Deccan Education Society's

Fergusson College (Autonomous), Pune

Learning Outcomes-Based Curriculum

for 1 or 2 years M. Sc. Programme

as per guidelines of

NEP-2020

for
M. Sc. I - Analytical Chemistry

With effect from Academic Year

2023-2024

Program Outcomes (POs) for M. Sc. Programme	
PO1	**Disciplinary Knowledge:** Demonstrate comprehensive knowledge of the discipline that form a part of a postgraduate programme. Execute strong theoretical and practical understanding generated from the specific programme in the area of work.
PO2	**Critical Thinking and Problem Solving:** Exhibit the skill of critical thinking and understand scientific texts and place scientific statements and themes in contexts and also evaluate them in terms of generic conventions. Identify the problem by observing the situation closely, take actions and apply lateral thinking and analytical skills to design the solutions.
PO3	**Social Competence:** Exhibit thoughts and ideas effectively in writing and orally; communicate with others using appropriate media, build effective interactive and presenting skills to meet global competencies. Elicit views of others, present complex information in a clear and concise and help reach conclusion in group settings.
PO4	**Research-related Skills and Scientific Temper:** Infer scientific literature, build sense of enquiry and able to formulate, test, analyse, interpret and establish hypothesis and research questions; and to identify and consult relevant sources to find answers. Plan and write a research paper / project while emphasizing on academics and research ethics, scientific conduct and creating awareness about intellectual property rights and issues of plagiarism.
PO5	**Trans-disciplinary Knowledge:** Create new conceptual, theoretical and methodological understanding that integrates and transcends beyond discipline-specific approaches to address a common problem.
PO6	**Personal and Professional Competence:** Perform independently and also collaboratively as a part of team to meet defined objectives and carry out work across interdisciplinary fields. Execute interpersonal relationships, self-motivation and adaptability skills and commit to professional ethics.
PO7	**Effective Citizenship and Ethics:** Demonstrate empathetic social concern and equity centred national development, and ability to act with an informed awareness of moral and ethical issues and commit to professional ethics and responsibility.
PO8	**Environment and Sustainability:** Understand the impact of the scientific solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.
PO9	**Self-directed and Life-long learning:** Acquire the ability to engage in independent and life-long learning in the broadest context of socio-technological changes.

Program Specific Outcomes (PSOs) for M. Sc. Analytical Chemistry	
PSO No.	**Program Specific Outcomes(PSOs) Upon completion of this programme the student will be able to**
PSO1	**Academic competence** (i) State and describe fundamental and advanced concepts in chemistry with analytical point of view. (ii) Illustrate broad knowledge and understanding of fundamental and advanced concepts in different areas of chemistry.\ (iii) Demonstrate skills related to basic and specialized techniques, modern instrumentations for chemical analysis and separation.
PSO2	**Personal and Professional Competence** (i) Execute critical thinking and theoretical concepts for efficient problem solving and seeking solutions to difficulties that emerge in various fields of chemistry and interdisciplinary fields. (ii) Apply different methodology in order to conduct chemical synthesis, analysis and other chemical investigation; and apply appropriate understanding. (iii) Identify problems, use relevant concepts and methods to solve them.
PSO3	**Research Competence** (i) Interpret and evaluate the findings and compare with the reference data. (ii) Illustrate and draw conclusions from the data through experiment / investigation / theoretical aspects. (iii) Recognise cause and effect relationships, ability to plan, execute and report the scientific conducts.
PSO4	**Entrepreneurial and Social competence** (i) Build teamwork culture and execute skills for scientific investigation and academic uprightness. (ii) Articulate communication skills through oral presentations / seminars / group discussion and the compiling of information in the form of reports. (iii) Develop awareness in academic and research ethics, scientific misconduct, misrepresentation and manipulation of data. (iv) Generate potential to compete for the available employment opportunities or work independently in research, industries and other analytical based fields.

Programme Structure

Department of Chemistry
M. Sc. - Analytical Chemistry

Semester	Paper Code	Paper Title	Credits
I	CHA-501	Advanced Organic Chemistry and Spectroscopy	4
	CHA-502	Advanced Inorganic Chemistry - I	4
	CHA-503 OR	Advanced Physical Chemistry - I	4
	CHA-504	Green Chemistry	
	CHA-510	Research Methodology	4
	CHA-520	Practical - I	2
	CHA-521	Practical - II	2
		Total Semester Credits	**20**
II	CHA-551	Reaction Mechanism in Organic Chemistry	4
	CHA-552	Advanced Inorganic Chemistry - II	4
	CHA-553 OR	Advanced Physical Chemistry - II	4
	CHA-554	Analytical Clinical Biochemistry	
	CHA-560	On Job Training / Field Project	4
	CHA-570	Practical - III	2
	CHA-571	Practical - IV	2
		Total Semester Credits	**20**
		Total PG-I Credits	**40**

