2. N. K. Vishnoi, *Advanced Practical Organic Chemistry, South Asia Books, 2010.* 3. K. Tanaka, *Solvent-free Organic Synthesis,* Wiley-VCH, 2nd Ed., 2009. 4. L. F. Fieser, K. L. Williamson, *Organic Experiments*, 7th Ed. D. C. Heath, 1992. 5. K. L. Williamson, K. M. Masters, *Macroscale and Microscale Organic Experiments*, 6th Ed., Cengage Learning, 2010.	

	6. R. K. Bansal, *Laboratory Manual in Organic Chemistry*, 5th Ed., New Age International, 2016. 7. S. Delvin, *Green Chemistry*, Sarup & Sons, 2005. 8. O. R. Rodig, C. E. Bell Jr., A. K. Clark, *Organic Chemistry Laboratory Standard and Microscale Experiments*, Saunders College Publishing, 3rd Ed., 2009. 9. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014.

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Programme: **M.Sc. Part-II (Organic Chemistry)**
Course Code: **CHOR-513**
Title of the course: **Retrosynthesis and Heterocyclic Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied Organic Chemistry courses at M.Sc. Part-I level.
Course Objective:	1.To apply the knowledge gained in organic synthesis for making new molecules. 2.To understand various strategies involved in retrosynthesis of organic molecules 3.To understand the concepts in heterocyclic chemistry and its applications 4.To be able to propose routes for synthesis of heterocycles
Course Outcome:	1.Students will be in a position to understand how a carbon-carbon bond can be constructed and/or cleaved 2.Students will be in a position to understand how retrosynthesis can be used in finding out easily available chemical precursors for making organic molecules 3.Students will be in a position to apply retrosynthetic strategies and propose routes for synthesis of organic molecules and heterocycles 4.Students will be able to understand and apply the concepts of the reactivity of heterocycles towards electrophilic, nucleophilic, reducing and oxidizing reagents.

Content	*Hours*
1. Disconnection approach – Introduction, types of disconnection a. One-group disconnection b. Disconnection of simple alcohols and compounds derived from alcohols, disconnections of simple olefins, simple/aryl ketones and carboxylic acids c. Two-group disconnection d. Disconnection of 1,3-dioxygenated skeletons, *β*-hydroxy carbonyl compounds, α,β-unsaturated carbonyl compounds, 1,5-dicarbonyl compounds, Mannich reaction e. 'Illogical' Two-group disconnection	15

f. Disconnection of the 1,2-dioxygenated skeleton, *α*-hydroxy carbonyl compounds, 1,2-diols, 'Illogical' electrophiles, disconnection for the 1,4-dioxygenated pattern in 1,4-dicarbonyl compounds, γ-hydroxy carbonyl compounds, Other 'Illogical' synthons, disconnection for the 1,6-dicarbonyl compounds, synthesis of lactones (*General review problems to be discussed for above approaches*)	
2. Disconnection strategies a. Disconnection of heteroatom and heterocyclic compounds such as ethers, amines, heterocycles, amino acids b. Disconnection strategies of few pericyclic reactions c. Convergent and divergent synthesis d. Strategic devices for carbon-heteroatom bonds, polycyclic compounds: the common atom approach e. Considering all possible disconnections f. Alternative FGI's before disconnection- the cost of synthesis g. Features which dominate strategy, functional group addition and molecules with unrelated functional groups	15
3. Heterocyclic compounds a. Introduction, classification and nomenclature of mono- and bicyclic heteroaromatic molecules b. Physical properties, dipole moment, acidity-basicity, aromaticity, electron density distribution and reactivity of furan, thiophene, pyrrole, indole, pyridine, pyridine-N-oxide, quinoline, isoquinoline, diazines and triazines, 1,3- and 1,2- azoles	15
4. Synthetic strategies for heterocycle synthesis General methods of synthesis of the following: furan, thiophene, pyrrole, indole, pyridine, quinoline, isoquinoline, chromones, imidazoles, oxazoles, thiazoles	15
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. S. Warren, *Designing Organic Synthesis*, John Wiley & Sons, 2009. 2. G. S. Zweifel, M. H. Nantz, P. Somfai, *Modern Organic Synthesis: An Introduction*, 3rd Ed. W. H. Freeman and Company, New York, 2022. 3. J. Clayden, N. Greeves & S. Warren, *Organic Chemistry*, Oxford, 2016. 4. J. A. Joule, K. Mills & G. F. Smith, *Heterocyclic Chemistry*, 3rd Ed., 1995. 5. J. A. Joule & K. Mills, *Heterocyclic Chemistry*, Wiley-Blackwell, 5th Ed., 2010. 6. T. L. Gilchrist, *Heterocyclic Chemistry*, Pitman Publishing, 2005. 7. R. M. Acheson, *An Introduction to Chemistry of Heterocyclic Compounds*, John Wiley and Sons, 3rd Ed, 1977. 8. D. W. Young, *Heterocyclic Chemistry*, Longman Group Ltd., London, 1975. 9. R. O. C. Norman and J. M. Coxon. *Principles of Organic Synthesis*, CRC Press, 3rd Ed., 2009.

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Programme: **M.Sc. Part-II (Organic Chemistry)**
Course Code: **CHOR-514**
Title of the course: **Chemistry of Natural Products**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied Organic Chemistry courses at M.Sc. Part-I level.
Course Objectives:	1. To study the main classes of natural products. 2. To understand the different methods that are used in natural product chemistry, including extraction, isolation and structural elucidation. 3. To understand the key biosynthetic pathways for the biosynthesis of terpenes, alkaloids and steroids.
Course Outcomes:	1. Students will be able to identify different types of natural products 2. Students will be able to describe the properties and structure of natural products, their occurrence, biosynthetic pathways 3. Students will be able to carry out independent investigations of plant materials and natural products 4. Students will be able to understand and explain the synthesis of some classes of natural products.

Content	*Hours*
1. Source and isolation of natural products General methods of isolation: The modern distillation process, maceration, enfleurage, extraction by cold pressing and extraction with solvents	2
2. General methods of purification and structure elucidation of Natural Products a. Fractionation of the crude extracts and purification of the individual compounds from the respective fractions using chemical and chromatographic techniques such as Column Chromatography, TLC, Preparative TLC, HPLC, etc. b. Chemical methods based on the functional groups present: Bicarbonate extraction, sodium bisulphite adduct formation, derivatization, etc. c. General approach to structure elucidation of the isolated pure compounds using UV, IR, NMR spectroscopy, MS spectrometry, optical polarimetry.	4
3. Structure elucidation by classical chemical methods a. Terpenoids: α-cedrene b. Alkaloids: Morphine, thebaine and codeine c. Steroids: Cholesterol, bile acids	12
4. Structure elucidation by combination of chemical and spectral methods a. Terpenoids: α- and β-vetivones, Ishwarone b. Hormones: Cecropia Juvenile hormone, brevicomin and frontalin c. Oxygen heterocycles: Aflatoxin-B1, rotenone	10
5. Structure elucidation involving stereochemistry, spectral and chemical methods a. Terpenoids: Menthol and hardwickiic acid b. Alkaloids: Reserpene	8
6. Synthesis of selected natural products, planning and execution	14

a. Terpenoids: Longifolene (E. J. Corey), Caryophyllene (E J Corey) Nootkatone (A. Yoshikoshi), Menthol (Tagasago) b. Alkaloids: Reserpine (R. B. Woodward), Morphine (Marshall Gates) c. Hormones: Cecropia JH (Edward), Progesterone d. Prostaglandins: Prostaglandin E2 (E. J. Corey) e. Antibiotics: Cephalosporin (R. B. Woodward)	
7. Biogenesis and biosynthesis of natural products a. Terpenoids and Steroids: General approach towards biosynthesis of mono-, sesqui-, di-, tri-, tetraterpenoids and steroids through mevalonate pathway with special reference to the biosynthesis of terpenoids and steroids included in topics 3 to 6 b. Alkaloids: The shikimate pathway formation of hydroxybenzoic acid derivatives, aromatic amino acids, L-phenylalanine, L-tyrosine, phenolic oxidative coupling, biosynthesis of thebaine, codeine and morphine.	10
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. I. L. Finar, *Organic Chemistry: Stereochemistry and the Chemistry of Natural Products*, Pearson Education India, 2002. 2. K. Nakanishi, *Natural Product Chemistry*, Academic Press, 2013. 3. D. R. Dalton, *The Alkaloids*. New York: M. Dekker, 1979 4. Barton and Olis, *Comprehensive Organic Chemistry*, Pergamon, 1979. 5. D. Paul, *Medicinal Natural Products: A Biosynthetic Approach*, John Wiley and Sons, 2002. 6. M. Paolo, *Biosynthesis of Natural Products*, Wiley, 2010 7. J. ApSimon, *The Total Synthesis of Natural Products*, John Wiley and Sons, 1992. 8. E. J. Corey & X-M. Cheng, *The Logic of Chemical Synthesis*, Wiley Interscience, a division of John Wiley and Sons Inc, 1995. 9. K. C. Nicolaou & E. J. Sorensen, *Classics in Total Synthesis*, Weinhem: VCH, 1996. 10. R. O. C. Norman and J. M. Coxon. Principles of Organic Synthesis, CRC Press, 3rd Ed., 2009.

Programme: **M. Sc. Part-II (Chemistry)**
Course Code: **CHOG-511**
Title of the Course: **Polymer Chemistry: Concepts, Synthesis and Processing**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied M.Sc. Part-I Chemistry.
Course Objective:	1. To introduce various concepts in organic polymer chemistry.

	2. To understand the synthesis, polymer processing and applications.	
Course Outcome:	1. Students will be in a position to understand and evaluate the differences in structures and properties of small molecules and macromolecules. 2. Students will be in a position to apply concepts involved in polymer synthesis, characterization and processing. 3. Students will be in a position to understand and apply concepts of synthesis and applications of organic polymers.	
Content:		*Hours*
1. Brief history of natural and synthetic polymers Classification & nomenclature of polymers, functionality concept- linear, -branched and -cross linked polymers. Introduction to biodegradable polymers.		5
2. Methods and chemistry of polymerization Bulk, solution, suspension, emulsion, addition, condensation polymerizations. Free-radical, Ionic and coordination polymerization reactions. Introduction to controlled free radical polymerization. Carothers equation in condensation polymerizations.		12
3. Properties of polymers a. Number and weight average molecular weights, Molecular weight distribution, polydispersity. b. Glassy state and glass transition temperature, crystallinity in polymers. c. Characterization of polymers.		10
4. Resources for monomers, manufacture of important monomers and reagents Ethylene, propylene, butadiene, isoprene, styrene, divinyl benzene, acrylonitrile, vinyl chloride, adipic acid, urea, bisphenol-A, melamine, phthalates, glycol, glycerol, ethylene oxide, epichlorohydrin, ϵ-caprolactum, di-isocyanates, pentaerythritol, allylic carbonate monomers.		12
5. Synthesis, properties and applications of polymers a. Vinyl polymers- LDPE, HDPE, PVC, PVA, polyvinyl acetate, polyacrylates, methacrylates, polystyrene, teflon, ABS, SBR, SAN. b. Condensation polymers- Nylons, polyesters, polyurethanes, polycarbonates. c. Thermoset polycarbonates like CR-39 Cellulose esters- cellulose acetate, nitrates and acetatebutyrates. d. Thermoset resins- phenol-formaldehyde, melamine-formaldehyde, epoxy resins - their curing. e. Natural rubber.		14
6. Additives in polymers and Polymer processing a. Lubricants, plasticizers, stabilizers, antioxidant, fire retardants, blowing agents, fillers, colorants, crosslinking agents, UV-Vis degradants etc. b. Introduction to compounding, and processing techniques like calendaring, casting, moulding and spinning in polymer processing.		7
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	

Text Books/ References / Readings	1. V. R. Gowarikar, N.V. Vishwanathan, J. Sreedhar, *Polymer Science*, New Age International, 2015. 2. J. R. Fried, *Polymer Science and Technology*, PHI Pvt. Ltd.,2000. 3. R. Sinha*, Outlines of Polymer Technology: Manufacture of Polymers*, PHI Pvt Ltd., 2000. 4. K. Y. Saunders, *Organic Polymer Chemistry*, Chapman and Hall, UK, 1976. 5. H. R. Kircheldorf, *Handbook of Polymer Synthesis, PART Aand B,* Marcel Dekkar Inc., 1992. 6. R. P. Brown, *Handbook of Plastic Test Methods,* 2nd Ed., George Godwin Ltd., 1981. 7. M. P. Stevens, *Polymer Chemistry- An Introduction*, 2nd Ed., Oxford Univ. Press, 1990. 8. W. Y. Mijs, *New Methods in Polymer Synthesis*, PelnumPress Ltd., NY, 1992. 9. M. Arora, *Polymer Chemistry,* Anmol Publications 2001. 10. C. E. Carraher, *Polymer Chemistry,* New York M. Dekker 2005. 11. P.C. Hiemenz, *Polymer Chemistry*, CRC Press, 2007. 12. V. K. Selvaraj, *Advanced Polymer Chemistry*, New Delhi Campus books, CRC Press, 2008. 13. A. Ravve, *Principles of polymer Chemistry,* Springer 2012. 14. J. David , *Polymers,* Oxford University Press 2015.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHOG-512**
Title of the course: **Concepts in Medicinal Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied the chemistry courses in M.Sc. Part I level.	
Course Objective:	1. To understand the concepts of drug discovery and development 2. To learn drug screening, target identification, lead discovery, optimization 3. To understand molecular basis of drug design and drug action	
Course Outcome:	1. Students will be able to explain classes of drugs and their structure activity relationship with examples of some important class of drugs. 2. Students will be able to explain mechanism of action of the drugs. 3. Students will be able to describe the therapeutic uses of drugs and specific side effect of 'Drug Substances'. 4. Students will be able to explain physico-chemical properties related to QSAR. 5. Students will be able to describe various approaches in designing of drug molecules including prodrug and combinatorial chemistry.	
Content		*Hours*

1. Introduction to Drugs Requirement of an ideal drug, sources of drugs, important terms used in chemistry of drugs, classification and nomenclature of drugs, drugs and the medicinal chemists. a. **Drug Design:** Analogues and pro-drugs, concept of lead compounds, features governing drug design – the method of variation, drug design through disjunction, conjunction, tailoring of drugs, cimetidine – a rational approach to drug design. b. **Drug Development:** Screening of natural products, isolation and purification, structure determination, structure-activity relationship, QSAR, synthetic analogues, natural products as leads for new pharmaceuticals, receptor theories, oxamniquine – a case study	15
2. Mechanism of drug action Introduction, enzyme stimulation, enzyme inhibition, membrane-active drugs, polymorphism and drug delivery.	10
3. Study of Pharmacodynamic Agents (minimum two examples for each) a. Local anesthetics b. Analgesics : narcotic and non-steroidal anti-inflammatory, narcotic antagonists c. Antiepileptic drugs d. Antiparkinsonism drugs e. Antihistaminics f. Seditives and hypnotics g. Antipsychotics h. Cardiovascular agents : Cardiovascular diseases, Antianginal agents and vasodilators, Antihypertensive agents, Antiarrhythmic drugs, Adrenergic blocking agents i. Antihyperlipidemic and antiatherosclerotic agents j. Anticoagulants, blood coagulation and anticoagulant mechanism k. Diuretics l. Antidiabetic drugs : Synthetic hypoglycemic agents	15
4. Study of Chemotherapeutic Agents and Antibiotics **a. Chemotherapeutic Agents (with examples)** i. Sulfonamides ii. Antitubercular and Antilepral agents iii. Antiamoebics iv. Anthelmintics v. Antimalarials vi. Antiviral agents vii. Antineoplastic Agents **b. Antibiotics : General information, mode of action and applications** i. β-Lactam antibiotics : Penicillins and Cephalosporins ii. Aminoglycocides : Streptomycin, Neomycin iii. Tetracyclines iv. Macrolides : Erythromycin, Rifamycin, Lincomycin v. Polypeptides : Bacitracin vi. Unclassified antibiotics : Chloramphenicol	15

5. New Developments in Drug Discovery Introduction, gene therapy, drug resistance, antisense drugs, cytokines, drugs to combat AIDS.	5
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. R. F. Doerge, J. B. Lippincott, *Wilson and Gisvold's Text book of Organic Medicinal and Pharmaceutical Chemistry*, 8th Ed, Philadelphia, USA, 2010 2. M. E. Wolff, *Burger's Medicinal Chemistry, Part I and II,* 4th Ed., John Wiley, 1980 3. W. O. Foye, *Principles of Medicinal Chemistry*, 7th Ed., K. M. Varghese and Co., Bombay, 2012. 4. Lednicer and Mitscher, *Organic Chemistry of Drug Synthesis*, Vols I and II, John Wiley, 1980. 5. G. Patrick, *An Introduction to Medicinal Chemistry*, Oxford University Press, Oxford, 1998. 6. D. J. Abraham, *Burgers Medicinal Chemistry and Drug Discovery*, Vol. I, 6th Ed.,, John Wiley and Sons, New Jersey, 2003. 7. J. Janata, Z. Kamenik, R. Gazak, S. Kadlcik and L. Najmanova, *Nat. Prod. Rep.*, **2018**, *35*, 257–289

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHOG-513**
Title of the course: **Concepts in Green Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied M.Sc. Part-I Chemistry/Biochemistry.
Course Objective:	1. To understand various concepts involved in Green synthesis 2. To understand green technologies used in chemistry 3. To learn application of green chemistry approaches to chemical industry
Course Outcome:	1. Students will be in a position to understand how chemistry can be done using greener alternatives 2. Students will be in a position to apply green technologies as a sustainable solution for making molecules 3. Students will be able to understand and apply the concepts of green chemistry to develop scalable processes in industry

Content	*Hours*
1. Principles and Concepts of Green Chemistry a. Introduction, twelve green principles, sustainable development and green chemistry. b. Atom Economy: atom economic reactions- rearrangement and addition reactions.	6

c. Atom un-economic reactions- substitution, elimination and Wittig reactions. Reducing toxicity.	
2. Waste: Production, Problems and Prevention a. Introduction, Some problems caused by waste, sources of waste from the chemical industry and the cost of waste. b. Waste minimization techniques: the team approach and process design for waste minimization, minimizing waste from existing processes. c. On-site waste treatment: Physical, chemical and biotreatment. d. Design for degradation: degradation and surfactants, DDT, polymers and some rules for degradation. e. Polymer recycling: separation and sorting, incineration, mechanical recycling and chemical recycling to monomers.	6
3. Measuring and Controlling Environmental Performance a. The importance of measurement: Lactic acid production, safer gasoline. b. Introduction to life cycle assessment and green process metrics. c. Environmental management systems: ISO and European Eco-Management and Audit Scheme, eco-labels, green chemical supply, Strategies, Legislation and integrated pollution prevention and control.	6
4. Catalytic processes and Green Chemistry a. Introduction to catalysis and comparison of catalyst types. b. Heterogeneous catalysts: Basics of heterogeneous catalysis, Zeolites and the bulk chemical industry, heterogeneous catalysis in the fine chemical and pharmaceutical industries. Catalytic converters. c. Homogeneous catalysis: Transition metal catalysts with phosphine ligands, greener Lewis acids and asymmetric catalysis. d. Phase transfer catalysis: Hazard reduction, C – C bond formation and oxidation using hydrogen peroxide. e. Biocatalysis and photocatalysis.	10
5. Organic Solvents: Environmentally Benign Solutions a. Organic solvents and volatile organic components, solvent free systems. b. Supercritical fluids: supercritical carbon dioxide and supercritical water. c. Water as a reaction solvent and water-based coatings. d. Ionic liquids as catalysts and solvents. e. Fluorous biphase solvents. f. Deep eutectic solvents	10
6. Renewable Resources a. Biomass as a renewable resource. Energy: Fossil fuels, biomass, solar power, fuel cells and other forms of renewable energy. b. Chemicals and polymers from renewable feedstock. c. Alternative economies: the syngas economy and the biorefinery.	6
7. Greener Technologies and Alternative Energy Sources a. Design for energy efficiency	10

b. Photochemical reactions: advantages of and challenges faced by photochemical processes, examples of photochemical reactions. c. Chemistry using Microwaves: microwave heating and microwave-assisted reactions. d. Sonochemistry and green chemistry examples. e. Electrochemical synthesis and examples. **f.** Flow chemistry	
8. Industrial case studies a. A brighter shade of green: synthesis of stilbene intermediates for optical brightners. b. Greening of acetic acid manufacture, EPDM rubbers and Vitamin C. c. Leather manufacture: tanning and fatliquoring. d. Dyeing to be green: some manufacturing and products improvement and dye application. e. Polyethene: Radical process, Ziegler – Natta and metallocene catalysis. **f.** Eco-friendly pesticides.	6
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. M. Lancaster, *Green Chemistry*, The Royal Society of Chemistry, Cambridge, UK, 2002. 2. V. K. Ahluwalia, *Green Chemistry: Environmentally Benign Reactions*, Ane Books India, New Delhi, 2006. 3. A. S. Matlack, *Introduction to Green Chemistry*, Marcel Dekker, Inc., New York, 2001. 4. P. T. Anastas and T. C. Williamson, *Green Chemistry: Frontiers in benign chemical synthesis and processes*, Oxford University Press, Oxford, Ed. 1998. 5. R. Sanghi and M. M. Srivastava, *Green Chemistry: Environment Friendly Alternatives*, Narosa Publishing House, Ed. New Delhi, 2007. 6. Samuel Delvin, *Green Chemistry*, IVY Publishing House, Delhi, 2006. 7. V. K. Ahluwalia and M. Kidwai, *New Trends in Green Chemistry*, Anamaya Publishers, New Delhi, 2004. 8. P. G. Jessop and W. Leitner, *Chemical Synthesis using Supercritical fluids*, Wiley – VCH, Verlag, Ed., Weinheim, 1999. 9. K. Tanaka, *Solvent Free Organic Synthesis*, Wiley – VCH GmbH and Co. KgaA, Weinheim, 2003. 10. P. T. Anastas and J. C. Warner, *Green Chemistry, Theory and Practice*, Oxford University Press, N. York, 1998. 11. C - Jun Li and T – Hang Chan, *Organic Reactions in Aqueous Media*, John Wiley and Sons INC., N. York, 2001. 12. F. Z. Dorwald, *Organic Synthesis on Solid Phase*, Wiley – VCH Verlag, Weinheim, 2002.

	13. P. Wasserscheid and T. Welton, *Ionic Liquids in Synthesis*, Wiley – VCH Verlag, Ed., Weinheim, 2003. 14. A. Loupy, *Microwaves in Organic Synthesis*, Wiley – VCH Verlag, Weinheim, (Ed.), 2002. 15. R. V. Eldik and F. G. Klarner, *High Pressure Chemistry*, Wiley – VCH Verlag, (Eds.), Weinheim, 2002. 16. F. Darvas, G. Dorman, V. Hessel, *Flow Chemistry - Fundamentals:* Vol.1, De Gruyter, 1st Ed. 2014.

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHOG-514**
Title of the course: **Chemistry of Life**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied M.Sc. Part-I Chemistry/Biochemistry.
Course Objective:	1. Introduction to the chemistry of amino acids, proteins, carbohydrates, lipids and their applicability in daily life. 2. Understanding chemicals used in food production through food processing, storage and cooking. 3. Understanding food analysis and the chemistry of the digestion of food and energy provided by food.
Course Outcome:	1. Students will be in a position to predict type of proteins, lipids and carbohydrates available in food. 2. Students will be in a position to explore the chemical structure and functionality for the macronutrient categories like carbohydrates, lipids, and proteins in food 3. Student will be able to design experiments through an inquiry-oriented, food chemistry focused laboratory program. 4. The students will be able to identify the essential chemical components of food and have knowledge of their analyses, and gain knowledge of the chemistry of lipids, carbohydrates and proteins

Content	*Hours*
1. Chemistry of Proteins: Structure, function and food analysis a. Introduction to amino acids and role of polar, non-polar, acidic and basic side chainsa, their properties and Isoelectric point b. Introduction to peptides, dipeptides and proteins, types of proteins [primary (1˚), secondary (2˚), tertiary, (3˚) and Quaternary (4˚)]: hydrogen bonding, salt bridges, hydrophobic - non-polar interactions and disulfide linkages c. Protein folding, denaturation and functional properties of proteins. d. Food Proteins – Source of Proteins, Analysis of amino acids and proteins in food	10
2. Chemistry of Nucleic Acids	15

Brief history of sugars and bases, conformation of sugar-phosphate backbone, hydrogen bonding by bases, the double helix: A,B, and Z double helices, stability of double helix, DNA intercalators, chemical synthesis of DNA, catalytic RNA, siRNA, micro RNA	
3. Chemistry of Carbohydrates and Lipids: Structure, function and food Analysis **a. Carbohydrates** i. Introduction to mono-, di- and oligosaccharides, polysaccharides: starch, dietary, fibre, their physical function. ii. Fischer projections, Haworth Projections, stereoisomerism in carbohydrates. iii. Food Carbohydrates – Source of carbohydrates, Analysis of carbohydrates in food iv. Sugars: Hydrolysis, thermal degradation, Maillard reaction (non-enzymic browning reaction between reducing carbohydrates and proteins), Amadori Rearrangement and Analysis of Sugars, Mutarotation **b. Lipids** i. Introduction to lipids, types of lipids and fatty acids ii. Monoglycerides, diglycerides, triglycerides, polar lipids iii. Reactions of fatty acids - Oxidative and hydrolytic rancidity iv. Sources of fats and analysis in food	20
4. Chemistry of Enzymes a. Introduction to Enzyme Catalysis and Kinetics b. The Catalytic Triad c. Enzyme Inhibition and Drug design d. Enzymes in Organic Synthesis e. Antibody Catalysed Organic Reaction f. Enzyme Models: Biomimetic Polyene Cyclisation and Squalene Biosynthesis	15
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. J. Clayden, N. Greeves, & S. Warren. *Organic Chemistry*, 2nd Ed., Oxford University Press, 2012. 2. T. P. Coultate, *Food - The Chemistry of its Components*, Royal Society of Chemistry, 5th Ed., 2009. 3. H. D. Belitz. & W. Grosch, *Food Chemistry*, 4th Ed., Springer, 2009. 4. B. Selinger, *Chemistry in the Marketplace*, 3rd Ed., Harcourt Brace, 1986. 5. O. R. Fennema, *Food Chemistry*, 4th Ed., Marcel Dekker, 2008. 6. H. Dugas, *Bioorganic Chemistry - A Chemical Approach to Enzyme Action*, 3rd Ed. Springer, 1999. 7. R. B. Silverman, *The Organic Chemistry of Enzyme-catalyzed Reactions*, Academic Press, San Diego, 717 pp., 2000. 8. J. S. Davies, *Amino acids, Peptides and Proteins*, Royal Society of Chemistry, UK, Vol. 35, 4, 2006. 9. L. Stryer, J. M. Berg, and J. L. Tymoczko, *Biochemistry*, 5th Ed., W. H. Freeman & Co Ltd, 2002.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHOG-515**
Title of the course: **Organometallic Chemistry and Rearrangement Reactions**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. Part-I level.
Course Objective:	1. To understand concepts and various strategies involved in organometallic chemistry. 2. To apply organometallic chemistry in the formation of carbon-carbon, carbon-hetero atom bonds. 3. To understand and apply molecular rearrangements for synthetic applications.
Course Outcome:	1. Students will be in a position to understand how a carbon-carbon and carbon-hetero atom bonds can be constructed using organometallic chemistry. 2. Students will be able to understand and apply the concepts of organometallic chemistry in syntheses of organic molecules. 3. Students will be in a position to write synthetic routes for organic molecules using various molecular rearrangements.

Content	*Hours*
1. Introduction to organometallic chemistry a. Introduction to Organometallic Chemistry, Definitions, Types of Metal-carbon bonds with main-group metals and transition metals b. *Sigma* and *pi* bonds: linear pi system and cyclic pi system c. Organic ligands, Nomenclature, heptacity, Electron counting and 18-electron rule d. Orbital interactions and bonding e. Kinetic stability	08
2. Organometallic compounds of main group elements a. Preparation, properties and applications of Lithium Magnesium, Cadmium, Zinc, Cerium, Mercury and Chromium Compounds. b. Heteroatom directed lithiation reactions	12
3. Role of transition metals in organic synthesis a. Preparation and properties of Copper, Palladium, Nickel, Rhodium, Ruthenium and Gold reagents/complexes. b. Mechanisms and applications of Mizoroki-Heck, Suzuki, Stille, Hiyama, Negishi, Sonogashira, Wacker, Kumada, Buchwald-Hartwig, carbonylation, homogenous hydrogenation, carbonylation, allylic substitution)	20
4. Molecular rearrangements and their synthetic applications a. Unifying principles and mechanisms of rearrangements taking place at an electron deficient and electron rich substrates. b. Rearrangements taking place at carbon: Arndt-Eistert, Wagner-Meerwein, benzil-benzilic acid, Pinacol-pinacolone, semipinacol, Tiffeneau Demjanov, dienone-	20

phenol, Wittig, Favorskii, Stevens, Wolff, Baker-Venkatraman, Barton decarboxylation, Pummerer rearrangement. c. Rearrangements at nitrogen: Hofmann, Curtius, Lossen, Schmidt, Beckmann, Neber, Stieglitz rearrangement. d. Rearrangements at oxygen: Payne (including aza- and thia-Payne) rearrangement, hydroperoxide rearrangement, Criegee rearrangement, Baeyer–Villiger oxidation e. Aromatic rearrangements: Benzidine, Fries, Von Richter, Sommelet-Hauser, Smile's, Jacobsen. Rearrangement on aniline derivatives- Bamberger rearrangement, Fischer-Hepp, Orton, Hofmann-Martius, Reilly-Hickinbottom, rearrangements of *N*-arylazoanilines, Phenylnitramines, Phenylsulfamines. f. Rearrangements involving fragmentations: Eschenmoser fragmentation.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. A. Edward, *Comprehensive Organometallic Chemistry*, 2nd Ed., 14 vols. Pergman, 1995. 2. F. R. Hartley, *Chemistry of Metal-Carbon Bond*, 6 vols. Wiley, 1982-83. 3. M. Schlosser, *Organometallics in Synthesis - A Manual*, John & Wiley, 1994. 4. R. H. CraJohn, *The Organometallic Chemistry of the Transition Metals*, Wiley, 1994. 5. G. R. Stephenson, *Transition Metal Organometallics for Organic Synthesis*, Cambridge University Press, 1991. 6. L. S. Liebeskind, *Advances in Metal Organic Chemistry*, Vols. 1 and 2 (Ed.), JAI Press, 1989. 7. J. P. Colliman, L. S. Hegedus, J. R. Norton & R. G. Finke, *Principles and Applications of Organotransition Metal Chemistry*, University Science Books, 1987. 8. A. Yamamoto, *Organotransition Metal Chemistry - Fundamental Concepts and Applications*, Wiley, 1986. 9. A. J. Pearson, *Metallo-Organic Chemistry*, John Wiley, 1985. 10. W. Caruthers & I. Colddham, *Modern Methods of Organic Synthesis*, 4th Ed., Cambridge University Press, 2016. 11. J. Clayden, N. Greeves and S. Warren, *Organic Chemistry*, Oxford, 2016. 12. F. A. Carey & R. J. Sundberg, *Advanced Organic Chemistry: Part A and B*, 5th Ed., Springer India Private Limited, 2007. 13. R. O. C. Norman & J. M. Coxon, *Principles of Organic Syntheses*, 3rd Ed. CRC Press Inc, 2009. 14. M. B. Smith & Jerry March, *Advanced Organic Chemistry- 50 Reaction, Mechanism and Structure*, 6th Ed., Wiley, 2006.

