ಮಂಗಳೂರು ವಿಶ್ವವಿದ್ಯಾನಿಲಯ

MANGALORE UNIVERSITY

(Accredited by NAAC)

ಕ್ರಮಾಂಕ/ No. : MU/ACC/CR 29/2023-24/A2

ಕುಲಸಚಿವರ ಕಛೇರಿ
ಮಂಗಳಗಂಗೋತ್ರಿ – 574 199
Office of the Registrar
Mangalagangothri – 574 199
ದಿನಾಂಕ/Date:10.10.2023

NOTIFICATION

Sub: Revised syllabus of M.Sc. Analytical Chemistry Programme
Ref: Academic Council approval vide agenda
No.: ಎಸಿಸಿ:ಶೈ.ಸಾ.ಸ.2:9 (2023–24) dtd 04.10.2023.

*****

The Revised syllabus of M.Sc. Analytical Chemistry programme which is approved by the Academic Council at its meeting held on 04.10.2023 is hereby notified for implementation with effect from the academic year 2024-25 and onwards.

Copy of the Syllabus shall be downloaded from the University Website (www.mangaloreuniversity.ac.in)

REGISTRAR

To

1. The Registrar (Evaluation), Mangalore University.
2. The Chairman, PG BOS in Analytical Chemistry, Dept. of Studies in Chemistry, Mangalore University.
3. The Co-ordinator, M.Sc. Analytical Chemistry Programme, Dept. of Studies in Chemistry, Mangalore University.
4. The Superintendent (ACC), O/o the Registrar, Mangalore University.
5. The Asst. Registrar (ACC), O/o the Registrar, Mangalore University.
6. The Director, DUIMS, Mangalore University – with a request to publish in the website.
7. Guard File.

MANGALORE UNIVERSITY

Department of Studies in Chemistry
Mangalagangothri-574199

M. Sc. Degree Programme

(CHOICE BASED CREDIT SYSTEM – SEMESTER SCHEME)

Syllabus for M.Sc. Degree Programme in

ANALYTICAL CHEMISTRY

(With effective from the Academic Year 2024-25)

MANGALORE UNIVERSITY

DEPARTMENT OF STUDIES IN CHEMISTRY

MANGALAGANGOTHRI – 574199

Two years Master Degree Programme (Four Semesters)
M.Sc. in Analytical Chemistry

Choice Based Credit System (CBCS) Semester Scheme
(With effective from the Academic Year 2024-25)

PREAMBLE

Revision of syllabi for the two year Master Degree (Choice Based Credit System- Semester Scheme) Programme in Analytical Chemistry.

PG BOS in Analytical Chemistry has revised and prepared the syllabus (CBCS based) for the PG programme in Analytical Chemistry by offering Hard Core, Soft Core and Open Elective courses with credits to each course amounting to 88 credits for the entire programme. The 9 theory courses (4 credits each) and 1 semester project work (20 credits) in IV semester are assigned as Hard Core courses with total credits of 56. Students have to study 2 soft core theory courses (3 credits each) in I semester and 1 Soft Core theory course (3 credits) each in II and III semesters. The choice has been given for the Soft Core courses in I, II and III semesters. The programme consists of 6 practical courses (2 courses each in I and II semesters of the programme with 2 credits each and 2 courses in III semester with 3 credits each) with a total of 14 credits, which will be taught as Soft Core courses. Total Soft Core credits amount to 26. The Board of Studies has carefully chosen two Open Elective courses (3 credits each) for thestudents from other disciplines, one each in II and III semesters, with total credits of 6. Therefore, grand total credits for the programme is 88. A detailed skeleton of the entire programme is being tabulated for the benefit of the aspiring post graduates. Other important aspects such as University question paper pattern, internal assessment examinations, allotment of marks and the approximate dates of the internal

examinations are being tabulated with a discussion in the BOS.

Sl. No.	Semester	Hard core theory paper credits (H)	Soft core theory paper credits (S)	Open elective credits (E)	Practical/ Project Work* credits (P)	No. of Practical Papers / Project Work* (S/H)	No. of Theory Papers (H/S)	Total Credits
1	I	12	6	--	4	2(S)	3(H)+2(S)	22
2	II	12	3	3	4	2(S)	3(H)+1(S)	22
3	III	12	3	3	6	2(S)	3(H)+1(S)	24
4	IV	20	--	--	20*	Project Work & Dissertation* (H)	--	20
Total		56	12	6	34	--	--	88

Total Credits from all the Four Semesters: 88

Total Hard Core credits = 36 (T) + 20 (P*) = 56 (63.64%)

Total Soft Core credits = 12 (T) + 14 (P) = 26 (29.54%)

Open Elective Credits = 6 (6.82% - Not to be considered for calculating the CGPA)

H = Hard Core, S = Soft Core, P = Practical/Project Work*, E = Open Elective

OBJECTIVES OF THE SYLLABUS

The revised syllabus is designed to provide a flexible structure within which students can choose the topic of their interest in addition to a specific knowledge. The syllabus takes into account the requirements for higher education to improve the quality of education and student competency level on par with national and international institutions. The syllabus is structured in such a way so as to ensure that students become aware of the practical applications of scientific knowledgeto build careers in the scientific field.

The syllabus aims to enable students to:

- To provide knowledge and skills in the field of analytical chemistry
- To generate manpower trained in analytical chemistry to meet the need of industry and academia and to pursue further studies by acquiring the knowledge and understanding of chemical principles.
- To appreciate, understand and use the scientific method in the solving of problems.

- To develop the ability to disseminate chemical information effectively.
- To acquire good laboratory skills and practice safety measures when using equipment and chemicals as well as the safe disposal of chemical waste.
- To apply chemical knowledge to everyday life situations and develop inquisitiveness in order to continue the search for new ways in which the resources of our environment can be usedin a sustainable way.
- To develop the personality of an individual by giving them the necessary skills.
- To offer 100% placement assistance.

SCOPE OF THE PROGRAMME

M.Sc. in Analytical Chemistry is a specialized post graduate programme with job opportunities in industry. The Research and Development and Quality Control divisions of every industry requires personnel who are trained in handling various instruments. The structure of the programme and curriculum is designed to enable the students to develop analytical and creative abilities which are very much needed by the industry. The programme is definitely at par with M.Sc. Chemistry, M.Sc. Organic chemistry, M.Sc. Industrial Chemistry, M.Sc. Applied Chemistry, etc.

ELIGIBILITY

- Candidates would have studied any branch of Physical or biological science with chemistry as one of the optional / major / special subjects in the under graduate level.
- Not less than 45% (40% in case of SC/ST students) marks in the aggregate excluding languages in the under graduate level.
- The students should have studied physics and Mathematics as optional / major / special / minor / subsidiary subjects either at B.Sc. or at P.U.C. / Higher Secondary level.
- B.Sc. Polymer Chemistry graduates are also eligible for admission to this programme provided they have studied Physics and Mathematics as major/subsidiary subjects at B.Sc. or P.U.C. / Higher Secondary level.

Detailed Structure, Credits and Scheme of Examination of the Postgraduate Courses of Analytical Chemistry under Choice Based Credit System-Semester Scheme for the entire programme

I Semester					
Description of the Course	**Hard Core/ Soft Core/ Open Elective Course**	**Teaching Hours per Week & Sem.**	**Credits**	**Hours of Examination**	**Max. Marks: Exam. + IA= Total**
CA H 411: Inorganic Chemistry	H	4 48	4	3	70 + 30 =100
CA H 412: Organic Chemistry	H	4 48	4	3	70 + 30 =100
CA H 413: Physical Chemistry	H	4 48	4	3	70 + 30 =100
CA S 414: Inorganic Spectroscopy and Optical Methods CA S 415: Environmental Chemistry (Any one of the two courses)	S	3 36	3	3	70 + 30 =100
CA S 416: Molecular Spectroscopy and Diffraction Techniques	S	3 36	3	3	70 + 30 =100
CA P 417: Inorganic Chemistry Practicals	S	4 48	2	4	35 + 15 =50
CA P 418: Organic Chemistry Practicals-I	S	4 48	2	4	35 + 15 =50
		Total	22		600

II Semester					
Description of the Course	**Hard Core/ Soft Core/ Open Elective Course**	**Teaching Hours per Week & Sem.**	**Credits**	**Hours of Examination**	**Max. Marks: Exam. + IA= Total**
CA H 461: Advanced Inorganic Chemistry	H	4 48	4	3	70 + 30 =100
CA H 462: Advanced Organic Chemistry	H	4 48	4	3	70 + 30 =100
CA H 463: Advanced Physical Chemistry	H	4 48	4	3	70 + 30 =100
CA S 464: Organic Spectroscopy CA S 465: Chemistry of Biomolecules (Any one of the two courses)	S	3 36	3	3	70 + 30 =100
CA E 466: Environmental, Electro- and Polymer Chemistry	E	3 36	3	3	70 + 30 =100
CA P 467: Organic Chemistry Practicals-II	S	4 48	2	4	35 + 15 =50
CA P 468: Physical Chemistry Practicals	S	4 48	2	4	35 + 15 =50
		Total	22		600

III Semester					
Description of the Course	**Hard Core/ Soft Core/ Open Elective Course**	**Teaching Hours per Week & Sem.**	**Credits**	**Hours of Examination**	**Max. Marks: Exam. + IA= Total**
CA H 511: Fundamentals of Advanced Inorganic Chemistry and Introduction to Analytical Chemistry	**H**	**4 48**	**4**	**3**	**70 + 30 =100**
CA H 512: Electroanalytical and Thermoanalytical Techniques	**H**	**4 48**	**4**	**3**	**70 + 30 =100**
CA H 513: Applied Analysis	**H**	**4 48**	**4**	**3**	**70 + 30 =100**
CA S 514: Analytical Chemistry of Polymers **CA S 515: Separation Techniques** **(Any one of the two courses)**	**S**	**3 36**	**3**	**3**	**70 + 30 =100**
CA E 516: Analytical and Green Chemistry	**E**	**3 36**	**3**	**3**	**70 + 30 =100**
CA P 517: Analytical Chemistry Practicals-I	**S**	**6 48**	**3**	**6**	**70 + 30 =100**
CA P 518: Analytical Chemistry Practicals-II	**S**	**6 48**	**3**	**6**	**70 + 30 =100**
		Total	**24**		**700**

IV Semester					
Description of the Course	**Hard Core/ Soft Core/ Open Elective Course**	**Teaching Hours per Week & Sem**	**Credits**	**Hours of Examination**	**Max. Marks: Exam. + IA= Total**
Project Work (4 Months) **CA H 561: Project Report** **CA H 562: Viva-Voce**	**H**		**20**		**320 + 180* =500** **100**
		Total	**20**		**600**
*** 75 (Project Guide evaluation-I) + 75 (Project Guide evaluation-II) + 15 (Assignment-Sem III) + 15 (Seminar-Sem III) = 180**					
		Grand Total	**88**		**2500**

BASIS FOR INTERNAL ASSESSMENT: Internal assessment marks in theory papers of I, II and III semesters shall be based on two tests conducted for 30 marks for each course. Question Papers for Internal Assessment in all the theory courses shall consist of Part A and B. For hard core theory courses - Part A shall contain eight (8) very short answer objective type questions carrying 2 marks each, out of which five (5) questions are to be answered. Part B shall contain four (4) descriptive answer questions with internal choice (a or b) carrying 5 marks each. For soft core and open electives, Part A shall contain 9 very short answer objective type questions carrying 2 marks each,

out of which five (6) questions are to be answered. Part B shall contain three (3) descriptive answer questions with internal choice (a or b) carrying 6 marks each. The tests may be conducted after 8 and 14 weeks from start of the semester. Average of two test marks will be considered as internal assessment marks. Practical internal assessment marks shall be based on tests and records. In I and II semesters ten (10) marks for experiment and five (5) marks for record are awarded. In III semester twenty (20) marks for experiment and ten (10) marks for record are awarded. The practical tests may be conducted after 12 weeks from start of the semester. Internal Assessment marks on Project work in the IV semester is based on one seminar of 45 minutes duration for 15 marks, one assignment for 15 marks and Project Guide-I and Project uide-II evaluation of the project work for 75 marks each. The Seminar and assignment are on the subject and are to be completed in 3rd semester.

THEORY QUESTION PAPER PATTERN FOR HARD CORE, SOFT CORE AND OPEN ELECTIVE COURSES

THEORY QUESTION PAPER PATTERN: The Syllabus of each theory course shall be grouped into units of 12 teaching hours. All hard core courses will have 4 units. Soft core and open elective courses will have 3 units. Question Papers in all the theory courses shall consist of Part A and B. For hard core theory courses - Part A shall contain eight (8) very short answer objective type questions carrying 2 marks each drawn from all the four units of the syllabus (2 questions per unit), out of which five (5) questions are to be answered. Part B shall contain eight (8) brief and/orlong answer questions carrying 12 marks each drawn from all the four units of the syllabus (2 questions per unit). Five (5) out of eight (8) questions are to be answered choosing at least one question from each unit. For soft core and open electives, Part A shall contain 9 very short answer objective type questions carrying 2 marks each drawn from all the three units of the syllabus (3 questions per unit), out of which seven (7) questions are to be answered. Part B shall contain six (6) brief and/or long answer questions carrying 14 marks each drawn from all the three units of the syllabus (2 questions per unit). There may be a maximum of four sub-divisions per question, carrying 3 or more marks per sub-division. Four (4) out of six (6) questions are to be answered choosing at least one question from each unit.

M.Sc. Analytical Chemistry Hard Core Course

Time: 3 Hours **Max. Marks: 70**

Answer any **Five** sub-divisions from **Question No. 1** in **Part-A** and **Four** questions from **Part-B**. Figures to the right indicate marks.

Part-A

1. Answer any **Five** subdivisions: **(5x2=10)**

a) b) } Unit-I c) d) } Unit-II e) f) } Unit-III g) h) } Unit-IV

Part-B

Answer any **Five** questions selecting minimum of **1 question** from each unit: **(5x12=60)**

Unit – I

2. a) b) } Or 2. a) b) c) } Or 2. a) b) c) d) } 3. a) b) } Or 3. a) b) c) } Or 3. a) b) c) d) }

Unit – II

4. a) b) } Or 4. a) b) c) } Or 4. a) b) c) d) } 5. a) b) } Or 5. a) b) c) } Or 5. a) b) c) d) }

Unit – III

6. a) b) } Or 6. a) b) c) } Or 6. a) b) c) d) } 7. a) b) } Or 7. a) b) c) } Or 7. a) b) c) d) }

Unit – IV

8. a) b) } Or 8. a) b) c) } Or 8. a) b) c) d) } 9. a) b) } Or 9. a) b) c) } Or 9. a) b) c) d) }

****

M.Sc. Analytical Chemistry Soft Core or Open Elective Course

Time: 3 Hours **Max. Marks: 70**

Answer any **Seven** sub-divisions from **Question No. 1** in **Part-A** and **Four** questions from **Part-B**. Figures to the right indicate marks.