Teaching and Evaluation (Only for FORMAL education courses)

Course Credits	No. of Hours per Semester Theory / Practical	No. of Hours per Week Theory / Practical	Maximum Marks	CE 40%	ESE 60%
1	**15 / 30**	**1 / 2**	**25**	**10**	**15**
2	**30 / 60**	**2 / 4**	**50**	**20**	**30**
3	**45 / 90**	**3 / 6**	**75**	**30**	**45**
4	**60 / 120**	**4 / 8**	**100**	**40**	**60**

Eligibility: As per the rules and regulations of Savitribai Phule Pune University (SPPU)

F. Y. M. Sc. Semester I		
Title of the Course and Course Code	**Advanced Organic Chemistry and Spectroscopy (CHA-501)**	**Number of Credits: 04**
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Recall the concept of aromaticity and its application to identify various organic compounds. Predict and cite examples of aromaticity of heterocyclic and non-heterocyclic compounds.	
CO2	Discuss aromatic substitution reactions and predict the products/intermediates and explain the type of reactions and write their mechanisms	
CO3	Applications of organometallic compounds, ylides and predict products. Determine selectivity and demonstrate their advantages.	
CO4	Identify the products of oxidation-reduction reactions, give examples and determine selectivity of reagents and demonstrate their nature.	
CO5	Review various terms in stereochemistry and explain aspects of configurations in various chiral compounds, prochirality, stereospecific and stereoselective reactions.	
CO6	Revise basic principles of spectroscopy and demonstrate applications of spectroscopic techniques. Propose structures using spectroscopic data.	

Unit No.	Title of Unit and Contents
I.	**Aromaticity:** Benzenoid, non-benzenoid, antiaromatic, nonaromatic and aromatic compounds
II.	**Aromatic Substitution:** Recapitulation of Aromatic Nucleophilic and Electrophilic substitution, Benzyne generation under different condition (basic and neutral), orientations and regioselectivity in arynes, and SN^i reactions
III.	**Organometallics and Ylides:** a. Reactions of organometalic reagents involving Li, Zn, Cu, Mg, Al, Si etc., Hydroboration and synthesis of borane reagents b. Ylides: Phosphorus, Nitrogen and Sulphur ylides in organic synthesis
IV.	a. **Oxidation Reactions:** CrO_3, PDC, PCC, IBX, $KMnO_4$, MnO_2, Swern, SeO_2, $NaIO_4$, $Pb(OAc)_4$, Pd-C, OsO_4, m-CPBA, H_2O_2, Oxone, TEMPO, O_3, etc. b. **Reduction Reactions:** Boranes and hydroboration reactions, MPV reduction and reduction with H_2/Pd-C, Willkinsons catalyst, DIBAL, transfer hydrogenation etc.
V.	**Stereochemistry:** a. Recapitulation R and S, E and Z, D and L nomenclature of compounds and chirality in allenes, hemisprane, spiranes andbiphenyls b. Prochiral relationship, stereospecific and stereoselective reactions
VI.	**Structure determination by spectroscopic techniques** a. UV: Factors affecting UV absorption and interpretation of UV spectra b. IR: Basic ideas about IR frequencies, interpretation of IR spectra c. ^{1}H-NMR: Fundamentals of ^{1}H-NMR, factors affecting chemical shift, integration coupling (1^{st} order analysis) d. Problems based on UV, IR and ^{1}H-NMR

Learning Resources

1. Organic Chemistry - by J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford)
2. Guide book to Reaction Mechanism - Peter Sykes
3. Advanced Organic Chemistry - by J. March 6th Edition
4. Stereochemistry of organic compound - by Nasipuri
5. Stereochemistry of carbon compound - by E. L. Eliel
6. Advanced Organic Chemistry (Part A) - by A. Carey and R. J. Sundberg
7. Organic Chemistry (5th Edn.) Robert. T. Morrison & N. Boyd. Hill edn.
8. Stereochemistry conformations and mechanism by P. S. Kalsi
9. Organic Chemistry - by Cram, Hammond, Pine and Handrickson
10. Introduction to Spectroscopy - D. l. Pavia, G. M. Lampman, G. S. Kriz, 3rd Edition
11. Spectroscopic methods in organic molecules - D. H. William & I Flemming Mc Graw Hill

Title of the Course and Course Code	Advanced Inorganic Chemistry-I (CHA-502)	Number of Credits: 04
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Outline the concept of symmetry to imagine molecules in three dimensions and identify the symmetry elements and symmetry operations and be able to pass through the molecule. Outline basics of substitution reactions of octahedral and square planar complexes.	
CO2	Classify the symmetry elements possessed by a molecule and assign it to a point group and determine optical activity and dipole moment.	
CO3	Generalise the importance of Orthogonality Theorem and learn the rules for constructing character tables.	
CO4	Explain molecular structure by the use of character tables and projection operator techniques. Develop basic understandings about redox reaction or electron transfer reactions.	
CO5	Review the concept of SALC. Develop the ability to generate a representation of SALC and to reduce it to its irreducible components.	
CO6	Specify and correlate the application of symmetry to spectroscopy to find out which modes are IR and Raman active.	