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCR-511**
Title of the course: **Research Methodology and instrumental techniques-I**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Introduction to Research Methodology a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	5
2. Scientific conduct and ethics a. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. b. Intellectual honesty and research integrity. c. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). d. Redundant publications: duplicate and overlapping publications. e. Selective reporting and misrepresentation of data.	5
3. Academic writing a. Publication ethics: definition, introduction and importance b. Conflicts of interest c. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa d. Violation of publication ethics, authorship and contributorship e. Identification of publication misconduct, complaints and appeals	5

f. Predatory publishers and journals	
4. Data bases and research metrics a. Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. b. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
5. Safety aspects in Chemistry a. Good laboratory practices. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	5
6. Softwares in Chemistry a. Data plotting b. Structure Drawing c. Reference management software	7
7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: a. Elemental analysis: CHNS analysis and AES b. Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) c. Nuclear magnetic resonance (^{1}H, ^{13}C) d. Chromatographic techniques: HPLC, GC, e. Hyphenated Techniques: LC-MS & GC-MS, f. Diffraction methods: XRD g. Thermal analysis: DSC h. Microscopy: SEM, TEM i. Methods for determination of magnetic & dielectric properties. j. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006.

	5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 14. A. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. A. Szabo, N. S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCR-512**
Title of the course: **Research Methodology and instrumental techniques-II**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I.
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing.

	4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Research Methodology, Scientific conduct, ethics & academic writing a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions. c. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. d. Intellectual honesty and research integrity. e. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). f. Redundant publications: duplicate and overlapping publications. g. Selective reporting and misrepresentation of data. h. Publication ethics: definition, introduction and importance i. Conflicts of interest j. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa k. Violation of publication ethics, authorship and contributorship l. Identification of publication misconduct, complaints and appeals m. Predatory publishers and journals	15
2. Softwares in chemistry, Data bases and Research metrics a. Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. b. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. c. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc d. Molecular Docking software	10
3. Safety practices in Chemical research	5

a. Introduction to lab safety. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	
4. Instrumental methods a. UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. b. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) c. Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) d. Electrochemical Impedance Spectroscopy (EIS) e. Resonance Raman and isotope labelling studies. f. Infrared (IR) spectroscopy applications g. ^{1}H, ^{13}C- NMR spectroscopy and applications h. Selected chromatographic techniques such as HPLC, GC. i. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS j. Diffraction methods: High temperature XRD k. Thermal analysis: TG/DTA/DSC l. Microscopy: Fe-SEM, HR-TEM m. Methods for determination Ms, Mr, Hc, Tc, ε^{l} and Tanδ. n. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986.

	8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989. 19. A. Leach, *Molecular Modelling, Principles and applications*, Longman, 1998. 20. W. Nam et al, *Dioxygen activation by Metalloenzymes & models*, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCD-511**
Title of the course: **Discipline Specific Dissertation**
Number of Credits: **16**Total Hours: **480** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	
Content		*Hours*
As per OA-35		480
Pedagogy	Dissertation carried out individually by each student throughout the academic year.	
Textbooks/ References / Readings	As required for the development of review and methodology.	

M.Sc. Inorganic Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III (Inorganic Chemistry)			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHIR-511**	Practical Course in Inorganic Chemistry-III	4
2.	**CHIR-512**	Practical Course in Inorganic Chemistry-IV	4
3.	**CHCR-511**	Research methodology and instrumental techniques-I	4
4.	**CHCR-512**	Research methodology and instrumental techniques-II	4
5.	**CHIG-511**	Bioinorganic Chemistry	4
6.	**CHIG-512**	Chemistry of p-block elements & their compounds	4
7.	**CHIG-513**	Environmental Chemistry	4
8.	**CHIG-514**	Inorganic Chemistry: Industrial Perspective	4
SEM IV (Inorganic Chemistry)			
1.	**CHIR-513**	Principles and applications in catalysis	4
2.	**CHIR-514**	Topics in Inorganic Chemistry	4
3.	**CHCD-511**	Discipline Specific Dissertation	16

Programme: **M.Sc. Part-II (Inorganic Chemistry)**

Course Code: **CHIR-511**

Title of the course: **Practical Course in Inorganic Chemistry-III**

Number of Credits: **04** Total Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course:	Should have studied Inorganic chemistry practical course at M.Sc. Part-I.	
Course Objective:	1. To introduce practical knowledge in Inorganic Chemistry. 2. To learn techniques of crystallization and synthesis of coordination compounds. 3. To learn characterization of compounds using different instruments. 4. To provide experience of synthesis and characterization of materials. 5. To introduce analysis of ores for metal content.	
Course Outcome:	1. Students will be in a position to purify ligands and will apply knowledge to synthesize coordination compounds. 2. Students will be able to study properties of coordination compounds using different instruments. 3. Students will apply knowledge to synthesize solid state material and can study their properties. 4. Students will be in position to separate metal ions by ion exchange chromatography. 5. Students apply knowledge to separate and analyze metals present in ores and alloys.	
Content		*Hours*
Minimum 23 experiments from the list shall be conducted.		
Unit – 1 Experiments in coordination chemistry: complex synthesis, metal analysis (Any Five) a. Purification (distillation/recrystallisation) of ligands like acacH, en, carboxylic acids etc.		30

b. Preparation of manganic tris(acetylacetonate) and estimation of manganese. c. Preparation of tris(thiourea)copper(I) sulfate and estimation of copper. d. Preparation of isomers; cis and trans-dichloro(ethylenediamine)cobalt(III) chloride and estimation of cobalt. e. Preparation and resolution of tris(ethylenediamine)cobalt(III) ion and estimation of cobalt. f. Preparation of cis and trans-potassium dioxalatodiaquochromate(III) and estimation of chromium. g. Preparation of nitro and nitrito-pentaaminecobalt(III) chlorides and estimation of cobalt. h. Preparation cobalt(III) porphyrin complex and estimation of cobalt. i. IR spectral characterization of free ligands and coordinated ligands. *NOTE: In complex synthesis, the student is expected to recrystallise the product, record IR spectra and carry out metal analysis. Spectral analysis can be carried over.*	
Unit –2 Experiments in Solid state chemistry (Any Eight) a. Preparation of spinel oxides by precursor method. b. Estimation of metals in precursors and oxides. c. Characterization of precursors by thermal analysis. d. Characterization of precursors and oxides by infrared analysis. e. X-ray diffraction studies of metal oxides. f. Direct current electrical resistivity of semiconductor (Ge/Si) by Four Probe method. g. Curie temperature determination of dielectric material (PZT) by measurement of dielectric constant v/s temperature. h. Measurement of saturation magnetization, Ms, Mr and Hc of ferromagnetic materials. i. Determination of Curie temperature of magnetic oxides by A.C. susceptibility studies. j. Preparation of CuO/SiO_2 or NiO/SiO_2 by wet impregnation method.	36
Unit – 3 Instrumental methods / spectral analysis / ion exchange (Any Six) a. Determination of stability constant of Fe(III) – salicylic acid compound (Job's Method). b. Determination of stability constant of Fe(III) – thiocyanate compound. c. Determination of stability constant of Fe(II) – 1,10-phenanthroline compound. d. Determination of instability constant for the reaction between Ag^+ and NH_3. e. Determination of instability constant for the reaction between Ag^+ and en. f. Determination of instability constant for the reaction between Cu^{2+} and NH_3. g. Determination of instability constant for the reaction between Cu^{2+} and en. h. Ion exchange chromatography: Separation of Mg^{2+} and Co^{2+} by anion exchange column. Separation of transition metal cations by anion exchange column.	30
Unit – 4 Ore / Alloy / commercial sample separation and analysis using Titrimetry / Gravimetry / spectroscopy method (Any Four) a. Analysis of Goan Iron ore: Hematite / magnetite b. Analysis of Devardas alloy c. Analysis of solder (Pb and Sn) d. Analysis of Pyrolusite	24

e. Analysis of Nickel-Aluminium alloy f. Analysis of Brass alloy g. Analysis of Bauxite h. Analysis of Magnesite	
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment.
Text Books/ References / Readings	1. G. Brauer, *Handbook of Preparative Inorganic Chemistry*, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, *Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods,* 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, *J. Chem. Ed*., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, *The Synthesis & Characterization of Inorganic Compounds*, Prentice-Hall, INC, 1970. 5. A. J. Elias, *General Chemistry Experiments*, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, *Vogel's Text Book of Quantitative Chemical Analysis*, 6th Ed.; Pearson, 2002. 7. G. Svehla, *Vogel's Text Book of Qualitative Inorganic Analysis*, 7th Ed.; Pearson, 2011. 8. G. Marr, B. W. Rockett, *Practical Inorganic Chemistry*, Van Nostrnad Reinhold London, 1972.

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Programme: **M.Sc. Part-II (Inorganic Chemistry)**

Course Code: **CHIR-512**

Title of the course: **Practical Course in Inorganic Chemistry-IV**

Number of Credits: **04** Total Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course:	Should have studied Inorganic chemistry practical course at M.Sc. Part-I.	
Course Objective:	1. To introduce to practical knowledge in Inorganic Chemistry. 2. To learn techniques of crystallization and synthesis of coordination compounds. 3. To learn characterization of compounds using different instruments. 4. To provide experience of synthesis and characterization of materials. 5. To introduce analysis of ores for metal content.	
Course Outcome:	1. Students will be in a position to explain general aspects involved in purification of ligands and will apply knowledge to synthesize ligands and coordination compounds. 2. Students will be able to characterize coordination compounds usinf instrumental techniques. 3. Students will be in a position to prepare solid state materials and study their properties. 4. Students will apply knowledge to separate metal ions by ion exchange chromatography. 5. Students will be able to analyze metals in ores and alloys	
Content		*Hours*
Minimum 20 experiments from the list shall be conducted.		

Unit–1 Preparation of ligands (including distillation / recrystallization) / metal-ligand compounds / inorganic compounds (Any 6) a. Preparation of Schiff's base and characterization by IR. Ex. Condensation of simple aldehydes with diammines (ethylene diammine, 1,3-propanediammine) b. Preparation of substituted benzoic acids and characterization. c. Preparation of acetylacetonate complexes of Co(II) and Co(III) and estimation of cobalt. d. Preparation of ammonium dichromate and ammonium heptamolybdate. e. Preparation of aluminium(III)tris(acetylacetonate) and estimation of aluminium. f. Preparation of potassium dihydroxodioxalatotitanate(IV) and estimation of titanium. g. Preparation of manganic acetate and estimation of manganese h. Preparation of chromium(II) acetate hydrate and estimation of chromium. i. Preparation of $K_2ON(SO_3)_2$ (Fremy's salt). *Note: Wherever possible IR and other spectral studies should be undertaken for prepared compounds*.	36
Unit –2: Syntheses, characterization and solid state study of ABO_3/AB_2O_4 oxides (Any 6) a. Preparation of Perovskite/Spinel oxide by oxalate precursor method. b. Characterization of precursor using CHN Analyser and estimation of metals in the precursors and oxides by gravimetric and volumetric analysis. c. Characterization of precursor and Perovskite/Spinel oxide by FTIR. d. Thermal analysis (TG/DTA) of prepared precursors. e. Isothermal Mass Loss Studies. f. X-ray diffraction studies of Perovskite/Spinel oxide prepared. g. Electrical resistivity measurement of the prepared oxide by Two probe / Four Probe method. h. Dielectric studies of prepared oxide: Dielectric constant and dielectric loss V/s I) Frequency and II) Temperature. i. Magnetic Characterization of prepared Spinel oxide by i) Hysteresis loop data (Ms, Mr, Hc) and ii) A.C Susceptibility. *Note: Wherever possible IR and other spectral studies should be undertaken.*	36
Unit – 3: Instrumental experiments/separation of metal ions by ion exchange resins (Any 6) a. Determination of stability constant of Fe(III)-Sulfosalicylic acid compound in the solution. b. UV-visible spectroscopy study of transition metal complexes. c. Potentiometric determination of cobalt/ nickel /zinc by EDTA. d. Conductance measurements: preparation and electrical conductivity measurements of some cobalt complexes. e. Determination of magnetic susceptibility of Mn(II), Cu(II) etc. salts/complexes. f. Colorimetric estimation of Hg/Cd g. Separation of transition metal cations by cation – exchange chromatography h. IR and NMR studies of Inorganic compounds. Ex. $VO(acac)_2$ i. Cyclic voltammetry experiment (ferrocene/hexacyanatoferrate).	36
Unit – 4: Ore analysis/ Alloy analysis using Titrimetry / Gravimetry / spectroscopy method (Any 2)	12

a. Analysis of Malanchite b. Analysis of Ilmenite c. Analysis of Nickel Steel alloy d. Analysis of Rolled Gold e. Analysis of Gun Metal f. Analysis of magnalium g. Analysis of Bronze	
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment.
Text Books/ References / Readings	1. G. Brauer, *Handbook of Preparative Inorganic Chemistry*, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, *Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods,* 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, *J. Chem. Ed*., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, *The Synthesis & Characterization of Inorganic Compounds*, Prentice-Hall, INC, 1970. 5. A. J. Elias, *General Chemistry Experiments*, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, *Vogel's Text Book of Quantitative Chemical Analysis*, 6th Ed.; Pearson, 2002. 7. G. Svehla, *Vogel's Text Book of Qualitative Inorganic Analysis*, 7th Ed.; Pearson, 2011. 8. G. Marr, B. W. Rockett, *Practical Inorganic Chemistry*, Van Nostrnad Reinhold London, 1972.

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Programme: **M.Sc. Part-II (Inorganic Chemistry)**

Course Code: **CHIR-513**

Title of the course: **Principles and applications in catalysis**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. Part-I.
Course Objective:	1. To understand the fundamentals concepts of chemical reactions over the catalysts. 2. To understand energy saving and making green processes in chemical reactions. 3. To understand fundamentals and basic concepts of chemical reactions for developing higher productivity and viability. 4. To provide knowledge on applications of heterogeneous, homogenous and other catalytic processes. 5. To make aware of catalytic approaches in environmental pollution control processes.
Course Outcome:	1. Students will be able to explain concepts and general properties of different types of catalysts. 2. Students will be able to explain the catalytic reaction mechanisms and green catalytic processes. 3. Students will be in position to prepare and characterized catalysts.

	4. Students will apply knowledge to develop reaction specific catalysts using basic concepts. 5. Students will apply knowledge to develop catalysts for useful chemical reactions and environmental pollution control processes.

Content	*Hours*
1. Origin and development of catalysts a. Introduction to heterogeneous, homogeneous and bio-catalysis, importance of catalysis in chemical reactions and its industrial applications. b. Concepts of Atom Economy, Turnover number and Turnover frequency.	5
2. Heterogeneous Catalysis a. Introduction to heterogeneous catalysis, energy profile diagram and diffusion of gas, general mechanisms such as Langmuir-Hinshelwood and Rideal-Eiley. b. Adsorptions: Physical and chemical adsorption, chemisorptions of gases on solid surfaces, nature of adsorbed layer, dissociative adsorptions, scattering, trapping and sticking, simple adsorptions isotherm, Langmuir adsorption, the BET adsorption isotherm and Surface area determination. c. Types of Catalysts: Preparations and separations of the catalysts, meso and micro porous materials, nano material catalysts and significance, zeolites and related molecular sieves, supported and bifunctional catalysts and catalyst regeneration, activity and life of the catalysts, active centers, promoters and poisons, catalyst deactivations. d. Characterization of solid catalysts: Structure and surface morphology, porosity, pore volume and diameter, particle size, X-ray diffraction , Thermal analysis (DTA/TG and DSC), SEM, TEM, X-ray absorption spectroscopy, XPS and Auger Electron Spectroscopy to surface studies, TPD for acidity and basicity of the catalysts. e. Heterogeneous reactions: Thermodynamic consideration in surface reactions, mechanism of catalytic reactions, ammonia synthesis, oxidation reduction reactions, CO oxidation, N_2O decomposition, Fisher tropsch catalysis, selective catalytic reduction, method of finding reaction rate and the rate determining steps. f. Theories of Catalysis: Boundary layer theory, catalysis by semiconductors, Wolkenstein theory, Balanding's approach, electronic factors in catalysis by metals, molecular orbital approach.	23
3. Homogeneous Catalysis a. Homogeneous catalytic reactions, merits and demerits, intermediate stages in homogenous catalysis, energy profile diagram, activation energy, general scheme for calculating kinetics of the reactions. b. Decomposition of hydrogen peroxide, acid-base catalysis. c. Homogeneous catalytic reactions: Hydrogenation, hydroformylation, isomerization, Monsanto acetic acid process, Carboxylation reactions, Wacker reaction, coupling reactions and asymmetric oxidations.	12
4. Photo-catalysis Homogeneous photo-catalysis, photo-sensitized and photo-oxidations reactions, heterogeneous photo-catalysis, semiconductor photo-catalysts, generation of hydrogen by photo-catalysts and harnessing solar energy, photo-degradation of dyes.	3

5. Catalytic polymerizations Homogeneous and heterogeneous catalysis in polymerizations reactions (few examples), Ziegler – Natta catalyst in polymerizations reactions.	5
6. Bio-catalysis Nomenclature and classification of enzymes, metal ions and metalloenzymes, general properties, enzymatic reactions such as redox and decomposition, action of enzymes, mechanistic pathways of few enzymatic reaction, factors affecting enzymes and enzyme applications.	3
7. Phase transfer catalysis Mechanism of PTC, types of phase transfer catalysis with selected examples, advantages and disadvantage.	3
8. Catalyst for energy and environment Catalytic gasification, electricity from gas turbine, steam reforming, electro-catalysis, fuel cells for energy production like methanol, molten carbonate and solid oxide fuel cells, catalysts for environmental pollution in emission control and selective catalytic reduction.	6

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. A.V. Salker, *Catalysis: Principles and Basic Concepts*, Scientific International, 2019. 2. P. H. Emmett, *Catalysis*, Vol I, Reinhold,1955. 3. D. K. Chakraborty, *Adsorption and Catalysis by Solids,* New Age International (P) Ltd., 2008. 4. J. M. Thomas, W.J. Thomas, *Heterogeneous Catalysis*, VCH publication, 1997. 5. A. Clark, *The Theory of Adsorption and Catalysis*, Academic Press, 1970. 6. E. R. Rideal, *Concept in Catalysis*, Academic Press, 1968. 7. G. M. Panchenov, V. P. Lebedev, *Chemical Kinetics and Catalysis*, Mir publication, 1976. 8. S. J. Thomson, G. Webb, *Heterogeneous Catalysis*, Oliver and Boyd Publications, 1968. 9. R. A. Van Santen, J. W. Niemantsvedict, *Chemical Kinetics and Catalysis*, Plenum Press, 1995 10. M. Beller, A. Renken, R. van Santen, *Catalysis*, Wiley VCH, 2012.

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Programme: **M.Sc. Part-II (Inorganic Chemistry)**
Course Code: **CHIR-514**
Title of the course: **Selected Topics in Inorganic Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Part-I
Course Objective:	1. To study the amorphous and glass materials. 2. To learn the properties of refractories and solid lubricants and their applications. 3. To understand the concepts of Inorganic electrochemistry. 4. To study the important instrumental techniques for characterization of Inorganic materials.

Course Outcome:	1. Students will be able to explain different amorphous and glass materials and their properties. 2. Students will be able to differentiate between the types of refractories and solid lubricants. 3. Students will be able to analyse a cyclic voltammogrames of inorganic compounds. 4. Students will apply knowledge to characterize inorganic materials by using instrumental techniques.

Content	*Hours*
1. Amorphous and Glass Materials a. Introduction to amorphous materials b. Glasses c. Glass transition temperature d. Composition of glasses e. Viscosity f. Glass forming methods g. Commercial glasses h. Chalcogenide glasses i. Ceramic glasses j. Metallic glasses	7
2. Refractories and Solid lubricants a. Classification of refractories b. Properties of refractories: Thermal expansion and contraction, Refractoriness, Spalting resistance, Thermal conductivities c. Resistance to melts-slags and glasses d. Refractory materials: Aluminous type, silica type, basic type, insulating type e. Special refractories: Oxide refractories, other refractories, ideal refractories f. Solid lubricants: Inorganic, organic, and nanomaterial lubricants	13
3. Fundamentals of Inorganic Electrochemistry a. Basic aspects of electrochemistry, electron transfer reactions at electrode surface, potential and electrochemical cells, b. Voltammetric techniques, linear voltammetry, cyclic voltammetry; reversible, irreversible, and quasi-reversible processes; applications of cyclic voltammetry with reference to ferrocenes, transition metal complexes.	5
4. Characterisation Techniques a. Diffraction methods (XRD, Neutron and Electron) b. X-ray spectroscopies (XRF, AEFS, EXAFS) c. Thermal analysis d. SEM, FESEM e. TEM (HR-TEM and Imaging) f. FTIR g. X-ray Absorption spectroscopy h. Electron spectroscopy (XPS, UPS, Auger) i. Atomic emission spectroscopy j. UV-Visible spectroscopy (DRS)	35

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. A.R. West, *Solid State Chemistry and Its Applications*, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007). 2. L.V. Azaroff, *Introduction to Solids,* 1st Ed. (33rd Reprint), Tata McGraw Hill, 2009. 3. D. K. Chakraborty, *Solid State Chemistry,* 2nd Ed.; New Age International Publisher, 2010. 4. H. V. Keer, *Principles of the Solid State,* 1st Ed. (Reprint 2008); New Age International (P) Ltd., (Wiley Eastern Ltd.), 1993. 5. W. D. Callister, *Materials Science and Engineering:An Introduction,* 7th Ed.; John Wiley, 2007. 6. B. D. Fahlman, *Materials Chemistry,* 2nd Ed.; Springer, 2011. 7. H. R. Allcock, *Introduction to materials chemistry,* 1st Ed.; John Wiley & Sons, 2011. 8. R. H. Doremus, *Glass Science*, 2nd Ed.; Wiley, 1973. 9. P. N. Ross, *Handbook of Fuel Cells*, 7th Ed.; Wiley, 2003. 10. D. T. Sawyer, A. Sobkowak, J. L. Roberts Jr., *Electrochemistry for chemists*, 2nd Ed.; John Wiley, Inc., 1995. 11. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong, *Shriver & Atkins' Inorganic Chemistry,* 5th Ed.; Oxford University Press, 2010. 12. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning, 2014. 13. A. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 6th Ed.; Cengage learning, 2007. 14. G. Aruldas, Molecular Structure and Spectroscopy, 2ed Ed.; PHI Learning Pvt. Ltd., 2015.

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHIG-511**
Title of the course: **Bioinorganic Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students have studied chemistry/biochemistry courses at M.Sc. Part-I.
Course Objective:	1. To understand the role of inorganic elementsespecially metal ions in biology. 2. To introduce metallobiolecules, metalloproteins & metalloenymes. 3. To understand the role of small molecule model compounds. 4. To introduce the concept of Biomimetic chemistry.
Course Outcome:	1. Students will be in a position to clarify the significance of essential elements in biology. 2. Students will be able to explain the role played by metal ions in vital processes like i) oxygen storage and transport and ii) electron transfer. 3. Students will be able to explain basic concepts in Biomimetic chemistry.

	4. The students will be able use different techniques in Bioinorganic Chemistry.

Content	*Hours*
1. Essential elements in biology Periodicity of elements, distribution of elements in biosphere, bio-availability, bio-stability, building blocks of the biosphere; carbohydrates, nucleic acids and proteins, biological importance of water, and brief review of the chemistry of biopolymers. Metallobiomolecules: classification, metalloproteins (enzymes), metal activated proteins (enzymes), metal functions in metalloproteins, Principles of coordination chemistry related to bioinorganic research, physical methods in bioinorganic chemistry.	12
2. Alkali and alkaline earth metals in biology Introduction, biological importance of the alkali and the alkaline earth cations, Cation transport through membranes (ion pumps). Photosynthesis, Hill reaction, Chlorin macrocycle and chlorophyll, Absorption of light by chlorophyll, role of metals in photosynthesis, in vitro photosynthesis.	12
3. Non-redox metalloenzymes Zinc metalloenzymes like carboxypeptidase, carbonic anhydrase and alcohol dehydrogenase, Bio-functions of zinc enzymes, active site structure and model complexes.	12
4. Biochemistry of a few transition metals Role of Fe, Mo, Cu and Ni. Oxygen carriers and oxygen transport proteins, iron porphyrins (Haemoglobin and myoglobin). Haemocyanins and Haemerythrins, Synthetic models for oxygen binding haemproteins. Cytochrome C, catalase, peroxidase, and superoxide dismutase, blue copper proteins, vitamin B_{12} coenzymes, nitrogen fixation and iron-sulfur proteins, biological nitrogen fixation, nitrogenase and dinitrogen complexes, iron-sulfur proteins, synthetic analogues for Fe-S proteins, core extrusion reactions. Metal transport and storage: A brief review of iron transport. transferrin, ferritin, hemosiderin, siderophores, iron biomineralization	12
5. Biomimetic Inorganic Chemistry Fundamentals of biomimetic chemistry, metal – oxygen intermediates, techniques used to probe the active sites of oxygen carriers, redox chemistry of free molecular dioxygen, spectroscopy of Fe-O-Fe moiety, geometry and electronic structure of coordinated dioxygen, other ligands for biological oxygen carriers, reactions of metal-oxygen compounds, oxygenases, Cytochrome P-450, synthetic procedures of simple ligands, isolation of S-containing amino acid or extraction of chlorophyll from green leaves, recrystallization of carboxylic acids. Non-Heme and heme ligands.	12

Pedagogy	Mainly lectures / tutorials / assignments /group discussion / self-study /presentations or a combination of some of these could also be used to some extent.
Textbooks / Reference / Readings	1. S. J. Lippard & J. M. Berg, *Principles of Bioinorganic chemistry*, Panima Publishing Corporation 2. B. I. Britini, H. B. Gray, S. J. Lippard & J. S. Valentine, *Bioiorganic chemistry*, University Science books, Mill Valey, CA, 1994. 3. D. E. Fenton, *Biocoordination Chemistry*, Oxford Chemistry Printers, 25 Oxford University Press, 1995

	4. E. E. Conn, P.K. Stumpf, G. Bruening & R. H. Doi, *Outlines of Bioinorganic Chemistry*, 5th Ed.; Wiley Eastern, 1983. 5. F.A. Cotton, G. Wilkinson, P.L. Gaus, *Basic Inorganic Chemistry*, 3rd Ed. (Chapter 31); WileyIndia, 2007. 6. M. Weller, T. Overton, J. Rourke & F. Armstrong *Inorganic Chemistry*, Int. Ed. (Chapter 25); Oxford University Press, 2018. 7. P Atkins, T Overton, J Rourke, M Weller & F Armstrong, *Shriver & Atkins' Inorganic Chemistry,* 5th Ed. (Chapter 27); Oxford University Press, 2010. 8. J. E. Huheey, E. A. Keiter, R. L. Keiter, *Inorganic Chemistry: Principles of Structure and Reactivity,* 5th Ed. (Chapter 19); Addison Wesley Publishing. 9. R. W. Hay, *Bioinorganic chemistry*, Ellis Horwood Chichester, 1984. 10. M.N. Hughes, *The Inorganic Chemistry of Biological processes*, 2nd Ed.; Wiley (Interscience), 1984. 11. R. R. Crichton, *Biological Inorganic Chemistry*, Elsevier, 2012. 12. R. Breslow, *Biomimetic Chemistry: Biology as an Inspiration*, The Journal of Biological Chemistry, vol. 284, no. 3, pp. 1337–1342, 2009. 13. C. Housecroft, A. G. Sharpe, *Inorganic Chemistry*, 4th Ed; Pearson Publishing, 2012.

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Programme: **M.Sc. Part-II (Chemistry)**

Course Code: **CHIG-512**

Title of the course: **Chemistry of p-block elements & their compounds**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry/biochemistry courses at M.Sc. Part-I.
Course Objective:	1. To study the different trends in physical and chemical properties of p-block elements. 2. To understand the variations in physical and chemical properties of compounds of p-block elements. 3. To study the preparation and structure of some important compounds of p-block elements. 4. To study the applications of some of their compounds.
Course Outcome:	1. Students will be able to explain the trends in physical properties in groups and periods in the periodic table. 2. Students will be able to explain the chemistry of p-block elements as this course will give sufficient information about p-block elements and their compounds in particular. 3. Students will be able to prepare some important compounds of p-block elements. 4. Students will apply the knowledge of chemical properties of compounds to solve day to day problems.