Part-A

1. Answer any **Seven** subdivisions: **(7x2=14)**

a), b), c) } Unit-I

d), e), f) } Unit-II

f), g), h) } Unit-III

Part-B

Answer any **Four** questions selecting minimum of **1 question** from each unit: **(4x14=56)**

Unit – I

2. a), b) } Or 2. a), b), c) } Or 2. a), b), c), d) }

3. a), b) } Or 3. a), b), c) } Or 3. a), b), c), d) }

Unit – II

4. a), b) } Or 4. a), b), c) } Or 4. a), b), c), d) }

5. a), b) } Or 5. a), b), c) } Or 5. a), b), c), d) }

Unit – III

6. a), b) } Or 6. a), b), c) } Or 6. a), b), c), d) }

7. a), b) } Or 7. a), b), c) } Or 7. a), b), c), d) }

****

PRACTICAL QUESTION PAPER PATTERN: In the Practical courses of I and II semesters, out of 35 marks, 5 marks shall be allotted for the viva-voce to be conducted during practical and 30 marks for the experiment. In the III semester Practical courses, out of 70 marks, 10 marks shall be allotted for the viva-voce to be conducted during practical and 60 marks for the experiment.

PROJECT REPORT: Candidates of IV semester shall undergo a compulsory project work either in the department or in an Institution or Industry for four months and prepare a report on their project work. The Project Report shall be evaluated by two examiners as in the case of theory papers for

320 marks. Viva-Voce examination is to be conducted as per the University regulations for 100 marks.

PROGRAMME OUTCOMES

- Master of Science in Analytical Chemistry basically aims at the training of students with a detailed knowledge base in Chemistry of potential utility in academia as well as Industry through advanced course work and laboratory work in the department and a project work in industries or premier institutions.
- To qualify NET/GATE/SET/Civil Services and other competitive examinations.
- For exploring global level research opportunities for doctoral and post-doctoral studies.
- For professional employment in different domains such as academics, industries, analytical laboratories, scientific organizations, entrepreneurship, administrative positions etc.
- For enhancing the connectivity between academic and industrial institutions.

PROGRAMME SPECIFIC OUTCOMES

- Students will equip themselves with up-to-date knowledge in the field of frontier areas of analytical chemistry.
- Attain confidence to take up professional career positions in teaching, higher education institutions, public sector and private companies.
- Get motivated to take up higher studies.
- Will be able to use their knowledge in day to day life and work for betterment of society.
- Understand the social responsibility of chemists in educating general public about protection of environment against pollution.
- Knowledge & Confidence to clear nation level competitive examinations.
- To make use of the analytical chemistry knowledge to analyze real samples like food samples, biological samples, pharmaceutical products and environmental samples.
- To propose/develop simple and accurate analytical methods as alternatives for the existing standard/official methods for the analysis of complex matrices/clinical samples.

FIRST SEMESTER

CA H 411: INORGANIC CHEMISTRY

Course Outcomes

- Learn the basics of ionic and covalent bonding, lattice and hydration energy.
- Enable the students to understand VSEPR and MOT theory.
- Enlighten the students to understand HSAB concept, non-aqueous solvents and ionic liquids.
- Get the knowledge alkali/alkaline earth metal complexes, compounds of boron, carbon and silicon.
- Understanding of use of organic precipitants and extraction techniques, masking and de-masking techniques, sampling techniques and statistical treatment of errors.

UNIT-I: Structures and Energetics of Ionic Crystals and Covalent Bonds [12 Hours]

Ionic Bond: Properties of ionic compounds, crystal lattices, closed packed structures, coordination number of an ion, radius ratio rule, structures of crystal lattices- NaCl, CsCl, ZnSand rutile. Lattice energy: Born Lande equation, Born-Haber cycle, uses of Born-Haber type of calculations. Covalent character in ionic bonds, Fajan's rules, hydration energy and solubility of ionic solids. Ionic radii, factors affecting the ionic radii, radius ratio rules.

Covalent Bond: Valence bond theory, resonance, hybridization and energetics of hybridization, Bent's rule, VSEPR theory-Deduction of molecular shapes. MOT of homo and heteronuclear diatomic and triatomic molecules& MO treatment for the molecules involving delocalized π-bonding (CO_3^{2-}, NO_3^- and CO_2). M.O. correlation diagrams (Walsh) for triatomic molecules.

UNIT-II [12 Hours]

Modern concept of acids and bases: Lux-Flood and Usanovich concepts, solvent system and leveling effect. Hard-Soft Acids and Bases, Classification and Theoretical backgrounds.

Non-aqueous solvents: Classification of solvents, Properties of solvents (dielectric constant, donor and acceptor properties), protic solvents (anhydrous H_2SO_4, HF and glacial acetic acid), aprotic solvents (liquid SO_2, BrF_3 and N_2O_4). Solutions of metals in liquid ammonia, hydrated electron. Super acids and super bases. Heterogeneous acid-base reactions.

Ionic liquids: Molten salt solvent systems, Ionic liquids at ambient temperature, Reactions in and applications of molten salt/ionic liquid media. Supercritical fluids: Properties of supercritical fluids and their uses as solvents. Supercritical fluids as media for inorganic chemistry.

UNIT-III: Chemistry of Non-Transition Elements [12 Hours]

Alkali and alkaline earth metal complexes of crown ethers, cryptands and calixarenes and their biological importance.

Synthesis, properties and structures of boron, carbon and silicon compounds: Chemistry of higher boranes, classification, structures and MO description of bonding, framework electron counting, Wade's rules, chemistry of B_5H_9, $B_{10}H_{14}$ and $B_nH_n^{2-}$, boron nitride, borazines, carboranes, metalloboranes, metallocarboranes; Graphite, graphene, carbon nanotubes and zeolites. cyclophosphazenes, phosphazene polymers and S-N compounds.

UNIT- IV **[12 Hours]**

Precipitation phenomena: precipitation from homogeneous solutions, organic precipitants in inorganic analysis. Solvent extraction of metal ions, nature of extractant, distribution law, partition coefficients, types of extractions and applications.

Theories of redox indicators, titration curves, feasibility of redox titrations.

Chelometric titrations: Titration curves with EDTA, feasibility of EDTA titrations, indicators for chelometric titrations, selective masking and demasking techniques, industrial applications of masking. Sampling techniques and preparation of samples for analysis.

References

1. Inorganic Chemistry: Principles of Structure and Reactivity, 4th edn., J. E. Huheey, E.A. Keiter, R. L. Keiter and O.K. Medhi, Pearson Education (2009).
2. Shriver & Atkins' Inorganic Chemistry, 5th edn., P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Oxford University Press (2010).
3. Inorganic Chemistry, 2nd edn., C. E. Housecroft and A.G. Sharpe, Pearson Prentice Hall(2005).
4. Concise Inorganic Chemistry, 5th edn., J. D. Lee, New Age International (1996).
5. Concise Inorganic Chemistry, 5th edn., J. D. Lee, Blackwell Science (2000).
6. Concepts and Models of Inorganic Chemistry, B. E. Douglas, D. McDaniel and A.Alexander, John Wiley & Sons (2001).
7. Basic Inorganic Chemistry, 3rd edn., F. A. Cotton, G. Wilkinson and P. L. Gaus, John Wiley and Sons (2002).
8. Inorganic Chemistry, 3rd edn., J. E. Huheey, Harper and Row Publishers (1983).
9. Inorganic Chemistry, 5th edn., G. L. Miessler, P. J. Fischer and D. A. Tarr, Pearson Education (2014).
10. Inorganic Chemistry, 6th edn., D. F. Shriver, M. Weller. T. Overton, J. Rourke and F. Armastrong, Oxford University Press (2014).
11. Inorganic Chemistry, 4th edn., C. E. Housecroft and A. G. Sharpe, Pearson Education (2012).
12. Introduction to Modern Inorganic Chemistry, K. M. Mackay and R .A. Mackay, Blackie Publication (1989).
13. Concepts and Models of Inorganic Chemistry 3rd edn., B. E. Douglas, D. H. McDaniel and Alexander, John Wiley & Sons (2001).
14. Ionic liquids-Classes and Properties, Ed. Scott T. Handy, Intech Publisher (2011).
15. Quantitative Analysis, R. A. Day and A. L. Underwood, 6th edn., Prentice Hall (2012).
16. Analytical Chemistry, Dhruba Charan Dash, 1st edn., PHI Learning (2011).
17. Basic Concepts of Analytical Chemistry, S. M. Khopkar, 3rd edn., New Age International (2008).

CA H 412: ORGANIC CHEMISTRY

Course Outcomes

- Enable the students to learn the bonding in organic systems, various aspects of aromaticity, electronic effects, acidity and basicity of organic compounds.
- To gain knowledge on methods of determination of reaction mechanism, various reaction intermediates, aliphatic electrophilic and nucleophilic substitution reactions.
- To understand the detailed aspects of optical and geometrical isomerism.

UNIT–I **[12 Hours]**

Localized chemical bonding: Hybridization index, bonding in cyclopropane, bond distances, bond angles, bond energies, bond polarity, dipole moment and calculation of heat of reactions.

Delocalized chemical bonding: Conjugation, cross conjugation, resonance, steric inhibition of resonance, hyperconjugation, tautomerism, valence tautomerism. Bonding in fullerenes.

Bonding weaker than covalent: Hydrogen bonding, EDA complexes, inclusion compounds, Addition compounds, catenanes, rotaxanes and fluxional molecules.

Aromaticity: HMO theory and its application to simple π systems-ethylene, allyl, cyclopropyl, butadienyl, cyclopentadienyl, pentadienyl, hexatrienyl systems.

Homo-aromatic, non-aromatic and anti-aromatic systems. Aromaticity in benzenoid and non benzenoid molecules-Tropones, tropolones, borazine and azulene. Annulenes and hetero-annulenes.

UNIT-II **[12 Hours]**

Organic acids and bases: Brönsted-Lowry, Lewis concepts of organic acids and bases, pH, pKa values. Electronic (resonance, inductive and hyperconjugation), steric, hydrogen bonding and solvent effects on the strengths of acids and bases. HSAB concept.

Methods of determining reaction mechanism: Identification of products, detection of intermediates, isotopic labeling, stereochemical evidences, cross-over experiments, kinetic evidences and kinetic isotopic effects. Limitation of reactions.

Reaction intermediates: Generation, structure, stability, reactivity, detection, trapping and reactions of classical and non-classical carbocations, carbanions, free radicals, carbenes, nitrenes and arynes. Singlet oxygen-generation and reactions with organic molecules.

UNIT-III **[12 Hours]**

Aliphatic nucleophilic substitution reactions: Mechanism and scope of aliphatic nucleophilic substitution reactions-S_N1, S_N2 and S_Ni. Stereochemistry of nucleophilic substitution reactions, allylic nucleophilic substitution reactions. Neighbouring group participation & anchimeric assistance. Factors influencing the rates of nucleophilic substitution reactions.

Aliphatic electrophilic substitution reactions: Bimolecular mechanisms-S_E1, S_E2 and $S_Ei$mechanism. Electrophilic substitution reactions accompanied by double bond shifts.

α-Halogenation of aldehydes and ketones, aliphatic diazonium coupling, nitrosation at carbon bearing active hydrogen, mercury exchange reactions.

UNIT-IV: Stereochemistry **[12 Hours]**

Optical isomerism: Conformation and configuration. Projection formulae, Fischer, Saw-horse, Newman and Flying wedge representations, interconversion of projection formulae. Absolute configuration (D,L) and (R,S) systems. Elements of symmetry, chirality, molecules with more than one chiral centre, threo and erythro isomers, Psedoassymmetric centres. Racemizations and resolution methods. Stereospecific and stereoselective reactions. Asymmetric synthesis-Cram's and Prelog's rules. Optical activity in the absence of chiral carbon atom-biphenyls, allenes, spiranes, adamentanes, ansa compounds, cyclophanes, *trans*-cyclooctene, binaphthyls, catenanes, rotaxanes and helicenes. Conformational analysis of cycloalkanes and decalins.

Geometrical isomerism: Cis-trans isomerism resulting from double bonds, monocyclic compounds & fused ring systems. E,Z-notations, determination of configuration of geometrical isomers, syn & anti isomers.

References

1. Organic Chemistry, P .Y. Bruice, Pearson Education (2002).
2. Organic Reactions and Their Mechanisms, P. S. Kalsi, New Age, New Delhi (1996)
3. Stereochemistry, Conformation and Mechanism, P. S. Kalsi, Wiley Eastern (1993).
4. Stereochemistry of Carbon Compounds, E. L. Eliel, Tata McGraw Hill (1994).
5. Advanced Organic Chemistry-Reactions, mechanisms & structure, J. March, Wiley Eastern (2000).
6. Organic Chemistry: Vol.-1, 2 & 3, S. M. Mukherji, S. P. Singh and R. P. Kapoor, Wiley Eastern (1994).
7. A guide book of mechanisms in Organic Chemistry, P. Sykes, Orient- Longman (1985).
8. Organic Chemistry, R. T. Morrison and R. N. Boyd, Prentice Hall (1994).
9. Organic Chemistry, 4th edn., S. H. Pine, McGraw-Hill (1987).
10. Advanced Organic Chemistry, R. A. Carey and R. J. Sundberg, Plenum (1990).
11. Modern Concepts of Advanced Organic Chemistry, R. P. Narein, Vikas (1997).
12. A Text book of Organic Chemistry, K. S. Tewari, N. K. Vishnoi, S. N. Mehrotra, Vikas (1998).
13. A Text book of Organic Chemistry, 3rd edn., R. K. Bansal, New Age (1997).
14. Organic Reaction Mechanisms, R. K. Bansal, Tata McGraw Hill, New Delhi (1978).
15. Organic Chemistry, 3rd edn., F. A. Carey, Tata McGraw Hill (1996).
16. Organic Chemistry, H. Pine, McGraw Hill (1987).
17. Organic Chemistry- Vol. I, I. L. Finar, ELBS Longmann (1984).
18. Advanced General Organic Chemistry, S. K. Ghosh, Book and Alleied (1998).

CA H 413: PHYSICAL CHEMISTRY

Course Outcomes

- To understand the theoretical basis of catalysis, corrosion, various complex reactions which find relevance in biological processes and are of industrial importance and photochemical aspects of chemical reactions.
- The students are introduced to the modern techniques developed for the practical applications of these concepts in different areas of science and technology.
- This course will enable the students to handle issues related to catalytic reactions, corrosion in the day to day life and in industrial reactors; enzyme mediated reactions in biochemistry, biotechnology, pharmaceutical chemistry, electronic spectroscopy and different category of photochemical reactions etc.

UNIT-I **[12 Hours]**

Catalysis: Homogeneous Catalysis-Equilibrium and steady state treatments, activation energies of catalysed reactions. Acid-base catalysis (general and specific), protolytic and prototropic mechanisms, catalytic activity and acid strength measurements. Kinetics of enzyme catalysed mechanisms-Michaelis-Menten mechanism. Effect of pH, temperature and inhibitors. Semiconductor catalysis, n- & p- type. Industrial applications of catalysis.

Surface Chemistry: A review of adsorption isotherms, Langmuir and Freundlich isotherms-derivation. Multilayer adsorption: BET equation-derivation, application in surface area determination. Harkin-Jura equation and application.

Mechanism of surface reactions. Langmuir-Hinshelwood & Langmuir Rideal mechanisms.

UNIT–II **[12 Hours]**

Composite reactions: Rate equation and derivation of rate constants, simultaneous and consecutive reactions, steady state treatment, rate determining steps, chain reactions (hydrogen-halogen reactions with comparison, derivation of rate equation for H_2-Br_2). Auto catalytic reactions (Hydrogen-Oxygen reaction), explosion limits and oscillatory reactions.

Reactions in solution: Solvent effects on the reaction rates, factors determining reaction rates in solution. Reaction between ions (effect of dielectric constant and ionic strength), substitution and correlation effects (Hammet and Taft equations-linear free energy relations).

Fast reactions: Introduction, study of fast reactions by-flow, relaxation (T & P jump methods).