Unit No.	Title of Unit and Contents
I	**Symmetry, Group theory and Spectroscopy:** a. Definitions and Theorems of Group Theory Defining properties of a group, group multiplication table, some examples of group, subgroups, classes. b. Molecular Symmetry and Symmetry Groups Symmetry elements and operations, Symmetry planes and reflections, the inversion centre, proper / improper axes and rotation, products of symmetry operations, equivalent symmetry elements and equivalent atoms, symmetry elements and optical isomerism, symmetry point groups, classes of symmetry operations, classification of molecular point groups. c. Representations of Groups, the great orthogonality theorem and its applications, Character tables. d. Reducible and irreducible representations, Wave function as a basis for irreducible representations. e. Applications of group theory to chemical bonding (hybrid orbitals for σ-bonding in different geometries and hybrid orbitals for π-Bonding. f. Application of Group Theory in Vibrational Spectroscopy.
II	**Inorganic reaction mechanism** a. Types of Mechanisms b. Lability and inertness based on Crystal field theory and Valence bond theory c. Substitution in octahedral complexes: SN1, SN2, SNICB mechanisms, steric effects on substitutions. Acid and Base hydrolysis d. Substitution in square planar complexes: trans effect, trans series, applications of trans effect e. Redox reactions: Inner and Outer Sphere reaction mechanisms. f. Complimentary and non-complimentary reactions g. Isomerization reactions and applications.

Learning Resources

1. Chemical Applications of Group Theory, 3rd Edn., Author - F. A. Cotton (Wiley, New York)
2. Symmetry and spectroscopy of molecules, 2nd Ed. 2009; K. Veera Reddy, (New Age International Publication)
3. Group Theory and its Chemical Applications, P. K. Bhattacharya.
4. Inorganic Chemistry: Shriver & Atkins (4th edition 2003, Oxford).
5. Concise Inorganic Chemistry, J. D. Lee, Fourth Edn. (Chapman and Hall).
6. Inorganic Chemistry: Principle of structures and reactivity, Huheey, Keiter, Keiter, Medhi, Pearson Education, 4th Edn. (2007).
7. Inorganic Chemistry: Catherine Housecroft.
8. Symmetry and Group Theory – Vijayalaxmi.
9. F. Basalo and R. G. Pearson, Mechanism of Inorganic Reactions, 2nd ed., Wiley, New York, 1967.
10. D. Benson, Mechanisms of Inorganic Reactions in Solution McGraw - Hill, New York, 1968.
11. J. O. Edwards, Inorganic Reaction Mechanisms, Benjamin, New York, 1974.

Title of the Course and Course Code	Advanced Physical Chemistry-I (CHA-503)	Number of Credits: 04
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Recall basic concepts and define different terminologies in thermodynamics, quantum chemistry and chemical kinetics. Differentiate order and molecularity, classical and quantum mechanics.	
CO2	Classify the chemical reactions on the basis of order. Determine the rate equations for the given chemical reaction, Schrödinger equation, wave equation and energy for particle in box	
CO3	Use simple models to predict the physical phenomenon associated with thermodynamics, quantum chemistry and chemical kinetics and apply appropriate mathematical tools for the calculation.	
CO4	Explain and illustrate quantum mechanical models and statistical thermodynamic properties. Summarize the role of quantum mechanics in chemistry and the relationship between statistical mechanics and quantum mechanics.	
CO5	Criticize different theories of Reaction rates. Justify activation energy concept and Arrhenius theory for reaction rate.	
CO6	Calculate and integrate the physicals parameters for given problems. Formulate and solve scientific problems based on the fundamentals of physical chemistry.	