Content	*Hours*
1. General trends of different properties in groups and periods in periodic table	4
2. Chemistry of Group 13 Elements and their Compounds	13

a. Introduction, physical properties, chemical reactions with oxygen, nitrogen, sulphur, halogens, HCl, NaOH, NH_3, mono-di-tri-chlorides, alums, organo-compounds of B and Al, difference between boron and other Gr. 13 elements, diagonal relationship. b. Preparation, bonding and structure of diborane, higher boranes, borane anions, carboranes and metallocarboranes. c. Borazine: Synthesis, properties, structure, bonding and some of its derivatives. d. Borates: Classification, structure and examples.	
3. Chemistry of Group 14 Elements and their Compounds a. Introduction, physical properties, allotropy, compounds of Gr.14: different types of oxides, di, tetra & catenated halides, hydrides, sulphides, cyanides. b. Coordination compounds, organosilicon compounds, silicones, cluster compounds of Ge, Sn and Pb. c. Silicates: classification with examples and applications, zeolite. d. Carbon dating, graphene, metallocarbohedrenes, freons. e. Intercalation compounds of graphite with oxygen and fluorine, heavier Group 1 elements, different halides including $FeCl_3$. f. Carbides: classification, preparation, properties and uses.	13
4. Chemistry of Group 15 Elements and their Compounds a. Introduction, allotropes, physical properties, Preparation, properties and structure of: Hydrides, halides, oxides, oxyacids, oxohalides. b. Preparation, properties and structure of Phosphorous: sulphides, oxosulphides, organophosphorous compounds. c. Classification, preparation, properties and structures of phosphazenes.	9
5. Chemistry of Group 16 Elements and their Compounds a. Introduction, allotropes, physical properties, Preparation, properties and structure of: Hydrides, halides, oxohalides, oxides, oxyacids, classification of oxides. b. Compound of sulphur and nitrogen: Preparation, properties and structure of $(SN)_x$, S_2N_2 and S_4N_4. c. Polyatomic sulphur cations, anionic polysulphides, compounds with sulphur as a ligand.	9
6. Chemistry of Group 17 Elements and their Compounds a. Introduction, physical properties; preparation, properties and structure of: oxides, oxyacids, halides, oxohalides, hydrogenoxide fluorides and related compounds. b. Preparation, properties and structure of: interhalogen compounds, polyhalide anions, polyhalonium cations, halogen cations.	8
7. Chemistry of Group 18 Elements and their Compounds a. Introduction, physical properties; preparation, properties, structure and bonding of xenon compounds (fluorides and oxides); organoxenon compounds, compound containing Xe-Xe bond. b. Preparation, properties and structure of compounds of other noble gases.	4
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.

Textbooks/ References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, *Shriver & Atkins Inorganic Chemistry*, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, *Inorganic Chemistry: Principles of Structure & Reactivity*, 4th Ed.; Pearson, 2011. 3. N. N. Greenwood, A. Earnshaw, *Chemistry of the Elements*, 2nd Ed. (reprinted); Elsevier, 2014. 4. J. D. Lee, *Concise Inorganic Chemistry*, 5th Ed. (reprint); Blackwell Science Wiley, 2015. 5. F. A. Cotton, G. Wilkinson, P. L. Gauss, *Basic Inorganic Chemistry*, 3rd Ed.; Wiley, 2008. 6. F. A. Cotton, G. Wilkinson, *Advanced Inorganic Chemistry*, 3rd Ed.; Wiley, 1984. 7. G. C. Miessler, D. A. Tarr, *Inorganic Chemistry*, 3rd Ed.; Pearson, 2004.

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHIG-513**
Title of the course: **Environmental Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry/ biochemistry courses at M.Sc.Part-I.
Course Objective:	1. To introduce to fundamentals of environmental chemistry. 2. To provide important knowledge of environmental chemistry in day-to-day life. 3. To give the basic knowledge of environmental pollution. 4. To make aware of the harmful effects of environmental pollutants and control measures.
Course Outcome:	1. Students will be in a position to know the basic environmental chemical processes. 2. Students will be able to explain the origin and harmful effects of toxic chemicals in the environment. 3. Students will be aware of the analysis of some pollutants. 4. Students will be in a position to give examples of case studies.

Content	*Hours*
1. Structure and properties of atmosphere: Introduction, Temperature profile of the atmosphere, Lapse rate, Temperature inversion.	4
2. Biogeochemical cycles Introduction, Biogeochemical cycles of Oxygen, Carbon, Sulphur, Nitrogen, Phosphorus, and Hydrogen.	8
3. Soil Pollution Introduction, Air and water in the soil, Inorganic and Organic components in the soil, Reactions in the soil, Waste pollutants in the soil and soil contamination, Excess usage of agrochemicals, Adsorption and decomposition of organic matter in the soil.	6

4. Air pollution Types of emissions, Air pollution dispersion models, Types of emission sources, Estimation of Dispersion parameters, Types of Plumes, global warming Particulate matter: Introduction, Particle size range, Health Hazards, Analysis of particulate matter, Control devices, Inorganic Particulates, Radioactive particulates, Organic particulates and other contaminants.	12
5. Water pollution and Conditioning a. Introduction. b. Hard water and water softening by chemical methods. c. Carbonate hardness removal by lime, Magnesium hardness removal by lime, and non-carbonated hardness removal by soda ash. d. Calcium carbonate solubility. e. Re-carbonation and acid process. f. Barium-lime cold process. g. Ion exchange process.	8
6. Plastic pollution a. Microplastics b. Global occurrence, distribution, and the fate of plastic in the environment. c. Weathering and degradation of plastics. d. Microplastics, types of microplastics, nanoplastics. e. Analysis and identification of microplastics. f. Impact on the terrestrial and marine environment (estuarine, open ocean, coral reefs). g. Inputs of microplastics into the oceans. h. Transfer of microplastics into the food chain: bioaccumulation and Biomagnification. Microplastic ingestion, toxicity, and impact on human health.	10
7. Selected industrial effluent treatment. a. Industrial effluent treatment, b. Effects of Industrial effluents on surface water and land, c. Manufacture process and treatment of fertilizers and pesticides, d. Electroplating process and treatment of the waste, e. Waste from the cement industry, Waste from the sugarcane and paper industry.	8
8. Waste Management and Case studies a. Waste Management (sources and types of solid wastes, disposal techniques, collection methods, waste management approach). b. Case study (Bhopal gas tragedy, use of DDT).	4
Pedagogy	Mainly lectures and tutorials. Seminars/term papers /assignments/presentations/self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, *Shriver & Atkins Inorganic Chemistry*, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, *Inorganic Chemistry: Principles of Structure & Reactivity*, 4th Ed.; Pearson, 2011.

	3. N. N. Greenwood, A. Earnshaw, *Chemistry of the Elements*, 2nd Ed. (reprinted); Elsevier, 2014. 4. J. D. Lee, *Concise Inorganic Chemistry*, 5th Ed. (reprint); Blackwell Science Wiley, 2015. 5. F. A. Cotton, G. Wilkinson, P. L. Gauss, *Basic Inorganic Chemistry*, 3rd Ed.; Wiley, 2008. 6. F. A. Cotton, G. Wilkinson, *Advanced Inorganic Chemistry*, 3rd Ed.; Wiley, 1984. 7. G. C. Miessler, D. A. Tarr, *Inorganic Chemistry*, 3rd Ed.; Pearson, 2004. 8. R. C. Hale, M. E. Seeley, M. J. La Guardia, L. Mai, E. Y. Zeng, *A global perspective on microplastics,* 2020, Journal of Geophysical Research: Oceans, Wiley, 125 (1), e2018JC014719. 9. S. Sharma, S. Chatterjee, *Microplastic pollution, a threat to marine ecosystem and human health: a short review*. 2017, Environmental Science and Pollution Research, Springer, 24, 21530–21547. 10. L. Andrady, *Microplastics in the marine environment*, 2011, Marine pollution bulletin, 62(8), 1596-1605. 11. R. C. Thompson, C. J. Moore, F. S. Vom Saal, S. H. Swan, *Plastics, the environment and human health: current consensus and future trends*. 2009, Philosophical transactions of the royal society B: biological sciences, Royal Society, 364 (1526), 2153-2166.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHIG-514**
Title of the Course: **Inorganic Chemistry: Industrial Perspective**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied M.Sc. Part-I chemistry courses.	
Course Objectives:	1. To discuss the economic importance of inorganic materials. 2. To teach the concepts in chemistry useful for inorganic industries. 3. To learn syntheses involved in industrial production. 4. To recognize applications of industrial inorganic materials in several other sectors.	
Course Outcomes:	1. Students will be able to discuss the economic importance of inorganic materials. 2. Students will be able to understand concepts in chemistry useful for inorganic industries. 3. Students will be able to describe syntheses involved in industrial production. 4. Students will be able to explain applications of industrial inorganic materials in several other sectors.	
Content		*Hours*

1. Economic importance of Inorganic materials in industry a. Chemical industries & their economic importance b. Commodity, fine and speciality chemicals c. Water: potable water, fresh water from sea water & / or brackish water d. Hydrogen: water electrolysis, petrochemical processes and coal gasification e. Peroxide and inorganic peroxo compounds: hydrogen peroxide, sodium peroxide, sodium perborate, sodium carbonate perhydrate, alkali peroxodisulfate f. Nitrogen / phosphorous / sulphur /halogens and their compounds: ammonia, hydrazine, hydroxylamine, phosphoric acid & its salts, organophosphorus compounds, sulphuric acid, other important sulphur compounds, compounds of fluorine, chloroalkali electrolysis, hydrochloric acid, chlorine-oxygen compounds, compounds of bromine and compounds of iodine	15
2. Minerals in fertilizer industry a. Nitrogen-containing fertilizers: ammonium sulphate, ammonium nitrate and urea b. Phosphorous-containing fertilizers: superphosphates, triple superphosphates, ammonium phosphates and nitrophosphates c. Potassium-containing fertilizers: potassium chloride, potassium sulphate and potassium nitrate	10
3. Metals / silicon and their compounds in industry a. Alkali metals: lithium, sodium and potassium b. Alkaline-earth metals: beryllium, magnesium, calcium, strontium and barium c. Others metals: aluminium, chromium, manganese and iron d. Silicon: silicon & its inorganic compounds andorgano-silicon compounds	15
4. Inorganic solids and their applications a. Silicates: glass, alkali silicates, zeolites b. Inorganic fibers: asbestos, textile glass, optical, carbon, metal and ceramic reinforcing fibers c. Ceramics: clay, electro, magneto and nonoxide ceramics d. Construction materials: lime, cement, gypsum, coarse ceramic and expanded products e. Enamels: enamel frit and its raw material as metal oxides / carbonates / nitrates / fluorides f. Metal carbides: titanium, zirconium, hafnium, vanadium, niobium tantalum, chromium, molybdenum, tungsten, thorium and uranium carbides g. Inorganic carbon: diamond, natural graphite, synthetic carbon & synthetic graphite, pyrolytic carbon & pyrolytic graphite and activated carbon h. Fillers: natural and synthetic fillers **i.** Inorganic pigments: white, coloured, black and speciality pigments	20
Pedagogy	Mainly lectures / tutorials / assignments / self-study/ industrial visits/ field trips in and around Goa or combination of some of these could also be used to some extent.

Textbooks / Reference books	1. K.H. Büchel, H.-H. Moretto& P. Woditsch, *Industrial Inorganic Chemistry*, 2nd completely revised Ed., Wiley VHC, 2000. 2. G. Buxbaum& G. Pfaff, *Industrial Inorganic Pigments*, 3rd Ed., Wiley VHC, 2005. 3. N.N. Greenwood & A. Earnshaw, *Chemistry of the Elements*, 3rd Ed., Pergamon Press, Exeter, 1998. 4. F.A. Cotton, G. Wilkinson & P. L. Gaus, *Basic Inorganic Chemistry*, 3rd Ed., John Wiley, 2007. 5. F.A. Cotton & G. Wilkinson, *Advanced Inorganic Chemistry*, 6th Ed., Wiley Eastern, 2007. 6. J.E. Huheey, E.A. Keiter, R.L. Keiter, *Inorganic Chemistry: Principles of structure and reactivity*, 4th Ed., Pearson, 1993. 7. J.D. Lee, *Concise Inorganic Chemistry*, 5th Ed., Wiley, 2008. 8. M. Weller, T. Overton, J. Rourke & F. Armstrong, *Inorganic Chemistry*, International Ed., Oxford University Press, 2018. 9. P. Atkins, J. De Paula & J. Keeler, *Atkins' Physical Chemistry*, International Ed., Oxford University Press, 2018. 10. A.R. West, *Solid State Chemistry and Its Applications*, 2nd Ed., John Wiley & Sons,2014.

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCR-511**
Title of the course: **Research Methodology and instrumental techniques-I**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Introduction to Research Methodology a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis;	5

generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	
2. Scientific conduct and ethics a. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. b. Intellectual honesty and research integrity. c. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). d. Redundant publications: duplicate and overlapping publications. e. Selective reporting and misrepresentation of data.	5
3. Academic writing a. Publication ethics: definition, introduction and importance b. Conflicts of interest c. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa d. Violation of publication ethics, authorship and contributorship e. Identification of publication misconduct, complaints and appeals f. Predatory publishers and journals	5
4. Data bases and research metrics a. Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. b. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
5. Safety aspects in Chemistry a. Good laboratory practices. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	5
6. Softwares in Chemistry a. Data plotting b. Structure Drawing c. Reference management software	7
7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: a. Elemental analysis: CHNS analysis and AES b. Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) c. Nuclear magnetic resonance (^{1}H, ^{13}C) d. Chromatographic techniques: HPLC, GC, e. Hyphenated Techniques: LC-MS & GC-MS, f. Diffraction methods: XRD g. Thermal analysis: DSC h. Microscopy: SEM, TEM i. Methods for determination of magnetic & dielectric properties. j. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these.

	ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 14. A. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. A. Szabo, N. S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCR-512**
Title of the course: **Research Methodology and instrumental techniques-II**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I.

Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Research Methodology, Scientific conduct, ethics & academic writing a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions. c. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. d. Intellectual honesty and research integrity. e. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). f. Redundant publications: duplicate and overlapping publications. g. Selective reporting and misrepresentation of data. h. Publication ethics: definition, introduction and importance i. Conflicts of interest j. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa k. Violation of publication ethics, authorship and contributorship l. Identification of publication misconduct, complaints and appeals m. Predatory publishers and journals	15
2. Softwares in chemistry, Data bases and Research metrics a. Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. b. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. c. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc d. Molecular Docking software	10
3. Safety practices in Chemical research a. Introduction to lab safety. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling	5

e. Safety Data Sheet	
4. Instrumental methods a. UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. b. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) c. Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) d. Electrochemical Impedance Spectroscopy (EIS) e. Resonance Raman and isotope labelling studies. f. Infrared (IR) spectroscopy applications g. ^{1}H, ^{13}C- NMR spectroscopy and applications h. Selected chromatographic techniques such as HPLC, GC. i. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS j. Diffraction methods: High temperature XRD k. Thermal analysis: TG/DTA/DSC l. Microscopy: Fe-SEM, HR-TEM m. Methods for determination Ms, Mr, Hc, Tc, ε^{l} and Tanδ. n. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning.

	14. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989. 19. A. Leach, *Molecular Modelling, Principles and applications*, Longman, 1998. 20. W. Nam et al, *Dioxygen activation by Metalloenzymes & models*, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCD-511**
Title of the course: **Discipline Specific Dissertation**
Number of Credits: **16**Total Hours: **480** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	
Content		*Hours*
As per OA-35		480
Pedagogy	Dissertation carried out individually by each student throughout the academic year.	
Textbooks/ References / Readings	As required for the development of review and methodology.	

M.Sc. Analytical Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III (Analytical Chemistry)			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHAR-511**	Practical Course in Analytical Chemistry-III	4
2.	**CHAR-512**	Practical Course in Analytical Chemistry-IV	4
3.	**CHCR-511**	Research methodology and instrumental techniques-I	4
4.	**CHCR-512**	Research methodology and instrumental techniques-II	4
5.	**CHAG-511**	Fundamentals of Crystallography	4
6.	**CHAG-512**	Advanced NMR and combined Spectroscopy	
7.	**CHAG-513**	Bioanalytical Techniques	4
8.	**CHAG-514**	Calibration and Validation in Analytical Chemistry	4
SEM IV (Analytical Chemistry)			
1.	**CHAR-513**	Advanced Mass Spectrometry	4

2.	**CHAR-514**	Selected Topics in Analytical Chemistry	4
3.	**CHCD-511**	Discipline Specific Dissertation	16

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Programme: **M. Sc. Part-II (Analytical Chemistry)**
Course Code: **CHAR-511**
Title of the Course: **Practical Course in Analytical Chemistry - III**
Number of Credits: **04** Total Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course:	Should have studied Analytical chemistry practical course at M.Sc. Part-I.
Course Objectives:	1. To study various experimental techniques for analysis. 2. To learn data analysis, handling and interpretation of spectra.
Course Outcomes:	1. Students will be able to use different techniques for qualitative and quantitative estimation. 2. Students will be able to interpret spectra and use statistical methods to analyse data.

Content	*Hours*
This course consists of 10 units of experiments in various areas of Analytical chemistry. Minimum 20 experiments which include at least 02 experiments from each unit shall be conducted.	*120*
Unit 1: Analysis of Pharmaceutical Tablets/Samples (Titrimetry) i. Estimation of Paracetamol by titrimetry. ii. Estimation of streptomycin in tablet sample by Maltol method. iii. Estimation of iron using Zimmermann-Reinhardt reagent by titrating against $KMnO_4$.	12
Unit 2: Ion exchange Chromatography and Solvent Extraction Method i. Determination of capacity of a cation exchange resin. ii. Concentration and determination of copper (II) ions from a brine solution using a chelating ion exchange resin and AES/AAS iii. Separation of organic mixture (acidic + basic + neutral) by extraction.	12
Unit 3: Planar and Column Chromatography i. Thin layer chromatography analysis of commercially available analgesic/antipyretic/antihistamine etc and to identify the active ingredients. ii. Purification and determination of amount of paracetamol from commercial tablet by column chromatography. iii. Separation of a mixture of benzoin and benzil on silica gel column.	12
Unit 4: Spectrophotometric Method i. Determination of pk value of methyl red indicator. ii. Determination of stoichiometry and stability constant of ferric salicylic acid complex by Job's method and mole ratio method.	12

iii. Determination of the Fe ion as Fe-oxine complex.	
Unit 5: HPLC Analysis i. Analysis of a mixture (benzene and toluene or nitrobenzene and toluene) by normal/reverse phase-HPLC. ii. HPLC analysis of an analgesic (e.g. Ibuprofen)/or any other drug with method development and validation. iii. Quantitative analysis of Paracetamol tablet by HPLC iv. Determination of plate height/number of theoretical plates by HPLC using Acetophenone as a reference material. v. Study of HPLC method development by using linear/stepwise gradient elution for binary system. vi. Determination of caffeine content in Tea or Coffee	12
Unit 6: Electrochemical Method i. pH-metric determination of the acid-base dissociation constant and isoelectric point of amino acid. ii. Determination of moisture content in tablet powder by Karl Fischer titration. iii. Analysis of mixture of carbonate/bicarbonate present in water sample using pH metry or Potentiometry.	12
Unit 7: Gas Chromatographic Analysis i. GC analysis of a given sample mixture (e.g. perfumes, cosmetics). ii. GC analysis of non-volatile analyte by derivatization. iii. Quantitative analysis of a mixture of chloroform and carbon tetrachloride. iv. Gas chromatographic analysis for a mixture of gases like O_2, N_2 and CO_2. v. Determination of alcoholic content in Beer or wine	12
Unit 8: Analysis of Ores/Minerals/Industrial Material i. Analysis of Iron Ore or Bauxite (from Goa). ii. Analysis of cement or plaster of Paris. iii. Analysis of limestone or dolomite.	12
Unit 9: Other Instrumental Techniques i. Electrophoretic techniques for the separation of nucleic acids or proteins ii. Study the dissolution rate of commercial tablets. iii. Determination of optical rotation of chiral compounds using polarimeter (e.g. Amino acids, drugs, natural products, lactic acid, tartaric acid etc) iv. Determination of sulphate ion content by turbidimetry. v. Determination of turbidity in water sample. vi. TG/DTA analysis of sample or mixture (e.g. $MgCO_3$-MgO).	12

vii. Determination of molar composition of Toluene-Anisole mixture by qNMR.	
Unit 10: Demonstration/Interpretation Exercises i. Demonstration/Interpretation of LC-MS spectra. ii. Demonstration/Interpretation of NMR spectra of Ethyl cinnamate/Vanilin. iii. Assessment of TG-DTA plot. iv. Statistical Evaluation of Data including Linear Regression Analysis. v. Analysis of materials using Microscopic Techniques. vi. Demonstration of XRD and interpretation of diffraction pattern.	12
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. J. H. Kennedy, *Analytical Chemistry Principles*, 2nd Ed., Saunders College Publishing, 1990. 2. G. D. Christian, *Analytical chemistry*, 5thEd., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Textbook of Quantitative Chemical Analysis,* 6thEd., Pearson Education Asia 2009. 4. A. J. Elias, *Collection of interesting chemistry experiments*, University press, 2002. 5. R.A. Day & A.L. Underwood, *Quantitative Analysis*, 6thEd., Prentice Hall, 2001. *6.* J. Kenkel, *Analytical Chemistry for Technicians*, 3rdEd., Lewis publishers, 2002.

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Programme: **M. Sc. Part-II (Analytical Chemistry)**
Course Code: **CHAR-512**
Title of the Course: **Practical Course in Analytical Chemistry - IV**
Number of Credits: **04** Total Contact Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course:	Should have studied Analytical chemistry practical course at M.Sc. Part-I.
Course Objectives:	1. To understand of various experimental techniques for analysis. 2. To learn data analysis, handling and interpretation of spectra.
Course Outcomes:	1. Students will be able to use different techniques for qualitative and quantitative estimation. 2. Students will be able to interpret spectra and use statistical methods to analyse data.

Content	*Hours*

This course consists of 10 units of experiments in various areas of Analytical chemistry. Minimum 20 experiments which include at least 02 experiments from each unit shall be conducted.	*120*
Unit 1: Analysis of Pharmaceutical Tablets/Samples i. Estimation of Ibuprofen by titrimetry. ii. Estimation of iron from given pharmaceutical drug sample using thioglycolic acid. iii. Estimation of sulphadiazine / sulphonamide	12
Unit 2: Ion exchange Chromatography and Solvent Extraction Method i. Determination of capacity of anion exchange resin ii. Separation and estimation of zinc and nickel ions using an anion exchange resin iii. Separation of organic mixture (acidic + basic + neutral) by extraction	12
Unit 3: Planar and Column Chromatography i. Separation of alpha amino acids by paper chromatography and to study effect of mobile phase on resolution. ii. Thin layer chromatography analysis of commercially available analgesic/antipyretic/antihistamine etc and to identify the active ingredients. iii. Separation of a mixture of benzaldehyde and benzoic acid on silica gel column	12
Unit 4: Spectrophotometry Method i. To estimate Cd/Hg by AES/AAS method. ii. To record the UV absorption spectrum of acetone in n-hexane and identify the various transitions. iii. Determination of phosphorous content from fruit juice.	12
Unit 5: HPLC Analysis i. Analysis of a mixture of hydrocarbons by reverse phase-HPLC ii. Quantitative analysis of Aspirin tablet by HPLC. iii. To determine the number of theoretical plates/plate height by HPLC of aromatic ketone or alcohols. iv. Study of HPLC method development by using linear/stepwise gradient elution for binary system. v. Determination of caffeine content in Soft drinks or Chocolates.	12
Unit 6: Electrochemical Method i. Determination of moisture content in tablet powder by Karl Fischer titration. ii. pH metric determination of dissociation constant of dibasic, oxalic acid iii. Potentiometric determination of dissociation constant for Cu-ammonia complex.	12

Unit 7: Gas Chromatographic Analysis i. GC analysis of a given sample mixture (e.g. Flavours and fragrances) ii. Quantitative analysis of a mixture of chlorinated solvents. iii. Optimum flow rate for the determination of chloroform using van Deemter equation. iv. Determination of alcoholic content in Rum or Local drinks.	12
Unit 8: Analysis of Ores/Minerals/Industrial Material i. Analysis of steel ii. Analysis of solder iii. Analysis of an aluminium alloy iv. Analysis of talcum powder	12
Unit 9: Other Instrumental Techniques i. Electrophoretic techniques for the separation of DNA ii. Determination of optical rotation of chiral compounds using polarimeter e.g. Amino acids, drugs, natural products etc iii. Determination of chloride ion content by turbidimetry iv. Determination of turbidity in water sample. v. Study the dissolution rate of pharmaceutical tablets. vi. Determination of molar composition of Toluene- methyl benzoate mixture by qNMR.	12
Unit 10: Demonstration/Interpretation Exercises i. Demonstration/Interpretation of GC-MS spectra. ii. Demonstration/Interpretation of NMR spectra iii. Assessment of TG-DTA plot. iv. Statistical Evaluation of Data including Linear Regression Analysis. v. Analysis of materials using Microscopic Techniques. vi. Demonstration of XRD and interpretation of diffraction pattern.	12
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. J. H. Kennedy, *Analytical Chemistry Principles*, 2nd Ed. Saunders College Publishing, 1990. 2. G. D. Christian, *Analytical chemistry*, 5th Ed., Wiley, 1994. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Textbook of Quantitative Chemical Analysis,* 6th Ed., Pearson Education Asia 2009. 4. A. J. Elias, *Collection of interesting chemistry experiments*, University press, 2002. 5. R. A. Day & A.L. Underwood, *Quantitative Analysis*, 6th Ed., Prentice Hall, 2001. 6. J. Kenkel, *Analytical Chemistry for Technicians*, 3rd Ed., Lewis publishers, 2002.

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Programme: **M.Sc. Part-II (Analytical Chemistry)**
Course Code: **CHAR-513**
Title of the course: **Advanced Mass Spectrometry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied analytical chemistry course at M.Sc. Part I.
Course Objective:	1. To study various ionisation sources and mass analyser. 2. To introduce tandem mass spectrometry techniques. 3. To learn interpretational aspects of spectral data obtained from hyphenated techniques.
Course Outcome:	1. Students will be able to explain principle behind different ionizations sources. 2. Students will be able to select mass analysers and ionization sources for analysis of particular type of analyte. 3. Students will be able to deduce structures of simple to moderately complex molecules/biomolecules by combining the spectral data obtained from hyphenated techniques.

Content	*Hours*
1. Ionization methods: a. Mass spectrometry: introduction, principle, general instrumentation, general interpretation procedure for mass spectra; b. Gas Phase ionization: electron ionization (EI), chemical ionization (CI), Field ionization and field desorption (FI, FD) c. Particle Bombardment: Fast atom bombardment (FAB), Secondary ion mass spectrometry (SIMS). d. Atmospheric pressure Ionization: electrospray ionization (ESI), atmospheric pressure ionization (APCI). e. Laser Desorption: MALDI. f. Inorganic ionization sources: thermal ionization, Spark source, Glow discharge, Inductively coupled plasma (ICP). g. Problem solving using mass spectrometry.	15
2. Mass analyzers: a. Characteristics of analysers: nominal mass, mass accuracy, resolving power, resolutions, isotopic composition, numericals to calculate nominal and accurate mass. b. Magnetic, electromagnetic and double focusing c. Single Quadrupole and triple quadrupole d. Time of flight analyzer e. Ion cyclotron resonance analyzer f. Hybrid instrumentation	15

g. Detectors: electron multiplier, photon multiplier, Faraday cup *Note: instrumentation, working principles, characteristic features, advantages, practical consideration shall be discussed*.	
3. Hyphenated Techniques: a. Coupled techniques, Importance of hyphenation of two analytical techniques, Interface and their characteristic features. b. Introduction, principle and instrumentation of following techniques: GC-MS, LC-MS, ICP-MS, CE-MS, TG-MS. c. Tandem mass (MS-MS): Introduction, concepts of tandem mass spectrometry, Ion activation methods. d. Analysis of chromatogram: Total ion chromatogram (TIC), Extracted Ion Chromatogram (XIC). e. Analysis of chemical data of natural product, drugs, etc. Dereplication using hyphenated technique.	15
4. Tandem Mass spectrometry applications: a. Pharmacokinetic studies: Fate of drug in living organisms, metabolite identification, biotransformation of ziprasidone. b. Tandem MS and fragmentation pattern of following drugs: Paracetamol, 2-mercaptonicotinic acid, Sulfasalazine, amphetamine, Trocade. c. Analysis of biomolecules: Proteins, Peptides, Oligonucleotides, structure and sequence determination using fragmentation, solve problems based on MS/MS data.	15

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. H. Jürgen, *Mass Spectrometry: A Textbook Gross,* 2nd Ed, Springer publisher, 2011. 2. E. De Hoffmann, V. Stroobant, *Mass Spectrometry: Principles and Applications,* 2nd Ed, Wiley, 2007. 3. R. B. Cole, *Electrospray and MALDI Mass Spectrometry: Fundamentals, Instrumentations, Practicalities and Biological Applications,* 2nd Ed, Wiley, 2010. 4. J. T. Watson, O. D. Sparkman, *Introduction to Mass Spectrometry: Instrumentation, Applications, and Strategies for Data Interpretation,* 4th Ed, Wiley, 2007. 5. K. Wanner, G. Höfner, *Mass Spectrometry in Medicinal Chemistry Applications in Drug Discovery,* 1st Ed, Wiley-VCH, 2007. 6. M. Kinter, N. E. Sherman, *Protein Sequencing and Identification Using Tandem Mass Spectrometry,* 1st Ed, Wiley, 2000. 7. P. James, *Proteome Research: Mass Spectrometry (Principles and Practice),* 1st Ed, Springer publisher, 2000. 8. J. K. Prasain, *Tandem Mass Spectrometry-Applications and Principles*, InTech publisher, 2012.