UNIT-III **[12 Hours]**

Electrochemistry: Ionic atmosphere-introduction and its effect on conductivity. Walden`s rule. Debye-Huckel limiting law (DHL), its modification and verification. Bjerrum theory of ion association, triple ion formation and its significance.

Corrosion: Introduction, principles, and classification. Techniques of corrosion rate measurement (instrumental and non-instrumental). Thermodynamics (Pourbaix diagram). Concept of mixed

potential theory and its importance in terms of Kinetics (Tafel and Evans diagram), passivity of corrosion. Protection against corrosion (Design improvement, anodic and cathodic protection, inhibitors, coating).

Unit IV **[12 Hours]**

Photochemistry: Introduction to photochemistry. Determination of quantum yield-Actinometry. Frank-Condon principle and its implications in predicting shapes of absorption and emission spectra. Effect of solute solvent interactions on electronic spectra-spectral shifts.Physicochemical properties of electronically excited molecules-excited state dipole moments, acidity constants. Flash photolysis technique.

Photochemical kinetics of unimolecular and bimolecular processes. Quenching-collisions in the gas phase and in solution (Stern-Volmer equation). Photoisomerization, photo Fries rearrangement and Norrish type cleavage reactions with specific examples.

References

1. Chemical Kinetics, 3rd ed.., K. J. Laidler, Pearson Education, Anand Sons (2008).
2. Fundamentals of Chemical Kinetics, M. R. Wright, Harwood Publishing, Chichesrer (1999).
3. Kinetics & Mechanisms of Chemical Transformations, J. Rajaram & J. C. Kuriacose, Macmillan (2007).
4. Chemical & Electrochemical Energy Systems, R. Narayan & B. Viswanathan, University Press (1998).
5. Industrial Electrochemistry, D. Peltcher and F. C. Walsh, Chapman & Hall (1990).
6. Principles and Applications of Electrochemistry, D. R. Crow, Chapman & Hall (2014).
7. An Introduction to metallic corrosion and its prevention, Raj Narayan, Oxford-IBH (1983).
8. Electrochemistry and Corrosion Science, Nebtor Ferez, Springer (2010).
9. Instrumental Methods of Chemical Analysis, H. Kaur, Pragati Prakashana (2018).
10. Fundamentals of Photochemistry, K. K. Rohatgi-Mukherjee, New Age Bangalore (2000).
11. Physical Chemistry, 7th edn., P. W. Atkins, Oxford University Press (2002).
12. Photochemistry, 2nd edn., Gurdeep Raj, Goel Publishing House (1991).
13. Photochemistry, Carol E. Wayne and Richard P. Wayne, Oxford University Press (1996).

CA S 414: INORGANIC SPECTROSCOPY AND OPTICAL METHODS

Course Outcomes

- Students will learn the basic principles and applications of ESR and Mossbauer spectroscopy.
- Students can be familiarizing with NQR and Photoelectron spectroscopy.
- Students will gain knowledge on Atomic Absorption Spectrometry, Emission Spectroscopy, Molecular Luminescence Spectroscopy and Light-Scattering methods for detection of metals, particles and particle size.
- Overall students can solve the problems related to above mentioned analytical techniques.

UNIT-I **[12 Hours]**

Electron Spin Resonance (ESR) Spectroscopy: Basic principles, selection rules, intensity, width, position of spectral line, multiplet structure of ESR spectra, hyperfine interaction, spin□orbit coupling, Zero Field splitting and Kramer's degeneracy, rules for interpreting spectra, factors affecting the magnitude of values. Instrumentation; Applications to the study simple inorganic and organic free radicals and to inorganic complexes, biological studies and rate of electron exchange reactions.

Mössbauer Spectroscopy: The Mössbauer effect, chemical isomer shifts, quadrupole interactions, measurement techniques and spectrum display, Application to the study of Fe^{2+} and Fe^{3+} compounds, Sn^{2+} and Sn^{4+} compounds (nature of M-L bond, coordination number and structure), structure determination of $Fe_3(CO)_{12}$, Prussian blue, oxyhemerythrin, hexacyanoferrates, nitroprusside, tin halides. Detection of oxidation states and inequivalent Mössbauer atoms.

UNIT-II **[12 Hours]**

Nuclear Quadrupole Resonance (**NQR) Spectroscopy:** Basic concepts-Nuclear electric quadrupole moment, electric field gradient, energy levels and NQR frequencies, effect of magnetic field on spectra; Factors affecting the resonance signal-Line shape, position of resonance signal; Relationship between electric field gradient and molecular structure. Interpretation of NQR data, structural information of PCl_5, $TeCl_4$, Na^+ $GaCl_4^-$, BrCN, HIO_3 and Hexahalometallates.

Photoelectron Spectroscopy: Basic principles, photoionization process, ionization energies, Koopman's theorem, Electron spectroscopy for chemical analysis (ESCA)-Photoelectron spectra of simple molecules-N_2, O_2 and F_2; Photoelectron spectra for the isoelectronic sequence-Ne, HF, H_2O, NH_3 and CH_4; chemical information from ESCA.

X-ray photoelectron and Auger electron spectroscopy: Principles and applications. Auger transitions, measurement techniques. Applications.

UNIT-III **[12 Hours]**

Flame Photometry: Flame emission spectroscopy (FES) and atomic absorption spectroscopy (AAS)-Introduction, principle, flames and flame spectra, variation of emission intensity with the flame, flame temperature, chemical reactions in flame, metallic spectra in flame, flame background. Total consumption and premix burners, role of temperature on absorption, emission and fluorescence. Effect of organic solvents. Comparative study of the basic components and difference in the instrumental design for atomic absorption and flame photometry. Precision and accuracy of AAS and FES. Relationship between AAS and FES, advantages over FES, devices used for the formation of an atomic vapour, applications, determination of sodium in different samples by flame photometry. Plasma emission spectroscopy-Principle, Inductively coupled plasma emission (ICP). ICP torch, instrumentation and applications.

References

1. Instrumental Analysis, D. A. Skoog, F. J. Holler and S. R. Crouch, Cengage Learning (2007).
2. Fundamental of Analytical Chemistry, 8th edn., D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, Saunders College Publishing, New York (2005).
3. Analytical Chemistry, 6th edn., G. D. Christian, Wiley-India (2015).
4. Analytical Chemistry, 4th edn., G. D. Christian, John Wiley & Sons (1986).
5. Instrumental methods of analysis, 7th edn., H. H. Wlliard, L. L. Merrit and J. J. Dean, Wadsworth (2012).
6. Instrumental Methods of Chemical Analysis, B. K. Sharma, Goel (2000).
7. Structural Methods in Inorganic Chemistry, E. A. V. Ebsworth, D. W. H. Ranklin and S. Cradock, Blackwell Scientific (1991).
8. Spectroscopy in Inorganic Chemistry: Vol I & II, C. N. R. Rao and J. R. Ferraro, Academic Press (1970).
9. Spectroscopy-Vol. 2, B. P. Straughan and S. Salker, John Wiley and Sons (1976).
10. Basic concepts of Analytical Chemistry, 3rd edn., S. M. Kopkar, New Age International (2009).
11. Principles of Instrumental Analysis, 8th edn., D. A. Skoog, F. J. Holler and T. A. Nieman, Cengage Learning (2012).
12. Analytical Chemistry: Principles, 2nd edn., J. H. Kennedy, Cengage (2011).
13. Chemical Analysis: An Instrumental Approach, 4th edn., Srivastava & Jain, S. Chand (201).
14. Instrumental methods of Chemical Analysis, 5th edn., Gurdeep R. Chatwal, Himalaya Publishing House (2015).
15. Fundamentals of Photochemistry, K. K. Rohatgi Mukherjee, New Age (2014).

CA S 415: ENVIRONMENTAL CHEMISTRY

Course Outcomes

- This course enlightens the students about environmental pollutions like air pollution, toxic chemicals in the environment and their control and safety measures.
- Hydrologic cycle, BOD, COD, radioactive waste management, sewage and industrial effluent treatment, water purification.
- Biochemical effects of pesticides and heavy metals.
- Students learn effect of toxic chemicals in environment.

UNIT-I **[12 Hours]**

Environmental segments, evolution of earth's atmosphere. Air pollution: Air pollutants, prevention and control, Greenhouse gases and acid rain. Carbon monoxide, industrial sources and transportation sources. SO_x-Sources, ambient concentration, test methods, control techniques-scrubbing, limestone injection process. Ozone hole and CFC's. Photochemical smog and PAN. NO_x-Sources, ambient concentration, test methods, thermodynamics and NO_x, control techniques. Particulates: Size distribution, particulate collection-settling chambers, centrifugal separators, wet scrubbers, electrostatic precipitators and fabric filters. Catalytic converters for mobile sources. Bhopal gas tragedy.

UNIT-II **[12 Hours]**

Hydrologic cycle, sources, chemistry of sea water, criteria and standards of water quality- safe drinking water, maximum contamination levels of inorganic and organic chemicals, radiological contaminants, turbidity, microbial contaminants. Public health significance and measurement of colour, turbidity, total solids, acidity, alkalinity, hardness, chloride, residual chlorine, sulphate, fluoride, phosphate and different forms of nitrogen in natural and polluted water. Chemicalsources of taste and odour, treatment for their removal, sampling and monitoring techniques. Determination and significance of DO, BOD, COD and TOC. Water purification for drinking and industrial purposes, disinfection techniques, demineralization, desalination processes and reverse osmosis.

UNIT-III **[12 Hours]**

Toxic chemicals in the environment, impact of toxic chemicals on enzymes. Detergents-Pollution aspects, eutrophication. Pesticides-Pollution of surface water. Sewage and industrial effluent treatment, heavy metal pollution. Chemical speciation-Biochemical effects of pesticides, insecticides, particulates, heavy metals (Hg, As, Pb, Se), carbon monoxide, nitrogen oxides, sulphur oxides, hydrocarbon, particulates, ozone, cyanide and PAN. Solid pollutants and its treatment and disposal. Radioactive waste management.

References

1. Environmental Chemistry, A. K. De, New Age International (2016).
2. Environmental Chemistry, S. K. Banerji, Prentice Hall India (1993).
3. Chemistry of Water Treatment, S. D. Faust and O. M. Aly, Butterworths (1983).
4. Chemistry for Environmental Engineering, 5th edn., C. N. Sawyer, P. L. McCarty and G. F. Parkin, McGraw Hill (2017).
5. Environmental Chemistry, I. Williams, John Wiley & Sons (2001).
6. Environmental Pollution Analysis, 2nd edn., S. M. Khopkar, New Age International (2020).
7. Physico-chemical examination of water, sewage and industrial effluents, N. Manivasakam, Pragati Prakashana (2008).
8. Environmental Chemistry, H. Kaur, New edition, Pragathi Prakshana (2014).

CA S 416: MOLECULAR SPECTROSCOPY AND DIFFRACTION TECHNIQUES

Course Outcomes

- Deals with the understanding of the spectroscopic techniques which are based on the interaction of the electromagnetic radiation in the microwave, infrared and X-ray region with the molecules.
- The techniques introduced here are major characterization techniques employed tounderstand the chemical composition of compounds and the physical characteristics.
- The paper has multidisciplinary relevance as these techniques are used in various fields namely, chemistry, physics biology and materials science.

Unit-I **[12 Hours]**

Introduction to spectroscopy, intensity of spectral lines, natural line width and broadening, rotational, vibrational and electronic energy levels, selection rules.

Microwave Spectroscopy: The rotation and classification of molecules, rotation spectra of diatomic and polyatomic molecules. Rigid and non-rigid rotator models. Determination of bond length, isotope effect on rotation spectra. Stark effect, nuclear and electron spin interaction. Microwave spectrometer.

Vibration Spectroscopy: Vibration spectra of diatomic molecules-Linear harmonic oscillator, vibrational energies, zero point energy, force constants and bond strengths; anharmonicity of molecular vibrations-Morse PE diagram, selection rules, fundamental, overtones and hot bands. Vibrations of polyatomic molecules-Normal modes of vibrations and nature of molecular vibrations (Ex. CO_2 and H_2O molecules).

UNIT-II **[12 Hours]**

Vibration-rotation spectra of diatomic and polyatomic molecules, selection rules, PQR branches. IR Spectrophotometer-Instrumentation.

Raman Spectroscopy: Classical and quantum theories of Raman effect, concept of polarizability and polarizability ellipsoid. Rotational and vibrational Raman spectra, selection rules, Raman activity of vibrations, vibrational-rotational Raman spectra, selection rules, mutual exclusion principle, polarization of Raman lines. An introduction to Laser Raman Spectroscopy. Raman spectrometer–Instrumentation. Applications of IR and Raman spectroscopy in elucidation of molecular structure (Ex - H_2O, N_2O & CO_2 molecules).

Unit-III **[12 Hours]**

Diffraction Techniques: Introduction, production of X-ray, Bragg`s law, Laue equations, Ewald`s diagram, X-Ray diffraction experiments–Diffraction of X-rays by a crystalline powder (Debye-Scherrer method), powder diffractometer. Single crystal technique: Laue and Rotation photographic methods. Moving Film method (Weissenberg method). Systematic absences.

Crystalline X-ray diffractometer (4 angle), X-ray scattering by atoms and molecules, Factors affecting X-ray intensities, introduction to Crystal structure analysis.

Electron Diffraction: Introduction, theory of electron diffraction, Wierl equation and its significance (qualitatively). Structure of surfaces-Low and high energy electron diffraction.

Electron microscopy (TEM & SEM): Principle and applications.

Theory and applications of neutron diffraction. Comparison between X-ray, electron and neutron diffractions.

References

1. Fundamentals of Molecular Spectroscopy, 4th edn., C. N. Banwell and E. M. McCash, Tata McGraw Hill (2017).
2. Spectroscopy, H. Kaur, Pragathi Prakashana (2017).
3. Introduction to Spectroscopy, D. L. Pavia, G. M. Lampmam, G. S. Kriz and J. A. Vyvyan, Cengage Learning (2014).
4. Spectroscopy, B.K. Sharma, Goel Publishing House (2015).
5. A Basic Course in Crystallography, J. A. K. Tareen and T. R. N. Kutty, University Press (2001).
6. Essentials of Crystallography, M. A. Waheb, Narosa Publishing House (2009).
7. X-ray methods, Clive Whiston, John Wiley & Sons (1987).

CA P 417: INORGANIC CHEMISTRY PRACTICALS

Course Outcomes

- Students will have hands on experience on the analysis of Hematite Dolomite, Pyrolusite, Solder.
- Analysis of halide mixture, Colorimetric determination and Gravimetric determinations.
- To understand complexometric determination and hardness of water.
- It enables the students to learn statistical analysis of data.

1. Analysis of Hematite-insoluble residue by gravimetry and Iron by volumetry using Ce^{4+}.
2. Analysis of Dolomite-Insoluble residue by gravimetry and Ca, Mg by complexometry.
3. Pyrolusite - Insoluble residue by gravimetry and manganese content by oxalate method.
4. Analysis of solder-Pb and Sn by EDTA method.
5. Complexometric determination of Mn, Ca, Mg, Cu, Ni and Fe-Cr mixture.
6. Hardness of water.
7. Analysis of halide mixture-Iodide by KIO_3 and total halide by gravimetrically.
8. Colorimetric determination of Iron by thiocyanate and Cu by aqueous ammonia.
9. Gravimetric determinations of Mn, Ni, Mo, Pb/Cr, sulphide, thiocyanate.
10. Preparation of Chrome alum/Chrome red/Lithopone/Mohr's salt.
11. Statistical analysis of data.