Unit No.	Title of Unit and Contents
I	**Quantum Chemistry** Postulates of quantum mechanics, wave functions and probabilities, operators, commutation relationships, Hermitian operators, Commutators. Eigen functions and eigenvalues of operators, States as probability distributions and expectation values. Schrodinger equation, particle in a box and degeneracy. Applications- Solution of the Schrodinger equation for the hydrogen atom, radial and angular probability distributions, atomic orbitals, shape of orbitals, radial function, its square and radial distribution curve for atomic orbitals.
II	**Statistical thermodynamics:** Recapitulation of fundamental concepts of thermodynamics, significance of statistical thermodynamics over classical thermodynamics. Statistical view of entropy, Laws of thermodynamics from statistical considerations, Molecular view of temperature and heat capacity, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics, Boltzman distribution law, molecular energy levels, Ensembles and canonical ensembles, equilibrium constant in terms of partition functions, residual entropy, translational, rotational and vibrational partition functions, obtaining thermodynamic properties from partition functions.
III	**Chemical Kinetics** a. Recapitulation: Elementary reaction, half integral order reaction - differential and integral equations, reversible reaction, parallel reaction, consecutive reaction, principle of microscopic reversibility, steady state approximation - elucidating mechanism of a reaction. b. Theories of Reaction Rates

	i. Arrhenius theory, collision theory and transition state theory, enthalpy, free energy and entropy of activation, correlation of steric factor in collision theory and entropy of activation, rationalizing steric factor. ii. Unimolecular reactions, dependence of rate constant on pressure, dielectric constant and ionic strength (primary and secondary salt effect). Enzyme catalysis - Michaelis Menton mechanism, Lineweaver and Eadieplot, Linear free energy relationship, potential energy surface.

Learning Resources

1. Physical Chemistry - P. W. Atkin and De Paule 8th edition (2010).
2. Physical Chemistry - T. Engel and P. Reid, Pearson Education (2006).
3. Physical Chemistry and molecular approach - D. Mcquarie and J. Simon (University Science) (2000).
4. Quantum Chemistry - I. Levine 5th edition, Prentice Hall, 1999.
5. Chemical kinetics, Keith J. Laidler, 3rd Edition Pearson Education (2003).

Course Outcome (COs)		
F. Y. M. Sc. Semester I		
Title of the Course and Course Code	**Green Chemistry (CHA-504)**	**Number of Credits: 04**
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Green chemistry and its principles.	
CO2	Green synthesis and reactions.	
CO3	Green chemistry for sustainable solutions.	
CO4	Understanding design of chemical reactions/chemical synthesis using green chemistry principles.	
CO5	Atom economy and design of chemical reactions using the principle.	
CO6	Understanding the use of green chemistry principle and processes in laboratory reaction	

Unit No.	Title of Unit and Contents
I	**Introduction to Green Chemistry:** Basic introduction and explaining goals of Green Chemistry. Limitations / Obstacles in the pursuit of the goals of Green Chemistry
II	**Principles of Green Chemistry and Designing a Chemical synthesis:** Twelve principles of Green Chemistry with their explanations and examples and special emphasis on Designing a Green Synthesis using these principles (Prevention of Waste / by-products; maximum incorporation of the materials used in the process into the final products, 79 Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions).
III	**Green Synthesis / Reactions:** 1. Green Synthesis of adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis). 2. Microwave assisted reactions in water: (Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols) and reactions in organic solvents (Diels-Alder reaction and Decarboxylation reaction). 3. Ultrasound assisted reactions: sonochemical Simmons - Smith Reaction (Ultrasonic alternative to Iodine) 4. Surfactants for carbon dioxide - replacing smog producing and ozone depleting solvents with CO2 for precision cleaning and dry cleaning of garments. 5. Designing of Environmentally safe marine antifoulant. 6. An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn. 7. Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils.
IV	**Future Trends in Green Chemistry:** Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; co crystal controlled solid state synthesis; Green chemistry in sustainable development.

Learning Resources

1. Ahluwalia, V. K., Kidwai, M. R. New Trends in Green Chemistry, Anamalaya Publishers (2005).
2. Anastas, P. T. & Warner, J.K, Green Chemistry- Theory and Practical, Oxford University Press (1998).
3. Matlack, A. S. Introduction to Green Chemistry, Marcel Dekker (2001).
4. Cann, M. C. and Connely, M. E. Real-World cases in Green Chemistry, ACS (2000). 80
5. Ryan, M. A. and Tinnesand, M. Introduction to Green Chemistry, American Chemical Society, (2002).
6. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, Second Edition, 2010.