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Programme: **M.Sc. Part-II (Analytical Chemistry)**

Course Code: **CHAR-514**

Title of the course: **Selected topics in analytical chemistry**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied analytical chemistry course at M.Sc. Part I.
Course Objective:	1. To understand the basic importance of Quality in industrial products. 2. To provide basic understanding of medical laboratory clinical chemistry. 3. To understand Packaging and regulatory aspects for food, drugs and cosmetics industries. 4. To understand the use of computers in chemistry
Course Outcome:	1. Students will understand the basic importance of Quality in industrial products and apply the knowledge in Quality Control and Quality Assurance. 2. Students will understand the medical laboratory clinical chemistry. 3. Students will understand the Packaging and regulatory aspects and apply the knowledge in food, drugs and cosmetics industries. 4. Students will understand the use of computers in chemistry

Content	*Hours*
1. Introduction to Quality Control and Quality Assurance: a. Basic concepts; quality assurance; aspect of specification and tolerance; quality acceptance; sampling reality; cost aspect of quality decisions; quality control in raw materials; production; finished product; b. Law related to quality control; case studies of quality control in various industries like agrochemicals, petrochemicals, pharmaceuticals, dyes, plastics and polymers.	8
2. Packaging and Regulatory Aspects: a. Introduction; types of packing material and regulations acts in Food and Pharmaceutical industries; testing of material for packing; legal consideration in packing; regulatory aspects of food, drugs and cosmetics; b. The Drug and Cosmetic Act, 1940; the Drug and Cosmetic Rules 1945; prevention of food adulteration; the Preventation of Food Adulteration Act, 1954; Fruit Product Order; Meat Product Order; I.S.I., Agmark and other standard for foods and Cosmetic particularly with reference the testing of foods, drug and cosmetic and the raw material concerned; c. The Government authorities concerned with the testing-their qualification, duties, powers and procedure to be followed; Record to be maintain under the Acts; C.G.M.P. and C.G.L.P.S. requirements of QC; Department of 'WHO' certification.	12
3. Computers in Chemistry: The students shall learn how to operate a PC and run standard programs and packages like MS-WORD, EXCEL, ORIGIN, SIGMA PLOT, and CHEM SKETCH; to solve Chemistry numerical (numerical taken preferably from Physical Chemistry for plotting first and second derivative curves, linear plots); numerical from Analytical Chemistry, Chemical Kinetics, Electrochemistry, Spectroscopy and other related topics; writing the structures of inorganic and organic molecules, chemical equations, and other applications.	10

4. Clinical Chemistry: a. Composition body fluid; detection of abnormal levels of certain constituents leading to diagnosis of diseases; sample collection and preservation of physiological fluids. b. Analysis of physiological fluids - blood, urine and serum; estimation of blood glucose, cholesterol, urea, haemoglobin; urine-urea, uric acid, albumin, globulins, barbiturates, acid and alkaline phosphates. c. Human-nutrition: d. Estimation of enzymes, carbohydrates, essential amino acids, proteins and lipids.	18
6. Food Analysis, Processing and Preservation: a. Analysis of food such as milk, milk products, tea, coffee and beverages (soft drinks, alcoholic drinks), Flour, starch, honey, jams and edible oils. Analysis of preservatives, colouring matter, micronutrients. b. Food processing and food preservation: Refining milling, canning, concentration, freezing Drying, pasteurisation sterilization irradiation.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. F. W. Fifield and D. Kealy, *Principles and Practice of Analytical Chemistry*; 5th Ed. Backwell Science Ltd. London, 2020. 2. G. D. Christian, *Analytical chemistry*, 5th Ed., Wiley, 1994. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Textbook of Quantitative Chemical Analysis,* 6th Ed., Pearson Education Asia 2009. 4. H. Kaur, *Instrumental Methods of Chemical Analysis*; Pragati Prakashan, 2012 5. *Indian Pharmacopeia*; Volume I and II, 2018 6. W. Funk, V. Dammann, G. Donnevert, *Quality Assurance in Analytical Chemistry*; VCH Weinheim, 1995 7. E. Prichard, *Quality in the Analytical Chemistry Laboratory*; John Wiley and Sons, NY, 1997 8. R. C. Gribbin, *Principals of package Development*, 2nd Ed. Springer, 2012 9. *Modern Packaging Encyclopedia*, Volume 30, McGraw-Hill Publisher, 1957 10. *Modern Packaging Encyclopaedia and planning guide*, McGraw-Hill Publications, 1972 11. M. L. Mehra, *The Handbook of Drug Laws*, Univ. Book Agency, 1997. 12. Government of India Publications of Food Drug Cosmetic Acts and Rules. https://cdsco.gov.in/opencms/opencms/en/Acts-Rules/ 13. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*; 9th Ed. Brooks Cole Publisher, 2013 14. K. V. Raman, *Computers in chemistry*, Tata Mc.Graw-Hill, 1993. 15. S. K Pundir, A. bansal, *Computers for Chemists*, Pragati prakashan, 2018 16. C. S. James, *Analytical Chemistry of Foods,* Blackie Academic and Professional Publisher, UK, 1995.

	17. R. L. Nath, *Practical Biochemistry in Clinical Medicine*, 2nd Ed. Academic Publishers, 1990, 18. V. Malik, *Drug and Cosmetics Act*, 25th Ed. Eastern book company, 2016, 19. A. H. Beckett, J.B. Stenlake, *Practical Pharmaceutical Chemistry* (Part-1), 4th Ed. CBS publisher, 2006, 20. S. R. Mikkelsen, E. Corton, *Bioanalytical Chemistry*, 2nd Ed. John Wiley and Sons, 2016, 21. M. B. Jacob, *Chemical Analysis of Food and Food Products*, 3rd Ed. CBS publisher, 2013. 22. *Encyclopaedia of Analytical Chemistry*, Volume 3, Academic Press, 1995. 23. D. White, N. Lawson, P. Masters, D. McLaughlin, *Clinical Chemistry*, CRC press, 2016 24. W. J. Marshall, M. Lapsley, A. Day, K. Shipman, *Clinical Chemistry*, Elsevier, 2020

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHAG- 511**
Title of the course: **Fundamentals of Crystallography**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied M.Sc. Part-I.
Course Objective:	1. To introduce basic concepts of crystallography. 2. To impart knowledge of single crystal and powder X-ray diffraction methods. 3. To analyse Materials and understand Structure.
Course Outcome:	1. Student will acquire fundamental concepts of crystallography. 2. Students will gain insights into single crystal and powder X-ray diffraction methods. 3. Students will be able to use X-ray diffraction methods for materials characterization.

Content	*Hours*
1. Basics of Crystallography a. The Crystalline state, symmetry elements. b. Lattices, unit cell, crystallographic directions, planes, point groups and symmetry classes. c. The Laue classes, the seven crystal systems, Bravais lattices, space groups and International Tables. d. Description of crystal structures, unit cell projections and atomic coordinates, unit cell content. e. Ionic crystals, molecules and molecular crystals, protein crystals, physical properties of crystals.	10
2. Diffraction of X-rays by Crystals: a. Interaction of X-rays with matter. b. Scattering of X-rays by an electron, atom, atomic scattering factor,	10

temperature factor, scattering by molecule or unit cell. c. Diffraction by crystals, structure factor, Bragg's law, the reflection and the limiting spheres, symmetry in reciprocal space, systematic absences, diffraction intensities. d. Experimental methods in X-ray crystallography: X-ray sources, monochromatization, collimation, and focusing of X-rays.	
3. Single Crystal X-ray Diffraction: a. Crystals and their properties: crystallization, growing and choosing crystals, microscopic observation b. Data collection techniques for single crystals, diffractometer geometry, measurement of the integrated intensities, data collection with area detectors, c. Data reduction: Lorentz correction, polarization correction, absorption corrections, radiation damage corrections, relative scaling. d. Solution and refinement of crystal structures: Wilson plot, the heavy atom method, Direct methods, phase determination procedures, figures of merit, e. Completing and refining the structure: difference Fourier method, least-squares method, absolute configuration. f. Introduction to crystallographic softwares (e.g. APEX 4, Olex2 etc) and IUCr validation of the data (CIF)	10
4. Powder X-ray Diffraction: a. Origin of powder diffraction pattern, position, shape, and intensity of powder diffraction peaks. b. Powder diffractometry: beam conditioning, goniometer design, nonambient powder diffractometry. c. Collecting quality powder diffraction data: sample preparation, data acquisition, quality of data, data processing. d. Determination of unit cell: indexing methods. e. Introduction to the Rietveld method. d. Introduction to powder diffraction softwares for indexing, unit cell refinement (e.g. Winplotr, UnitCell).	10
5. Applications of Crystallography: a. Chemistry and Materials science: understanding crystal structures of compounds, alloys, metals, polymers, phase transitions etc. b. Geology, mineralogy, gemology. c. Pharmaceuticals: polymorphs, excipient analysis, active pharmaceutical ingredients. d. Forensics and environmental analysis. e. Nano materials characterization. f. Biomolecules: determination of structures of proteins, nucleic acids and other biological macromolecules. g. Other diffraction techniques: neutron diffraction, thin film, microstructure properties, pair distribution function analysis, etc.	10

6. Analysis of Materials and Structural Understanding: a. Characterisation of Solids using diffraction techniques. b. Introduction to databases: powder diffraction files, inorganic and organic crystal structure database, protein data bank etc. c. Inspection of crystals/powders with light microscope. d. Visualization of crystal structures using softwares (e.g. Diamond, VESTA). e. Beyond ideal crystals: crystal twins, modulated structures, quasicrystals.	10
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. M. Milanesio, G. Zanotti, G. Gilli, M. Catti, H. Monaco, G. Ferraris, G. Artioli, P. Gilli, D. Viterbo, C. Giacovazzo - *Fundamentals of Crystallography*, 3rd Ed., Oxford University Press, 2015. 2. C. Hammond - *The Basics of Crystallography and Diffraction (International Union of Crystallography Texts on Crystallography)* 4th Ed., Oxford University Press, 2015. 3. R. West, *Solid State Chemistry and Its Applications*, 2nd Ed.; Wiley, 2022. 4. F. Hoffmann, *Introduction to Crystallography*, 1st Ed. Springer, 2020. 5. D. Sherwood, *Crystals, X-rays and Proteins: Comprehensive Protein Crystallography*, 1st Ed. Oxford University Press, 2015. 6. A. Hofmann, S. Clokie, *Wilson and Walkers Principles and Techniques of Biochemistry and Molecular Biology*, 8th Ed.; Cambridge University Press, 2018. 7. V. Pecharsky and P. Zavalij, *Fundamentals of Powder Diffraction and Structural Characterization of Materials*, 2nd Ed.; Springer, 2009. 8. R. Young, *The Rietveld Method*, 1st Ed., Oxford University Press, 1995 9. W. David, K. Shankland, L. McCusker, C. Bärlocher, *Structure Determination from Powder Diffraction Data*, 1st Ed., Oxford University Press, 2006. 10. B. He, *Two-dimensional X-ray Diffraction*, 1st Ed., Wiley, 2009. 11. W. Massa, *Crystal Structure Determination*, 2nd Ed., Springer, 2010. 12. R. Dinnebier, S. Billinge, *Powder Diffraction: Theory and Practice*, 1st Ed., Royal Society of Chemistry, 2008.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHAG-512**
Title of the course: **Advanced NMR and combined Spectroscopy**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied Chemistry courses in MSc Part-I.
Course Objective:	1. To understand advance 2D NMR techniques. 2. To develop skills of interpreting spectral data pertaining to two or more 2D NMR techniques. 3. To train students to interpret NMR for quantitative analysis.

	4. To understand NMR hyphenated techniques.
Course Outcome:	1. Students will be able to understand various 2D NMR techniques and analyse the 2D NMR spectra of small molecules. 2. Students will be skilled to interpret combined spectral data pertaining to two or more 2D NMR techniques for structural analysis. 3. Students will be skilled to interpret qNMR data for quantitative analysis. 4. Students will be able to understand and apply hyphenated NMR techniques for analysing mixtures.

Content	*Hours*
1. **Selected concepts in IR and MS** a. IR: Spectral data interpretation for common functional groups like keto, aldehyde, acid, ester, amides, nitro, etc., Correlation of common functional groups with IR spectral differences. b. MS: Factors governing Mass fragmentation processes, β-cleavage, cleavage α to heteroatoms, cleavage α to carbonyl groups, retro Diels-Alder reaction, McLafferty rearrangement.	5
2. **Selected concepts in NMR** a. Chemical Shifts spectral data for proton and carbon nuclei like aliphatic, aromatic, acyl, methoxy, etc., Correlation of common proton and carbon nuclei with NMR signal differences. b. Nuclear Overhauser Effect c. Decoupling in ^{13}C NMR Spectroscopy (DEPT-45, DEPT-90, DEPT-135), Proton coupled CMR. d. ^{15}N-NMR, ^{19}F-NMR, ^{29}Si-NMR, & ^{31}P-NMR spectroscopy: Chemical shift range for ^{15}N, ^{19}F, ^{29}Si & ^{31}P in NMR spectra, coupling with neighbouring nuclei and splitting pattern.	10
3. **2D-NMR** a. Introduction to 2D-NMR, General Principles, Classification of 2D-NMR experiments. b. Homonuclear Correlation Spectroscopy Proton-Proton Interactions - COSY, DQF-COSY, TOCSY, NOESY, REOSY. Carbon-Carbon Interactions - INADEQUATE. c. Heteronuclear Correlation Spectroscopy HETCOR Heteronuclear Single Bond Correlation - HSQC, HMQC and me-HSQC Heteronuclear Multiple Bond Correlation - HMBC d. Analysing and interpreting spectral data from above 2D spectra for small molecules. e. Assigning NMR signals based on PMR, CMR, ^{1}H-^{1}H &^{1}H-^{13}C Correlation Spectra.	10
4. **Structural analysis of simple compounds using some combined spectral techniques**: PMR, CMR, COSY, HSQC, me-HSQC, HMBC, TOCSY, NOESY, INADEQUATE, along with IR, UV and MS data wherever necessary.	20
5. **Quantitative NMR analysis** a. Analysis of mixture of compounds using qNMR technique, Relative proportions (mole %) of the 2 or 3 components from NMR integrals. b. Calibration standards, Selection criteria for suitable Reference material. c. Molar concentration Determination, Purity or Yield Determination.	10

6. **Hyphenated NMR techniques** a. Development of LC-NMR, Technical Considerations regarding LC-NMR: Solvent Compatibility, Solvent Suppression, NMR Flow Cell, LC-NMR Sensitivity. Modes of Operation: On-Flow Mode, Stop-Flow Mode. Applications of LC-NMR. b. Introduction to other hyphenated NMR techniques, Technical Considerations regarding LC-MS-NMR: Modes of Operation, Online coupling in series or in parallel, Challenges in Hyphenated NMR techniques.	5
Pedagogy	Mainly lectures and tutorials, Seminars / assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning. *(Note: More emphasis shall be given for structural elucidation using combined spectroscopic data*)
Textbooks/References /Reading materials	1. W. Kemp; *Organic Spectroscopy*; 3rd Ed, Palgrave, 1991. 2. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 3. R. M. Silverstein, F. X. Webster, D. J. Kiemle, D. L. Bryce, S. D. Samant, V. S. Nadkarni; *Spectrometric identification of Organic Compounds*; An Indian Adaptation, 8th Ed, Wiley, 2022. 4. P. S. Kalsi; *Spectroscopy of Organic Compounds*; 6th Ed, New Age International, 2009. 5. E. Pretsch, P. Buhlmann, C. Affolter; *Structural Determination of Organic Compounds*, 2nd Ed, Springer, 2005. 6. L. D. Field, S. Sternhell, J. R. Kalman; *Organic Structures from Spectra*, 4th Ed, Wiley, 2007. 7. L. D. Field, H. L. Li, A. M. Magill; *Organic Structures from 2DNMR Spectra*, Wiley, 2015. 8. W. Kemp; *NMR in Chemistry: A Multinuclear Introduction*, Macmillan, 1986. 9. D. H Williams, I. Fleming; *Spectroscopic methods in organic chemistry*, 6th Ed, Tata Mcgraw Hill Education, 2011. 10. J. H. Simpson; *Organic Structure Determination using 2-D NMR Spectroscopy*, Elsevier, 2008. 11. H. Friebolin; *Basic One- and Two-Dimensional NMR Spectroscopy*, Wiley, 2011. 12. K. S. Parikh, H. H. Gadape; *Quantitative NMR Spectroscopy in Pharmaceuticals*, Lambert Academic Publishing, 2012. 13. U. Holzgrabe, I. Wawer, B. Diehl; *NMR Spectroscopy in Pharmaceutical Analysis*, Elsevier, 2008. 14. M. V. Silva Elipe; *LC-NMR and Other Hyphenated NMR Techniques: overview and applications*, Wiley, 2012.

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Programme: **M. Sc. Part-II (Chemistry)**
Course Code: **CHAG-513**
Title of the course: **Bioanalytical Techniques**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied Chemistry courses at M.Sc. Part-I
Course Objective:	1. To introduce various bioanalytical techniques used in biochemical analysis and diagnosis. 2. To depict the various concepts used in Biomolecular techniques, Immunochemical Techniques, Radioisotope tracer Techniques, Computed Tomography, and Magnetic Resonance Technology and their significance in clinical analysis.
Course Outcome:	1. Students will be able to identify, formulate, analyze and solve problems in the analysis of biological compounds. 2. Students will be able to differentiate between various methods, assays, and procedures which will enable them to understand/analyze the substances present in living organisms/ chemical reactions. 3. Students will understand the applications of various diagnostic techniques used in clinical analysis.

Content	*Hours*
1. Biomolecular techniques a. Introduction, Structure of nucleic acid, Isolation of DNA: Conventional methods of extraction; kit-based extraction; detection of DNA, Extraction of RNA: Conventional methods of extraction; kit-based RNA extraction, DNA sequencing methods: Sequencing by chemical degradation method; Dideoxy chain termination method b. Polymerase Chain Reaction Thermocycler (PCR thermocycler): Principle; components of PCR, thermal cycler, optimization of PCR, Analysis of PCR product, Reverse Transcriptase PCR(RT-PCR): Steps of RT-PCR; application of RT-PCR, Real-time PCR(q-PCR): Application of PCR c. Protein DNA Interaction Assays: Specific and non-specific interactions d. Microarrays: DNA-based microarrays and protein microarrays	12
2. **Immunochemical Techniques** a. Introduction: Development of immune system, Harnessing the immune system for antibody production; antibody structure and function b. Antibody preparation: Polyclonal antibody production; monoclonal antibody production; Cell banking; Growing hybridomas for antibody production; Antibody recognizing small molecules; Anti-Idiotypic antibodies; Phage display for development of antibody fragments; Antibody Purification; Antibody modification c. Immunoassay formats: Enzyme immunosorbent Assays; Double antibody Sandwich ELISA (DAS ELISA); Triple antibody Sandwich ELISA (TAS ELISA); Enhanced ELISA system; Competitive ElISA; Modification of traditional sandwiched ELISA d. Immunomicroscopy: Immunoflurosecence Microscopy; Immunosorbent electron microscopy	12

e. Lateral Flow devices; Epitope mapping; Immunoblotting; Fluorescence-Activated Cell Sorting (FACS); Cell and Tissues staining Techniques; Immunoaffinity Chromatography; Antibody-Based biosensors; Luminex Technology; Therapeutics Antibodies	
3. Radioisotope tracer Techniques Introduction, Autoradiography: Principle of Autoradiography, Selection of emulsion and film. Choice of isotopes; Background; Time of exposure. Practical techniques for use of autoradiography	6
4. X-Ray Imaging a. Introduction to X-ray imaging, Background: History and basic physics b. Instrumentation, Components; Beam Generation; Reduction of Scattered Radiation; Image Detection, c. Clinical Applications: Diagnostic Devices; Projection Radiography; Mammography; Fluoroscopy; Angiography	8
5. Computed Tomography a. Introduction to Computed Tomography b. Instrumentation: X-ray Tube and Generator; MDCT Detector Design and Slice Collimation c. Data Rates and Data Transmission; Dual Source CT; Measurement Techniques; MDCT Sequential (Axial) Scanning; 109 MDCT Spiral (Helical) Scanning, Pitch; Collimated and Effective Slice Width d. Multi slice Linear Interpolation and z-Filtering; Three-Dimensional Back projection and Adaptive Multiple Plane Reconstruction (AMPR); Double z-Sampling, ECG-Triggered; and ECG-Gated Cardiovascular CT e. Principles of ECG-Triggering and ECG-Gating; ECG-Gated Single-Segment and Multisegmented Reconstruction f. Principles of prositron emission tomography (PET) g. Clinical Applications of Computed Tomography	10
6. Magnetic Resonance Technology a. Introduction, Magnetic Nuclei Spin in a Magnetic Field: A Pulsed rf Field Resonates with Magnetized Nuclei, the MR Signal, Spin Interactions Have Characteristic Relaxation Times b. Image Creation: Slice Selection; The Signal Comes Back—The Spin Echo; Gradient Echo, Image Reconstruction: Sequence Parameters, Image Resolution, Noise in the Image—SNR, Image Weighting and Pulse Sequence Parameters TE and TR: T2-Weighted Imaging; T∗2 -Weighted Imaging; Proton-Density-Weighted Imaging; T1-Weighted Imaging c. Clinical applications: A Menagerie of Pulse Sequences: EPI; FSE; Inversion-Recovery; DWI; MRA; Perfusion, Enhanced Diagnostic Capabilities of MRI—Contrast Agents, Molecular MRI, Functional MRI	12
Pedagogy	Mainly lectures and tutorials. Seminars/term papers /assignments/ presentations /or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.

Textbooks/ References / Readings	1. R. Salzer, *Biomedical Imaging: Principles and Applications,* 1st Ed. Wiley; 2012. 2. K. Wilson, J. Walker, *Principles and Techniques of Practical Biochemistry;* 8th Ed. Cambridge University Press; 2010. 3. S. Ghosal, A. S. Avasthi*, Fundamentals of Bioanalytical Techniques and Instrumentation,* 2nd Ed. PHI learning Pvt. Ltd. Delhi, 2010. 4. D. J. Holme, H. Peck.; *Analytical Biochemistry*; 3rd Ed. Prentice Hall, Pearson Education Limited; 1998. 5. B. M. Dale, M. A. Brown, R. C. Semelka, *MRI: Basic principles and applications,* 5th Ed. Wiley, 2015.

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Programme: **M. Sc. Part-II (Chemistry)**

Course Code: **CHAG-514**

Title of the Course: **Calibration and Validation in Analytical Chemistry**

Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied M.Sc. Part-I.
Course Objectives:	1. To understand the terminologies used in measurement science 2. To classify the nature of errors involved in measurements 3. To study the concept of calibration and matrix effect in Analysis 4.To comprehend the role method validation and development in Analytical laboratories of pharmaceutical, clinical, environmental and forensic studies. 5. To gain the knowledge on application of statistical tools in Analysis
Course Outcomes:	1. Students will be able to differentiate between technique, method, protocol and procedure. 2. Students should be able to identify and correct any measurement errors. 3. Students will be able to analyse the reliability of results for a chosen method of analysis 4. Student will be able to evaluate the suitability of method for intended purpose 5. Student will learn to draw conclusions based on statical method.

Content	*Hours*
1. Introduction a. The vocabulary of analytical chemistry: Analysis, determination and measurement; techniques, methods, procedures, and protocols b. Classifying analytical techniques: Qualitative, quantitative and structural determination, separation and hyphenated techniques, basic principle of analysis and limitations c. Selecting an analytical method: Identification of analytical problem, understanding the selection criteria viz. accuracy, precision, sensitivity, selectivity, robustness, ruggedness, scale of operation, analysis time, availability of equipment, and cost; developing analytical procedure d. Errors in analytical measurements: Classification, methods of minimization of errors, significance of gaussian curve, probability distribution of errors.	10
2. Calibration and Statistical treatment of data	22

a. Calibration in analytical chemistry: Significance and need for calibration, compensating for interferences (method blank), chemical standard, reference material, calibration of glassware and its tolerance limit (standard deviation) b. Matrix effect: Effect of matrix on signal measurement, importance of correlation coefficient, concept of curve fitting, linear regression of good data, linearity and sensitivity of instrumental measurement c. Calibration methods: External standard, standard additions and Internal standard method, case scenario to understand the suitability of each method for a given analysis. d. Statistical evaluation of analytical results: Confidence limits and interval, testing for significance, detection of bias and presence of outliers, control charts e. Calibration of important analytical instruments: UV-visible spectrophotometer, FTIR spectrophotometer, conductivity meter, GC, HPLC.	
3. Validation a. Quality in Analytical Laboratories: Good laboratory practices, quality control, quality assurance, accreditation system. b. Validation and qualification: Overview of installation, operation, and performance qualification (IQ, OQ, PQ) of analytical equipment. c. Method validation in pharmaceutical industry: Regulatory requirements for analytical method validation International conference on harmonization (ICH) guideline Q2R1, method validation parameters and timeframe as per ICH guidelines, linearity and range criteria and their role in instrumental method validation, detailed discussion on accuracy and precision role in the method validation, Role of quantification limit and specificity -Limit of Detection (LOD) and Limit of Quantification (LOQ) for a given method.	18
4. **Case study of method development and modifications** a. Environment sample monitoring: Estimation of nitrite, lead in wastewater, Measurement of calcium by flame emission spectroscopy b. Food and medicine: Generic drugs, health supplements, nutritional labels and daily nutritional requirement c. Clinical studies: Determination of glucose in human blood and urine, preservation of biological fluid for analysis of different analytes. b. Forensic analysis: Determination of blood alcohol content, Analysis of narcotic drugs, adulterations.	10
Pedagogy:	Mainly lectures and tutorials, Seminars / assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning.
Textbooks / References/ Readings	1. M. E. Swartz, I. S. Krull, *Analytical method development & validation*, CRC Press book, 1997. 2. G. H. Jeffery, J. Bassett, J. Mendham, R C. Denney, *Vogel's Text Book of Quantitative Chemical Analysis*, 5th Ed. Wiley, 1989. 3. A. H. Wachter, R. A. Nash, *Pharmaceutical Process Validation,* Marcel Dekker Inc, 2003.

	4. L. Huber, *Validation and Qualification in Analytical Laboratories*, Informa Healthcare USA Inc; 2007. 5. M. Valcarcel, *Principles of analytical chemistry: A text book*, Springer Publications, 2000. 6. D. Harvey, *Modern Analytical Chemistry*, MC Graw Hill, 2000. 7. D. A. Skoog, D. M. West, F. J. Holler, *Fundamentals of Analytical Chemistry*, 9th Ed. Sounders College publishing, 2014. 8. B. W. Wenclawiak, M. Koch, E. Hadjicostas, *Quality Assurance in Analytical Chemistry*, Springer, 2004. 9. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 10. J. H. Kennedy, *Analytical Chemistry: Principles*, 2nd Ed.; Saunders College Publishing, 1990. 11. B. Magnusson, U. Ornemark, *The Fitness for Purpose of Analytical Methods – A Laboratory Guide to Method Validation and Related Topics*, 2nd Ed; Eurachem, 2014 12. Willard, *Instrumental Methods of Analysis*, 7th Ed., CBS Publishers, 1986

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCR-511**
Title of the course: **Research Methodology and instrumental techniques-I**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Introduction to Research Methodology a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	5
2. Scientific conduct and ethics	5

a. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. b. Intellectual honesty and research integrity. c. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). d. Redundant publications: duplicate and overlapping publications. e. Selective reporting and misrepresentation of data.	
3. Academic writing a. Publication ethics: definition, introduction and importance b. Conflicts of interest c. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa d. Violation of publication ethics, authorship and contributorship e. Identification of publication misconduct, complaints and appeals f. Predatory publishers and journals	5
4. Data bases and research metrics a. Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. b. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
5. Safety aspects in Chemistry a. Good laboratory practices. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	5
6. Softwares in Chemistry a. Data plotting b. Structure Drawing c. Reference management software	7
7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: a. Elemental analysis: CHNS analysis and AES b. Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) c. Nuclear magnetic resonance (^{1}H, ^{13}C) d. Chromatographic techniques: HPLC, GC, e. Hyphenated Techniques: LC-MS & GC-MS, f. Diffraction methods: XRD g. Thermal analysis: DSC h. Microscopy: SEM, TEM i. Methods for determination of magnetic & dielectric properties. j. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.

Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 14. A. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. A. Szabo, N. S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCR-512**
Title of the course: **Research Methodology and instrumental techniques-II**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I.
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing.

	4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Research Methodology, Scientific conduct, ethics & academic writing a. Research- meaning, objectives, motivation, types and methodology. **b.** Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions. c. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. d. Intellectual honesty and research integrity. e. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). f. Redundant publications: duplicate and overlapping publications. **g.** Selective reporting and misrepresentation of data. h. Publication ethics: definition, introduction and importance i. Conflicts of interest j. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa a. Violation of publication ethics, authorship and contributorship b. Identification of publication misconduct, complaints and appeals **k.**Predatory publishers and journals	15
2. Softwares in chemistry, Data bases and Research metrics a. Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. b. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. c. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc d. Molecular Docking software	10
3. Safety practices in Chemical research a. Introduction to lab safety. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	5
4. Instrumental methods	30

a. UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. b. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) c. Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) d. Electrochemical Impedance Spectroscopy (EIS) e. Resonance Raman and isotope labelling studies. f. Infrared (IR) spectroscopy applications g. ^{1}H, ^{13}C- NMR spectroscopy and applications h. Selected chromatographic techniques such as HPLC, GC. i. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS j. Diffraction methods: High temperature XRD k. Thermal analysis: TG/DTA/DSC l. Microscopy: Fe-SEM, HR-TEM m. Methods for determination Ms, Mr, Hc, Tc, ε^{l} and Tanδ. n. Potentiometry	
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning.