References

1. Vogel's Text Book of Quantitative Chemical Analysis, 5th edn., G. H. Jeffrey, J. Bassette, J. Mendham and R. C. Denny, Longman (1999).
2. Quantitative Analysis, 5th edn., R. A. Day and A.L. Underwood, Prentice Hall (1998).
3. Quantitative Analysis, 5th edn., R. A. Day and A. L. Underwood, Prentice Hall (1998).
4. Vogel's Qualitative Inorganic Analysis, 7th edn., G. Svehla, Longman (2001).
5. Advanced Practical Inorganic Chemistry, 28th edn., Gurudeep Raj, Goel Publishing House (2019).
6. Practical Inorganic Chemistry, Shika N. Gulati, J. L. Sharma and Shagun Manocha, CBS Publishers & Distributors (2017).

CA P 418: ORGANIC CHEMISTRY PRACTICALS–I

(Any twelve preparations are to be carried out)

Course Outcomes

- Student will learn the setting up of reaction and handling of glassware and reagents
- Enlighten the students to understand the method of organic preparation by utilizing various kinds of organic reactions.
- Explain the principle and mechanistic aspects of various basic organic reactions.
- Learn the isolation and purification of products.
- Acquire the experimental skills for the preparation of organic compounds.

Preparation of the following compounds through single step and isolation, recrystallization and determination of melting point & yield.

1. Preparations of p-bromoacetanilide from acetanilide, 2,4,6-tribromophenol from phenol, phenacyl bromide from acetophenone,1-bromo-2-naphthol from 2-naphthol and α,β-dibromocinnamic acid from cinnamic acid through bromination reactions.
2. Preparations of p-niroacetanilide from acetanilide, methyl m-nitrobenzoate from methyl benzoate, 2,4-dinitrochlorobenzene from chlorobenzene and 2,4-dinitroanisole from anisole through nitration reactions.
3. Preparations of p-nitroaniline from p-nitroacetanilide and p-bromoaniline from p-bromoacetanilide through hydrolysis reactions.
4. Preparations of nerolin (β-naphthyl methyl ether from β-naphthol and N-methylanthranilic acid from anthranilic acid through methylation reactions.
5. Preparations of α-and β-D-glucose penta-acetates from glucose, β-naphthyl acetate from β-naphthol and resacetophenone from resorcinol through acetylation.
6. Preparations of phenoxyacetic acid from phenol, o-cresyloxyacetic acid, 2,4-dichlorophenoxyacetic acid from 2,4-dichlorophenol and p-aminobenzoic acid from p-chlorobenzoic acid through nucleophilic substitution reactions.
7. Preparation of s-benzylisothiuronium chloride from benzylchloride through nucleophilic substitution reaction.
8. Preparation of cyclohexene from cyclohexanol and succinic anhydride from succinic acidthrough dehydration reactions.
9. Preparations of adipic acid from cyclohexanol and p-nitro benzoic acid from p-nitrotoluene through oxidation reactions.
10. Preparations of *p*-benzoquinone from hydroquinone and anthraquinone from anthraceneby oxidation reaction.
11. Preparations of benzhydrol from benzophenone, azobenzene from nitrobenzene and m-nitroaniline from meta-dinitrobenzene through reduction reactions.
12. Preparation of 4-formyl-N,N-dimethyl aniline from N,N-dimethylaniline through Vilsmeier-Haack formylation reaction.
13. Preparation of o-hydroxybenzophenone from phenyl benzoate via Fries rearrangement.

14. Preparation of p-chlorobenzoic acid from p-toluidine through diazotisation and Sandmeyer reaction.
15. Preparations of benzoic acid and benzyl alcohol from benzaldehyde and 4-chlorobenzoic acid and 4-chloro benzyl alcohol from 4-chlorobenzaldehyde by Cannizzaro reactions.
16. Preparations of benzalacetone and dibenzalacetone from benzaldehyde and acetone through Claisen-Schmidt condensation.
17. Preparation of cinnamic acid from benzaldehyde through Perkin condensation reaction.
18. Preparation of o-benzoyl benzoic acid from phthalic anhydride and benzene through Friedel-Craft's acylation.
19. Preparation of triphenylmethanol from benzoic acid through Grignard reaction.
20. Preparation of diazoaminobenzene from aniline through diazotisation and coupling reactions.
21. Preparations of p-iodonitrobenzene and o-iodobenzoic acid *via* diazotisation and nucleophilic substitution.
22. Preparation of osazone derivatives of monosaccharides through condensation reaction.
23. Preparation of hippruic acid from glycine through condensation reaction.

References

1. Practical Organic Chemistry, Ajay Kumar Manna, Books & Allied (2018).
2. Advanced Practical Organic Chemistry-Vol. II, Jag Mohan, Himalaya Publishing House (1992).
3. Laboratory Manual in Organic Chemistry, 3rd edn., R. K. Bansal, New Age (1996).
4. Experimental Organic Chemistry-Vol. I & II, *P. R. Singh*, D. S. Gupta and, K. S. Bajpai, Tata McGraw-Hill (1981).
5. Laboratory Manual in Organic Chemistry, B. B. Dey and M. V. *Sitaraman*, Books & Allied(1992).
6. Vogel's Text Book of Practical Organic Chemistry, 5th edn., B. S. Furniss, A. J. Hannaford, P. W. Smith and A. R. Tatchell, Longman-ELBS (2005).
7. A Text Book of Practical Organic Chemistry including Qualitative Organic Analysis, A.I. Vogel, Longman (1970).
8. Practical Organic Chemistry, F. G. Mann & B. C. Saunders, Orient Longman (2004).
9. Vogel's Text Book of Quantitative Chemical Analysis, 4th & 6thedn., J. Mendham, R. C.Denney, J. D. Barnes and M. J. Thomas, Pearson Education (2009).
10. Advanced Practical Organic Chemistry, J. Leonard, B. Lygo and G. Proctor, CRC Press (2013).
11. Techniques and Experiments for Organic Chemistry, 6th edn., Addison Ault, University Science Book (1998).
12. Comprehensive Practical Organic Chemistry-Preparation and Qualitative Analysis, V. K. Ahluwalia and Renu Aggarwal, Sangam Books Ltd. (2001).
13. An Advanced Course in Practical Chemistry, 3rdedn., A. K. Nad, B. Mahapatra and A. Ghoshal, New Central Book Agency (2011).

SECOND SEMESTER

CA H 461: ADVANCED INORGANIC CHEMISTRY

Course Outcomes

- Students will learn the predictions of spectral and structural properties of organic and inorganic molecules through symmetry elements and symmetry operation.
- Understand the halogen and noble gas chemistry.
- Study the chemistry of silicates and silicone polymers.
- Acquire knowledge on metallurgical aspects of oxide ores, metal oxides, nitrides, fluorides and sulphides.
- Study the chemistry of reactions in non-aqueous media.
- Learn the industrial biological applications of ceramic materials.
- Know the chemistry and applications of lanthanoids and actinoides.

UNIT–I **[12 Hours]**

Symmetry and group theory: Symmetry elements and symmetry operations. Point groups used with Molecules: Concept of a group, definition of a point group. Classification of molecules into point groups. Subgroups. Hermann-Maugin symbols for point groups. Multiplication tables (C_{2V}, C_{2h} and C_{3V}). Matrix notation for the symmetry elements. Classes and similarity transformation. Representation of groups: The great orthogonality theorem and its consequences. Character tables (Cs, Ci, C_2, C_2v, C_{2h} and C_3v). Applications of group theory to chemical bonding (hybrid orbitals for σ-bonding in different geometries and hybrid orbitals for π- bonding. Symmetries of molecular orbitals in BF_3, C_2H_4 and B_2H_6.

UNIT-II **[12 Hours]**

Halogens and noble gas chemistry: Interhalogens, psuedohalogens, polyhalide ions, oxyhalogen species, oxoacids of halogens, xenon oxides and fluorides.

Oxy and Peroxy acids of N, P and S.

Silicates: Structure, classification-Silicates with discrete anions, silicates containing chainanion, silicates with layer structure, silicones with three dimensional net-work and applications.

Silicones: General methods of preparation, properties.

Silicone polymers: silicone fluids, silicone greases, silicone resins, silicone rubbers and their applications.

UNIT–III **[12 Hours]**

Chemistry of Ti subgroup and inner transition elements

Trends in oxidations states, stereochemistry and ionic sizes of metals, comparison of 3d, 4d and 5d series by taking Ti and Ni subgroups as examples.

Lanthanoid Chemistry: General trends, Electronic and optical properties. Abundance and

extraction, General principles: Conventional, solvent extraction and ion-exchange methods. Separation from monazite. Chemistry of principal oxidation states (II, III and IV). Stability of tetrahalides, dihalides and aqua ions of simple lanthanide compounds. Redox potentials. Uses: Lanthanides as shift reagents, lanthanides as probes in biological systems. High temperature super conductors.

Actinoid Chemistry: General trends and electronic spectra. Occurrence and preparation of elements, Isolation of the elements: thorium and uranium, enrichment of uranium for nuclear fuel, uranium hydrides, oxides and chlorides. Chemical reactivity and trend. Chemistry of trans- uranium elements.

UNIT–IV **[12 Hours]**

Metallurgy and redox potentials: Methods of reduction of oxide ores, chemical and electrolytic reductions, Ellingham diagram, specialized techniques for the extraction of metals- Amalgamation, hydrometallurgy, solvent extraction, Ion exchange chromatography. Reduction potentials, Latimer and Frost diagrams–features and applications. Effect of complexation on potential.

Metal oxides, nitrides and fluorides: Monoxides of the 3d metals, higher oxides and complex oxides, oxide glasses, nitrides and fluorides.

Sulfides, intercalation compounds and metal rich phases: Layered MS2 compounds and intercalation, Chevrel phases.

Ceramic materials: Sol-gel process and applications of biomaterials of ceramics.

References

1. Group Theory in Chemistry, 2nd edn., M. S. Gopinathan and V. Ramakrishnan, Vishal Publishing (2007).
2. Symmetry and Group theory in Chemistry, 1st edn., R. Ameta, New Age International (2013).
3. Chemical Applications of Group Theory, 3rd edn., F. A. Cotton, John Wiley & Sons (1990).
4. Symmetry and Spectroscopy of Molecules, 2nd edn., K. Veera Reddy, New Age International (2009).
5. Inorganic Chemistry, 4th edn., P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Oxford University Press (2006).
6. Inorganic Chemistry, 4th edn., J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, Pearson Education (2013).
7. Concepts and Models of Inorganic Chemistry, 3rd edn., B. E. Douglas, D. McDaniel and A. Alexander, Wiley (2007).
8. Inorganic Chemistry, 2nd edn., C. E. Housecroft and A. G. Sharpe, Pearson Prentice Hall (2005).
9. Inorganic Chemistry: A Unified Approach, 2nd edn., W. W. Porterfield, Elsevier (2005).

10. Advanced Inorganic Chemistry, 6th edn., F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, Wiley (2014).
11. Advanced Inorganic Chemistry-Vol. II, 4th edn., Satya Prakash, G. D. Tuli, S. K. Basu and R. D. Madan, S. Chand (2014).
12. Principles of Inorganic Chemistry, 31st edn., B. R. Puri, L. R. Sharma and K. C. Kalia, Vishal Publishing (2013).
13. Lanthanide and Actinide Chemistry, Simon Cotton, John Wiley and Sons (2006).
14. Inorganic Chemistry: A Unified Approach, W. W. Porterfield, Elsevier (2005).
15. Chemistry of the Elements, 2nd edn., N. N. Greenwood and A. Earnshaw, Butterworth (2005).
16. Essential of Materials Science and Engineering, Donald R. Askeland and Pradeep P. Fulay, 2nd edn., Cengage Learning (2009).
17. Nature and Properties of Engineering Materials, Z. D. Jastrazebski, John Wiley & Sons (1989).

CA H 462: ADVANCED ORGANIC CHEMISTRY

Course Outcomes

- Students will gain an understanding of all details of aromatic electrophilic and nucleophilic substitution reactions.
- Learn about various free radical reactions and elimination reactions including pyrolytic eliminations.
- Gain an understanding of formation and hydrolysis of esters.
- Study the all types of addition to carbon-carbon and carbon-heteroatom multiple bonds.
- Know the reaction mechanism and synthetic uses of organic named reactions.

UNIT-I **[12 Hours]**

Aromatic Electrophilic and Nucleophilic Substitution Reactions: Mechanism of aromatic electrophilic substitution reactions-nitration, halogenation, sulphonation, Friedel-Crafts alkylation and acylation, orientation and reactivity, energy profile diagram. The ortho/para ratio, ipso attack, orientation in other ring systems. Mechanism of Vilsmeir-Haack reaction, Mannich reaction, Diazonium coupling, Pechmann reaction and Fries rearrangement. Mechanisms of aromatic nucleophilic substitution reactions- S_NAr, S_N1 &aryne mechanism. Von-Richter rearrangement, Sommelet-Houser rearrangement, Smiles rearrangement.

UNIT-II **[12 Hours]**

Free Radical Reactions: Mechanisms of free radical substitution reactions &neighbouring group assistance. Reactivity for the aliphatic and aromatic substances at a bridgehead. Reactivity of attacking radical. Effect of solvent on reactivity. Auto-oxidation, coupling of alkynes. Arylation of aromatic compounds by diazonium salts. Sandmeyer, and Hunsidiecker reactions.

Elimination Reactions: Discussions of E1, E2 and E1cB mechanisms. Orientation during elimination reactions. Saytzeff and Hofmann rules. Reactivity-effects of substrate structures, attacking base, leaving group and solvent medium.

Pyrolytic Eliminations: Mechanisms of pyrolysis of acetates. Xanthate pyrolysis-Chugaev reaction, Hofmann degradation and Cope elimination.

UNIT-III **[12 Hours]**

Formation and Hydrolysis of Esters: Plurality of mechanism. Mechanism of esterification reactions. Ester hydrolysis-$A_{AC}2$, $B_{AC}2$, $B_{AL}1$, $B_{AL}2$, $A_{AC}1$ & $A_{AL}1$ mechanisms. Trans-esterification.

Addition to Carbon-Carbon Multiple Bonds: Addition reactions involving electrophiles, nucleophiles and free radicals. Cyclic mechanisms. Orientation and stereochemistry. Addition of halogens, hydrogen halides, oxygen-epoxidation, carboxylic acids and amines. Michael addition, Addition to cyclopropanes.

Addition to Carbon-Hetero Multiple Bonds: Electrophilic, nucleophilic and free radical additions to C=O and C=N systems. Addition of Grignard reagents. Reformatsky reaction, aldol condensation, Knoevenagel condensation, Perkin reaction and Wittig reactions.

UNIT-IV **[12 Hours]**

Organic Name Reactions: Reactions, Mechanisms and synthetic uses of the following: Stobbe condensation, Darzen condensation, Gattermann-Koch reaction, Duff reaction, Chichibabin reaction, Benzoin condensation, Claisen-Schmidt condensation, Claisen reaction, Stork Enamine reactions, Sharpless asymmetric epoxidation, Suzuki coupling, Heck reaction, Ullmann reaction, Bucherer reaction, Shapiro reaction, Mitsunobu reaction, Stephen reaction.