Course Outcome (COs)		
F. Y. M. Sc. Semester I		
Title of the Course and Course Code	**Research Methodology (CHA-510)**	**Number of Credits: 04**
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Learn the various aspects of the research process, framing useful research questions, research design, data collection, analysis, writing and presentation	
CO2	Understand the research problem, methods/techniques to be adopted	
CO3	Apply statistical tools for analysing the data while performing their research	
CO4	Develop skills in qualitative and quantitative data analysis and presentation	
CO5	Analyse for fitting, errors in the measurements and able to withdraw conclusions from the analysed data	
CO6	Execute a quality research paper and patents in science and technology	

Unit No.	Title of Unit and Contents
I	History of research. Indian, Egyptian, Greek ideas methodologies and research in chemistry. Ancient Indian research methodology applications. Basic Concepts of Research: Research-definition and types of research, Research methods vs methodology.
II	Data Collection and Documentation of Observations: Maintaining a laboratory record; Tabulation and generation of graphs Statistical analyses and its significance, Exploratory and confirmatory research, Planned and ad-hoc methods of data collection, Non-response and methods of recovering the missing response, various softwares for analysis. The module will consist of case studies of the research performed in various subjects using statistical methods.
III	Literature search, use of search engines, selection of research topic (case study based), and maintaining laboratory records (case study based). Safety in Laboratories, Ethical considerations, effective verbal and non-verbal communication, field data collection, safety in field. Key chemistry research areas, chemoinfomatics
IV	Writing research paper and / or thesis, making a presentation, writing a research proposal, and patents in Science, technology. (Authors, acknowledgements, reproducibility, Numbers, units, abbreviations and nomenclature used in scientific writing. Writing references. Power point and poster presentation. Scientific writing and ethics, Introduction to copyright-academic misconduct / plagiarism)

Learning Resources

1. 'History of the Scientific Methods' by Martin Shuttleworth, https://explorable.com/history-of-the scientific-method.
2. 'The Statistical Analysis of Experimental Data' by, John Mandel, ISBN: 0486646661, ISBN13: 9780486646664
3. Dawson, C. (2002). Practical research methods. UBS Publishers, New Delhi.
4. C. R. Kothari (2004), Research Methodology: Methods and Techniques. New Age International Publications

Title of the Course and Course Code	Analytical Chemistry Practical - I (CHA-520)	Number of Credits: 04
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Use safe chemical handling protocols and outline the environmental issues and importance of MSDS and GLP.	
CO2	Outline and recall basic knowledge of fundamentals and application of organic and physical chemistry through chemical and scientific theories.	
CO3	Standardize/calibrate the apparatus and instrument.	
CO4	Separate components from ternary mixture of organic compounds and determine type of given mixture and physical constants.	
CO5	Carry out purification techniques.	
CO6	Interpret, tabulate, conclude and write the experimental results.	

Unit No.	Title of Unit and Contents
I	**Organic Practicals** a) Separation of three component mixture b) Purification techniques
II	**Physical Practicals** pH metry: To determine dissociation constant and isoelectric point of an amino acid by pH metry b) Conductometry: To determine concentrations of strong acid and weak acid present in the mixture by titration with strong base by conductometric measurements. b) Spectrophotometry: To estimate amount of copper by photometric titration with EDTA To determine molecular weight of Cobalt Complex / amine picrate. c) Potentiomerty: To determine stability constant of a silver ammonium complex. d) Thermodynamics: To determine molar volume and partial molar volume of the components. e) Theoretical experiment: To plots the polar graphs for s and p orbitals using origin software

Title of the Course and Course Code	Analytical Chemistry Practical - II (CHA-521)	Number of Credits: 04
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Outline and recall basic knowledge of fundamentals and application of inorganic and physical chemistry through chemical and scientific theories.	
CO2	Perform the experiment and tabulate the observations.	
CO3	Illustrate safety measures related to experiments carried out.	
CO4	Separate components from different analytes using various methods / techniques	
CO5	Standardize / calibrate the apparatus and instrument.	
CO6	Develop skills in procedures and instrumental methods applied in practical tasks. Interpret, conclude and write the experimental results.	

Unit No.	Titleof Unit and Contents
I	**Inorganic Practicals** 1. Analysis of silica and manganese from pyrolusite ore. 2. Determination of tin and lead from solder alloy. 3. Synthesis and Characterization of Chloro penta-ammine cobalt (III) chloride 4. Synthesis and Characterization of Nitro penta-amminecobalt (III) chloride 5. Synthesis and Characterization of Potassium tri-oxalato aluminate 6. Synthesis and Characterization of Tris acetylacetonato iron (III) 7. Synthesis and Characterization of Trans-bis glycinato copper (II) 8. Determination of equilibrium constant of M - L systems Fe(III)–sulphosalicylic acid by Job's continuous variation method spectrometrically. 9. Verification of Debye Huckle theory of ionic conductance for strong electrolytes KCl, $BaCl_2$, $K_3[Fe(CN)_6]$ by conductometry. 10. Analysis of aluminium from alum 11. Synthesis of MnO_2 / ZnO nanoparticle and its application.
II	**Physical Practicals** **1. Chemical kinetics:** a. To study Kinetic decomposition of diacetone alcohol by dilatometry. b. To determine an order of iodide and persulphate ions by fractional change method. c. To investigate the rate constant of an autocatalytic reaction between potassium permanganate and oxalic acid. d. To investigate effect of Brönsted primary salt on reaction e. To determine temperature coefficient and energy of activation of acid catalyzed ester hydrolysis reaction. **2. Conductometry** a. To study hydrolysis of ethyl acetate by NaOH using conductometric measurements. b. To determine solubility product and thermodynamic properties of sparingly soluble salt by conductometry.