	15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989. 19. A. Leach, *Molecular Modelling, Principles and applications*, Longman, 1998. 20. W. Nam et al, *Dioxygen activation by Metalloenzymes & models*, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCD-511**
Title of the course: **Discipline Specific Dissertation**
Number of Credits: **16**Total Hours: **480** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	
Content		*Hours*
As per OA-35		480
Pedagogy	Dissertation carried out individually by each student throughout the academic year.	
Textbooks/ References / Readings	As required for the development of review and methodology.	

M.Sc. Physical Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III (Physical Chemistry)			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHPR-511**	Practical Course in Physical Chemistry-III	4
2.	**CHPR-512**	Practical Course in Physical Chemistry-IV	4
3.	**CHCR-511**	Research methodology and instrumental techniques-I	4
4.	**CHCR-512**	Research methodology and instrumental techniques-II	4
5.	**CHPG-511**	Solid State Chemistry: Concepts and Applications	4
6.	**CHPG-512**	Nanoscience: Concepts and Applications	4
7.	**CHPG-513**	Physical aspects of Polymer Chemistry	4
8.	**CHPG-514**	Colloids and Surface Chemistry	4
SEM IV (Physical Chemistry)			

1.	**CHPR-513**	Heterogeneous Catalysis: Fundamentals and Applications	4
2.	**CHPR-514**	Applied Electrochemistry	4
3.	**CHCD-511**	Discipline Specific Dissertation	16

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Programme: **M. Sc. Part-II (Physical Chemistry)**
Course Code: **CHPR-511**
Title of the Course: **Practical Course in Physical Chemistry - III**
Number of Credits: **04** Total Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course:	Should have studied Physical chemistry practical course at M.Sc. Part-I.
Course Objectives:	1. To introduce concepts of Kinetics and Thermodynamics 2. To introduce concepts of Surface science and Catalysis 3. To introduce various concepts of Electrochemistry 4. Introduction to the use of computers and computational tools in chemistry
Course Outcomes:	1. Student should be able to apply the concepts of physical chemistry in M.Sc. Dissertations. 2. Students shall be equipped with practical skills needed for research and development.

Contents	Hours
Note: A minimum of 7 experiments from each Unit I-III are to be completed. **Unit - I. Instrumental** a. To determine the redox potential of Fe^{2+}/Fe^{3+} system using rotating disk voltammetry method. b. To determine the instability constant of the reaction $[Ag(NH_3)_2]$----> $Ag + 2NH_3$ potentiometrically. c. To determine the transport number of ions using moving boundary method. d. To verify Nernst equation and determine the standard oxidation potential of copper and zinc electrodes. e. To study effect of ionic strength on activity coefficient of Ag^+ ions. f. To investigate the reaction kinetics between Potassium Persulphate and Potassium Iodide colorimetrically. g. To determine the equivalent conductance of a strong electrolyte (KCl) at several concentrations and verify Onsager's equation. h. To estimate the concentration of Sulphuric acid, Acetic acid and Copper sulphate in a given solution conductometrically. i. To determine the concentration of Fe^{2+} ions by titrating with potassium dichromate conductometrically. j. To study the kinetics of hydrolysis of tertiary butyl chloride by conductometry. k. To determine the half wave potential of $Cu^{2+}/Cd^{2+}/Zn^{2+}$ by using polarography. l. To study the effect of sol-gel and hydrothermal method of synthesis on crystallite size and surface area of a semiconductor catalyst. m. To investigate the effect of catalyst loading on photocatalytic degradation of azo dye using semiconductor catalyst.	40

n. To study the stress-strain response of polymeric materials and compare their strength. o. To determine the degradation rate of the polymers using thermogravimetric methods. p. To determine the curie temperature of conducting polymer samples. q. To determine the resistivity of polymeric material using four probe method.	
Unit - II. Non-Instrumental a. To determine the critical micelle concentration of three types of surfactants using stalagmometer. b. To determine the partial molal volume of sodium chloride-water, ethanol-water and methanol-water system by apparent molal volume method. c. To study the effect of surfactants on surface tension of water using stalagmometer. d. To study the variation of viscosity with composition of mixtures and to verify the formation of compounds by Oswald's viscometer. e. To study the effect of pH on the kinetics of iodination of Aniline. f. To study the kinetics of reaction between H_2O_2 and KI (clock reaction). g. To study the kinetics of rapid reaction between Bromine and Iodine in aqueous media. h. To investigate the autocatalytic reaction between Potassium Permanganate and Oxalic acid. i. To study the electroless deposition of Ni on non-conductor substrate and to determine the rate of deposition. j. To study the variation in catalytic activity of three different metal oxides for H_2O_2 decomposition reaction. k. To investigate the effect of pH on adsorptive separation of azodye from water using MCM-41.	40
Unit - 3. Computational Chemistry a. To generate a mark sheet and understand various features of spreadsheets. b. To generate a plot for a given function such as solutions of 1D box, harmonic oscillator, H-like atom wave functions, Gaussians distributions etc. c. To write a computer program to obtain equivalence point in pH metry and potentiometric experiments (derivative method). d. To write a computer program to find percent composition for various atoms of a given molecular formula. e. To write a computer program to obtain slope and intercept for linear data using least square fit method. f. To write a computer program to obtain center of mass of a given molecule and moment of inertia, hence obtain classification of the given molecule. g. To write a computer program to find out various parameters for data analysis viz. minimum, maximum, average, standard deviation, variance, covariance, correlation coefficient, frequency distribution etc. h. To write a computer program to obtain thermodynamic probability. i. To write a computer program to obtain degeneracy of a given energy level for a particle in a cube. j. Calculate the ground state energy of hydrogen atom using various basis sets using *ab-initio* program.	40

k. Calculate and interpret the IR, RAMAN and NMR spectra of simple organic molecules using *ab-initio* program.	
Pedagogy:	Mainly pre-labs / practicals or a combination of some of these could also be used to some extent.
Textbooks / Reference Books	1. A. Finlay and J.A. Kitchener, *Practical Physical Chemistry,* Longman Publisher, 1963. 2. A. M. James, *Practical Physical Chemistry*, Longman Publisher, 1974. 3. D.P. Shoemaker and C.W. Garland, *Experimental Physical Chemistry,* McGraw-Hil, 1981. 4. J. B. Yadav, *Advance Practical Physical Chemistry*, Krishna Educational Publishers, 2014. 5. S.Attila, and N. S. Ostlund. *Modern quantum chemistry: introduction to advanced electronic structure theory*. Courier Corporation, 2012. 6. P.P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, CH-20: *Photocatalytic and microbial degradation of Amaranth dye*, Advances in Biological Science Research-A Practical Approach 2019, 327-345, Academic Press. 7. J.B. Foresman, E. Frisch*, Exploring Chemistry with Electronic Structure Methods: A Guide to Using Gaussian,* 2nd Ed. Gaussian, 1996

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Programme: **M. Sc. Part-II (Physical Chemistry)**
Course Code: **CHPR-512**
Title of the Course: **Practical Course in Physical Chemistry - IV**
Number of Credits: **04** Total Hours: **120** Effective from AY: **2023-24**

Prerequisites for the course:	Should have studied Physical chemistry practical course at M.Sc. Part-I.	
Course Objectives:	1. To introduce concepts of Kinetics and Thermodynamics 2. To introduce concepts of Surface science and Catalysis 3. To introduce various concepts of Electrochemistry 4. Introduction to the use of computers and computational tools in chemistry	
Course Outcomes:	1. Student should be able to apply the concepts of physical chemistry in M.Sc. Dissertations. 2. Students shall be equipped with practical skills needed for research and development.	
Content		Hours

Unit - I. Instrumental a. To estimate the concentration of glucose calorimetrically. b. To determine the redox potential of Fe^{3+}/Fe^{2+} system using rotating disk voltammetry method. c. To determine the transport number of ions using moving boundary method. d. To verify Nernst equation and determine the standard reduction potential of Ag and Zn electrodes. e. To determine the equivalent conductance of a strong electrolyte (NaCl) at several concentrations and verify Onsager's equation. f. To estimate the concentration of Hydrochloric acid, Monochloro acetic acid and Copper sulphate in a given solution conductometrically. g. To determine the half wave potential of $Ni^{2+}/Cd^{2+}/Cu^{2+}$ by using polarography. h. To study the effect of precipitation and hydrothermal method of synthesis on acidic sites of a semiconductor catalyst using NH_3 TPD method. i. To investigate the effect of solution pH on photocatalytic degradation of methylene blueusingsemiconductorphotocatalyst. j. To determine the curie temperature of polyaniline.	40
Unit II. Non-Instrumental a. To determine the critical micelle concentration of Sodium dodecyl sulphate, Cetrimonium bromide using stalagmometer. b. To study the kinetics of the reaction between acetone and Iodine using titrimetry. c. To study the effect of pH on the kinetics of iodination of aniline. d. To study the kinetics of Briggs Rauscher reaction (oscillatory reaction). e. To study the kinetics of rapid reaction between Bromine and Iodine in aqueous media f. To investigate the autocatalytic reaction between Potassium Permanganate and Citric acid. g. To study the electroless deposition of Cu on alpha-alumina and to determine the rate of deposition. h. To compare the catalytic activity of MnO_2, NiO with Degussa-P25 towards H_2O_2 decomposition reaction. i. To investigate the effect of pH on adsorptive separation of Amaranth dye from water over NiO catalyst. j. To determine the radius of a glycerol molecule by viscosity measurements.	40
Unit III. Computational Chemistry a. To write a computer program to find out various parameters for data analysis viz. minimum, maximum, average, standard deviation, variance, covariance, correlation coefficient, frequency distribution etc. b. To write a computer program to obtain slope and intercept for linear data using least square fit method c. To analyze the Gaussian output files and extracts molecular coordinates. d. To construct and optimize the molecular structure of H_2O, H_2O_2 and HOF using Gaussian/ NWCHEM and calculate bond distances and bond angles. e. To obtain the transition state of the reaction between CH_3Br and OH^-ions using Gaussian/ NWCHEM. f. To study the effect of solvent on the transition state of the reaction between CH_3Br and OH^- using Gaussian/ NWCHEM.	40

g. To study the thermochemistry of the reaction between CH_3Cl and OH^- using Gaussian/ NWCHEM. h. To generate a plot for a given function such as solutions of 1D box, harmonic oscillator, H-like atom wave functions, Gaussians distributions etc. i. To write a computer program to obtain degeneracy of a given energy level for a particle in a rectangular box. j. Calculate the ground state energy of hydrogen atom using various basis sets using Gaussian 16 program. *Note: A minimum of 7 experiments from each Unit I-III are to be completed.*	
Pedagogy:	Mainly pre-labs / practicals or a combination of some of these could also be used to some extent.
Textbooks / Reference Books	1. A. Finlay and J.A. Kitchener, *Practical Physical Chemistry,* Longman Publisher, 1963. 2. A. M. James, *Practical Physical Chemistry*, *Longman Publisher, 1974*. 3. D.P. Shoemaker and C.W. Garland, *Experimental Physical Chemistry,* McGraw-Hil, 1981. 4. J. B. Yadav, *Advance Practical Physical Chemistry*, Krishna Educational Publishers, 2014. 5. S. Attila, and N.S. Ostlund. *Modern quantum chemistry: introduction to advanced electronic structure theory*. Courier Corporation, 2012. 6. P. P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, CH-20: *Photocatalytic and microbial degradation of Amaranth dye*, Advances in Biological Science Research-A Practical Approach 2019, 327-345, Academic Press. 7. J.B. Foresman, E. Frisch*, Exploring Chemistry With Electronic Structure Methods: A Guide to Using Gaussian,* 2nd ed. Gaussian, 1996.

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Programme: **M. Sc. Part-II (Physical Chemistry)**
Course Code: **CHPR-513**
Title of the Course: **Heterogeneous Catalysis: Fundamentals and Applications**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied Chemistry courses at MSc Part-I.
Course Objectives:	1. To introduce concepts of surface science and catalysis. 2. To provide fundamental knowledge of theories that govern heterogeneous catalytic reactions. 3. To introduce newer methods of synthesizing nanocatalysts and its characterization. 4. To introduce latest developments about application of catalyst in environment and energy sector.
Course Outcomes:	1. Students will be able to design a nanocatalysts for adsorption application. 2. Students will be able to interpret characterization data of nano catalysts. 3. Students will be able to design a catalyst for environmental and energy applications.

	Content	Hours
1.	**Basic Concepts** a. General Introduction: Catalysis and activation energy. Heterogeneous reactions with suitable illustrations. Catalytic activity, selectivity and stability. Steps in a heterogeneous catalytic reaction. Factors affecting rate of reaction such as temperature, flow rates, molar composition etc. b. Adsorption and Surface Area: Cause of adsorption. No of molecules striking the surface and sticking probability. Types of adsorption and potential energy profiles for adsorption of H_2. Adsorption isotherms for gases and solutes. Basic types of BET isotherms. Gibbs adsorption equation and changes in surface tension. Free energy, enthalpy and entropy of adsorption. Chemisorption of H_2, O_2 and CO. Surface area and Porosity: Determination of surface area. Porosity and pore size distribution. c. Classification of catalysts based on electrical conduction. Adsorption on specific crystal planes; geometric factor in catalysis: Balandin's multiplet theory and Valence angle conservation. Cumulative & depletive adsorption, Electronic effect in catalysis by metals. Role of diffusion in catalysis.	20
2.	**Kinetics and mechanisms of catalyzed reactions** Kinetics of catalyzed reactions and rate expressions. Mechanism of catalyzed reactions obeying Langmuir-Hinshelwood, Eley- Rideal and Mars van Krevelen models with suitable examples.	5
3.	**Preparation of Catalysts** Various methods for preparation of bulk catalysts: Precipitation method, Impregnation method catalyst impregnation with or without interaction between support and catalyst. Synthesis of microporous solids. Synthesis of mesoporous solids.	5
4.	**Thermal and Spectroscopic Methods in Heterogeneous Catalysis** Characterization of the catalysts by temperature programmed desorption using probes such as ammonia and pyridine molecules. Characterization of surface area using BET method. Characterization of adsorbed molecules/intermediates by IR spectroscopy and XPS. Introduction to EXAFS and Mössbauer spectroscopy in characterizing catalysts.	10
5.	**Zeolite based Catalysis and industrial applications** Structure building in zeolites such ZSM-5. Nature of active sites and their characterization. Role of Zeolite acidity and Shape Selectivity in catalytic reactions. Zeolite based catalysis in MTG process.	5
6.	**Semiconductor catalysis and its application in energy and environmental sector** Introduction to semi-conductor surface and catalysis with application in photocatalytic water splitting and CO_2 reduction to value added chemicals. Case studies on photocatalytic degradation of dyes. Practical demonstration of photocatalytic treatment of laboratory waste water contaminated with dyes, adsorptive separation and kinetic analysis.	10

7. **Electrocatalysis and applications** Basic electro-catalytic concepts, comparison of electro-catalysts. Electrocatalytic water splitting reaction. Role of catalytic materials in energy storage applications.	5
Pedagogy:	Mainly lectures, tutorials, assignments, demonstration, self-study or a combination of some of these could also be used to some extent.
Textbooks / Reference Books	1. D. K. Chakrabarty and B. Viswanathan, *Heterogeneous Catalysis,* New Age International Publishers, 2008. 2. G. A. Somorjai, *Introduction to Surface Chemistry and Catalysis,* John Wiley, 2002. 3. M. Thomas and W. J. Thomas, *Principles and Practice of* Heterogeneous Catalysis, VCH Publishers, 1996. 4. P.P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, *CH-20: Photocatalytic and microbial degradation of Amaranth dye*, Advances in Biological Science Research-A Practical Approach 2019, 327-345, Academic Press. 5. B.H.R. Suryanto, Y. Wang, R. K. Hocking, *Overall electrochemical splitting of water at the heterogeneous interface of nickel and iron oxide*. Nature Commun. 2019, 10, 5599. 6. A. V. Salkar; S. V. Bhosale; P. P. Morajkar, *CH-6: Nanostructured WO_{3-x} Based Advanced Supercapacitors for Sustainable Energy Applications*, Advances in Metal Oxides and Their Composites for Emerging Applications; Elsevier, 2022, 213–238. ELSEVIER. 7. A.V. Salker, *Catalysis: Principles and Basic Concepts*, Scientific International, 2019.

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Programme: **M.Sc. Part-II (Physical Chemistry)**
Course Code: **CHPR-514**
Title of the course: **Applied Electrochemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied Chemistry courses at M.Sc. Part-I.
Course Objective:	1.Introduction to core concepts of electrochemical applications 2. To enable design and development of electrochemical systems for specific applications 3. Introduction of applications and working principles of electrochemical devices in day-today life eg. batteries, solar cells, capacitors
Course Outcome:	1. Students will be in a position to apply these concepts during the lab course in physical chemistry. 2. Students will gain knowledge and apply the same in electrochemistry dissertation and research work.

Content	*Hours*
1. Electroanalytical Techniques	10

Principles and applications of the following techniques: a. Amperometry b. Cyclic voltammetry c. Voltammetry at rotating disk electrodes d. Electrochemical impedance spectroscopy	
2. Corrosion a. Corrosion and electrochemical kinetics. Pourbaix diagrams Mechanism of electrochemical corrosion. b. Mixed electrode and mixed potential. Overpotential and polarization. c. Current density – potential curves and determination of corrosion current density. d. Hydrogen and oxygen overpotentials and corrosion e. Types of electrolytic corrosion and forms of localized corrosion, practical cases of corrosion. Corrosivity and passivity f. Corrosion prevention. Corrosion inhibitors. Corrosion Testing. Cathodic and anodic protection g. Polarization tests and impedance spectroscopic measurements.	10
3. Electrochemical Power Sources: Batteries, Fuel Cells and Supercapacitors a. Electrical characteristics of batteries. Batteries with aqueous and non-aqueous electrolytes. Types of batteries, Ohmic losses and thermal processes in batteries. Next generation batteries: Lithium ion batteries, Sodium ion batteries b. Thermodynamic aspects of fuel cells. Working principles of fuel cells. Types of fuel cells: polymer electrolyte membrane fuel cells (PEMFCs), direct liquid fuel cells (DLFCs), molten carbonate fuel cells (MCFCs), solid oxide fuel cells (SOFCs), alkaline fuel cells (AFCs) c. Properties of electrical double layer capacitors. Energy density. Power density. Electrochemical supercapacitors with carbon electrodes. Pseudocapacitor electrodes and supercapacitors. Hybrid supercapacitors: metal oxide (MeO_x/C) and electronically conducting polymer/carbon (ECP/C) types .	10
4. Electrocatalysis and Electrochemical Sensors a. Introductory aspects to fuel cell electrocatalysis. Electrochemical energy conversion. b. Electrocatalytic surfaces. Structure stability and mass transport on electrode surfaces, Basic electrocatalytic mechanisms and kinetics c. Electrochemistry of methanol electrooxidation d. Types of electrocatalysts, Electrochemistry of ORR and HER e. Introduction to principles of chemical sensing; Signal transduction; Physico-chemical and biological transducers; Sensor types and technologies, Chemically modified electrodes for sensing i. Types of electrochemical sensors (voltammetric, potentiometric, amperometric, impedimetric), Methods for sensors fabrication: self-assembled monolayers, screen printing, photolithography, microcontact printing, MEMS k. Test-strips for glucose monitoring	15
5. Photoelectrochemical devices a.Photoelectrochemical cell design, photoconversion efficiency, photoelectrochemical water splitting	15

b. Principles and applications of dual-working-electrode photoelectrochemistry c. Principles and working of first and second generation solar cells d. Fabrication and operational principles of third generation photovoltaics: perovskite solar cells, dye-sensitized solar cells, quantum dot solar cells e. Tandem photovoltaic cells	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. J.O.M. Bockris and A.K.N. Reddy*, Modern Electrochemistry*, Vol. 1, 2 and 3, Kluwer Academic Publishers, New York, 2002 2. A. Vincent & B. Sacrosati, *Modern Batteries*, John Wiley, NewYork, 1997. 3. J.O.M.Bockris & S.Srinivasan, *Fuel cells: Their Electrochemistry*, McGraw-HillBookCo., 1969. 4. E. Santos & W. Schmickler, *Catalysis in Electrochemistry: From Fundamental to Strategies for Fuel Cell Development*, Wiley, 2011 5. J. Lipkowski& P. N. Ross, *Electrocatalysis*, Wiley-VCH, New York, 1998 6. A.J. Bard, M. Stratmann , S. Licht, *Encyclopedia of Electrochemistry, Semiconductor Electrodes and Photoelectrochemistry*, Wiley-VCH, 2002. 7. S. Gimenez & J. Bisquert, *Photoelectrochemical Solar Fuel Production: From Basic Principles to Advanced Devices*, Springer International Publishing, 2016 8. V. S. Bagotsky, A. M. Skundin& Y. M. Volfkovich, *Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors*, John Wiley & Sons, Inc., New Jersey, 2015 9. N. Perez, *Electrochemistry and Corrosion Scienc*e, Kluwer Academic Publishers, Boston, 2004. 10. C. Jiang, S. J. A. Moniz, A. Wang, T. Zhang, J. Tang, *Photoelectrochemical devices for solar water splitting – materials and challenges*, Chem. Soc. Rev., 2017, 46, 4645-4660. 11. M. Stanley, W. R. F. Savinell, T. Zawodzinski, *Introduction: Batteries and Fuel Cells*, Chem. Rev., 2004, 104, 10, 4243 12. E. Bakker, Y. Qin, *Electrochemical Sensors*, Eric Bakker, Anal. Chem. 2006, 78, 3965-3984

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHPG-511**
Title of the course: **Solid State Chemistry: Concepts and Applications**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied the chemistry/physics courses at M.Sc. Part-I
Course Objective:	1.To introduce concepts and provide fundamental knowledge of principles of materials chemistry, characterization methods and techniques 2. To provide fundamental knowledge of molecular solids, description of crystal chemistry and classification of phase structure and significance of imperfections in solids.

	3. To provide basic understanding of temperature dependence of crystal structure, phase modifications and its influence on magnetic and electronic properties of materials 4. To provide a comparative evaluation of data obtained from various techniques and their use in elucidating the chemical and morphological structure of solid materials
Course Outcome:	1.Students will be in a position to explain the concept of solid state synthesis, identify different crystal structure 2. Students will be in a position to explain the design of the instrumental techniques, data acquisition, and analysis to elucidate structural information of solid materials 3. Students will be able to apply the concepts learned to make the best choice of a characterization technique(s) for elucidation of unknown solids under investigation.

Content	*Hours*
1. Solid State: Introduction a. General Principles and experimental procedure. b. Various methods in solid-state synthesis c. Kinetics of solid-state reactions, ion exchange, and intercalation reactions.	6
2. Crystal Chemistry and X-Ray Diffraction: a. Crystal systems, Bravais lattices and Quasicrystals. b. Ionic structures and covalent networks. c. Some important structure types –rock salt, zinc blende, wurtzite, nickel arsenide, rutile, and van der Waals heterostructures. d. Factors that Influence Crystal Structures: valences and coordination numbers. e. Significance of radius ratio rule and non-bonding electron effects. f. Powder X-ray diffraction experiment, instrumentation g. Introduction to single-crystal X-ray diffraction. Applications of high-temperature powder diffraction. h. Identification of crystal phases and evaluation of lattice characteristics	15
3. Crystal Defects and non-stoichiometry a. Types of defects. Point defects and thermodynamics. b. Colour Centres, vacancies, and interstitials in non-stoichiometric crystals. c. Dislocations, mechanical properties, and reactivity of solids	6
4. Phase Diagrams and Phase Transitions a. Basic Concepts and definitions. b. Three-component condensed systems. Martensitic transformations. Order-disorder transitions.	6
5. Electronic Properties and Band Theory a. Electronic structure and band theory of solids. Band structure of metals and semiconductors. b. Magnetic properties of transition metal oxides and applications Electrical conductivity, free electron theory, fermi energy, insulators, semiconductor and conductors, band theory of semiconductor, Brilliouin zones, Hall effect, the Seebeck effect, Superconductivity, BCS theory, Meissner effect, high temperature superconductor.	6

6. Electronic Microscopic Techniques a. Introduction to Electron Microscopy: Generation of electron beam, elastic and inelastic scattering of electrons by atoms. b. Scanning Electron Microscopy (SEM): Instrumentation, optics, resolution and compositional imagining, Preparation of specimen, crystallographic information from SEM and Environmental Scanning Electron Microscopy (E-SEM) c. High Resolution Transmission Electron Microscopy (HR-TEM): Instrumentation, contrast mechanism, high voltage and Scanning Transmission Electron microscopy (STEM), preparation of specimen and data interpretation. d. Cryogenic Electron Microscopy (Cryo-TEM)	8
7. X-Ray Spectroscopy a. Intensities: scattering of X-Rays and factors that affect intensities, powder x-ray pattern b. XRF, X-ray absorption near edge structure (XANES) and extended x-ray absorption fine structure (EXAFS): Absorption coefficient, absorption edges, resonance emission, extended absorption and photoelectron scattering. c. X-ray photoelectron spectroscopy (XPS): Surface analysis, sensitivity and specificity, photoelectron intensities, binding energies and spectra analysis c. Instrumentation and design, characterization of transition metal oxides.	8
8. Thermal Analysis a. Thermogravimetric analysis, Differential Thermal Analysis b. Differential scanning calorimetry c. Application to the characterization of materials	5
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. A. R. West, *Solid State Chemistry and Its Applications*, John Wiley & Sons 2003. 2. H. V. Keer, *Principles of the Solid State*, New Age International Publishers, 1993. 3. C. N. Banwell, E. M. McCash, *Fundamentals of Molecular Spectroscopy*, McGraw-Hill Education (India) Private Limited, 1994 4. P. van der Heide, *X-ray Photoelectron Spectroscopy: An Introduction to Principles and Practices*, John Wiley & Sons, Inc. 2012

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHPG-512**
Title of the course: **Nanoscience: Concepts and Applications**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied the M.Sc. I courses of chemistry/ physics/ biological sciences
Course Objective:	1. Introduction of various concepts for nanoscience. 2. Introduction of various synthesis methods of nanomaterials. 3. Introduction of various characterisation techniques and

	application study of nanomaterials
Course Outcome:	1. Students will learn different techniques of synthesis and characterisation of nanomaterials. 2. Students should be in a position to understand and explain magnetic, electrical, optical and catalytic properties of materials at nanoscale. 3. Students should be in a position to apply the knowledge of subject for their dissertation and research work.

Content	*Hours*
1. Essential Concepts and definitions Nanoscale, quantum effects, thermal properties of nanomaterials, optical properties of nanomaterials, electrical properties of nanomaterials, Metallic nanowires and quantum conductance, Surface to volume ratio of nanoparticles, surface effects and surface energy on Nanoparticle surface. Chemistry of solid surfaces.	15
2. Methods of nanomaterial synthesis Principles, methods, formation mechanism and structures of nanomaterials for: Gas-phase processes, Liquid-phase processes, Solid-phase processes, Self-assembly processes	10
3. Characterization techniques Beam Probe methods (SEM, TEM), Scanning probe method (STM, AFM), optical method: principle, sample preparation technique and applications. Case studies: core-shell nanoparticles, metal nanoparticles, composite nanoparticles.	10
4. Important nanomaterials **Silica**: discussion of sol-gel and liquid crystal synthesis method, self-assembly of colloidal silica particles, photoluminescence property of opals, different surface functionalization methods and application study. **Gold:** Different colloidal synthesis methods, self-assembly methods, surface Plasmon resonance (SPR) of colloidal gold nanoparticles surface functionalization strategies and application study. **CdSe:** Different synthesis methods, synthesis of core-shell particles, Study of CdSe excitons and CdSe quantum dots, functionalization and application study. **Iron oxide (Fe_3O_4):** Different synthesis methods, Superparamagnetism property of nanoparticles, Hysteresis and magnetisation of Fe_3O_4 nanomaterial, catalytic and Biomedical applications. **Carbon:** synthesis methods for carbon nanotubes, Graphene and Buckminster fullerene, structural study of these materials, electrical property study of these materials, surface functionalization statergies and application study.	15
5. Applications of nanomaterials Heterogeneous catalysts for the synthesis of fine chemicals, Polymer vesicles for drug delivery, Surface-modified metal nanoparticles for recognition of toxic organic molecules, Use of nano TiO_2 and ZnO for water and air pollution control, Carbon Materials for Energy Storage, Thermoelectric Nanomaterials	8
6. Nanomaterials: risk, toxicity Toxicity of inorganic-based, carbon-based, composite-based nanomaterials, environmental, health, and safety issues.	5

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	i. L. Cademartiri and G.A.Ozin, *Concepts of Nanochemistry*, Wiley-VCH, 2009. ii. C.N.R. Rao and A. Govindaraj, *Nanotubes and nanowires,* Royal society of Chemistry, *2005*. iii. G. Cao, *Nanostructures and Nanomaterials,* Imperial College Press, 2004. iv. J. M. Tour, *Molecular Electronics*, Imperial College Press, 2004 v. H. S. Nalwa (Ed), *Encyclopedia of Nanoscience and Nanotechnology,* American Scientific Publishers,2004. vi. E. Roduner, *Nanoscopic Materials Size-Dependent Phenomena*, RSC, Publishing, Cambridge, 2006. vii. G.A. Ozin and A.C. Arsenault, *Nanochemistry: A Chemical Approach to Nanomaterials*, RSC Publishing, Cambridge, 2005. viii. C.P. Poole and F.J. Owens, I*ntroduction to Nanotechnology*, John Wiley and Sons, 2003. ix. B. Zhang, *Physical Fundamentals of Nanomaterials*, Chemical industry press, 2018. x. C. M. Hussain, *Handbook of Nanomaterials in Analytical Chemistry*, Elsevier, 2020. xi. A. Barhoum and A. S. H. Makhlouf, *Emerging Applications of Nanoparticles and Architecture Nanostructures: Current Prospects and Future Trends,* Elsevier, 2018. xii. R.G. Chaudhuri and S. Paria. *Core/shell nanoparticles: classes, properties, synthesis mechanisms, characterization, and applications,* Chemical reviews ACS, 2012, 112, 2373-2433.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHPG-513**
Title of the course: **Physical aspects of Polymer Chemistry**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. I.
Course Objective:	1. To introduce physical and chemical aspects of polymer chemistry. 2. To introduce kinetics of polymerization, different characteristics of polymers, applications of biodegradable and thermoset polymers.
Course Outcome:	1. Students will be able to explain various fundamental concepts of polymer chemistry. 2. Students should be in a position to apply the knowledge of polymer chemistry for their dissertation and research work. 3. Students should be in a position to apply these concepts during the lab course.