References

1. Organic Reactions and Their Mechanisms, P. S. Kalsi, New Age (1996).
2. Advanced Organic Chemistry, 4th edn., J. March, Wiley Eastern (2000).
3. Organic Chemistry: Vol.-1,2 & 3, S. M. Mukherji, S. P. Singh and R. P. Kapoor, Wiley Eastern, (1994).
4. Mechanism and Theory in Organic Chemistry, Lowry T. H., Richardson K. S., Harper and Row (1987).
5. Reaction Mechanisms in Organic Chemistry, S. M. Mukherji, S. P. Singh and R. P. Kapoor, McMillan (1978).
6. Organic Chemistry, P. Y. Bruice, Pearson Education (2002).
7. Organic Reaction Mechanism, R. K. Bansal, Wiley Eastern (1993).
8. A guide book of mechanisms in Organic Chemistry, P. Sykes, Orient-Longman (1985).
9. Advanced Organic Chemistry-Vol-1, I. L. Finar, Longmann (1984).
10. Advanced General Organic Chemistry, S. K. Ghosh, Books and Allied (1998).
11. Synthetic Organic Chemistry, G. R. Chatwal, Himalaya Publishing House (1994).
12. Organic Reaction Mechanisms, V. K. Ahluwalia and R. K. Parashar, Narosa (2006).
13. Advanced Organic Chemistry, 3rd edn., F. A. Carey and R. J. Sundberg, Part A & B, Plenum Press (1990).
14. Organic Chemistry, J. Clayden, N. Greeves and S. Warren, Oxford University Press (2001).
15. Name reactions and reagents in organic synthesis, B. P. Mundy, M. G. Ellerd and F. G. Favaloro, 2nd edn., John Wiley and Sons (2005).
16. Named organic reactions, 2nd edn., T. Laue and A. Plagens, John Wiley and Sons (2005).
17. Named Reactions, J. J. Li, 3rd edn., Springer Verlag (2006).

CA H 463: ADVANCED PHYSICAL CHEMISTRY

Course Outcomes

- It is an advanced level course which helps to understand the concepts of physics and their subsequent applications in the field of chemistry. The concepts of chemical thermodynamics helps in the design of processes in chemical industries.
- The concepts of statistical thermodynamics find relevance in understanding the nature of solids and metals in specific.
- Quantum chemistry forms the basis of chemical bonding, photochemistry and spectroscopy.
- Reaction dynamics deals with advanced aspects of chemical kinetics.

UNIT-I: Chemical Thermodynamics [12 Hours]

Entropy: Physical significance, entropy change in an ideal gas. Entropy change in reversible and irreversible processes. Thermodynamic equations of state.

Free energy, Maxwell's relations and significance. Gibbs-Helmholtz equation and its applications.

Nernst heat theorem: Its consequences and applications. Third law of thermodynamics-statements, applications and Comparison with Nernst Heat theorem.

Chemical affinity and thermodynamic functions. Effect of temperature and pressure on chemical equilibrium-van't Hoff reaction isochore and isotherms.

Chemical potential: variation of chemical potential with temperature. Gibbs-Duhem equation. Thermodynamic functions of mixing, Gibbs-Duhem-Margules equation.

Fugacity: Relationship between fugacity and pressure. Determination of fugacity-Graphical method and Lewis Randall rule.

Activity and activity coefficient: Determination of activity by vapour pressure method.

UNIT-II: Statistical Thermodynamics [12 Hours]

Thermodynamic Probability, phase space, micro and macrostates, statistical weight factor, assembly, ensemble-significance, classification and comparison. Derivation of Distribution laws, Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac Laws, Limit of applicability of various laws. Partition function, Significance, Relationship between partition function and thermodynamic functions-Average energy, heat capacity, free energy, chemical potential for molecular particles.

Thermodynamic quantities in terms of partition function of particles: Evaluation of translational, vibrational, rotational, electronic partition functions. Law of equi-partition principle. Partition function and equilibrium constant. Applications of partition function to mono atomicgases, diatomic molecules.

Statistical thermodynamic properties of solids (Heat capacity): Introduction, thermal characteristics of crystalline solid, Einstein model, Debye modification equilibrium constant.

UNIT-III: Quantum Chemistry **[12 Hours]**

Particle waves, its character and significance. De-Broglie concept, uncertainty principle, Formulation of Shrodinger equation- significance and characteristics of wave function, Statistical significance of ψ. Normalization and orthogonality, Acceptable wave functions.

Postulates of quantum Mechanics, Operators, Operator algebra, types and applications, operators for the dynamic variables of a system (position, linear momentum, angular momentum, kinetic energy, potential energy and total energy). Eigen values and Eigen functions. Solution of SE for particle in a box (1D & 3D), particle in a ring, H atom. Applications of quantum mechanics to chemical bonding. Covalent bond-Valence bond and molecular orbital approaches with comparison.

Unit-IV: Reaction Dynamics **[12 Hours]**

Kinetics of Composite Reactions: Inorganic reaction mechanism (decomposition of N_2O_5 and phosgene). Organic reaction mechanism-decomposition of acetaldehyde, Gold-Finger, Letort-Niclause rules, combustion of hydrocarbon.

Transition state theory: Derivation of rate constant, equilibrium hypothesis, Concept of tunnelling. Applications of TST to reactions in solution & reaction between atoms, Thermodynamic formulation of transition-State theory, limitations of TST. Extension of TST. **Potential energy surfaces:** Features & construction. Theoretical calculation of E_a. Features of potential energy surfaces (attractive and repulsive surfaces for exothermic reaction). A brief account of stripping and rebound mechanisms. Spectroscopy of transient species.

References

1. Thermodynamics for Chemists, S. Glasstone, East West Press (1960).
2. Atkin's Physical Chemistry, Peter Atkins and Julio De Paula, Oxford University Press (2002).
3. Chemical Themodynamics, J. Rajaram and J. C. Kuriokose, East-West Press-Pearson (2013).
4. Thermodynamics, 3rd edn., R.C. Srivastava and Subit K. Saha, Prentice-Hall of India (2007).
5. Statistical Thermodynamics, M. C. Gupta, New age International (2007).
6. Principles of Physical Chemistry, B. R. Puri, L. R. Sharma and M. S. Pathania, VishalPublishers (2014).
7. Atomic Structure and Chemical Bond, Manasa Chanda, Tata McGraw Hill (1991).
8. Quantum Chemistry, R. K. Prasad, New Age International (1991).
9. Advanced Physical Chemistry, Gurdeep R. Chatwal, Goel Publishers (1992).
10. Introductory Quantum Chemistry, A. K. Chandra, Tata McGraw Hill (1994).
11. Quantum Chemistry, A. B. Sannigrahi, Books and Allied (2013).
12. Quantum Chemistry, Donald A. P., Viva Books (2013).
13. Chemical Kinetics, 3rd edn., K. J. Laidler, Pearson Education, Anand Sons (2008).
14. Fundamentals of Chemical Kinetics, M. R. Wright, Harwood Publishing, Chichesrer (1999).
15. Kinetics & Mechanisms of Chemical Transformations, J. Rajaram and J. C. Kuriacose, Macmillan (2007).

CA S 464: ORGANIC SPECTROSCOPY

Course Outcomes

- Enable the students to understand the principle, theory, instrumentation and applications of UV/Electronic, IR, NMR (^{1}H, ^{13}C, ^{19}F, ^{31}P) and Mass spectroscopy.
- To solve the composite problems involving the applications of UV, IR, NMR (^{1}H &^{13}C) and Mass spectroscopic techniques.
- To develop the ability to analyse the spectrum and arrive at the correct structure of the compounds.
- Overall students can get confidence in solving spectroscopic problems.

UNIT-I **[12 hours]**

UV/Electronic Spectroscopy: Basic principles, chromophores, auxochromes, Instrumentation and application. Factors affecting the positions of UV bands. Electronic transitions and empirical correlations of predicting λ_{max} of organic compounds. Woodward–Fieser rules. UV absorption of aromatic compounds-effect of substituents and solvent effects. Empirical rules to calculate $\lambda_{max.}$ Application of UV spectroscopy in the structural study of organic molecules.

IR Spectroscopy: Basic principles, Application of infrared spectroscopy in the structural study-identity by finger printing and identification of functional groups. Characteristic vibrational frequencies of common functional groups (alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines). Study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, anhydrides and acids). Factors affecting band positions and intensities such as effect of hydrogen bonding, phase and solvent on vibrational frequencies, overtones, combination bands and Fermi resonance.

UNIT-II: Nuclear Magnetic Resonance Spectroscopy **[12 hours]**

Theory and principle, NMR spectrometer, FT NMR and its advantages. Solvents used, chemical shift and its measurements, factors affecting chemical shift. Integration of NMR signals, spin-spin coupling, coupling constant. Shielding and deshielding. Chemical shift assignment of major functional groups, Classification (ABX, AMX, ABC, A_2B_2), spin decoupling, effects of chemical exchange, fluxional molecules, Hindered rotation through NMR spectrum, Karplus relationships (Karplus curve–variation of coupling constant with dihedral angle), double resonance techniques, NMR shift reagents, solvent effects and Nulear Overhauser Effect. Applications of NMR spectroscopy in structure elucidation of simple organic and inorganic molecules. Use of NMR in Medical diagnostics.

NMR of nuclei other than proton: ^{13}C chemical shift & factors affecting it. Decoupling-Noise decoupling & broad band decoupling. Off-resonance proton decoupling-some representative examples. Introduction to ^{19}F & ^{31}P NMR.

UNIT-III: Mass Spectrometry **[12 hours]**

Basic principles, Instrumentation, interpretation of mass spectra, resolution, exact masses of nucleides, molecular ions, meta-stable ions and isotope ions.

Fragmentation processes-Representation of fragmentation, basic fragmentation types and rules. Factors influencing fragmentations and reaction pathways. McLafferty rearrangement. Fragmentations associated with functional groups- alkanes, alkenes, cycloalkanes, aromatic hydrocarbons, halides, alcohols,phenols, ethers, acetals, ketals, aldehydes, ketones, quinines, carboxylic acids, esters, amides, acid chlorides, nitro compounds and amines. Ion analysis, ion abundance, retro Diels-Alder fragmentation. Nitrogen rule. High resolution mass spectroscopy.

Composite problems involving the applications of UV, IR, ^{1}H and ^{13}C NMR and mass spectroscopic techniques. Structural elucidation of organic molecules.

References

1. Spectrometric Identification of Organic Compounds, R. M. Silverstein, G. C. Bassler and T. C. Monnill, Wiley Eastern (1981).
2. Applications of Absorption Spectroscopy of Organic Compounds, J. R. Dyer, Prentice Hall (1965).
3. Spectroscopy of Organic Compounds, 3rd edn., P. S. Kalsi, New Age, New Delhi (2000).
4. Spectroscopic Methods in Organic Chemistry, D. H. Williams and I. Fleming, Tata McGraw Hill (1987).
5. Introduction to Spectroscopy, D. L. Pavia, G. M. Lampman, G. S. Kriz and J. A. Vyvyan, 5th edn., Cengage Learning (2014).
6. Spectrometric Identification of Organic Compounds, 8th edn., R. M. Silverstein, F. X. Webster and D. J. Kiemle, Wiley (2014).
7. Organic Spectroscopy, 3rd edn., W. Kemp, Pagrave Publishers (1991).
8. Modern Spectroscopy, J. M. Hollas, 4th edn., John Wiley and Sons (2004).
9. Organic Structures from Spectra, 5th edn., L. D. Field, S. Sternhell and J. R. Kalman, Wiley Eastern (2013).

CA S 465: CHEMISTRY OF BIOMOLECULES

Course Outcomes

- Enable the students to learn about cell structures, structure and functions of lipids and lipoproteins.
- To understand the importance and functions of enzymes and coenzymes in biologicalsystems.
- It helps in understanding metabolic pathways of cholesterol, bile acids, and prostaglandins.
- Mechanism of reactions catalyzed by the above coenzymes.

UNIT-I **[12 Hours]**

Cell Structure and Functions: Structure of prokaryotic and eukaryotic cells, intracellular organelles and their functions, comparison of animal and plant cells. Overview of metabolic processes-Catabolism and anabolism. ATP- the biological energy currency. Origin of life-Unique properties of carbon, chemical evolution and rise of living systems.

Lipids: Fatty acids, essential fatty acids, structure and function of triacylglycerides, glycerophospholipids, sphingolipids, cholesterol, bile acids, prostaglandins.

Lipoproteins: composition and function, role in atherosclerosis, properties of lipid aggregates, micelles, bilayers, liposomes and their biological functions. Biological membranes- Fluid mosaic model of membrane structure. Lipid metabolism (β-oxidation of fatty acids).

UNIT-II **[12 Hours]**

Enzymes: Introduction**,** Classification, Enzyme substrate complex formation models: Lock and Key model, Host-Guest and Induced-Fit model. Factors affecting enzyme activity (pH, temperature), enzyme inhibition (reversible and irreversible) and immobilised enzymes. Examplesof some typical enzyme mechanisms for Triose phosphate isomerase, α-Carboxy peptidase-A and Ribonuclease. Enzymatic synthesis of α-amino acids and peptides. Transformations of lipases and esterases. Kinetic resolutions of carboxylic acids, esters and alcohols-Trans- esterification. Enzymatic synthesis of α-amino acids and peptides. Transformations of lipases andesterases.

UNIT-III **[12 Hours]**

Coenzymes: Introduction, Co-factors-co-substrates-prosthetic groups. Classification-Vitamin derived coenzymes and metabolite coenzymes. Structure and biological functions of coenzyme A, thiamine pyrophosphate (TPP), pyridoxal phosphate (PLP), oxidized and reduced forms of nicotinamide adenosine dinucleotide / their phosphates (NAD, NADH, $NADP^+$, NADPH), Flavin adenine nucleotide (FAD, FADH2), Flavin mononucleotide (FMN, FMNH2) and tetrahydrofolate. Adenosine triphosphate (ATP) and adenosine diphosphate (ADP). Mechanism of reactions catalyzed by the above coenzymes.

References

1. Lehninger Principles of Biochemistry, 7th edn., D. L. Nelson and M. M. Cox, Worth Publishers (2000).
2. Biochemistry, L. Stryer, W. H. Freeman and Company (1975).
3. Biochemistry, J. D. Rawn, Neil Patterson Publishers (1989).
4. Biochemistry, 4th edn., Voet Donald and Voet Judith G., John Wiley and Sons (2010).
5. Outlines of Biochemistry, 5th edn., E. E. Conn, P. K. Stumpf. G. Bruening and R. H. Doi, John Wiley & Sons (2006).
6. Enzyme structure and mechanism, F. Alam, W. H. Freeman and Company (1977).
7. Principles of Biochemistry, L. Moran, R. Horton, G. Scrimgeour and M. Perry, Pearson Education (2013).
8. Bioorganic Chemistry-A chemical approach to enzyme action, Herman Dugas and Christopher Penney, Springer (1989).

CA E 466: ENVIRONMENTAL, ELECTRO- AND POLYMER CHEMISTRY

Course Outcomes

- It is an elective course offered to students from disciplines other than chemistry.
- It aims at enhancing their general understanding of chemistry. Few important topics such as sources and detection of air pollution, batteries as power sources, devices of solar energy conversion.
- It enables to understand polymers used in day to day life and their medical and technical applications.
- It creates awareness of plastic pollution and technique of plastic waste management.

UNIT-I **[12 Hours]**

Environmental segments, evolution of earth's atmosphere. Air pollution: Air pollutants, prevention and control, Greenhouse gases and acid rain. Carbon monoxide, industrial sources and transportation sources. SO_x-Sources, ambient concentration, test methods, control techniques - scrubbing, limestone injection process. Ozone hole and CFC's. Photochemical smog and PAN. NO_x-Sources, ambient concentration, test methods, thermodynamics and NO_x, control techniques. Particulates: Size distribution, Particulate collection-Settling chambers, centrifugal separators, wet scrubbers, electrostatic precipitators & fabric filters. Catalytic converters formobile sources. Bhopal gas tragedy.