Learning Resources

1. Text book of Quantitative Analysis, A. I. Vogel 4th Edn. (1992).
2. Experimental Inorganic Chemistry, Mounir A. Malati, Horwood Series in Chemical Science (Horwood Publishing, Chichester) 1999.
3. Experiments in Chemistry, D. V. Jahagirdar, Himalaya Publishing House.
4. General Chemistry Experiments, Anil J. Elias, University Press (2002).
5. Ligand Field Theory, B. N. Figgis.

F.Y. M.Sc. Semester II		
Title of the Course and Course Code	**Reaction Mechanism in Organic Chemistry (CHA-551)**	**Number of Credits: 04**
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Define and explain recall principles of photochemistry.	
CO2	Explain pericyclic reactions and justify their mechanisms by using correlation diagrams and FMO approach	
CO3	Demonstrate concepts of Carbanions, Enamines and Ynamines and explain their stability, reactivity, selectivity and predict the products.	
CO4	Classify rearrangements. Predict the product and illustrate the reactions involving rearrangements	
CO5	Review carbenes, nitrenes, free radicals and discuss their methods of synthesis and predict products in related reactions.	
CO6	Specify neighbouring group participation (NGP) and predict the products in reactions involving NGP. Explain different mechanisms of ester and amide hydrolysis.	

Unit No.	Title of Unit and Contents
I	**Photochemistry:** General basic principles, initiators and sensitizers photochemistry of carbonyl compounds, alkenes, dienes, polyenes and aromatic compounds, photo rearrangements and named reactions
II	**Pericyclic reactions:** Electrocyclic, Cycloaddition, Sigmatropic and ene reactions. 1,3-dipolar additions, Analysis by correlation diagrams, FMO approach and ATS concept. Application of pericyclic reactions.
III	**Carbanions, Enamines and ynamines:** Formation, stability and related name reactions
IV	**Reactions of carbenes and nitrenes:** *N*-heterocylcic carbene and nitrenes-generation, stability and reactivity
V	**Neighbouring group participation:** NGP involving Nitrogen, Sulphur and Carbon atoms, C-C and C=C.
VI	**Rearrangements:** Anionic, cationic and free radical
VII	**Free radical:** Generation, stability, Nucleophilic and electrophilic radicals, characteristics reactions, -free radical substitution, addition to multiple bonds, Radicals in synthesis: Inter and intra molecular C-C bond formation via mercuric hydride, tin hydride, thiol donors, cleavage of C-X, C-Sn, C-Co, C-S, O-O bonds, Oxidative coupling, C-C bond formation in aromatics, SNAr reactions
VIII	**Ester and amide hydrolysis** (only major acid, base catalyzed and neutral condition mechanisms)

Learning Resources

1. Mechanism and Structure in Organic Chemistry - E. S. Gould (Holt, Rinehart and Winston).
2. Advanced Organic Chemistry by J. March, 6th Ed.
3. Advanced Organic Chemistry. F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007).
4. A guidebook to mechanism in Organic Chemistry - Peter Sykes 6th Ed. Orient Longman.
5. Organic Chemistry - J. Clayden, N. Greeves, S. Warren and P. Wothers. Oxford University Press (2001).
6. Radicals in Organic Synthesis B. Giese, Pergamon Press (1986).
7. Physical Organic Chemistry - J. Hine
8. A Guidebook to mechanism in Organic Chemistry - Peter Sykes 6th Ed. Orient Longman
9. Modern Synthetic reactions - H. O. House.

Title of the Course and Course Code	Advanced Inorganic Chemistry-II (CHA-552)	Number of Credits: 04
Course Outcome (COs) **On completion of the course, the students will be able to:**		
CO1	Describe the selection rule and construction of microstate table for various configuration. Recall the importance of bioinorganic chemistry. Describe the structure and bonding aspects of simple organometallic compounds.	
CO2	Outline the fundamental requirement for interpretation of electronic spectra of metal compounds for prediction of their properties. Discuss the role of metals in Metalloproteins. Classify the different types of organo-transition metal complexes, catalyzed reactions and factors affecting it.	
CO3	Identify the factors responsible for different magnetic behaviour of materials. Illustrate the importance and transport of metal ions. Identify back bonding in organometallics.	
CO4	Explain catalytic reaction involving organometallic compounds. Describe the metal carbonyls, metal clusters, metal nitrosyls and its preparation, structures and properties.	
CO5	Justify the importance and function of metal ions in metalloprotein. Evaluate problems based on electron count in organometallics.	
CO6	Specify the various Quenching of orbital angular momentum. Specify the environmental impact of the most inorganic compounds produced on the industrial scale and know different applications of organometallic compounds in medicines.	