Content	*Hours*
1. Introduction to polymer chemistry a. Historical development in polymer chemistry, polymer industry in 21st century.	10

b. Classification of polymers, Polymer nomenclature. Polymer tacticity, geometry and stereoregularity. c. Thermoplastics and thermosets- Plastics, elastomers, fibres. Concepts of Functionality, terminal groups, homopolymers and copolymers etc. d. Addition and condensation polymers- - linear, branched, IPN and cross-linked polymers-graft and block co-polymers.	
2. Molecular weight and other classification of polymers a. Polymer molecular weight, arithmetic mean – Number average, weight average, polydispersity and Polydispersity index (PDI)) b. Degree of polymerization and its impact on MW and mechanical properties. c. Amorphous and crystalline polymers. Methods of analysis of crystallinity. d. Glass transition temperature and other thermal transitions. Importance of T_g –Plasticizers and their action. Secondary bonding forces in polymers.	10
3. Polymerization techniques a. Methods of polymerization (homogeneous and heterogenous polymerization) b. Co-ordination polymerization, Zeigler–Natta and other catalytic polymerization techniques. c. Atom transfer radical polymerization (ATRP), Reversible addition-fragmentation chain transfer polymerization (RAFT). d. Advantages and disadvantages of polymerization techniques	10
4. Polymer molecular weight and its determination a. Molecular weight averages: Arithmetic mean; Number average molecular weight; Weight average molecular weight. b. Molecular weight determination: end group analysis; colligative property measurement; dilute solution viscosity; Mark-Houwink-Sakurada (MHS) equation. c. Gel permeation Chromatography	8
5. Kinetics of polymerization Introduction; Free radical chain polymerization; Equation for kinetic chain length; degree of polymerization; ceiling temperature, Anionic polymerization, Cationic polymerization, Polycondensation; Non catalyzed polycondensation; catalyzed polycondensation	8
6. Characterization of polymers by various techniques a. Instruments and testing methods for polymer characterization b. Characterization of chemical structure of polymers: by chemical reaction methods; IR spectroscopy; Raman spectroscopy; UV-Visible spectroscopy; NMR and ESR spectroscopy. c. Characterization of polymer morphology and Physical structure of Polymers: TEM; X-ray scattering; WAXS; SAXS; AFM. d. Characterization of Thermal Properties of Polymers: Differential thermal analysis (DTA), Physical transitions, melting thermograms, Melt crystallization; Differential Scanning coulometry (DSC); Thermogravimetric analysis (TGA).	14

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. V. R. Gowarikar, N. V. Viswanathan, and J. Sreedhar, *Polymer Science*, Wiley Eastern Ltd., 1986. 2. P. Bahadur and N. V. Sastry, *Principles of Polymer science,* Narosa Publishing House, 2003. 3. J. R. Fried, *Polymer Science and Technology*, PHI Pvt Ltd., 2000. 4. R. Sinha, *Outlines of Polymer Technology: Manufacture of Polymers*, PHI Pvt Ltd., 2000. 5. R. Sinha, *Outlines of Polymer Technology: Processing Polymers*, PHI Pvt Ltd., 2003. 6. J. A. Brydson, *Plastic Materials*, Newnes-Butterworths, 1979, 3rd edition. 7. J. Urbanski, W. Czerwinski, K. Janicka, F. Majewska, and H. Zowall, *Handbook of analysis of synthetic polymers and plastics*, John Wiley, 1977. 8. K. Y. Saunders, *Organic polymer chemistry*, Chapman and Hall, UK, 1976. 9. R. W. Lenz, *Organic chemistry of synthetic high polymers*, 1967. 10. R. P. Brown, *Handbook of plastic test methods*, George Godwin Ltd., 1981, 2nd edition. 11. M. P. Stevens, *Polymer Chemistry- An Introduction*, Oxford Univ. Press, 1990, 2nd edition. 12. W. Y. Mijs, *New methods in polymer synthesis*, Plenum Press Ltd., NY, 1992. 13. P. C. Hiemenz, *Polymer chemistry- the basic concepts*, Marcell Dekker Inc., 1984. 14. W. R. Moore, *Introduction to polymer chemistry*, Univ. of London Press, 1961. 15. N. P. Cheremisinoff (Ed), Handbook of polymer science and technology, Marcel Dekker Inc., 1989. 16. M. Chanda, *Introduction to polymer science and chemistry, A problem-solving approach*, CRC press, 2006. 17. W. F. Su, *Principles of Polymer design and synthesis*, Volume 82, Springer, 2013. 18. R. M. Silverstein, F. X. Webster, B. J. Kimley, D. L. Bryce, S. D. Samant, V. S. Nadkarni, *Spectrometric Identification of Organic Compounds, An Indian Adaptation*, 8th Ed. Wiley, 2022.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHPG-514**
Title of the course: **Colloids and Surface Chemistry**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. I.
Course Objective:	1. To introduce some core concepts of colloidal chemistry including DLVO theory, electrokinetic phenomena and diversity in colloids. 2. To introduce fundamental concepts and applications of colloids in day-today life.
Course Outcome:	1. Students will be able to explain various fundamental and core concepts of colloid chemistry.

	2. Students should be in a position to apply the knowledge of colloidal chemistry for their dissertation and research work 3. Students should be in a position to apply these concepts during the lab course in physical chemistry.

Content	*Hours*
1. Colloids and Liquid Surfaces a. Colloids: General introduction, classification and structural characteristics of colloidal system, preparation and purification b. Microscopic picture of liquid surface c. Surface tension and its measurement. Surfactant and reduction of surface tension. Curved liquid surfaces. d. Nucleation theory. e. Surface modification: self-assembly monolayer formation. Physisorption of polymers. Polymerization on surfaces.	10
2. Electrostatic Forces and Electrokinetic Phenomenon a. Electrical double layer. Surface interactions between surfaces (dipole, induced dipole, H-bonding) b. Surface forces: Van der Waals forces between molecules. Surface energy and Hamaker constant. Measurement of surface forces. The DLVO theory c. Charged surfaces such as mercury, silver iodide and oxides. Measurement of surface charge densities d. Electrocapillarity - theory and measurement e. Electrokinetic phenomena: concept of zeta potential. Electroosmosis and streaming potential. Electrophoresis and sedimentation potential. f. Contact angle and its measurements. Wetting and dewetting. Important wetting geometries.	12
3. Colloidal Stability a. Charged colloids. Electrical charge distribution at interfaces b. Factors affecting colloidal stability. Effect of electrolyte. c. Flocculation and coagulation. Kinetics of coagulation d. Steric stabilization of solid and liquid colloids	8
4. Preparation of colloids a. Chemical methods for synthesis of colloids: Sol-gel method, polyol synthesis, plasma enhanced chemical vapor deposition, hydrothermal synthesis b. Colloidal synthesis of semiconductor nanoparticles: Hot-injection synthesis. Synthesis of colloidal core-shell heterostructures c. Surface directed colloidal patterning: Colloidal self-assembly approaches d. Reducing agents in colloidal nanoparticle synthesis	12
5. Surfactants, Micelles, Emulsions and Thin Liquid Films a. Classification of surfactants. Solubilization and micelle formation b. Spherical micelles: cmc and influence of temperature. Thermodynamics of micellization. Structure of surfactant aggregates. c. Emulsions: Macro and microemulsions, properties, formation and factors	13

affecting the stability. Evolution and aging. Coalescence and demulsification. Size of droplets. Elasticity of surfactant films. d. Thin films on surfaces of liquids: Introduction and phases. Bubbles and foams. Optical and X-Ray methods to study monolayers. e. Langmuir Blodgett Transfer	
6. Applications of Colloids in Science, Technology and Industry a. Colloids as drug delivery agents b. Colloidal nanocrystals for optical applications and solar cells. c. Biomedical applications	5
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. H. J. Butt, K. Graf and M. Kappl, *Physics and Chemistry of Interfaces*, Wiley-VCH, 2003. 2. A. W. Adamson and A.P.Gast, *Physical Chemistry of Surfaces*; Wiley-VCH, 1997, 6th edition 3. R. D. Vold and M. J. Vold, *Colloid and Interface Chemistry*, Addison-Wesley, 1983. 4. K. S. Birdi, *Surface and Colloid Chemistry, Principles and Applications*; Taylor & Francis Group ,2010. 5. D. Meyers, *Surfaces*, *Interfaces and Colloids, Principles and Applications;* John Wiley & Sons, Inc. 1999. 2nd edition. 6. E. D. Shchukin, A. V. Pertsov, E. A. Amelina, A. S. Zelenev, *Studies in Interface Science, Colloid and Surface Chemistry*; Elsevier, 2001. 7. D. J. Shaw, *Introduction to Colloid and Surface Chemistry*, 4th Ed. Elsevier, 1992. 8. F. Caruso, *Colloids and Colloid Assemblies*, Wiley-VCH, 2004. 9. V. Lesnyak, M. Yarema, S. Miao, *Colloidal Semiconductor Nanocrystals: Synthesis, Properties and Applications*, Frontiers Media SA, 2020.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCR-511**
Title of the course: **Research Methodology and instrumental techniques-I**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry.

	3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Introduction to Research Methodology a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	5
2. Scientific conduct and ethics a. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. b. Intellectual honesty and research integrity. c. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). d. Redundant publications: duplicate and overlapping publications. e. Selective reporting and misrepresentation of data.	5
3. Academic writing a. Publication ethics: definition, introduction and importance b. Conflicts of interest c. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa d. Violation of publication ethics, authorship and contributorship e. Identification of publication misconduct, complaints and appeals f. Predatory publishers and journals	5
4. Data bases and research metrics a. Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. b. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
5. Safety aspects in Chemistry a. Good laboratory practices. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	5
6. Softwares in Chemistry a. Data plotting b. Structure Drawing c. Reference management software	7
7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: a. Elemental analysis: CHNS analysis and AES b. Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) c. Nuclear magnetic resonance (^{1}H, ^{13}C) d. Chromatographic techniques: HPLC, GC,	30

e. Hyphenated Techniques: LC-MS & GC-MS, f. Diffraction methods: XRD g. Thermal analysis: DSC h. Microscopy: SEM, TEM i. Methods for determination of magnetic & dielectric properties. j. Cyclic voltammetry	
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 14. A. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. A. Szabo, N. S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989.

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Programme: **M.Sc. Part-II (Chemistry)**

Course Code: **CHCR-512**
Title of the course: **Research Methodology and instrumental techniques-II**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I.
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Content	*Hours*
1. Research Methodology, Scientific conduct, ethics & academic writing a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions. c. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. d. Intellectual honesty and research integrity. e. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). f. Redundant publications: duplicate and overlapping publications. g. Selective reporting and misrepresentation of data. h. Publication ethics: definition, introduction and importance i. Conflicts of interest j. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa k. Violation of publication ethics, authorship and contributorship l. Identification of publication misconduct, complaints and appeals m. Predatory publishers and journals	15
2. Softwares in chemistry, Data bases and Research metrics a. Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. b. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. c. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc	10

d. Molecular Docking software	
3. Safety practices in Chemical research a. Introduction to lab safety. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	5
4. Instrumental methods a. UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. b. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) c. Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) d. Electrochemical Impedance Spectroscopy (EIS) e. Resonance Raman and isotope labelling studies. f. Infrared (IR) spectroscopy applications g. ^{1}H, ^{13}C- NMR spectroscopy and applications h. Selected chromatographic techniques such as HPLC, GC. i. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS j. Diffraction methods: High temperature XRD k. Thermal analysis: TG/DTA/DSC l. Microscopy: Fe-SEM, HR-TEM m. Methods for determination Ms, Mr, Hc, Tc, ε^{l} and Tanδ. n. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. Bird, *Philosophy of Science*, Routledge, 2006. 3. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; *Spectrometric identification of Organic Compounds*; 6th Ed, Wiley, 2011.

	10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, *Principles of the Solid State,* 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 13. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989. 19. A. Leach, *Molecular Modelling, Principles and applications*, Longman, 1998. 20. W. Nam et al, *Dioxygen activation by Metalloenzymes & models*, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHCD-511**
Title of the course: **Discipline Specific Dissertation**
Number of Credits: **16**Total Hours: **480** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	
Content		*Hours*
As per OA-35		480
Pedagogy	Dissertation carried out individually by each student throughout the academic year.	
Textbooks/ References / Readings	As required for the development of review and methodology.	

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Annexure II

M.Sc.Pharmaceutical Chemistry Part-II Syllabus for AY 2023-24 (SEM III and SEM IV) based on NEP-2020

SEM III			
Sr. No.	*Paper code*	*Paper title*	*Credits*
1.	**CHHR-511**	Practical Course in Pharmaceutical Chemistry-III	4
2.	**CHHR-512**	Practical Course in Pharmaceutical Chemistry-IV	4
3.	**CHHR-515**	Pilot Plant Scale-Up Techniques for Pharmaceuticals	4
4.	**CHHR-516**	Research Methodology in Pharmaceutical Chemistry and instrumental techniques	4
5.	**CHHG-511**	Polymers in Pharmaceuticals and novel drug delivery systems	4
6.	**CHHG-512**	Pharmacotherapeutics	4
7.	**CHHG-513**	API Process, Manufacture and Green Chemistry	4
8.	**CHHG-514**	Pharmaceutical and Spectral analysis	4
9.	**CHHG-515**	Bioorganic and Medicinal Chemistry	4
SEM IV			
1.	**CHHR-513**	Retrosynthetic Approach and Heterocyclic Drug Synthesis	4
2.	**CHHR-514**	Pharmacological and Toxicological Screening Techniques	4
3.	**CHCD-511**	Discipline Specific Dissertation	16

Programme: **M. Sc. Part-II (Chemistry)**
Course Code: **CHHR-511**
Title of the Course: **Practical Course in Pharmaceutical Chemistry-III**
Number of Credits: **04** Total Hours:**120**Effective from AY: **2023-24**

Prerequisites for the course	Should have studied the courses at M.Sc. Part-I.
Course Objective:	1.To translate certain theoretical concepts learnt earlier into experimental knowledge. 2.To provide hands-on experience of laboratory techniques required for drug syntheses, analysis and purification.
Course Outcome:	1. Students will be in a position to perform synthesis of drugs. 2. Students will be in a position to understand stoichiometric requirements in drug syntheses. 3.Students will be able to analyse drug spectrophotometrically and chromatographically 4.Students will be able to carry out purification of drug by column separation. 5. Students will be able to apply this knowledge for their dissertation work.

Content	*Hours*
1. Syntheses of drugs and drug like entities (Minimum 8 experiments of 6h each) a)Phenothiazine from diphenylamine b)Propranolol from α-Naphthol c) Eosin from Fluorescein d) Gramine from Indole e) 3-Methyl-1-phenyl pyrazolone from phenyl hydrazine	48

f) Schiff base of Antipyrine with p-bromobenzaldehyde g) Methyl Salicylate from Salicylic acid h) Sulphanilamide from p-acetamido benzene sulphanilamide i) Chlorbutanol from acetone j) 1,2,3,4-Tetrahydrocarbazole from cyclohexanone k) 1,5-Benzodiazepine from acetophenone alidixate from 2-amino-6-methylpyridine m) 2-Phenyl Benzothiazole from 2-Amino thiophenol n) 2-Methylbenzimidazole from o-phenylenediammine o) Monastrol from thiourea, ethylacetoacetate and 3-hydroxybenzaldehyde p)Substituted chalcone from 4-chlorobenzaldehyde (Claisen Schmidt condensation)	
2. Selected experimentsin organic synthesis (Minimum 3 experiments of 4h each) a) p-Iodotoluene from p-toluidine.(Diazotisation) b) Cinnamic acid from benzaldehyde (Perkin reaction) c) Benzanilide from benzophenone (Beckmann Rearrangement) d) Vanillin to Vanillyl alcohol (using $NaBH_4$) e) Methyl orange from sulphanilic acid (coupling diazotization process) f) Benzhydrol from Benzaldehyde (Grignard reaction)	12
3.Titrimetric assay of the following bulk drug/tablets. (Any 2) Paracetamol, Isoniazid, Dapsone, Metronidazole, Calcium Gluconate	6
4. Spectrophotometric assay of the following tablets. (Any 2) inol, Propranolol, p-Aminosalicylic acid	6
5.Dissolution Experiments (Any 2) Carbamazepine tablets, Diclofenac, Ibuprofen, Isoniazid	8
6. Quality Control Evaluation of Tablets (1 experiment) Hardness tests, friability testing and disintegration testing to be performed.	4
7. Chromatographic techniques **a. Thin Layer Chromatography (Any 1)** i. To identify the given drug amongst the Ibuprofen, Aspirin and caffeinecitrate with the help of thin layer chromatography and calculate its Rf value. ii. To identify the given sulpha drug amongst the sulphacetamide, sulphanilamide and trimethoprim with the help of thin layer chromatography and calculate its Rf value. **b. Column Chromatography (Any 1)** i. Salicylic acid and Acetylsalicylic acid ii. p-Aminobenzoic acid and Benzocaine iii. Benzil and Dilantin iv. Salicylaldehyde and 3-Acetyl coumarin c.**HPLC analysis of the following drugs and combination of drugs: (Any 2)** i. Paracetamol ii. Ibuprofen iii. Celecoxib	20

iv. Sulphanilamide v. Diclofenac sodium and Paracetamol in combined dosage form.	
8. Identification of following drugs by IR spectroscopy (Any 2) Celecoxib, Antipyrine, Chloramphenicol, Sulphanilamide	4
9. Drug Design Experiments Use of software packages in chemistry for the following: Towrite a computer program to obtain a slope and intercept forlinear data using least square fit. a. Use of ChemDraw, ISISDraw for drawing structures, chemicalreactions, equations. b. Molecular docking softwares such as Hex software orautodocking. c. Energy minimization of molecules and finding intermolecularinteractions of small molecule with macromolecule such as Coxinhibitor, thymidilate synthase, glycogen synthase, E.Coli protein. **(Any 2)** d. Viewing Tools and Graphics Tools: Rasmol (http://www.umass.edu/microbio/rasmol/) VMD (http://www.ks.uiuc.edu/Research/vmd/) Molscript (http://www.avatar.se/molscript/) e. Determination of log P, MR, hydrogen bond donors and acceptors of selected drugs using softwares. f. 2D based experiments.	12

Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.
Textbooks / References /Readings	1. K.A. Connors, *Text book of Pharmaceutical analysis*, 3rd Ed., Wiley Interscience Publication 1990, 2. J. Bassett, J. Mendhan, R.C. Denny, *Vogel's Text Book of Quantitative Chemical Analysis,* revised by G.H. Jeffery, 6th Ed., Pearson Education Publication, 2007. 3. Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 4. JEF Reynolds, Martindale, *The Extra Pharmacopoeia*, The Pharmaceutical Press, London, 1989. 5. M. Jahangir, *Pharmaceutical Laboratory Procedures*, 1st Ed., New Delhi Cengage Learning India Pvt. Ltd. 2010. 6. A. Kar,*Advanced Practical Medicinal Chemistry*, New Age International Limited Publishers 2004. 7. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall 2011. 8. N.K. Vishnoi,*Advanced Practical Organic Chemistry, South Asia Books,* 2010. 9. L. F. Fieser, K. L. Williamson, *Organic Experiments*, 7th Ed., D. C. Heath, 1992. 10. R. K. Bansal, *Laboratory Manual in Organic Chemistry*, 5th Ed. New Age International, 2016. 11. S. Delvin, *Green Chemistry*, Sarup& Sons, 2005. 12. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014. 13. F.D. King, *Medicinal Chemistry: Principles and Practice*, Royal Society of Chemistry: Cambridge, 1994.

	14. K.V. Raman, *Computers in Chemistry*, Tata Mc.Graw-Hill, 1993. 15. S.K Pundir, A.Bansal, *Computers for Chemists*, PragatiPrakashan, 2010. 16. A. Leach, *Molecular Modelling, Principles and applications*, Longman, 1998.

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Programme: **M. Sc. Part-II (Chemistry)**
Course Code: **CHHR-512**
Title of the Course: **Practical Course in Pharmaceutical Chemistry-IV**
Number of Credits: **04** Total Contact Hours:**120**Effective from AY: **2023-24**

Prerequisites for the course	Should have studied the courses at M.Sc. Part-I.
Course Objective:	1. To translate certain theoretical concepts learnt earlier into experimental knowledge. 2. To provide hands-on experience of laboratory techniques required for drug syntheses, analysis and purification.
Course Outcome:	1. Students will be in a position to perform synthesis of drugs. 2. Students will be in a position to understand stoichiometric requirements in drug syntheses. 3. Students will be able to analyse drug spectrophotometrically and chromatographically 4. Students will be able to carry out purification of drug by column separation. 5. Students will be able to apply this knowledge for their dissertation work.

Content	*Hours*
1. Syntheses of drugs and drug like entities (Minimum 8 experiments of 6h each) a. 2-Phenylbenzimidazole from o-phenylenediammine and benzoic acid b. 6-Bromo-2-chloro-3-formylquinoline from acetanilide c. Schiff base of Antipyrine with p-Chlorobenzaldehyde d. Sodium benzoate from Salicylic acid e. Sorbic acid from crotonaldehyde f. Barbiturate from diethyl-n-butylmalonate g. Tolbutamide from p-toluene sulphonamide h. 1,4-dihyropyridine from ethylacetoacetate i. 2-MethylBenzothiazole from 2-Amino thiophenol j. Substituted of 2'-hydroxychalcone (Claisen Schmidt condensation) k. Synthesis of azo-stilbene compounds	48
2. Selected experiments in organic synthesis (Minimum 3 experiments of 4h each) a)Benzhydrol from benzophenone (Reduction) b) p-Iodobenzoic acid from p-aminobenzoic acid (Diazotization) c) 3-Acetylindole from Indole (Friedal Crafts reaction) d) Acetophenone oxime to Acetanilide (Beckmann Rearrangement) e) Enzymatic reduction of ethylacetoacetate using Baker's yeast **f)** Terephthalic acid from p-xylene (Oxidation process).	

3.Titrimetric assay of the following bulk drug/tablets. (Any 2) Ferrous sulphate by Cerimetry, Chlorpheniramine Maleate ,Benzyl Penicillin, Phenobarbitone	6
4. Spectrophotometric assay of the following tablets. (Any 2) Chloroquine phosphate (CHP) Zolmitriptan. Promethazine HCl, Indomethacin,	6
5.Dissolution Experiments(Any 2) Saccharin, Celecoxib, Chlorpheniramine maleate, Chloramphenicol	8
6. Quality Control Evaluation of Capsules(1 experiment) Hardness tests, friability testing and disintegration testing to be performed.	4
7. Chromatographic techniques **a) Thin Layer Chromatography (Any 1)** i. i) To identify the given drug amongst the paracetamol, acetanilide, and caffeinecitrate with the help of thin layer chromatography and calculate its Rf value. ii. To identify the given sulpha drugs amongst the Dapsone, sulphaacetamide and trimethoprim with the help of thin layer chromatography and calculate its Rf value. **b) Column Chromatography (Any 1)** i. Benzil and Benzilic acid ii. Glycine and Hippuric acid iii. o-phenylene diamine and 2,3-diphenylquinoxaline iv. Salicylaldehyde and coumarin **c) HPLC analysis of the following drugs: (Any 1)** i. Methyl Dopa ii. Sulphaacetamide iii. Paclitaxel	20
8. Identification of following drugs by IR spectroscopy (Any 2) Benzocaine, Caffeine, Phenytoin, Suphaacetamide	4
9. Drug Design Experiments Use of software packages in chemistry for the following: To write a computer program to obtain a slope and intercept for linear data using least square fit. a. Use of ChemDraw, ISISDraw for drawing structures, chemical reactions, equations. b. Molecular docking softwares such as Hex software or autodocking. c. Energy minimization of molecules and finding intermolecular interactions of small molecule with macromolecule such as Cox inhibitor, thymidilate synthase, glycogen synthase, E.Coli protein. **(Any 2)** d. Viewing Tools and Graphics Tools: Rasmol (http://www.umass.edu/microbio/rasmol/)	12

VMD (http://www.ks.uiuc.edu/Research/vmd/) Molscript (http://www.avatar.se/molscript/) e. Determination of log P, MR, hydrogen bond donors and acceptors of selected drugs using softwares. f. 2D based experiments.	
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.
Textbooks / References /Readings	1. K.A. Connors, *Text book of Pharmaceutical analysis*, 3rd Ed., Wiley Interscience Publication 1990. 2. J. Bassett, J. Mendhan, R.C. Denny, *Vogel's Text Book of Quantitative Chemical Analysis,* revised by G.H. Jeffery, 6th Ed., Pearson Education Publication, 2007. 3.Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 4. J.E.F. Reynolds, Martindale, *The Extra Pharmacopoeia*, The Pharmaceutical Press, London, 1989. 5. M. Jahangir, *Pharmaceutical Laboratory Procedures*, 1st Ed., New Delhi Cengage Learning India Pvt. Ltd. 2010. 6.A. Kar,*Advanced Practical Medicinal Chemistry*, New Age International Limited Publishers 2004. 7. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall 2011. 8. N.K. Vishnoi,*Advanced Practical Organic Chemistry, South Asia Books,* 2010. 9. L. F. Fieser, K. L. Williamson, *Organic Experiments*, 7th Ed., D. C. Heath, 1992. 10. R. K. Bansal, *Laboratory Manual in Organic Chemistry*, 5th Ed. New Age International, 2016. 11. S. Delvin, *Green Chemistry*, Swarup & Sons, 2005. 12. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014. 13.F. D. King, *Medicinal Chemistry: Principles and Practice*, Royal Society of Chemistry: Cambridge, 1994. 14.K. V. Raman, *Computers in Chemistry*, Tata Mc.Graw-Hill, 1993. 15.S. K Pundir, A. Bansal, *Computers for Chemists*, PragatiPrakashan, 2010. 16.A. Leach, *Molecular Modelling, Principles and applications*, Longman, 1998.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHHR-513**
Title of the course: **RetrosyntheticApproach and Heterocyclic Drug Synthesis**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied Pharmaceutical Chemistry courses at M.Sc. Part-I.

Course Objective:	5.To apply the knowledge gained in organic synthesis for making new molecules. 6.To understand various strategies involved in retrosynthesis of organic molecules 7.To understand the concepts of heterocyclic chemistry in drug designing 8.To be able to propose routes for synthesis of heterocycles
Course Outcome:	5.Students will be in a position to understand how a carbon-carbon bond can be constructed and/or cleaved 6.Students will be in a position to understand how retrosynthesis can be used in finding out easily available chemical precursors for making molecules 7.Students will be in a position to apply retrosynthetic strategies and propose routes for synthesis of containing heterocycles 8.Students will be able to understand and apply the concepts of the reactivityof heterocycles towards electrophilic, nucleophilic, reducing and oxidizing reagents. 9.Students will be able to apply this knowledge for their dissertation work.

Content	*Hours*
1. Synthon approach and retrosynthetic applications a. Basic principles, terminologies and advantages of retrosynthesis; guidelines for dissection of molecules. Functional group interconvertion and addition (FGI and FGA) b. C-X disconnections; C-C disconnections – alcohols and carbonyl compounds; 1,2-, 1,3-,1,4-, 1,5-, 1,6-difunctionalized compounds c. Strategies for synthesis of three, four, five and six-membered ring.(*General review problems to be discussed for above approaches*)	12
2. Disconnection strategies a. Disconnection of heteroatom and heterocyclic compounds such as ethers, amines, heterocycles, amino acids b. Convergent and divergent synthesis c. Strategic devices for carbon-heteroatom bonds, polycyclic compounds: the common atom approach d. Considering all possible disconnections e. Alternative FGI's before disconnection- the cost of synthesis f. Features which dominate strategy, functional group addition and molecules with unrelated functional groups	12
3. Protecting groups a. Role of protection in organic synthesis b. Protection for the hydroxyl group, including 1,2-and1,3-diols: as ethers, esters, carbonates, cyclic acetals & ketals c. Protection for the carbonyl group: as acetals and ketals d. Protection for the carboxyl group: as amides and hydrazides, esters e. Protection for the amino group: as carbamates and amides.	12
4. Heterocyclic Chemistry: Introduction, classification and nomenclature of mono- and bicyclic heteroaromatic molecules. Organic Name reactions with their respective mechanism and application involved in synthesis of drugs containing five, six membered and fused heterocyclics such as Debus-Radziszewski imidazole synthesis, Knorr Pyrazole Synthesis Pinner Pyrimidine Synthesis, CombesQuinoline Synthesis, BernthsenAcridine Synthesis, Smiles rearrangement and Traube purine synthesis.	12
5. Synthesis of representative drugs with retrosynthetic approach	

Retrosynthetic approach and synthesis of few representative drugs containing these heterocyclic nucleus such as Metronidazole, Miconazole, Celecoxib, Alprazolam, Triamterene, Sulfamerazine, Trimethoprim, Hydroxychloroquine, Quinacrine, Prochlorpherazine, Chlorpromazine,Theophylline, Mercaptopurine and Thioguanine.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. S. Warren, *Designing Organic Synthesis*, John Wiley & Sons, 2009. 2. G. S. Zweifel, M. H. Nantz, P. Somfai, Modern *Organic Synthesis: An Introduction*, 3rd Ed. W. H. Freeman and Company, New York, 2022. 3. J. Clayden, N. Greeves & S. Warren, *Organic Chemistry*, Oxford, 2016. 4. J. A. Joule, K. Mills & G. F. Smith, *Heterocyclic Chemistry*, 3rd Ed., Wiley-Blackwell, 1995. 5. J. A. Joule & K. Mills, *Heterocyclic Chemistry*, 5th Ed., Wiley-Blackwell, 2010. 6. T. L. Gilchrist, *Heterocyclic Chemistry*, Pitman Publishing, 2005. 7. R. M. Acheson, *An Introduction to Chemistry of Heterocyclic Compounds*, 3rd Ed., John Wiley and Sons, 1977. 8. D. W. Young, *Heterocyclic Chemistry*, Longman Group Ltd., London, 1975. 9. A. Weissberger & E. Taylor, *Chemistry of Heterocyclic Compounds*,Vol.47,Wiley Publishers, 1987. 10. A. R. Katritzky, *Advances in Heterocyclic Chemistry*, 1st Ed., Academic Press Inc., Vol.47,1990. 11. R. O. C. Norman and J. M. Coxon. *Principles of Organic Synthesis*, 3rd Ed., CRC Press, 2009. 12. Stephen R Wilson & Anthony W Czarnik, *Combinational Chemistry – Synthesis and applications*, Wiley – Blackwell, 1997. 13.V.K Ahluwalia and R. Agarwal, *Organic Synthesis - Special Techniques,* Narosa Publishers, 2001. 14. D. Shriram, P. Yogeshwari, Medicinal Chemistry, Pearson Education, 2007. 15. D. Lednicer& L.A. Mitcher*Organic Chemistry of Drug Synthesis* Vol. I to III. John Wiley & Sons, 2005. 16. Drug Preparation Database.http://www.drugfuture.com/synth/synth_query.asp

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHHR-514**
Title of the course: **Pharmacological and Toxicological Screening Techniques**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied Pharmaceutical Chemistry courses at M.Sc. Part-I.
Course Objective:	1. To learn screening methods of biological assay. 2. To learn terms involved in toxicology. 3. To learn methods of analysis for toxicology

Course Outcome:	1.Students will be able to apply the role of various screening methods in bioassay. 2.Students will be able to create various in vivo and in vitro assay methods for various targets. 3. Students will be able to evaluate various effects of toxins. 4. Students will be able to analyse the safety aspects in pharmaceuticals 5. Students will be able to apply this knowledge for their dissertation work.