UNIT-II **[12 Hours]**

Corrosion: Introduction, consequence, type, prevention, & measurement. Conventional sources of energy, limitations, Importance of storage, Battery-Electrodes, Cell, battery Brief account of primary, secondary, lithium battery and fuel cells. Semiconductor electrodes and solar energy system.

Introduction to bio-electrochemistry, electrochemical communication in biological organisms. Theory and applications of Electroplating and electroless plating.

Reaction Kinetics: Theory and applications of different types of reactions-Oscillatory, chain reaction, branched chain reaction. Energy of activation and thermodynamic parameters, Collision theory of reaction rates limitations and basics of transition state theory.

UNIT-III **[12 Hours]**

Polymers: Introduction-Basic concepts and classification of polymers, Molecular weight and its distribution, Chemistry of polymerization- Step, chain, Coordination, Copolymerization.

Polymerization techniques- bulk, solution, suspension, emulsion, poly-condensation, solid and gas phase polymerization. Chemical and geometrical structure of polymer molecules, Structure-property relationship-Physical, thermal and mechanical properties.

Synthesis, properties, structural features and applications of some important commercial polymers (PE, PP, PS, PVC, PMMA, PET, Nylon-6, Nylon-6,6), Engineering polymers (Kevlar, Nomex,

ABS, PC, Teflon). Applications of polymers in separations: Reverse osmosis, ultra and nano-filtration. Applications in electronics-Conducting polymers and electronic shielding, Applications of polymers in medicine.

Management of plastics in environment-Recycling, incineration and biodegradation.

References

1. Environmental Chemistry, A.K. De, New Age International (2016).
2. Environmental Chemistry, S.K. Banerji, Prentice Hall, India (1993).
3. Chemistry for Environmental Engineering, 3rd edn., C. N. Sawyer and P. L. McCarty, McGraw Hill (1978).
4. An Introduction to metallic corrosion and its prevention, Raj Narayan, Oxford-IBH, NewDelhi (1983).
5. Chemical& Electrochemical Energy Systems, R. Narayan and B. Viswanathan, University Press(1998).
6. Industrial Electrochemistry, D. Peltcher and F. C. Walsh, Chapman and Hall (1990).
7. Text book of Polymer science, 3rd edn., F.W. Billmeyer, Wiley-Interscience Publication, New York (2005).
8. Polymer Science, V.R. Gowariker, New Age International, New Delhi (2012).
9. Specialty Polymers, R.W. Dyson, Chapman and Hall, New York (1987).
10. Polymer Science and Technology, J.R. Fried, Prentice Hall of India, New Delhi (1999).
11. Polymer Science and Technology, P. Ghosh, Tata-McGraw Hill, New Delhi (1995).

CA P 467: ORGANIC CHEMISTRY PRACTICALS-II

(Analysis of 6 binary mixtures is to be carried out)

Course Outcomes

- Student will gain the in-depth knowledge and skill in identification and separations of organic compounds from binary mixtures of organic compounds containing both mono and bi- functional groups, their purifications and systematic qualitative analyses.
- Understand the purification of the components, determination of boiling point/melting point for components and melting point of their derivatives.
- Learn the application of concepts of different organic reactions studied in theory part of organic chemistry.
- Study the complete identification of organic compound with melting point and preparation of a suitable derivative.
- Learn the use glassware, equipment and chemicals and follow experimental procedures in the laboratory.

Identification of components in the binary mixture of organic compounds and the method of separation. Systematic semi-micro qualitative analysis by the Identification of the functional group(s) present in each of the compound and preparation of one solid derivative each for their confirmation.

Demonstration of identification and method of separation of organic compounds from ternary mixtures of organic compounds.

References

1. Practical Organic Chemistry, Ajay Kumar Manna, Books and Allied (2018).
2. Advanced Practical Organic Chemistry-Vol. II, Jag Mohan, Himalaya Publishing House (1992).
3. Practical Organic Chemistry, F .G. Mann and B. C. Saunders, ELBS, England (2001).
4. Practical Organic Chemistry, A. I. Vogel, Longman-ELBS, England (1971).
5. Experimental Organic Chemistry–Vol. I & II, *P.R. Singh,* D.S. Gupta and K.S. Bajpai, Tata McGraw-Hill (1981).
6. Semimicro Qualitative Organic Analysis-The Systematic Identification of Organic Compounds, Nicholas D. Cheronis, John B. Entrikin, Ernest M. Hodnett, Wiley-Eastern, New Delhi (1965).
7. A Text Book of Practical Organic Chemistry including Qualitative Organic Analysis, A.I. Vogel, Longman (1970).
8. Vogel's Text Book of Practical Organic Chemistry Including Qualitative Organic Analysis, B. S. Furniss, A. J. Hannaford, P. W. Smith and A. R. Tatchell, *Longman-ELBS, England (1978).*
9. *Laboratory Manual in Organic Chemistry, Dey B. B. and* Sitaraman M. V, Books &Allied (1992).
10. Modern Experimental Organic Chemistry, John H. Miller and E.F. Neugil, D. C. Heath and Company (1982).
11. Hand book of organic analysis, H. T. Clarke and J. N. Collie, E. Arnold and Co., London (1975).
12. Experiments in Organic Chemistry, 2nd edn., L. F. Fieser, D. C. Heath and Co. (1941).
13. Organic Experiments, 8th edn., Ed. L. F. Fieser and K. L. Williamson, Houghton Mifflin (1998).

CA P 468: PHYSICAL CHEMISTRY PRACTICALS

(**Any 12 experiments are to be carried out)**

Course Outcomes

- Experiments have been designed which make use of the concepts of electrochemistry, thermodynamics, solution chemistry and surface chemistry.
- Students get hands on experience in use of various instruments and will be able to test the theoretical concepts.

1. Determination of transport number of Cd^{2+} and SO_4^{2-} ions by EMF method.
2. Determination of thermodynamic parameters of a cell reaction by EMF method.
3. Determination of pK values phosphoric acid by potentiometric/pH metric method.
4. Potentiometric titration of halides in mixtures (Cl^-, Br^- and I^-) with silver nitrate.
5. Verification of Nernst equation for Ag^+, $Cu^{2+}$and Zn^{2+} species.
6. Determination of Solubility product and the Instability constant by potentiometric method.
7. Potentiometric determination of solubility of insoluble silver halide and the standard electrode potential using quinhydrone electrode.
8. Conductometric titrations of displacement and precipitation reactions.
9. Determination of equivalent conductance and dissociation constants of weak acid and base.
10. Determination of solubility of lead iodide at different T & hence molar heat of solution
11. Determination of hydrolysis constant of aniline hydrochloride.
12. Determination of degree of hydrolysis of CH_3CO_2Na and NH_4Cl by conductivity method.
13. Determination of pH of buffer solutions with a pH meter and evaluation of pK_a of acids
14. Verification of Walden`s rule (relation between viscosity of a solution and the electrical conductivity.
15. Study of variation of viscosity of a liquid with temperature.
16. Determination of parachor value for CH_2 group and some elements by Surface Tension Method.
17. Determination of the composition of a solution by S.T measurements. .
18. Determination of the Critical Micelle Concentration by surface tension/conductometric measurements.
19. Determination of specific and molar refractivity of liquids and parachor value of a species by refractometric method.

Any other relevant experiments of interest.

References

1. Findlay's Practical Physical Chemistry, Alexander Findlay and B. P. Levitt, Prentice Hall Press (1973).
2. Practical Physical Chemistry, 3rd edn., A. M. James and F.E. Prichard, Longman (1974).
3. Experimental Physical Chemistry, 7th edn., F. Daniels, Tata McGraw Hill (1970).
4. Experimental Physical Chemistry, R. C. Das and B. Behera, Tata McGraw Hill, New Delhi (1983).
5. Advanced Practical Physical Chemistry, J. B. Yadav, Krishnaprakashan Media Publication (2016).
6. Experiments in Physical Chemistry, J. C. Ghosh, Bharathi Bhavan, New Delhi (1974).
7. Practical Physical Chemistry, B. Viswanathan and P. S. Raghavan, ViVa Books, New Delhi (2017).

THIRD SEMESTER

CA H 511: FUNDAMENTALS OF ADVANCED INORGANIC CHEMISTRY AND INTRODUCTION TO ANALYTICAL CHEMISTRY

Course Outcomes

- Students will get an exposure to the Chemistry of d- and f- block elements including their spectral and magnetic properties.
- Understand the catalysis by organometallic compounds in synthesis and Inorganic reaction mechanisms.
- Learn the stability constants of metal complexes and their applications.
- Know the evaluation of analytical data in terms of statistics and interpretation of the sources of random errors and effects of random errors on analytical results.
- Learn and analyse the different gravimetric and titrimetric analysis methods.

Unit-I: Chemistry of d- and f-block elements [12 Hours]

Term-symbols, Russel-Saunders states, Crystal field theory and splitting in O*h*, T*d*, D*4h* and C*4v* systems, Orgel and Tanabe-Sugano diagrams, determination of *Dq* and Racah parameters, oxidation states and electronic absorption spectra of complex ions. Spectrochemical series and effects of covalency. Nephelauxetic series, magnetic properties of transition metal complexes and lanthanides.

Unit-II: Catalysis and Inorganic Reaction Mechanisms [12 Hours]

Transition metal ion catalysts for organic transformations and their application in hydrogenation (using symmetric and chiral organometallic catalysts), isomerization, olefin oxidation, carbonylation and polymerization reactions.

Mechanisms of substitution reactions of tetrahedral, square planar, trigonal bipyramidal, square pyramidal and octahedral complexes. Potential energy diagrams, transition states and intermediates, isotope effects, Berry's pseudo rotation mechanism, factors affecting the reactivity of square planar complexes, Swain-Scott equation, Trans effect and its application to synthesis of complexes.

Unit-III: Stability constants of metal complexes and their applications [12 Hours]

Stoichiometric and thermodynamic equilibrium constants, stepwise formation of complexes, formation functions, φ, *n* and αC and relationship between different functions. Calculation of stability constants. Graphical Methods: using sets of data {φ,[A]}; {αC,[A]} and {*n*,[A]}. Curve fitting method, Elimination method, Numerical method, Potentiometric method, Method of corresponding solutions, Ion exchange method, Solvent extraction, Polarographic method. Spectrophotometric methods which include Job's method of continuous variation, Logarithmic method, Bent and French mole ratio method. Turner and Anderson methods and Yatsimirskiis method.

Unit-IV: Errors and Evaluation & Analytical methods [12 Hours]

Definition of the terms-mean and median, precision–standard deviation, relative standard deviation, accuracy-absolute error. Types of errors in experimental data determination (systematic), indeterminate (random) and gross. Sources of errors and their effect upon the analytical results. Methods for reporting analytical data. Statistical evaluation of data - indeterminate errors. The use of statistics.

Analytical applications of complex formation; gravimetric analysis, complexometric titrations, Conditional constants, titration curves, titration error, detection of end point using metal indicators and instrumental methods. Indicator errors, Indicator correction etc. Simultaneous titrations, stepwise titrations, back titrations). Use of masking and demasking agents in complexometric titrations.

References

1. Mechanism of Inorganic Reactions, D. Katakis and G. Gordon, John Wiley and Sons (1987).
2. Ligand Substitution Processes, H. Langford and H. B. Gray, W. A. Benjamin (1966).
3. Inorganic Reaction Mechanisms, Ed. M. Tobe and F. C. Wadington, Thomas Nelson (1973).
4. Inorganic Chemistry, 2nd edn., D. F. Shriver, P. W. Atkins and C. H. Langford, Oxford Univ. Press (1998).
5. Inorganic Chemistry, K. F. Purcell, and J. C. Kotz, W. B. Saunders and Co. (1985).
6. Inorganic Chemistry Univ. Science books, G. Wulfsberg, USA Viva Books, New Delhi (2000).
7. Electronic Spectra of Transition Metal Complexes, D. Sutton, McGraw-Hill, New York (1968).
8. Analytical applications of complex equilibria, J. Inczedy, Halsted Press, New York (1976).
9. A. E. Martell & M. Calvin, Chemistry of the Metal Chelate Compounds, Prentice-Hall (1952).
10. Complexation in Analytical Chemistry, A. Ringbom, Wiley Eastern (1963).
11. Solution Equilibria, F. R. Hartley, C. Burgess & R. M. Alcock, Prentice-Hall (1980).
12. Chemistry of Complex Equilibria, van Nostrand Reinhold: M. T. Beck, New York (1970)
13. The Determination of Stability Constants, Rossotti F. J. C. and Rossotti, H McGraw Hill, London (1961).
14. Analytical Chemistry, 6th Ed., G. D. Christian, John Wiley & Sons (2004).
15. Fundamental of Analytical Chemistry, 8th edn., D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, Saunders College Publishing (2005).
16. Analytical Chemistry, 6th edn., G. D. Christian, John Wiley and Sons, (2007).
17. Analytical Chemistry Principles, 2nd edn., John H. Kennedy, Saunders College Publishing(1990).
18. Principles and Practice of Analytical Chemistry, 3rd edn., F.W. Fifield and D. Kealey, Blackwell Science (2000).
19. Modern Analytical Chemistry, David Harvey, McGraw Hill, New Delhi (2000).
20. Titrations in Non-aqueous solvents, Huber Walter, Academic Press (2012).
21. Chemical Analysis (Advanced Chemistry), H. A. Laitinen, McGraw Hill (1960)
22. Analytical Chemistry-Principles and Techniques, Larry G. Hargis, Prentice Hall (1988).

CA H 512: ELECTROANALYTICAL AND THERMOANALYTICAL TECHNIQUES

Course Outcomes

- Student will understand the principles of electrochemistry and applications of electromotive force.
- Acquire knowledge on chemical and biosensors and their analytical uses.
- Gather knowledge about polarographic and voltammetry techniques and their applications.
- Demonstrate a systematic understanding of the key aspects of coulometry, amperometry and electrogravimetry and their analytical applications.
- Understand the theory and applications TGA, DTA and DSC.

UNIT-I: Basic Concepts in Electrochemical Techniques [12 Hours]

Electrochemical cell: Components, conduction, reactions, liquid junctions, salt bridge representation. Faradaic and non-faradaic currents. Reversible and irreversible cells.

Electrode potential: Nature, measurement, sign convention, effect of concentration. Standard electrode potential, calculation limitations.

Cell potential: Thermodynamics, liquid junction potential, effect of current, ohmic potential. **Polarization:** Sources, overvoltage, concentration polarization, mechanism of mass transport, **Potentiometric methods:** Reference electrodes-Calomel, silver/silver chloride and hydrogen electrodes, potentiometric titrations and applications.

Metallic electrodes: Electrodes of first, second & third kind.

Membrane electrodes: Classifications, properties, principle, design of ion selective electrodes, membrane potential, selectivity, crystalline liquid membrane and enzyme electrodes.

Glass electrode: Composition, hygroscopicity, asymmetry potential, acid and alkali errors. **Conductometric methods**: Definitions, conductance measurement, conductrometric titrations and applications.

UNIT-II [12 Hours]

Polarography and voltammetry: Theory of classical polarography, polarograhic measurements, polarograms, polarographic currents, current and concentration relationship, factors influencing diffusion currents, Half wave potential, Oxygen interference, Advantages and limitations. Modified voltammetric methods, pulse polarography, fast, linear-sweep polarography, first & second order polarographic techniques, organic polarography.