Unit No.	Title of Unit and Contents
I	**Coordination Chemistry** a. Atomic Spectroscopy: Energy levels in an atom, coupling of orbital angular momenta, coupling of spin angular momenta, spin orbit coupling, spin orbit coupling p2 case, Determining the Ground State Terms-Hund's Rule, Hole formulation, Calculation of the number of the microstates b. Electronic Spectra-Splitting of spectroscopic terms (S, P, D. F and G, H, I), d1-d9 systems in weak fields, strong field configurations, transitions from weak to strong crystal fields c. Correlation diagrams (d1-d9) in Oh and Td environments, spin-crossover in coordination compounds. Tanabe Sugano diagrams, Orgel diagrams, evaluation of B, C and β parameters. d. Electronic spectra of complex ions- Selection rules (Laporte, orbital and spin selection rules), band intensities, band widths, spectra in solids, spectra of aqueous solutions of d1-d9 ions in Oh and Td environments, Evaluation of 10 Dq, Spectrochemical and Nephelauxetic series, charge-transfer spectra e. Magnetochemistry: Origin of Magnetic moment, factors determining paramagnetism, application of magnetochemistry in coordination chemistry (spin only moment, Russell Saunder's coupling, quenching of orbital angular moment, orbital contribution to a magnetic moment) in spin free and spin paired octahedral and tetrahedral complexes.
II	**Bioinorganic Chemistry** 1. Principles of Coordination Chemistry related to Bioinorganic Research and Protein

	2. Biological Chemistry of Iron a) Haemoglobin & Myoglobin b) Storage & Transport Proteins of Iron viz., Ferritin & Transferrin c) Transport of Iron d) Cytochromes e) Iron-Sulfur Protein 3. Biological Chemistry of Copper a) Type I, II & III b) Blue Copper Proteins (Plastocyanins Azurins & Blue Oxidases) c) Non-blue copper proteins e.g. Tyrosinase, Galactose Oxidase, SOD etc.
III	**Organometallic Chemistry** a) Introduction, definition, and scope of organometallic Chemistry b) Types of ligands and their classifications in organometallic compounds c) 16 and 18 electron rule and its limitations. d) Hapto-nomenclature,M-M bond calculations e) Metal carbonyls- synthesis, structure and bonding aspect f) Homogenous and Heterogenous Catalysis: Comparison Fundamental reaction steps, turn-over number, turn over frequency catalytic cycle. g) Hydrogenation of alkene

Learning Resources

1. D. Banerjea, Coordination Chemistry, Tata McGraw Hill, New Delhi, 1993.
2. Principle of Bioinorganic Chemistry: S. J. Lippard and J. M. Berg.
3. Bioinorganic Chemistry: Inroganic Elements in Chemistry of Life: W. Kaim and B. Schwederski.
4. Bioinorganic Chemistry: Bertini, Gray, Lippard and Valentine.
5. Bioinorganic Chemistry: R. J. P. Willams.
6. Bioinorganic Chemistry: Robert Hay
7. Bioinorganic Chemistry: M. N. Hughes
8. James Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry - Principles of Structure and Reactivity, 4th Edition, Harper Collins, 1993
9. Puri, Sharma and Kalia, Principles of Inorganic Chemistry - 31st Edition, Milestone Publishers, 2010.
10. R. Sarkar, General and Inorganic Chemistry, Books & Allied (P) Ltd. Calcutta, 2001.
11. R. C. Mehrotra, A. Singh, Organometallic Chemistry: A unified approach - 2nd Edition, New Age International Publication, 2006.

Title of the Course and Course Code	Advanced Physical Chemistry-II (CHA-553)	Number of Credits: 04
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Recall and define basic terminologies in spectroscopy, chemical bonding and nuclear chemistry.	
CO2	Illustrate, classify and compare theoretical and instrumental aspects for various spectroscopic and radioanalytical techniques. Summarize different molecular spectroscopic concepts and rules to deduce the molecular structures.	
CO3	Solve and work with numerical based on spectroscopic, radioanalytical and chemical bonding concepts. Interpret different types of molecular spectra and structure to evaluate valuable data from it.	
CO4	Explain molecular orbital theory for homonuclear, heteronuclear and polynuclear molecules using quantum rules.	
CO5	Review and relate the concepts involved in different spectroscopic techniques.	
CO6	Formulate and solve scientific problems based on the advanced physical chemistry concepts. Specify the applications of spectroscopy, radioanalytical techniques and concepts of chemical bonding in chemistry and interdisciplinary fields.	