Content	*Hours*
1. Laboratory Animals, Principles of Biological Standardisation, Screening methods a. Introduction to pharmacological research. Animal ethics, regulations for conducting animal experimentation. Common laboratory animals: Description, handling and applications of different species and strains of animals. Transgenic animals: Production, maintenance and applications Anaesthesia and euthanasia of experimental animals. Maintenance and breeding of laboratory animals. CPCSEA guidelines to conduct experiments on animals Good laboratory practice. b. Statistical treatment of model problems in evaluation of drugs-methods of biological assay, principles of biological assays-methods used in bioassay of vitamins, hormones, vaccines, cardiac drugs and other pharmacopeial preparations. c. Zebrafish model to screen pharmaceutical molecules Organisation of Screening for the pharmacological activity of new substances. Anti-inflammatory agents-carrageenan induced paw oedema, cotton pellet method. Anticonvulsants: Convulsions induced by chemicals, induced by electroshock, combined procedures. Sympathomimetic agents: Mydriasis, the uterus and ascending colon of the rat.	20
2. Introduction to Toxicology: Definition and types of toxicology, Basic principles of toxicology, Carcinogenicity, mutagenicity, teratogenicity, acute, sub acute and chronic toxicity. Detailed toxicity(mild/moderate/severe toxicology wherever applicable) and treatment of drugs such as salicylates/ paracetamol, opium, quinine, ethyl alcohol, etc. Toxic chemicals in the environment, impact of toxic chemicals on enzymes. Biochemical effects of arsenic, lead mercury, cadmium, carbon monoxide, pesticides and carcinogens	12
3. Essentials of Analytical Toxicology Physicochemical, biochemical & genetic basis of toxicity; Principles of toxicokinetics, mutagenesis and carcinogenesis – Behavioural, inhalation toxicity, hypersensitivity and immune response, range finding tests – Acute, subacute and chronic toxicity studies. Classification of Toxins: Acute toxicity tests, Determination of LD50 value, Subacute tests - Histopathological and biochemical estimations on toxicity induced in animal models – Modern methods of analysis for Toxins-Barbiturate poisoning, Amphetamine poisoning.	12

4. Safety aspects in pharmacological studies Preclinical toxicological requirements for biological and biotechnological products: Safety analysis; problems specific to recombinant products secondary pharmacology. Safety Pharmacology - ICH S7 and S7B guidelines. Safety pharmacological studies for pharmaceuticals. Safety pharmacological studies for biological products.	8
5. Applications of Toxicology Clinical Toxicology, Environmental Toxicology/ Ecotoxicology Forensic Toxicology/ Post-mortem, Toxicology Industrial/Occupational Toxicology. Food Toxicology Behavioural toxicology Preventive toxicology Descriptive Toxicology Mechanistic Toxicology Regulatory Toxicology Genetic Toxicology Systemic Toxicology.	8

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	15. S.K. Gupta, Uma Singh and T. Velpandian, *Analytical Toxicology for Poisoning Management and Toxicovigilance*, Varosa Publishing House, 2002. 16. E.G.C.Clarke, *Isolation and Identification of Drugs, Body Fluids and Post-mortem Material.*The Pharmaceutical Press, 1986. 17. A.K. De, *Environment Chemistry*, Wiley Eastern Ltd., New Delhi, 2003. 18. R.K. Trivedi& P.K. Goel, *Chemical and Biological Methods for Water, Pollution Studies*, Environment Publications, Karad (India), 1984. 19. B. K. Sharma*, Industrial Chemistry,*1st Ed., Narosa Publishing House,1998. 20. W. Andrew, *Pharmaceutical Manufacturing Encyclopaedia Vol I and II*, 3rd Ed., William Andrew Publishing, 2007. 21. R.A. Turner,P.Hebborn, *Screening Methods in Pharmacology, Vol.-1 &2*, Elsevier Science & Technology Books, 1971. 22. H. G. Vogel & W. H. Vogel, *Drug Discovery and Evaluation*,Springer, 2006. 23. S.K. Kulkarni, *Handbook of Experimental Pharmacology*, VallabhPrakashan, Delhi, 1993. 24. R.S. Satoskar& S.D. Bhandarkar, *Pharmacology andPharmacotherapeutics*, Popular Prakashan Ltd, 2006. 25. Louis S. Goodman & Alfred Gillman, *The Pharmacology Basis of Therapeutics*, McGraw-Hill Professional Publishing, 2010. 26. H.P. Rang & M.A. Dale, *Pharmacology*, Elsevier – Health Sciences Division, 2011. 27. CPCSEA guidelines (http://cpcsea.nic.in)

Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHHR-515**
Title of the course: **Pilot Plant Scale-Up Techniques for Pharmaceuticals**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.

Course Objective:	1. To understand the various Pilot Plant scale-up techniques as adopted for industrial processes. 2. To examine Pilot Plant formula to determine its ability to with stand Batch-scale and process modification 3. To learn unit processes involving various chemical reactions. 4. To learn industrial synthesis of selected list of drugs. 5. To learn the need for pilot plant in industry and also the flowchart on various manufacturing methods of drugs.
Course Outcome:	1.Students will be able to explain unit processes for various organic chemical reactions. 2.Students will be able to apply industrial synthesis knowledge for the synthesis of drug like molecules in laboratory. 3.Students will be able to apply the knowledge of waste effluent treatment methods. 4.Students will be able to apply the knowledge of pilot plant scale-up techniques in industry.

Content	*Hours*
1. Introduction to Pilot Plant: Definition, objectives and significance of Pilot Plant. Need to conduct Pilot Plant studies. Uses of Pilot Plant Scale-Up. Several considerations in Pilot Plant scale up activities in R and D development Scale up process. The layout of the relationship between different activities during technology transfers from the pilot plant to the production facility. Future developments. The layout of the relationship between different activities during technology transfers from the pilot plant to the production facility. Limitations of pilot plant.	10
2. Unit processes for various chemical reaction types for pilot plant: Concept of unit processes in systematization of chemicalreactions, explanation of one example each for unit processes:Alkylation, amination, (by ammonolysis, reduction), carbonylation,carboxylation, condensation, dehydration, diazotization, disproportionation, esterification, halogenation, hydration,hydroformylation, hydrogenation, hydrolysis, hydroxylation,nitration, oxidation and reduction.	10
3. Industrial Synthesis: Introduction to pharmaceutical manufacturing – raw materials, detailed manufacturing procedure, therapeutic function, commonname, chemical name, structural formulae of the following drugs:Acyclovir, alprazolam, propanolol, naproxen, ibuprofen, aspirin,levodopa and cimetidine, lidocaine, ethambutol hydrochloride, 5-fluorouracil, amoxycillin sodium.	12
4.General Considerationsfor Pilot Plant scale up process: Reporting Responsibility: Space requirements, Personnel requirements, Training, Review of the Formula, Raw Materials, Relevant processing equipment, process rate and evaluation, Preparation of Master Manufacturing Procedure, GMP Consideration-advantages and disadvantages, Transfer of Analytical Methods to Quality Assurance, Pilot plant scale up considerations for solids.	10
5. Pilot Plant Scale Up considerations for solids, oral liquids and semi-solids.	12

Layout of pilot plant, Stages of Production of Tablets, Material handling, Dry blending, Granulation, Drying, Reduction of particle size, Blending, Direct compression, Slugging (dry granulation techniques). Process evaluation. Master Manufacturing Procedures, Product, stability, and uniformity. Good Manufacturing practices. Flow chart on Pilot plant process scale-up.Steps of liquid manufacturing process, Critical aspects of liquid manufacturing, solution, suspension, emulsions. Pilot plant scale up considerations for semi-solids.Contract manufacturing: Scope and limitations	
6. SUPAC (Scale Up and Post-approval changes guidelines) and Platform Technology: The SUPAC Guidelines define, the components or composition changes, The site changes of manufacture, Changes in Batch Size (Scale-Up/Scale-Down), Manufacturing Changes. Introduction to platform technology:Pharmaceutical Platform technologies, Importance platform technology, Types of platform technology.	6
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations /industry visits/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. Levin M. *Pharmaceutical Process Scale-Up*. New York: Marcel Dekker, Inc..2001. 2. Groggins, *Unit processes in Chemical Engineering*, 1st Ed., McGraw-Hill, 1958. 3. Drydens, *Unit processes in chemical engineering*, McGraw-Hill Higher Education, 2004. 4. William Andrew, *Pharmaceutical Manufacturing Encyclopedia Vol.I& II*., 3rd Ed William Andrew, 2007, 5. W.W.M. Wenland, *Thermal Analysis*, 2nd Ed., John Willey & Sons, New York, 1974, 6. S.B. Chandalia, *Hand Book of Process Development*, Multitech Publishing Company, Mumbai, 1998. 7. K. G. Gadamasetti, *Process Chemistry in PharmaceuticalIndustries*, 1st Ed., Taylor & Francis Group, 1999. 8. Shreve's, *Chemical Process Industries*, 5th Ed., McGraw Hill Book Company, 2000. 9. M.V. Krishnan, *Safety Management in Industries*, Jaico Publishers, Mumbai, 2002. 10. R. K. Khar, S.P. Vyas, F. J. Ahmad, G.K. Jain, *Industrial Pharmacy*. 4th Ed., New Delhi: CBS Publishers & Distributors Pvt Ltd, 2013. pp. 947-1002. 11. V.P. Shah, J.P. Skelly, W.H. Barr, H. Malinowski, G.L. Amidon. *Scale-up of Controlled ReleaseProducts - Preliminary Considerations*. Pharm Technol1992; 16(5):35-40. 12. N.V.N. Mounica, R.V. Sharmila, S. Anusha, L. Evangeline, M. V. Nagabhushanam, D. Nagarjunareddy. *Scale up and Postapproval changes (SUPAC) Guidance for Industry: A Regulatory note*. Int J Drug Regul. Aff., 2017; 5(1): 13-19. 13. L. Lachman, H. A. Lieberman, J. L.Kanig: *The Theory and Practice ofIndustrial Pharmacy: Section IV: Chapter 23:Pilot Plant Scale-Up Techniques:* 3rd edition,Varghese Publishing house, 2009; 681-710.

	14. J. Swarbrick, J. C.Boylan: *Encyclopedia of Pharmaceutical Technology: PilotPlant Design, Volume 12* New York, 2001; 171-186. 15. Leon Lachman, Herbert A. Lieberman, Joseph B. Schwartz: *Pharmaceutical dosageforms: Tablets. Volume 3*,2nd edition. 2001, 303-365. 16. J. P. Sitompul, H.W. Lee, Y. C. Kim &W. Mathew, A. Chang: *Scaling-up Synthesis from Laboratory Scale toPilot Scale and to near Commercial Scalefor Paste-Glue Production,* J. of Eng. and Tech. Sci. 2013; 45(1): 9-24. 17. J. W. Zawistowski, A.I.A. and J.D. Rago, *Pilot Plant Scale-Up Facilities:Establishing the Basis for a Design*, J. of Pharm. eng.july/august. 1994, 24-32.

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Programme: **M. Sc. Part-II (Chemistry)**
Course Code: **CHHG-511**
Title of the Course: **Polymers in Pharmaceuticals and novel drug delivery systems**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.
Course Objective:	1. To learn classification synthesis and properties of polymers. 2.To learn the role of polymers in drug delivery systems. 3.To learn new innovations in drug delivery systems
Course Outcome:	1. Students will be able to identify the type of polymers that canbe used for drug delivery systems. 2.Students will be able to get the knowledge of innovative drugdelivery systems and apply it for their lab project.

Content:	*Hours*
1. Brief history of natural and synthetic polymers Classification & nomenclature of polymers, functionality concept- linear, -branched and -cross linked polymers. Introduction to biodegradable polymers:General methods of synthesis, properties, mechanism of biodegradation in the body.Analytical methods for monitoring biodegradation processes of environmentally degradable polymers. Characterization and evaluation of biodegradable polymers.	8
2. Introduction to Novel drug delivery systems Foundations of drug delivery in a conceptual and mathematical context. Drug delivery carriers, routes of administration. Recent developments in responsive polymers, polymer therapeutics, and advanced systems designed for molecular recognition or engineered for intracellular delivery of novel therapeutics. Polymeric devices for drug delivery systems: Diffusion-controlled (monolithic devices), solvent-activated (swelling- or osmotically-controlled devices), chemically controlled (biodegradable), or externally-triggered systems (e.g., pH, temperature).	10
3. Types of polymersfor novel drug delivery systems	8

Poly lactic-co-glycolic acid (PLGA), PGA(poly glycolic acid), Polyglutamic acid (PGA) , Polylactic acid, PNIPAAm [Poly(N-isopropylacrylamide)], pHEMA[Poly 2-hydroxyethyl methacrylate], PPy [Polypyrrole], PAMAM [Poly (amidoamine)], DEXTRAN.	
4. Types of drug delivery systems Theory of controlled release drug delivery systems. Microencapsulation – Methods of encapsulation. Transdermal drug delivery systems – Theory, formulation, production and evaluation. Targeted drug delivery systems – concept of drug targeting, importance in therapeutics.	8
5.Advanced biopolymeric systems for drug delivery Critical Points in Biopolymeric-Controlled Release Matrix Systems, Biopolymeric Gels in Drug Delivery, In Situ Polymeric Gels for Topical Drug Delivery, Smart Polysaccharide Hydrogels in Drug Delivery and Release, Polysaccharide-Based Nanoparticles: Nanocarriers for Sustained Delivery of Drugs, Polysaccharide-Based Nanocarriers for Oral Delivery of Insulin in DiabetesLiposomes and Dendrimers for Advanced Drug Delivery, Marine Polysaccharides Systems for Drug Delivery applications.	14
6.Recent Innovations in polymeric drug delivery systems and its applications Recent innovations in conventional dosage form like tablets, capsules, sterile dosage forms, pellets, Mucoadhesive system, GRDDS, peptide drug delivery, supercritical fluid technique, PEGylation, Nanoparticulate drug delivery. Sustained In Vitro and In Vivo Delivery of Metformin from Plant Pollen-Derived Composite MicrocapsulesPolymeric Hydrogels for Controlled Drug Delivery to Treat ArthritisAdvancements in Rectal Drug Delivery Systems: Clinical Trials, and Patents Perspective.Future opportunities and challenges.	12

Pedagogy	Lectures/ tutorials/ project work/ industry visits/viva/seminars/ term papers/assignments/ presentations/ self-study/Case Studies etc. or a combination of some of these. Sessionshall be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. V. R. Gowarikar, N.V. Vishwanathan, J. Sreedhar, *Polymer Science*, New Age International, 2015. 2. J. R. Fried, *Polymer Science and Technology*, PHI Pvt. Ltd.,2000. 3. R. Sinha*, Outlines of Polymer Technology: Manufacture of Polymers*, PHI Pvt Ltd., 2000. 4. K. Y. Saunders, *Organic Polymer Chemistry*, Chapman and Hall, UK, 1976. 5. H. R. Kircheldorf, *Handbook of Polymer Synthesis, PART Aand B,* Marcel Dekkar Inc., 1992. 6. R. P. Brown, *Handbook of Plastic Test Methods,* 2nd Ed.,George Godwin Ltd., 1981. 7. M. P. Stevens, *Polymer Chemistry- An Introduction*, 2nd Ed., Oxford Univ. Press, 1990. 8. W. Y. Mijs, *New Methods in Polymer Synthesis*, PelnumPress Ltd., NY, 1992. 9. M. Arora, *Polymer Chemistry,* Anmol Publications 2001. 10. C. E. Carraher, *Polymer Chemistry,* New York M. Dekker 2005. 11. P.C. Hiemenz, Polymer Chemistry, CRC Press, 2007. 12. V. K. Selvaraj, *Advanced Polymer Chemistry*, New Delhi Campus books, CRC Press, 2008. 13. A. Ravve, *Principles of polymer Chemistry,* Springer 2012.

	14. J. David ,*Polymers,* Oxford University Press 2015. 15. U.S. Beans, A.K. Beckett & J.E. Caralem, *Advances in Pharm Sci*,Vol 1-4, Elsevier, 2009. 16. G.S. Banker, *Modern Pharmaceutics*, Dekker Incorporated, Marcel, 2002. 17. L.Lliun& S. S. Davis, *Polymer in Controlled Drugs Delivery*, Wright, Bristol, 1987. 18. J. R.Crompton, *Analysis of Polymer- An Introduction*, Pergamon Press, Oxford, 1989. 19. M. P. Steven, *Polymer Chemistry An Introduction*, New York, Oxford, Oxford University Press, 1990. 20. M. Charin, *Biodegradable Polymers as Drug Delivery Systems*, Informa HealthCare, 1990. 21. A.H. Beckett &J. B. Stenlake, *Practical Pharmaceutical Chemistry Vol I &II*, CBS Publishers, 2005. 22. P. J. Sinko, M*artin's Physical Pharmacy andPharmaceutical Sciences*, 6th Ed.,Lippincott William and Wilkins, 2006. 23. S.J. Carter, Cooper and Gunn's *Tutorial Pharmacy*, 6th Ed., CBS Publisher Ltd, 2008. 24. Indian Pharmacopoeia, British Pharmacopoeia. 25. J.R. Robinson & Vincent H.L. Lee, *Controlled Drug Delivery, Drugs and Pharm. Sci. Series*, Vol. 29, Marcel Dekker Inc. N.Y, 987. 26. J.R. Juliano, *Drug Delivery Systems*, Oxford University Press, Oxford, 1980. 27. M.I. Gutcho, *Microcapsules and Microencapsulation Techniques*, Noyes Data Corporation, 1976. 28. A. Lendlein&A. Sisson, *Handbook of Biodegradable Polymers: Isolation, Synthesis, Characterization and Applications*, 1st Ed., Wiley Publishers, 2011. 29. V. V. Ranade & J. B. Cannon, *Drug Delivery Systems*, 3rd Ed., CRC Press, 2011. 30. A.K. Nayak & Md. S. Hasnain,*Advanced Biopolymeric Systems for Drug Delivery*, 1st Ed., Springers, 2020. 31. V.A. Guerrera, *Innovative Polymers for controlled drug delivery*, *Pharmaceutics*, 1st Ed., Vol.14, Multidisciplinary Digital Publishing Institute, 2022.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHHG-512**
Title of the course: **Pharmacotherapeutics**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.
Course Objective:	1. To enable the students to understand the different approaches to treat and manage various disease conditions. 2. To impart knowledge and skills in optimizing drug therapy of a patient by personalizing the treatment. 3. To summarize the therapeutic approach for management of various diseases.

	4. To explain the rationale for drug therapy andplan through evidence-based medicines.
Course Outcome:	1. Students will be able to discuss the clinical controversies in drug therapy. 2. Students will be able to identify the patient specific parameters relevant in initiating drug. 3. Students will be able to prepare individualized therapeutic plans based on diagnosis, medicine therapy, and monitoring therapy.

Content	*Hours*
1. Diseases of central nervous system: Epilepsy, Parkinson's disease, Stroke, Headache, Alzheimer's disease, Neuralgias and Pain pathways and Pain management. Psychiatric disorders: Schizophrenia, Depression, Anxiety disorders, Sleep disorders, drug induced psychiatric disorders.	10
2. Infectious diseases: General guidelines for the rational use of antibiotics and surgical prophylaxis, urinary tract infections, respiratory tract infections, Gastroenteritis, tuberculosis, malaria, bacterial endocarditis, septicemia. meningitis, HIV and opportunistic infections, rheumatic fever, dengue fever, H1N1, helmenthiasis, fungal infections. Neglected tropical diseases: leishmaniasis, schistosomiasis, chagas, sleeping sickness.	10
3. Diseases of cardiovascular and respiratory system: Hypertension, Congestive cardiac failure, Acute coronary syndrome, Arrhythmias, Hyperlipidemias, Asthma, Chronic obstructive airways disease, Drug induced pulmonary diseases.	10
4. Diseases of gastrointestinal system: Peptic ulcer diseases, Reflux esophagitis, Inflammatory bowel diseases, Jaundice & hepatitis, Cirrhosis, Diarrhea and Constipation, Drug-induced liver disease.	10
5.Oncologicaldisorders: General principles of cancer chemotherapy, pharmacotherapy of breast cancer, lung cancer, head & neck cancer, hematological malignancies, management of nausea and vomiting, Palliative care.	8
6. Other Diseases Bone and joint disorders: Rheumatoid arthritis, osteoarthritis, gout, osteoporosis. Dermatological Diseases: Psoriasis, eczema and scabies, impetigo, drug induced skin disorders. Ophthalmology: Conjunctivitis, glaucoma. Diseases of renal system: Acute renal failure, chronic renal failure, renal dialysis, drug induced renal disease.Gynaecological disorders: Dysmenorrhea, hormone replacement therapy. Endocrine system: Diabetes Mellitus, thyroid diseases. Hematological diseases: Anaemia, deep vein thrombosis, drug induced hematological disorders.	12

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. R.Walker.*Clinical Pharmacy and Therapeutics*,5thEd., Churchill Livingstone publication, 2012. 2. J. DiPiro, *Pharmacotherapy: A Pathophysiologic Approach*, 7thEd., McGraw Hill Publishers 2008. 3. S.L.Robins,*Pathologicbasis of disease*., 9thEd.,W.B. Saunderspublication 2014.

	4. E. T. Herfindal. *Clinical Pharmacy and Therapeutics*, 3rdEd.,Lippincott Williams and Wilkins Publication,1984. 5. L.Young andM.A. Koda-Kimble,*Applied Therapeutics: The clinical Use of Drugs*, 9th Ed.,Lippincott Williams and Wilkins, 2008. 6. C.B. Wells, S. Malone andJ. P.Dipiro. *Pharmacotherapy Principles and practice*, 4thEd.,McGraw HillPublication. 2016. 7. C. M. Porth.*Principles of Pathophysiology,* 3rdEd.,Lippincott Williams and Wilkins Publications, 2010. 8. Harrison's *Principles of Internal Medicin*e. (Vol1 and 2), 20thEd.,McGraw Hill Publications, 2018. 9. **R.Mannhold&H.Buschmann, *Neglected Tropical Diseases Drug Discovery and Development*, Vol 37, John Wiley and Sons, 2019.** **10.** P. Hotez, ***Neglected Tropical Diseases,* Vol 1-5(book series), Springers, 2022.**

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHHG-513**
Title of the course:**API Process, Manufacture and Green Chemistry**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course:	Should have studied courses at M.Sc. Part-I.
Course Objective:	1. To learn about the selected drugs. 2. To learn about the role of process chemistry. 3. To understand the process research and development of PenicillinG CAS and Rabeprazole CAS 4. To understand the drug optimization and drug discovery. 5. To understand various concepts involved in green synthesis. 6. To understand green technologies used in chemistry. 7. To learn application of green chemistry approaches to pharmaceutical industry.
Course Outcome:	1. Students will be able toacquire knowledge about the Top drugs. 2. Students will be to learn about the role of process chemistry and understand the Process research and development of PenicillinG CAS and Rabeprazole CAS 3. Students will be able to understand the drug optimization and drug discovery. 4. Students will be in a position to understand how chemistry can be done using greener alternatives. 5. Students will be able to apply green technologies as a sustainable solution for making drug molecules. 6. Students will be able to understand and apply the concepts of green chemistry to develop scalable processes in industry.

Content	*Hours*
1.Process chemistry in pharmaceutical industry – Background of process chemistry – role of process chemistry. Strategy of process research & development in pharma industry. Case studies: A practical synthesis of Ifetroban sodium. Synthesis of 5-lipoxygenase inhibitors Chemistry of Vitamin D: A challenging field for process researchDilevalol Hydrochloride: Development of a	

commercial processThe process research and development of DuPont Merck's cyclic urea diols, a new class of HIV protease inhibitors.Process research and development of PenicillinG CAS Reg. No.[61-33-6] (antibacterial); Fosinopril CAS Reg. No.[98048-97-6](antihypertensive) ; Combinatorial chemistry: Introduction – Drug Optimization – Drug discovery – Solid Phase Technique – parallel synthesis – Mixed Combinatorial Synthesis.	12
2.Biocatalysis, phase transfer catalysis, asymmetric synthesis and polymorphism: Biocatalysis and Engineering: An interdisciplinary approach to the manufacture of the Benzodiazepine drug candidate LY 300164. Application of phase transfer catalysis technology in pharmaceutical industry for drug synthesis. Asymmetric Synthesis and Enantioselectivity: Enantioselective synthesis of chiral 2-hydroxycarboxylic acids and esters – asymmetric catalysis – eg. asymmetric hydrogenation – L-Dopa process ;Sharpless asymmetric epoxidationseg. synthesis of Fluoxetine enantiomers. Chiral (Salen)Mn(III) Complexes in asymmetric epoxidations: Practical Synthesis of cis-Aminoindanol and its application to enantiopure drug synthesis. Practical Enantio- and Diastereo-selective Processes for Azetidinones. Polymorphism – solid state – crystallization – recrystallization of drug molecules eg. isolation techniques and characterization of polymorphs of Venlafaxine hydrochloride[99300-78-4] Clopidogrelbisulphate [135046-48-9] and Lorazepam[846- 49-1] (any two).	12
3.Chemical Process safety norms: Concept of Green Chemistry, its 12 principles and Green Chemistry Metrics. Introduction, industrial disasters of the world, definition of green chemistry, twelve green principles, Need for green chemistry in pharmaceuticals, green chemistry for better sustainability. Green Chemistry metrics for measuring greenness (E-factor, atom economy, mass intensity, process mass intensity, process mass efficiency, chemical yield). Waste prevention, management andhierarchy. Atom Economy: Calculation and predicting greenness of a reaction. Comparison of Diels Alder reaction and Wittig Reaction. Addition v/s Elimination v/s Substitution. Less hazardous chemical synthesis: Avoiding use of hazardous substances for any synthesis (Thiamine hydrochloride to be preferred over KCN for benzoin condensation). Role of chirality in the need for designing safer chemicals with illustration of Thalidomide.	8
4. Safer solvents in chemistry. Knoevenagel condensation by grinding method. Advantages and disadvantages of solvent-free reaction. Water as green solvent in organic synthesis (Diels Alder Reaction). In water and on water mechanisms. Ionic liquids as designer solvents with one application. Supercritical solvents and their application in extractions. Deep Eutectic solvent (DES) with example and one application. Fluorous solvents and biphasic extraction.	8
5. Emerging greener technologies for energy efficiency and catalysis Organic synthesis at ambient temperature and pressure, photochemical reactions as green process (advantages). Microwave assisted organic synthesis: Principle and applications. Sonochemistry as a sustainable alternative for organic synthesis, giving examples. Electrifying organic synthesis in designing new target molecules.	10

Continuous flow synthesis as a sustainable technology for pharmaceutical industry. Impact of continuous flow chemistry in the synthesis of natural products and active pharmaceutical ingredients. Recent examples of green chemistry articles of interest to the pharmaceutical industry: C-H activation, green fluorination, continuous processing and process intensification.	
6. Green Synthesis of representative drugs Multicomponent synthesis: Ugi, Biginelli, Passerni, Mannich, Strecker. One-Pot Synthesis of (S)-Baclofen.Synthesis of Ibuprofen, Boots (conventional) and green synthesis. Comparison and atom economy. Green synthesis of Paracetamol, Aspirin, Celecoxib, Sildenafil citrate, Sertraline, Artemisinin, Paroxetine, Pregabalin, Imatinib, Simvastatin, Quinapril HCl.	10
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / industry visits/field trips/self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. M. Lancaster, *Green Chemistry*, The Royal Society of Chemistry, Cambridge,UK, 2002. 2. V. K. Ahluwalia, *Green Chemistry: Environmentally Benign Reactions*, Ane Books India, New Delhi, 2006. 3. A. S. Matlack, *Introduction to Green Chemistry*, Marcel Dekker, Inc., New York, 2001. 4. P. T. Anastas and T. C. Williamson, *Green Chemistry: Frontiers in benign chemical synthesis and processes*, Oxford University Press, Oxford, Eds. 1998. 5. R. Sanghi and M. M. Srivastava, *Green Chemistry: Environment Friendly Alternatives*, Narosa Publishing House, Eds. New Delhi, 2007. 6. Samuel Delvin, *Green Chemistry*, IVY Publishing House, Delhi, 2006. 7. V. K. Ahluwalia and M. Kidwai, *New Trends in Green Chemistry*, 1st Ed., Anamaya Publishers, New Delhi, 2004. 8. P. G. Jessop and W. Leitner, *Chemical Synthesis using Supercritical fluids*, Wiley – VCH, Verlag, (Eds., Weinheim, 1999. 9. K. Tanaka, *Solvent Free Organic Synthesis*, 2nd Ed., Wiley – VCH GmbH and Co. KgaA, Weinheim, 2003. 10. P. T. Anastas and J. C. Warner, *Green Chemistry, Theory and Practice*, Oxford University Press, N. York, 1998. 11. C - Jun Li and T – Hang Chan, *Organic Reactions in Aqueous Media*, John Wiley and Sons INC., N. York, 2001. 12. F. Z. Dorwald, *Organic Synthesis on Solid Phase*, Wiley – VCH Verlag, Weinheim, 2002. 13. P. Wasserscheid and T. Welton, *Ionic Liquids in Synthesis*, Wiley – VCH Verlag, Ed., Weinheim, 2003. 14. A. Loupy, *Microwaves in Organic Synthesis*, Wiley – VCH Verlag, Weinheim, 2002. 15. R. V. Eldik and F. G. Klarner, *High Pressure Chemistry*, , Wiley – VCH Verlag, Weinheim, 2002. 16. R. Hilfiker, *Polymorphism in Pharmaceutical industry*, Wiley-VCH, 2006. 17. H. G.Brittain, *Polymorphism in Pharmaceutical solids*, 2nd Ed.,CRC Press, 1998. 18. C. Starks, C. Liotta, M. Halpern, "*Phase-Transfer Catalysis: Fundamentals, Applications and Industrial Perspectives*," Chapter 16, Chapman & Hall, New York,1994.