Voltammetric principles: Voltammetry at solid electrodes-Hydrodynamic voltammetry, triangular voltammetry or cyclic voltammetry.

Stripping analysis: Principle, methodology, electrodes & cell design, applications and determination of lead in water by voltammetry.

Chemical sensors and biosensors: Sensors, electrochemical sensors, optical sensors, thermal and mass-sensitive sensors, determination of glucose in blood by biosensor, determination of copper (I) in water using anodic stripping voltammetry.

UNIT-III **[12 Hours]**

Coulometry: Principle, constant current and controlled potential coulometry. Coulometric titrations-Principles, apparatus, comparison of coulometric titrations with conventional titrations, automatic coulometric titrations and applications.

Amperometry: Principle, titrations, advantages and limitations. Applications of biamperometric tritrations.

Electrogravimetry: Faraday's laws of electrolysis, requirements, decomposition potential and its significance. Over voltage and factors influencing overvoltage. Effect of experimental variables-Physical and chemical. Electrolysis at constant current and at controlled potentials, applications. **Chrono Methods**: Basic concepts, methodology and application of chronopotentiometry, chronoampermetry and chronocoulometry.

UNIT IV: Thermoanalytical Techniques **[12 Hours]**

Thermogravimetric analysis (TGA): Types, principle and method. Automatic thermogravimetric analysis, instrumentation, types of recording thermo balances, sample holders, factors affecting results. Applications-Purity and thermal stability, evaluation of correct drying temperature,analysis of complex mixture and determination of kinetic parameters of thermal degradation,isothermal analysis.

Differential thermal analysis (DTA): Principle of working, theory and instrumentation. Simultaneous TA-TGA curves, factors affecting results. Applications-Analysis of the physical mixtures and thermal behaviour study, determination of melting point, boiling point and decomposition point. Differences between TGA and DTA.

Differential scanning calorimetry (DSC): Principle, differences between DTA and DSC. Instrumentation, applications studies of thermal transitions and isothermal crystallization. Pharmaceutical industry for testing the purity of the samples.

Thermometric titration: Introduction, apparatus and applications (Acid-base, precipitation, complexation, redox and non-aqueous titrations). Chemiluminescence methods.

References

1. Principles and Practice of Analytical Chemistry, 3rd edn., F. W. Fifield and Kealey, Blackwell Science Ltd. (2000).
2. Analytical Chemistry Principles, 2nd edn., J. H. Kennedy, Saunders College Publishing, California (1990).
3. Modern Analytical Chemistry, David Harvey, McGraw Hill, New Delhi (2000).
4. Introduction to Instrumental Analysis, 2nd edn., R. D. Braun, Pharm. Med. Press India (2012).

5. Instrumental Methods of Chemical Analysis, 5th edn., G. W. Ewing, McGraw Hill India (2013)
6. Electroanalytical Chemistry, B. H. Vassos and G. W. Ewing, John Wiley and Sons (1983).
7. Principles of Electroanalytical methods, T. Riley and C. Tomlinson, John Wiley and Sons (1987).
8. Principles of Instrumental Analysis, 4th edn., D. A. Skoog and D.M. West, Saunders College Publication (1992).
9. Principles of Instrumental Analysis, 7th edn., D. A. Skoog, F. J. Holler and S. R. Crouch, Cengage India Pvt. Ltd. (2020).
10. Instrumental Methods of Analysis, 7th edn., H. H. Willard, L. L. Merritt and J. A. Dean, CBS Publishers, New Delhi (1988).
11. Quantitative Analysis, 6th edn., R. A. Day and A. L. Underwood, Prentice Hall India Learning Pvt. Ltd., New Delhi (1993).
12. Vogel's Textbook of Quantitative Chemical Analysis, 6th edn., J. Mendham, R. C. Denney, J. D. Barnes and M. J. K. Thomas, Pearson Education Pvt. Ltd., New Delhi (2007).

CA H 513: APPLIED ANALYSIS

Course Outcomes

- Enable the students to understand the basic principles of soil and fuel sampling and apply the suitable analytical method for their analysis.
- Gain a domain knowledge about quality control of drugs and pharmaceuticals and apply the suitable method for their analysis.
- Imbibe knowledge about various biomedical samples and their analysis.
- Gather knowledge on various types of poisons and estimation of poisonous materials.
- Describe the general methods of determination of various parameters of different food products.
- Learn about the different kinds of Food additives, adulterants and contaminants and their analysis.

UNIT-I: Soil and Fuel Analysis **[12 Hours]**

Soil Analysis: Preparation of laboratory sample. Measurement of pH and conductivity, acidicand alkaline soil. Analysis of major constituents-Organic matter, nitrogen, sulphur, potassium and calcium. Analysis of trace elements-Copper, molybdenum, zinc and boron. Analysis of major constituents-Organic matter, nitrogen, sulphur, potassium and calcium.

Fuel Analysis: Definition and classification of fuels, Characteristics of fuels, sampling, proximate and ultimate analysis. Combustion calculations, Calorific value determination by Junker's gas calorimeter, Liqiud fuels-Determination of flash point, fire point and aniline point. Knocking of fuels, Octane and Cetane numbers, carbon residues. Gaseous fuels-Analysis of Coal, water gas, producers gas, gober gas and blast furnace gas; Calorific value determination by Junker's gas calorimetry.

UNIT-II: Drugs and Pharmaceutical Analysis **[12 Hours]**

Importance of quality control, drugs and pharmaceuticals, Sources of impurities in pharmaceutical chemicals, Analytical quality control in finished/final products, Common methods of assay.

Analysis of common drugs: Analgesics-Aspirin, paracetamol; Authelmentics-Mebendazole; Antiallergies-chlorpheneramine malleate; Antibiotics-Pencillin, chloromecytin; Anti-inflammatory agents-Oxyphenbutazone; Antimalasials-Primaquine phosphate; Antituberculosists-1 NH; Narcotics-Nicotine, morphine; Expectorants-Benadryl; Sedatives-diazepam; Vitamins-A, C, B_1, B_2, B_6, niacin & folic acid.

UNIT-III: Biomedical and Forensic Analysis **[12 Hours]**

Composition of body fluids and detection of abnormal levels of certain constituents leading to diagnosis of disease; Sample collection and preservation of physiological fluids, Analytical methods for the constituents of physiological fluids (blood, serum, urine); Blood-Estimation of glucose, cholesterol, urea, haemoglobin and bilirubin; Urine-Urea, uric acid, creatinine, calcium

phosphate, sodium, potassium and chloride; Biological significance, analysis and assay of enzymes (pepsin, monoaminoxide, tyrosinase); Vitamins (thiamine, ascorbic acid, vitamin A) and Harmones (progesterone, oxytocin, insulin) [Chemical, instrumental and biological assays to be discussed wherever necessary].

Forensic analysis: General discussion of poisons with special reference to mode of action of cyanide, organophosphates and snake venom; Estimation of poisonous materials such as lead, mercury and arsenic in biological materials; Forensic Toxicology-Analysis of various types of poisons (corrosive, analgesic, hypnotic, narcotic, stimulants, paralytic, antihistamine).

UNIT-IV: Food Analysis **[12 Hours]**

General methods for the determination of moisture, ash, crude protein, fat, crude fiber, carbohydrates, calcium, potassium, sodium and phosphates. Dairy products-composition of milk and milk products. Alcohols test, fermentation, dye reduction, methylene blue and resazurin tests. Analysis of fat content, minerals in milk and butter. Estimation of added water in milk.

Oils and fats: General composition of edible oils, Detection of purity, rancidity of fats and oil, Estimation of rancidity, Tests for common edible oils like groundnut oil, castor oil, cottonseed oil and mustard oil. Tests for adulterants like aregemone oil and mineral oils.

Beverages: Soft drinks, Alcoholic drinks, tea, coffee and fruit juices; Analysis of caffeine in coffee and tea, Detection of chicory in coffee and chloral hydrate in toddy; Estimation of methyl alcohol in alcoholic beverages.

Food additives, adulterants and contaminants: Food preservatives like benzoates, propionates, sorbates, bisulphites; Artificial sweeteners like saccharin, dulcin and sodium cyclamate; Flavours like vanillin, esters (fruit flavours) and monosodium glutamate; Artificial food colourants like coal tar dyes and non-permitted colours and metallic salts; Pesticide residues in food; Control of food quality-Codex alimentarices, Indian Standards.

References

1. Soils in our Environment, 8th edn., R. W. Miller and D. T. Gardiner, Prentice Hall (1998).
2. Chemistry for Environmental Engineering, 3rd edn., C. N. Sawyer and P. L. McCarty, McGraw Hill (1978).
3. A Text Book of Soil Analysis, T. C. Baruah and H. P. Barthakur, Vikas Publishing House Pvt. Ltd., New Delhi (1997).
4. A Textbook of Soil Chemical Analysis, 11th edn., P. R. Hesse, CBS Publishers and Distributors Pvt. Ltd. (2002).
5. Handbook of Petroleum Product Analysis, J. G. Speight, John Wiley and Sons (2015).
6. Fuels and combustion, 3rd edn., S. Sarkar, Universities Press (2009).

7. Fuels, solid, liquid and gaseous-Their analysis and valuation, H. Joshua Phillips, General Books (2010).
8. An introduction to combustion–Concepts and applications, S. R. Turns, McGraw-Hill (2000).
9. Principles of combustion, K. Kanneth, John Wiley and Sons (2005).
10. Fuels and combustion, S. P. Sharma and C. Mohan, Tata McGraw-Hill (1984).
11. Pharmaceutical analysis, T. Higuchi, John Wiley and Sons (1966).
12. Pharmaceutical drug analysis, Ashtosh Kar, New Age International Pvt. Ltd., (2005).
13. The Quantitative Analysis of Drugs, 3rd edn., D. C. Garratt, Chappman and Hall (1976).
14. Pharmaceutical Analysis: Modern Methods-Parts A and B, James W. Munson, Informa Health Care (2012).
15. Handbook of Pharmaceutical Analysis- Vol. II, L. O. McNeil and A. J. Streete, Marcel Dekker (2002).
16. The Chemical Analysis of Foods, H. E. Cox and D. Pearson, Chemical Publishing Company (1962).
17. Foods: Facts and Principles, 4th edn., N. Shakuntala Many and S. Swamy, New Age International (1998).
18. The Essential of Forensic Medicine and Toxicology, K. S Narayana Reddy, Jaypee Brothers (2022).
19. Official Methods of Analysis, 11th edn., W. Horwitz, Association of Official Analytical Chemists, Washington DC (1970).
20. Forensic Medicine, K. Simpson and B. Knight, 9th edn., Edward Arnold Publishers Ltd.,London (1985).
21. Laboratory Manual in Biochemistry, J. Jayaraman, Wiley Eastern (1981).
22. An Introduction to Practical Biochemistry, David T. Plumomer, Tata McGraw Hill (1979).
23. Practical Clinical Biochemistry, 4th edn., Harold Varley, Alan H. Gowenlock and Maurice Bell, William Heinemann Medical Books (1980).

CAS 514: ANALYTICAL CHEMISTRY OF POLYMERS

Course Outcomes

- Student will be able to understand fundamentals of polymers, polymerization processes, Tg and Tm.
- Gather knowledge about advanced polymeric materials, polymer processing techniques, stability and testing.
- Describe the different methods of molecular weight determination, thermal characterization, and measurements of mechanical and electrical properties of polymeric materials.

UNIT-I: Fundamentals of polymers **[12 Hours]**

Basic concepts-Monomers, repeat units, degree of polymerization; Linear, branched andnetwork polymers; Polymerization-Condensation, addition, free-radical, ionic, co-ordination,Ring-opening and Electro chemical. Polydispersion, average molecular weight and size concept-number average, weight average, viscocity average and Z-average molecular weights. Averageend to end distance and radius of gyration, Practical significance of molecular weight,Geometrical structure. Glass transition and melting transitions, Effect of polymer structure on Tgand Tm temperature, Tg-transitions and associated properties, importance of Tg, effect ofcrystallinity on the properties of polymers and Tg.

UNIT-II **[12 Hours]**

Advanced polymeric materials: Polymer blends interpenetrating networks & composites–Types, preparation techniques, properties & applications.

Polymer Processing: Processing of plastics, elastomers and fibers; Compounding and processing techniques-Calendering, casting, moulding, foaming, fiber spinning and reinforcing techniques. Identification of commonly used thermoplastics (ABS, Teflon, Acrylics, PE, PP, PVC) and thermosets (epoxy and formaldehyde based polymers).

Environmental stability and testing: Photo, oxidative and biodegradation. Solvent resistance testing, Polymer additives and roles-Fillers, plasticizers, antioxidants, coloring agents, UV stabilizers, heat stabilizers and flame retardants.

UNIT-III **[12 Hours]**

Determination of molecular weight: End group analysis, viscosity, light scattering, osmometry, cryoscopy, ebulliometry and ultra-centrifugation method.

Thermal characterization: Thermal properties, Techniques of measurement of transition temperatures and stability, Dilatometry, DSC, DTA, DTG, TGA. Measurement of thermal conductivity, thermal expansion and heat deflection temperature.

Mechanical properties: Tensile impact and flexural strengths; Deflection temperature, Dynamic mechanical thermal analysis and Flammability test-Limiting oxygen index;

Electrical properties: Measurement of dielectric strength, dielectric constant and arc resistance. Characterization and structural property relationship of polymers (phthalocyanine polymers, conducting polymers, flame retardant polymers, bio-medical polymers) with special interest. Special techniques-UV, IR, NMR, ESR, X-Ray Diffraction and Scanning Electron Microscopy methods of analysis.

References

1. Polymer Science, 4th edn., V. R. Gowariker, N. V. Viswanathan and J. Sridhar, New Age International (2021).
2. Textbook of Polymer Science, F. W. Billmeyer, 3rd edn., John Wiley and Sons (2007).
3. A Text Book of Polymer Science, P. L. Nayak and S. Lenka, Kalyani Publishers (2001).
4. Introductory Polymer Chemistry, G. S. Mishra, New Age international (2008).
5. Fundamental Principles of Polymer materials, 3rd edn., C. S. Brazel and S. L. Rosen, John Wiley and Sons (2012).
6. Polymer Science and Technology, J. R. Fried, Printice Hall (2014).
7. Functional Monomers and Polymers: Procedures, Synthesis and Applications, K. Takemoto, Marcel Dekker (1987).
8. Polymer Characterization-Physical Techniques, 2nd edn., D. Campbell, R. A. Pethrick and J. R. White, Chapman and Hall (2000).
9. Plastics Chemistry and Technology,1st edn., W. E. Driver, Van Nostrand Reinhold Co. (1979).
10. Composite Materials: Engineering and Science, F. L. Matthews and R. D. Rawlings, Woodhead Publishing (1999).
11. Composite Materials: Science and Engineering, 4th edn., K. K. Chawla, Springer-Cham (2019).

CA S 515: SEPARATION TECHNIQUES

Course Outcomes

- Enable the students demonstrate the fundamentals of different solvent extraction techniques and their applications in separation.
- Illustrate the principles, separation mechanisms and applications of affinity chromatography of chromatography.
- Explain the basic concepts, Instrumentation, methodology, separation and identification of compounds by electrophoresis technique.
- Understand the theory, instrumentation and applications of GC and HPLC.
- Demonstrate the principle of GFC and GPC techniques used in isolation, purification, identification and analysis of macromolecules.
- Learn applications of ultracentrifugation in purification and characterization of biomolecules.
- Acquire a critical knowledge of capillary electrophoresis and Capillary electro chromatography for the separation of organic, inorganic and natural products.

UNIT–I **[12 Hours]**

Solvent Extraction: Definition, Types, Principle and Efficiency of extraction. Sequence of extraction process. Factors effecting extraction-pH, Oxidation state, Modifiers, Synergistic, Masking and salting out agents. Techniques-Batch and continuous extraction; Applications.

Affinity Chromatography: Definitions. Separation mechanism - Matrices, Matrix activation, Role of spacer arms and applications.

Electrophoresis: Theory and classification; Factors influencing the mobility-Macromolecular size and Charge, Interaction with supporting electrolyte, pH and Concentration discontinuities. Factors affecting electrophoretic phenomena-Electrolysis, Electroosmosis, Temperature and Supporting media, Instrumentation; Methodology-Preparation of gels-Staining and Destaining, Applications.

UNIT–II **[12 Hours]**

High Pressure Liquid Chromatography (HPLC): Apparatus, pumps, column packing, characteristics of liquid chromatographic detectors-UV, IR, refractometer & fluorescence detectors, Advantages & Applications.

Exclusion Chromatography: Theory & principle of size exclusion chromatography. Experimental techniques for gel filtration chromatography (GFC) and gel-permeation Chromatography (GPC), Materials for packing-Factors governing column efficiency, Methodology and Applications.

Gas Chromatography (GC): Principle, comparison of GSC and GLC; Instrumentation Columns-Packed and tubular; Study of detectors-Thermal conductivity, Flameionization, Electron capture and Mass spectrometry, Factors affecting separation, Applications of GC/MS technique.

UNIT-III **[12 Hours]**

Ultra centrifugation: Principle, Sedimentation constant, Sedimentation equilibrium, Sedimentation velocity, Methodology and Applications.

Capillary electrophoresis: Overview, Types, The basis for electrphoretic separations, Migration rates and Plate heights, Electro-osmotic flow, Instrumentation, Capillary zone electrophoresis, Capillary gel electrophoresis, Capillary isoelectrophoresis, Capillary isoelectric focusing.

Capillary electro-chromatography: Packed column electro-chromatography, micellar electrokinetic capillary chromatography and applications.

References

1. Chromatography, Part A and Part B, 5th edn., E. Heftman, Elsevier (1992).
2. Chromatography Today, D. F. Poole and S. K. Poole, Elsevier (1991).
3. Principles of Instrumental Analysis, 7th ed., D. A. Skoog, F. J. Holler and S. R. Crouch, Cengage India Pvt. Ltd., (2020).
4. Principles of Instrumental Analysis, 4th ed., D. A. Skoog and D. M. West, Saunders College Publications (1992).
5. QuantitativeAnalysis, 5th edn., R. A. Day and A. L. Underwood, Prentice-Hall (1998).
6. AnalyticalChemistry, 5th edn., G. D. Christian, John Wiley and Sons (2001).
7. Instrumental Methods of Analysis, 7th edn.,H. H. Willard, L. L. Merritt and J. A. Dean, CBS Publishers, New Delhi (1988).
8. Instrumental Methods of Chemical Analysis, 19th edn., B. K. Sharma, Goel, 2000.

CA E 516: ANALYTICAL AND GREEN CHEMISTRY

Course Outcomes

- Enable the students to understand the basic principles and theory of UV/Electronic, Infra-Red, Nuclear Magnetic Resonance and Mass Spectroscopy.
- Study the utility of these techniques in structure elucidation of simple organic molecules.
- Know about water cycle, water sources, water quality, and significant measurements of water parameters and treatment of water for drinking and industrial purposes.
- Learn about principles and use of green chemistry in laboratory synthesis.
- Understand the green chemistry principles, basic principles and utility of sonochemistry and Microwave induced organic synthesis.

UNIT-I **[12 Hours]**

UV/Electronic Spectroscopy: Basic principles, Beer-Lambert law, types of absorption bands, Factors affecting the positions of UV bands. Theoretical prediction of λmax for polyenes, α,β-unsaturated aldehydes, ketones (Woodward-Fieser rules) and substituted benzenes.

IR Spectroscopy: Basic principles, Application of infrared spectroscopy in the structural study-identity by fingerprinting and identification of functional groups. Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines). Study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides and acids). Factors affecting band positions and intensities.

Nuclear Magnetic Resonance Spectroscopy: Basic principles, Solvents used, chemical shift and its measurements, factors affecting chemical shift. Integration of NMR signals, spin-spin coupling, coupling constant. Shielding and deshielding. High resolution ^{1}H NMR. Applications of NMR spectroscopy in structure elucidation of simple organic molecules.

Mass Spectrometry: Basic principles, molecular ions, meta-stable ions and isotope ions. Fragmentation processes, McLafferty rearrangement. Retro Diels-Alder fragmentations. Nitrogen rule.

UNIT-II **[12 Hours]**

Hydrologic cycle, sources, chemistry of sea water, criteria and standards of water quality- safe drinking water, maximum contamination levels of inorganic and organic chemicals, radiological contaminants, turbidity, microbial contaminants. Public health significance and measurement of colour, turbidity, total solids, acidity, alkalinity, hardness, chloride, residual chlorine, sulphate, fluoride, phosphate and different forms of nitrogen in natural and polluted water. Chemicalsources of taste and odour, treatment for their removal, sampling and monitoring techniques.

Determination and significance of DO, BOD, COD and TOC. Water purification for drinking and industrial purposes, disinfection techniques, demineralization, desalination processes and reverse osmosis. Treatment of liquid radioactive wastes.

UNIT-III **[12 Hours]**

Green Chemistry: Definition and principles, planning a green synthesis in a chemical laboratory, Green preparation-Aqueous phase reactions, solid state (solventless) reactions, photochemical reactions, Phase transfer catalyst catalysed reactions (Quaternary ammonium salts & Crown ethers), enzymatic transformations & reactions in ionic liquids.

Sonochemistry: Introduction, instrumentation, the phenomenon of cavitation, Sonochemical esterification, substitution, addition, oxidation, reduction and coupling reactions.

Microwave induced organic synthesis: Introduction, reaction vessel and reaction medium, concept, specific effect, atom efficiency, % atom utilisation, advantages and limitations, alkylation of active methylene compounds, N-alkylation, condensation of active methylene compounds with aldehydes, Diels-Alder reaction, Leuckardt reductive amination of ketones, ortho ester Claisen rearrangement.

References

1. Organic Spectroscopy, 3rd edn., W. Kemp, Pagrave Publishers (1991).
2. Spectrometric Identification of Organic Compounds, 8th edn., R. M. Silverstein, F. X.Webster, D. J. Kiemle, D. L. Bryce, Wiley (2014).
3. Applications of Absorption Spectroscopy of Organic Compounds, J.R. Dyer, Prentice Hall (1965).
4. Spectroscopy of Organic Compounds, 3rd edn., P. S. Kalsi, New Age International (2000).
5. Spectroscopic Methods in Organic Chemistry, D. Williams and I. Fleming, McGraw-Hill (1995).
6. Environmental Chemistry, A. K. De, Wiley Eastern Ltd. (1990).
7. Environmental Chemistry, S. K. Banerji, Prentice Hall India (1993).
8. Chemistry of Water Treatment, S. D. Faust and O. M. Aly, Butterworths (1983).
9. Chemistry for Environmental Engineering, 3rd edn., C. N. Sawyer and P. L. McCarty, Tata McGraw Hill (1978).
10. Environmental Chemistry, I. Williams, John Wiley (2001).
11. Environmental Pollution Analysis, S. M. Khopkar, Wiley Eastern (1993).
12. Organic Synthesis, Special Techniques, V. K. Ahluwalia and R. Aggarwal, Narosa (2001).
13. Green Chemistry, Environment friendly alternatives, R. Sanghi and M. M. Srivatsava, Narosa (2003).
14. Green Chemistry-Environment benign reactions, V. K. Ahluwalia, Ane Books India (2006).

CA P 517: ANALYTICAL CHEMISTRY PRACTICALS-I

(A minimum of twelve experiments are to be carried out)

Course Outcomes

- Student will be able to analyze the common and rare cations in a mixture by differentvolumetric, complexometric and gravimetric techniques.
- The students will have practical experience in the determination of COD, DO and BOD.
- The students will have hands on experience in the Analysis of Brass, Cu-Ni alloy, Stainless Steel.
- This course also train the students in separation and determination of cations and anions by Ion-Exchange Chromatography and ion exchange capacity of a resin.
- Students can study the applications of electrogravimetry, flame photometry, nephelometry and fluorimetry.

1. Analysis of Na_2CO_3 and $NaHCO_3$ in baking soda by acid base titration.
2. Analysis of chloride in natural and polluted water samples by argentimetric titration.
3. Analysis of copper in ore/alloy by iodometric titration.
4. Analysis of DO, BOD and COD of a waste water sample by titrimetry.
5. Determination of 1,2-glycols or glycerol by periodate oxidation.
6. Determination of Calcium in limestone by redox titration.
7. Determination of total hardness of water by EDTA titration.
8. Analysis of Calcium and lead-using EDTA.
9. Determination of aluminium and magnesium in antacids by EDTA Titration.
10. Assay of calcium in milk powder by EDTA titration.
11. Assay of Vitamin-C by iodine titration and by bromination using $KBrO_3$.
12. Assay of iron in pharmaceutical preparation by titration with $Ce(SO_4)_2$.
13. Quantitative analysis of mixtures: a) Chloride and iodide; b) iodide volumetrically using KIO_3 & ii) total halide gravimetrically.
14. Analysis of Copper-Nickel alloy i) Copper volumetrically using KIO_3 and ii) Nickel Gravimetrically using DMG.
15. Analysis of Brass-Cu gravimetrically using α-benzoin oxime and Zn complexometrically.
16. .Analysis of Stainless steel-Ni gravimetrically using DMG, Fe volumetrically using Ce(IV), Cr volumetrically by persulphate oxidation.
17. Separation and determination of chloride and bromide on anion-exchanger.
18. Estimation of total cation concentration in water by ion-exchange method.
19. Determination of nickel in Cu-Ni alloy by electrogravimetry.
20. Analysis of ores-Hematite and Pyrolusite.
21. Determination of sodium and potassium in soil by flame photometry.

22. Estimation of potassium in agricultural water supplies by flamephotometry.
23. Nephelometric determination of barium and phosphate in domestic waste water.
24. Nephelometric determination of sulphate in ground water samples.
25. Nephelometric determination of chloride in brackish waters.
26. Fluorimetric determination of Quinines, cadmium aluminium and zinc.

References

1. A Text-Book of Quantitative Inorganic Analysis, 3rd edn., A. I. Vogel, Longman (1961).
2. Vogel's text book of quantitative inorganic analysis, 4th edn., G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, ELBS (1978).
3. Colorimetric Determination of Traces of Metals, 3rd edn., E. D. Sandell, John Wiley & Sons (1959).
4. Vogel's Textbook of Quantitative Chemical Analysis, 6th edn., J. Mendham, R.C. Denney, J. D. Barnes and M.J.K. Thomas, Third Indian Reprint, Pearson Education Pvt. Ltd., New Delhi (2007).
5. Quantitative Analysis, 6th edn., R.A. Day and A. L. Underwood, Prentice Hall India Learning Pvt. Ltd., New Delhi(2009).
6. Quantitative analysis, C. T. Kenner and K. W. Busch, Macmillan (1979).

CA P 518: ANALYTICAL CHEMISTRY PRACTICALS - II

(A minimum of twelve experiments are to be carried out)

Course Outcomes

- Student will understand and able to handle conductometry, potentiometry and spectrometry for various determinations.
- Handle and apply spectroscopic techniques as analytical tool in chemistry.
- Analyse samples by polarographic techniques.
- Study polymer preparation, kinetics of polymerization and their analysis.

1. Conductometric determination of total acidity of waste water.
2. Conductometric determination of chloride content of a sample of industrial effluent.
3. Conductometric determination of total alkalinity of waste water.
4. Conductometric determination of total acidity of waste water.
5. Conductometric determination of chloride content of a sample of industrial effluent.
6. Determination of pH of hair shampoos by potentiometric titration.
7. Potentiometric determination of equivalent weight and Kaofapureun known acid.
8. Determination of sulpha-drugs by potentiometry.
9. Determination of pH of hair shampoos by potentiometric titration.
10. Assay of iron in pharmaceutical preparation by potentiometric titration with $Ce(SO_4)_2$.
11. Determination of Phosphate in domestic waste water by spectrophotometry.
12. Determination of NH_3-N/NO_2-N/NO_3-Nin soil & waste waters by spectrophotometry.
13. Analysis of mercury/lead in industrial effluents by spectrophotometry.
14. Determination of ascorbic acid in goose berry/bitter gourd by titrimetry and spectrophotometry.
15. Catalytic determination of iodide/selenium by spectrophotometry.
16. Enzymatic determination of glucose in blood by spectrophotometry.
17. Estimation of blood cholesterol by spectrophotometry.
18. Determination of chloride content in tap water by spectrophotometry.
19. Evaluation of the composition of complex by spectrophotometry.
20. Determination of composition and stability constant of metal complexes ($Fe^{3+}$and salicylic acid, Fe(II)/Ni (II) and 1,10-phenanthroline) by spectrophotometry.
21. Determination of Iron in mustard seed by spectrophotometry.
22. Determination of blood urea and uric acid by spectrophotometry.
23. Assay of urinary creatinine by spectrophotometry.
24. Evaluation of composition and stability constant of Fe(III)–T iron complex by Turner and Anderson method.
25. pH-metric determination of soda ash in washing soda.
26. Determination of water in hydrated calcium sulphate by Karl-Fischer titration.

27. Polarographic determination of Cd and zinc in solutions individually and in a mixture.
28. Polarographic evaluation of stability constant of lead oxalate complex.
29. Determination of urinary reducing sugar, chlorides, urea and uric acid by titrimetry.
30. Assay of asprin/caffeiene/phenacetin by UV-spectroscopy.
31. Determination of Vitamin A in Vanaspathi by UV spectroscopy.
32. Preparation of 6,10-Nylon [poly(hexamethylene) sebacamide) by interfacial polymerization and its characterization by m.p., inherent viscosity and IR studies.
33. Study of kinetics of polymerization.
34. Determination of molecular weight of polymer by viscosity and turbidimetry.
35. Analysis of phenol-formaldehyde reaction products by TLC.

References

1. A Text-Book of Quantitative Inorganic Analysis, 3rd edn., A. I. Vogel, Longman (1961).
2. Vogel's Textbook of Quantitative Inorganic Analysis, 4th edn., G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, ELBS (1978).
3. Colorimetric Determination of Traces of Metals, 3rd edn., E. B. Sandell, John Wiley and Sons (1959).
4. Analytical Chemistry, 5th edn., G.D. Christian, John Wiley and Sons (2001).
5. Numerical Methods in Chemistry, K. J. Johnson, Marcel Dekker (1980).

FOURTH SEMESTER

PROJECT WORK AND DISSERTAION

CA P 561: PROJECT REPORT

Course Outcomes

Student undergoes training at chemical industries for 4 months internship and prepare dissertation on the work carried out.

- Students will acquire analytical skills and capabilities that intersect effectively with the needs of industry.
- Apply and practice good communication skills.
- Gain experiences in understanding the principles and hands on experience on analytical instruments that might lead to future employment.
- Demonstrate and apply research skills to complete a project.
- Apply the theoretical concepts to solve industrial problems.

CA P 562: VIVA-VOCE

Course Outcomes

Oral examination based on project report.

- Student will be able to report research findings in verbal forms and defend the findings.

****