	19. A. Kumar&A. Anjali, *Adoption of green methodology in industry for the synthesis of sildenafil citrate and Celecoxib: case study*.Volume 60, Part 2, 2022, Pages 1021-1025. 20. P. J. Harrington, *Pharmaceutical Process Chemistry for Synthesis: Rethinking the Routes to Scale-Up*, Wiley Publishers, 2011. 21. J. M.DeSouza, R.Galaverna, A. A. N. De Souza, T. J. Brocksom, J. C. Pastre, R.M.A. De Souza &K. T. De Oliveira.*Impact of continuous flow chemistry in the synthesis of natural products and active pharmaceutical ingredients*, Anais da Academia Brasileira de Ciências,2018, 90(1 Suppl. 2): 1131-1174. 22. F. Fanelli, G.Parisi, L.Degennaro& R. Luisi,*Contribution of microreactor technology and flow chemistry to the development of green and sustainable synthesis*,Beilstein J. Org. Chem. 2017, 13, 520–542. 23. E. Yu, H. P. R. Mangunuru, N.l S. Telang, C. J. Kong, J.Verghese,S. E. Gilliland , S. Ahmad, R. N. Dominey& B. F.Gupton, Beilstein , *High-yielding continuous-flow synthesis of antimalarial drug hydroxychloroquine*, J. Org. Chem. 2018, 14, 583–592. 24. R. Porta, M.Benaglia, & A. Puglisi. *Flow Chemistry: Recent Developments in the Synthesis of Pharmaceutical Products.* Org. Process Res. Dev*. 2016, 20, 2−25.* 25. K. G. Gadamasetti, *Process chemistry in the pharmaceutical industry*, 1st Ed., Taylor and Francis, 1999. 26. K. G. Gadamasetti, *Process chemistry in the pharmaceutical industry: Challenges in an everchanging climate*, 2nd Ed., Taylor and Francis, 2019.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHHG-514**
Title of the course: **Pharmaceutical and Spectral Analysis**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.
Course Objective:	1. To study the advanced pharmaceutical analytical techniques. 2. To acquire the knowledge of theory and practical skills of instruments. 3. To understand and interpret the spectral data.
Course Outcome:	1. Students will be able understand various pharmaceutical analytical techniques. 2. Students will be able to apply this knowledge to various pharmaceutical industries. 3. Students will be able to explain all characterization techniques for pharmaceutical products. 4. Students will be able to analyse spectral data.

Content	*Hours*
1. Introduction to pharmaceutical analysis and techniques: Scope and range of modern pharmaceutical analysis. Listing of various pharmaceutical analytical techniques, with broad discussion on their instrumentation, working and pharmaceutical applications:HPLC, GC, HPTLC, DSC-DTA, XRD. Material and product specifications: Definition of specifications, study of ICH Q6 guidelines and understanding of specifications through study of pharmacopoeial monographs on drug substances and products. Reference standards used: Types (primary,	10

secondary, working and test standards), preparation, containers, labelling, storage and use. Documentation of analytical data-STPs, certificate of analysis, laboratory books: Typical documents used in a GLP laboratory including standard test protocols, COA and laboratory notebooks. Electronic records & signatures (21CFR Part-11 requirement)	
2. Calibration and Validation: Method validation: Definition and methodology, discussion on each parameter with examples, special considerations in bioanalytical method validation. Calibration and qualification of equipment: Difference of definitions, calibration standards, calibration frequency, examples of calibration of pH meter, potentiometer, Flame photometer, FTIR, UV spectrophotometer and HPLC. Definition of qualification process involving URS [user requirement specification], DQ, IQ, OQ, CQ and PQ.	10
3. Quality and risk management in analytical laboratory: Definition of quality risk management in ICH Q9 guideline. Its importance and application to analytical laboratory with examples. Quality of analysis by design. Impurity profiling: Types of impurities in drug substances and products. Method development for impurity analysis, techniques, identification and quantization. Management of analytical laboratory: Organization of laboratories based on their types, staffing, skill development and training, budgeting and financing, purchase of costly equipment, qualities of laboratory manager and management styles. Laboratory inspections and audit: Internal inspection, external audit, concepts, preparing for inspections and audits.	8
4. Spectral Analysis-I **i) Ultra Violet (UV)-visible spectroscopy and its pharmaceutical applications**: a) Electronic excitations, Beer Lamberts Law, predicting UV absorption using Woodward-Fieser, Fieser-Kuhn and Nelson rules; Calculation of λmax for β-Carotene, Lycopene, Piperine, Curcumin, Factors affecting UV spectra Non-conjugative effect, solvent effect, S-Cis band. Types of UV spectroscopic analytical techniques with illustrative examples: Simultaneous equation method: Paracetamol and Diclofenac sodium, Norfloxacin and Tinidazole, Quercetin, curcumin, and piperine. Difference spectrophotometric method:Leflunomide, Pioglitazone and metformin. Derivative spectrophotometric method: Quantitative assay of Diazepam. Variants of derivative spectroscopy: Ratio derivative: Successive ratio derivative spectra method, absorption ratio method with application. **ii) Infrared (IR)spectroscopy**: Principle of Infra Red spectroscopy, Hooke's Law, types of vibrations, Correlation of structure with IR spectra: Influence of substituents, ring size, hydrogen bonding, vibrational coupling and field effect on frequency. Applications: Identification of functional groups in the following drugs:Acyclovir, Chloroquine, Mebendazole, Ethambutol, Metronidazole,Dapsone, Cis-Platin, Ibuprofen, Chloramphenicol, Lidocaine, Aminohippuric acid, Theophylline, Determination of stereochemistry-Ethambutol and Methyl Dopa. Spectral interpretation with examples. Problem solving of UV and IR for structure elucidation.	12
5.Spectral Analysis-II **Nuclear Magnetic Resonance (NMR) spectroscopy**: Principle of proton NMR spectroscopy,chemical shift-shielding and deshielding effect, magnetic anisotropic	14

effect, TMS as reference standard, spin-spin splitting-coupling constant, NMR solvents and their residual peaks. Interpretation of NMR spectra of some compounds and drugs (Ibuprofen, Metronidazole, Morphine, Chloramphenicol, Isoniazid, Mebendazole, Lidocaine, 2-methylbenzothiazole, benzoxazole, pyrimidine,2-phenylbenzminidazole).^{13}C-NMR, correlation of structure with spectra: Chemical environment, shielding and carbon-13 chemical shift, calculation, proton-coupled Carbon Spectra, Protondecoupled Cspectra, Nuclear Overhauser Enhancement (NOE), Distortion less Enhancement by Polarization Transfer (DEPT), Heteronuclear coupling for carbon to deuterium, carbon to ^{19}F, carbon to ^{31}P.Fluorine chemical shift Anisotropy and exchange for Screening (FAXS). Three Fluorine Atoms for Biochemical Screening (3-FABS). NMR for Lead optimization and SAR studies. Explanation of spectra of some compounds and drugs. (Fluconazole, Thiotepa, Chlorphenaramine, Dapsone, Nitrogen mustard) NMR problem solving for structure elucidation.	
6.Mass spectrometry (MS): Molecular ion and metastable peak, fragmentation patterns, nitrogen and ring rules, McLafferty rearrangement, electron and chemical ionization modes, applications. Mass spectra of any 2 drugs. (Combined UV, IR, NMR, Mass Problems for structure elucidation)	6
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. F. Rouessac& A.Rouessac, *Chemical Analysis: Modern Instrumentation Methods and Techniques*, 2nd Ed., Wiley Publishers, 2013. 2. M.Valcarcer, *Principles of Analytical Chemistry*,2000th Ed., Springers, 2012. 3. M. E. Swartz& I. S. Krull, *Analytical Method Development and Validation*, 1sted., 1997,CRC Press. 4. J. P. Seiler, *Good Laboratory Practices*, Springer, 2001. 5. D. A. Skoog, F. J. Holler & T. A. Nineman, *Principles of Instrumental Analysis*, 7th Ed., 2018. 6. S. Ahuja & S.Scypinski, *Handbook of Modern Pharmaceutical Analysis*, 2nd Ed., Elseviers Publishers, 2010. 7. R. F. Venn, *Principles and Practice of Bioanalysis*, CRC Press, 2008. 8. D. L Pavia, Gary M Lampman, George S Kriz, James A Vyvyan. *Spectroscopy*, 3rd Ed., Thomson learning, 2001. 9. W. Kemp, *Organic Spectroscopy*, 3rd Ed., New York Palgrave, 2019. 10.D. H. Williams & I. Fleming,*Spectroscopic Methods in Organic Chemistry*, 5th Ed., McGraw Hill, 1995. 11. R. M. Silverstein, F. X. Webster & D. J. Kiemie,*Spectrometric Identification of Organic Compounds*, 7th Ed., Wiley and Sons, 2005. 12. J. R. Dyer, *Applications of Absorption Spectroscopy of Organic Compounds,* Prentice Hall of India Pvt.Ltd., 1978. 13. D.M. Atole& H. H. Rajput*, Ultraviolet spectroscopy and its pharmaceutical applications-A brief review*, *Asian J Pharm Clin Res*, Vol 11, Issue 2, 2018, 59-66. 14. P. Agarwal, *NMR Spectroscopy in Drug Discovery and Development*, Materials and Methods, 2014, 4, 599. 15. M. Pellecchia, D. Sem & K. Wuthrich, *NMR in drug discovery*. Nat. Rev. Drug Discov., 2002;1:211-9.

	16. Y. Zhong , K. Huang, Q. Luo, S. Yao, X. Liu ,N. Yang, C. Lin ,& X. Luo, *The Application of a Desktop NMR Spectrometer in Drug Analysis*, Hindawi International Journal of Analytical Chemistry, Volume 2018, Article ID 3104569. 17. H.W. Dibbem, *UV and IR Spectra of some important drugs, Annals of Pharmacotherapy*, Vol.15 (2), Editio Cantor Aulendorf Publishers, 1978. 18. D. T. Rossi & M. Sinz, *Mass Spectrometry in Drug Discovery*, 1st Ed., Taylor and Francis, 2001. 19. I. Sunshine &M.Caplis, *CRC handbook of mass spectra of drugs*, Boca Raton Fla: CRC Press, 1981.

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Programme: **M.Sc. Part-II (Chemistry)**
Course Code: **CHHG-515**
Title of the course: **Bioorganic and Medicinal Chemistry**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2023-24**

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.
Course Objective:	1. To understand the concepts of bioorganic chemistry and medicinal chemistry. 2. To study in brief about carbohydrates, nucleic acids and enzyme chemistry. 3. To introduce the topic of biomimetics. 4. To acquire knowledge on biosynthesis of natural products. 5. To understand the concept of drugs as enzyme inhibitors. 6. To synthesize selected drugs and understand its mechanism.
Course Outcome:	1.Students will be able to apply the knowledge of carbohydrates, proteins, nucleic acids, enzymes, co-enzymes for designing enzyme inhibitors. 2.Students will be able to put into practice the knowledge of biomimetics. 3.Students will be able to biosynthesize natural products. 4.Students will be able to synthesize drugs, present structure activity relationship studies and also write its mechanism.

Content	*Hrs*
1. Introduction to Bioorganic chemistry: Basic concepts, definition, Proximity effects in organic chemistry and overlapping subject biochemistry and organic chemistry, Molecular adaptation, Molecular recognition.	4
2. Carbohydrates, Nucleic acids and Protein Chemistry. Chemical structure and properties of nucleosides, nucleotides, nucleic acids. The biological and biochemical mechanisms of DNA replication and transcription.The structure of amino acids and the primary, secondary and tertiary structure of peptides and proteins. Determination of configuration of Glucose (Fischer's proof). Cyclic structure of glucose. Mutarotation Haworth projections. Lobry de Bruyn-van Ekenstein rearrangement; stepping–up (Kiliani- Fischer method) and stepping–down (Ruff's &Wohl's methods) of aldoses; end-group interchange of aldoses. Linkage between monosachharides, structure of disacharrides (sucrose, maltose, lactose.)	6

3. Enzyme Chemistry: Introduction, Nomenclature, classification and extraction of enzymes, Introduction to catalysis and enzymes; Multifunctional catalysis, Intramolecular catalysis, mechanism of enzyme action, factors responsible for enzyme specificity, enzyme activity and kinetics (Michaelis Menten and Lineweaver–Burk plots), enzyme inhibitions (Reversible and irreversible), structure, mechanism of action and applications of α-Chymotrypsin, Ribonuclease, lysozyme and Carbopeptidase-A. Enzymes in synthetic organic chemistry. [Reactions to be covered- Additions, eliminations, substitutions, condensations, oxidations, reductions and rearrangement]	8
4. Biomimetics and Biosynthesis of Natural products- **Biomimetics**: Definition**,** biological mechanisms, natural mechanisms, biomimetic structures, biomimicry at the cell-material interface, tissue structure and biomimetic applications. Biomimetic chemistry for NADH model. **Biosyntheses of natural products:**Biosyntheses of Alkaloids: Types of Metabolites of plants (Primary and secondary), Types of metabolic pathways: Shikimic and Mevalonic. Biosyntheses of Morphine from tyrosine and Nicotine from Ornithine. Biosyntheses of Steroids: Testosterone and Cholesterol.Biosyntheses of 6-methylsalicylic acid, tetracyclins. Modular polyketide synthase, Erythromycin biosynthesis, engineering novel polyketide antibiotics.	10
5. Co-Enzyme Chemistry-Chemical structures of co-enzymes and cofactors, Oxidoreduction (NAD+, NADP+), Pyridoxal phosphate (PLP) in transamination, Thiamine pyrophosphate (TPP), Biotin (CO_2 carrier), Haemoglobin (O_2- carrier), Flavin (FMN, FAD, $FADH_2$), Oxene Reactions, Lipoic acid, Mechanisms of reactions catalyzed by co-factors. Oxidation by cytochrome-450. Hansester as NADH model (give an example)	10
6. Medicinal Chemistry and Pharmacology Role of medicinal chemistry, properties of drug and receptor, Pharmacophore, toxicophore and metabiophore. Pharmacodynamics and Pharmacokinetics. Drug Design based on Target based and phenotype approach. Enzyme inhibitors as drugs. Antagonist behaviour of Caffeine, Role of Enoylacpreductase, cyclooxygenase inhibitors, Kinase, α-Glucosidase, Dihydrofolate reductase, ACE-2 in the biological processes. Designing the drug and Mechanism of action of Isoniazid, Ibuprofen, Erlotinib, acarbose, captopril. Concept of molecular docking in computer aided drug designing.Structure –activity relationships of drug molecules, binding role of –OH group,-NH_2 group, double bond and aromatic ring to receptor. SAR of following drugs (Chloramphenicol, Procaine, Isoniazid, Chloroquine, Methyl Dopa).	12
5. Synthesis of drugs with mechanism: **Anti inflammatory Drugs**: Naproxen, Celecoxib. **Anti-hypertensive Drugs**: Captopril, Atenolol. **Drugs acting on CNS**: (a) CNS Stimulant : Dextro-amphetamine (b) Respiratory Stimulant : Doxapram (c) CNS anti-depressant : (i) Chlorpromazine (Antipsychotic) (ii) Diazepam (Anxiolytic) (iii) Phenobarbital (Antiepileptic) (d) Anaesthetic Drugs: (a) General : Ketamine (b) Local : (i) Lidocaine. **Antibiotics**: Amoxycillin**. Antimycobactrial**: Ethambutol. **Antiviral**: Acyclovir. **Antimicrobial**: Sulfamethoxazole. **Antidiabetics**: Tolbutamide (k). **Antineopastic Drugs**: (a) Antagonist: Fluorouracil (b) Alkylating agents: i) Chlorambucil (ii) Cis-Platin. **Antimalarial**: Hydroxychloroquine	10

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. D. A. Williams & T. L. Lemke, *Foye's principles of medicinal chemistry*, 5th edition, Lippincott Williams and Wilkins, 2006. 2. J. M. Beale & J. M. Block, *Wilson &Gisvold's Text book of Organic Medicinal & Pharmaceutical Chemistry*, Lippincott Williams and Wilkins; 2004. 3. D. J. Abraham & D. P. Rotella, *Burger's Medicinal Chemistry Drug Discovery and Development*, 7th edition, John Wiley & Sons N.Y, 2010. 4. D. Shriram, P. Yogeshwari, *Medicinal Chemistry*, Pearson Education, 2007. 5. G. L. Patrick: *Introduction to Medicinal Chemistry*, Oxford University Press, UK. 6th edition, 2017. 6. D. Lednicer& L. A. Mitscher, *The Organic Chemistry of Drug Synthesis*. (6 volume set) III. John Wiley & Sons, 2005. 7. H. Singh & V. K. Kapoor, *Medicinal and Pharmaceutical Chemistry*, VallabhPrakashan, 2010. 8. G. R Chatwal, *Medicinal Chemistry (Organic Pharmaceutical Chemistry)*, Himalaya Publishing house, 2002. 9. N. K. Tripathi & R. C. Verma, *Bioorganic and Medicinal Chemistry, Theory and Practical*s, Thakur Publications Pvt Limited, 2021. 10.T. M. Kutchan,*Alkaloid biosynthesis – the basis for metabolic engineering of medicinal plants*. Plant Cell, 1995. 7, 1059-1070. 11. Y. Bar-Cohen, *Biomimetics: Nature-Based Innovation*, CRC Press, 2012. 12. I. L. Finar, *Organic Chemistry: Stereochemistry and the Chemistry of Natural Products*, Pearson Education India, 2002. 13. K. Nakanishi, *Natural Product Chemistry*, Academic Press, 2013. 14. D. R. Dalton, *The Alkaloids*. New York: M. Dekker, 1979. 15. D. Barton & W. D.Olis, *Comprehensive Organic Chemistry*, Pergamon, 1979. 16.D. Paul, *Medicinal Natural Products:A Biosynthetic Approach*, John Wiley and Sons, 2002. 17.M. Paolo, *Biosynthesis of Natural Products*, Wiley Publishers, 2010. 18. J. ApSimon, *The Total Synthesis of Natural Products*, John Wiley and Sons, 1992. 19. J. M. Beale Jr. & J. Block, *Wilson and Gisvold's Textbook of organic and medicinal chemistry*, 12th Ed.,Wolters Kluwer India Pvt. Ltd,2010.

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Programme: **MSc Part-II (Pharmaceutical Chemistry)**
Course Code: **CHHR-516**
Title of the course: **Research Methodology in Pharmaceutical Chemistry and instrumental techniques**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2023-24**

Prerequisites	Students should have studied chemistry courses at MSc-I.

Course Objective:	1.To introduce various aspects of research methodology. 2.To provide understanding ethics & scientific conduct 3. To introduce academic writing 4. To introduce databases used in chemistry 5.To provide understanding and importance of lab safety. 6.To understand the usefulness of various instrumental techniques in characterization of chemical compounds. 7.To provide knowledge about tissue culture for pharmacological screening methods.
Course Outcome:	1.Students will be able to apply the concepts of research methodology during their research work. 2.Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques. 5.Students will acquire adequate knowledge on animal tissue culture.

Content	*Hours*
Unit 01: Introduction to Research Methodology a. Research- meaning, objectives, motivation, types and methodology. b. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	**5**
Unit 02: Scientific conduct and ethics a. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research b. Intellectual honesty and research integrity c. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP) d. Redundant publications: duplicate and overlappingpublications e. Selective reporting and misrepresentation of data	**5**
Unit 03. Academic writing a. Publication ethics: definition, introduction and importance b. Conflicts of interest c. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa d. Violation of publication ethics, authorship and contributorship e. Identification of publication misconduct, complaints and appeals f. Predatory publishers and journals	**5**
Unit 04. Data bases and research metrics	**3**

Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	
Unit 06. Safety in Chemistry a. Good laboratory practices. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	**5**
Unit 06. Softwares in Chemistry a. Data plotting b. Structure Drawing c. Molecular docking softwares	**7**
5. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques. a. Elemental analysis: CHNS analysis and AES b. Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) c. Nuclear magnetic resonance (^{1}H, ^{13}C) d. Chromatographic techniques: HPLC, GC, e. Hyphenated Techniques: LC-MS & GC-MS, f. Diffraction methods: XRD g. Thermal analysis: DSC	**20**
6. Animal Tissue Culture for pharmacological screening a. Basic concepts b. Laboratory safety and Biohazards c. Role of media components d. Handling and storage of cell lines e. Cell culture technique f. Types of cell culture system	**10**
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C.R. Kothari. *Research Methodology: Methods & Techniques* New Age International Pvt. Ltd., 2004. 2. Bird, A. *Philosophy of Science*. London:Routledge. 2006. 3. Anne M. Coghill&Lorrin R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, OXFORD University press 2006. 4. Y K Singh *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 5. *Prudent practices in the laboratory: handling and management of chemical hazards,* The National Academies Press, USA, 2011. 6. B.S. Furniss, A.J. Hannaford, V. Rogers, P.W.G. Smith & A. R. Tatchell. *Vogel'sTextbook of Practical Organic Chemistry*, 5th Ed., ELBS London, 2007.

	7. E.A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, ELBS, 1987. 8. R.S. Drago. *Physical Methods in Chemistry*,W. B. Saunders Company, 2016. 9. R. M. Silverstein, G. C. Bassler & T.C. Morrill, *Spectrometric Identification of organic Compounds*,5th Ed.,John Wiley 1991 10. J. Mendham, R.C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*6th Ed.,Pearson Education Asia, Delhi, 2002. 11. H. V. Keer, *Principles of the Solid State* new Age International, 1994 12. G.D. Christian, *Analytical Chemistry*, 6th Ed.,Wiley, 2004. 13. D. A. Skoog, D. M. West, F. J. Holler & S. R. Crouch. *Fundamentals of Analytical Chemistry* Cengage learning 9th Ed., 2013. 14. D. A. Skoog, F. J. Holler & S. R. Crouch. *Principles of Instrumental Analysis,*7th Ed.,Cengage learning 2017 15. D. Pavia, G. Lampman, G. Kriz& J. Vyvyan, *Introduction to Organic Spectroscopy* 5th Ed, Cengage Learning, 2015. 16. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 17. A. Szabo & N. S. Ostlund, *Modern Quantum Chemistry Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, New York 1989. 18. F.D. King, *Medicinal Chemistry: Principles and Practice*, Royal Society of Chemistry, 1994. 19. K.V. Raman, *Computers in Chemistry*, Tata Mc.Graw Hill,1993. 20. S.K Pundir, A. Bansal, *Computers for Chemists*, PragatiPrakashan, 2010. 21. A. Leach, *Molecular Modelling, Principles and applications*, Longman Publications, 1998. 22. R. R. Spier, J. B. Griffiths, *Animal Cell Biotechnology*, Academic Press, London, 1990. 23. E. J. Gareth, *Human Cell Culture Protocols*, Humana Press.1996. 24. E. Julio, Celis, *Cell Biology-A Laboratory Hand Book, Vol. I-IV*, 2nd Ed., Academic Press, New York. 1998. 25. M. Butler, *Animal Cell Technology*, 2nd Ed., BIOS Scientific Publishers, U.K. 2004. 26. R. T. Freshney, *Culture of Animal Cells*, 5th Ed., John Wiley and Sons, New York. 2006.

Programme: **M.Sc. Part-II (Pharmaceutical Chemistry)**
Course Code: **CHCD-511**
Title of the course: **Discipline Specific Dissertation**
Number of Credits: **16**Total Hours: **480** Effective from AY: **2023-24**

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I.
Course Objective:	To develop the skills of preparing and conducting independent research.

Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.

Content	*Hours*
As per OA-35	480

Pedagogy	Dissertation carried out individually by each student throughout the academic year.
Textbooks/ References / Readings	As required for the development of review and methodology.

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Annexure III

Programme: Ph.D. Chemistry
Paper-I Syllabus
Title of the course: **Research Methodology**
Number of Credits: **04**Total Hours: **60** Effective from AY: **2022-23**

Prerequisites	Provisional registration for PhD in Chemistry
Course Objective:	1. To introduce research students to various aspects of research methodology. 2. To provide understanding of various databases used in chemistry for literature survey 3. To provide fundamental roles of computers in chemical research 4. To provide understanding and importance of lab safety. 5. To make students aware of the statistical methods used in chemical research. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.
Course Outcome:	1. Students will be able to apply the concepts of research methodology 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will take safety precautions in chemical lab. 4. Students will apply statistical methods of data handling in their research. 5. Students will be able to apply characterization techniques for sample analysis.

Content	*Hours*
1. Introduction to Research Methodology a) Research- meaning, objectives, motivation, types and methodology. b) Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions. c) Nature of scientific information- types of books, types of presentations published in journals, standard format for reporting original research, introduction to various scientific (chemistry) databases & sources from the internet.	10
2. Role of Computers in Research and chemistry a) Applications of computers in research. Applications of computer in Chemistry - Need of computers in chemistry- introduction & history; Introduction to programming & programming languages; Solving a problem with computers- algorithm, flowchart and program; Use of software for data handling, plotting graphs and drawing molecular structures, visualisation of 3-D data; Software for literature survey, software for reference citing b) Optimisation techniques and applications in molecular geometry optimisation	10

3. Safety aspects in Chemistry a) Introduction to lab safety. b) Handling of various chemicals, solvents & glassware. c) Fires and fighting with fires. d) Hazardous substances, classification and handling e) Safety data sheet	8
4. Introduction to Statistical methods a) Errors & their types, precision & accuracy in chemical analysis. b) Application of statistical methods to data treatment & evaluation. c) Confidence limits; hypothesis testing. d) F-tests, Chi square test, correlation and linear regression. e) Use of software for statistical analysis.	10
5. Instrumental methods of analysis Data analysis in following techniques: a) Elemental analysis: CHNS analysis and AES b) Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) c) Nuclear magnetic resonance (^{1}H, ^{13}C) d) LC-MS, GC-MS e) X-ray diffraction f) Thermal analysis: TG/DTA g) Microscopy: SEM, TEM h) Methods for determination of magnetic & dielectric properties. i) Cyclic voltammetry j) AFM k) BET	22
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Textbooks/ References / Readings	1. C. R. Kothari, *Research Methodology: Methods & Techniques*, New Age International Pvt. Ltd., 2004. 2. M. Coghill & L. R. Garson, *The ACS Style Guide: Effective Communication of Scientific Information*, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 3. Y. K. Singh, *Fundamentals of Research Methodology & Statistics*, New Age International Pvt. Ltd., 2006. 4. National Research Council, *Prudent practices in the laboratory: handling and management of chemical hazards*, The National Academies Press, USA, 2011. 5. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, *Vogel's Text book of Practical Organic Chemistry*, 5th Ed.; Longman, 1989 6. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, *Structural Methods in Inorganic Chemistry*, Blackwell Scientific Publishers, 1986 7. R. S. Drago, *Physical Methods in Chemistry*, 2nd Ed. W. B. Saunders Co. Ltd. 2016

	8. R. M. Silverstein, F. X. Webster; *Spectrometric Identification of Organic Compounds*; 6th Ed, Wiley, 2011. 9. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Ed.; Pearson Education Asia, 2002. 10. H. V. Keer, *Principles of the Solid State,* 1st Ed. (Reprint 2005); New Age International (P) Ltd., 1993. 11. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 12. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning. 13. A. Skoog, F. J. Holler, S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage learning. 14. Pavia, G. Lampman, G. Kriz and J. Vyvyan, *Introduction to Organic Spectroscopy*, 5th Ed.; Cengage Learning, 2015. 15. N. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, *A Practical Beginner's Guide to Cyclic Voltammetry*, J. Chem. Educ. 2018, 95, 197−206. 16. V. Rajaraman, *Computer Programming in Fortran 90 And 95*, PHI Learning Pvt. Ltd., 2013. 17. A. Szabo, N. S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover Publications, Inc. Mineola, 1989.

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