Unit No.	Title of Unit and Contents
I	**Molecular spectroscopy:** a. Electromagnetic spectra, spectral regions, spectral line width, spectral line intensity. Spectrophotometer, resolving power, signal to noise ratio, introduction to Fourier transitions. b. Visible spectrophotometry and colorimetry: Theory of spectrophotometry and colorimetry, fundamental laws of absorption, Lambert's law, Beer's law, additivity of absorbance, instrumentation, applications. c. Rotational Spectroscopy: Rotational spectra, classification of molecules, rigid and non-rigid rotor, diatomic molecules, effect of temperature and isotope substitution on the rotation spectra, linear and nonlinear polyatomic molecules, relative intensities of spectral lines, stark effect. d. Vibrational Spectroscopy: Vibrating diatomic molecule, simple and anharmonic oscillator, diatomic vibrating rotator, vibrational and rotational spectrum of CO, breakdown of the Born Oppenheimer approximation, overtones and combinations, the vibration of polyatomic molecules, instrumentation of IR, principle and application of FTIR. e. Raman Spectroscopy: Introduction, Rotational Raman- spectra, Vibrational Raman, Spectra, polarization of light and Raman effect, structure elucidation from combined Raman and IR spectroscopy, applications in structure elucidation. f. Electronic spectroscopy of molecules: Born - Oppenheimer approximation, electronic spectra of diatomic molecules, intensity of vibrational - electronic spectra: The Franck-Condon principle, dissociation energy and dissociation products, rotational fine structure of electronic - vibration transitions, the Fortrat diagram, predissosiation. g. Magnetic resonance spectroscopy: ^{1}H NMR, chemical shift, spin coupling, factors affecting chemical shifts. Introduction to ^{13}C NMR, g factor,

	applications. h. Mossbauer spectroscopy: Principles and applications of Mossbauer spectroscopy.
II	**Chemical bonding:** Introduction to electronic structure of molecule, Born Oppenheimer's Approximation, Quantum Theory of molecules, Approximate solution of Schrödinger equation, Approximate method - Variation Method, Valance bond theory (VBT) and Molecular Orbital Theory(MOT), Molecular orbital treatment of hydrogen molecule ion and hydrogen molecule, Approximations underlying Huckel theory, Applications of Huckel theory to ethylene, allyl system, butadiene and benzene, alternate and non-alternate hydrocarbons.
III	**Nuclear and radiation Chemistry:** a. Types and detection of ionizing radiations - α, β, γ decay and their energies b. Applications of radioisotopes - neutron activation analysis, isotope dilution analysis, radiometric titration and problem solving.

Learning Resources

1. Fundamentals of molecular spectroscopy: C.N. Banewell and E. Mc. Cash (Fourth edition).
2. Elements of Nuclear Chemistry, H.J. Arnikar, 4 th edition, New Age Publishers (2008).
3. Physical Chemistry, T. Engel and P. Reid, Pearson Education (2006).
4. Atkins Physical Chemistry, P. W. Atkins and DePaula (Oxford, Eighth Edition).
5. Physical Chemistry and molecular approach - D. Mcquarie and J. Simon (University Science) (2000).

Title of the Course and Course Code	Analytical Clinical Biochemistry (CHA-554)	Number of Credits: 04
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Recall and define basic terminologies in spectroscopy, chemical bonding and nuclear chemistry.	
CO2	Illustrate, classify and compare theoretical and instrumental aspects for various spectroscopic and radioanalytical techniques. Summarize different molecular spectroscopic concepts and rules to deduce the molecular structures.	
CO3	Solve and work with numerical based on spectroscopic, radioanalytical and chemical bonding concepts. Interpret different types of molecular spectra and structure to evaluate valuable data from it.	
CO4	Explain molecular orbital theory for homonuclear, heteronuclear and polynuclear molecules using quantum rules.	
CO5	Review and relate the concepts involved in different spectroscopic techniques.	
CO6	Formulate and solve scientific problems based on the advanced physical chemistry concepts. Specify the applications of spectroscopy, radioanalytical techniques and concepts of chemical bonding in chemistry and interdisciplinary fields.	

Unit No.	Title of Unit and Contents
I	**Structure, properties and functions of carbohydrates, lipids and proteins: Carbohydrates:** Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle. Isolation and characterization of polysachharides.
II	**Proteins:** Classification, biological importance; Primary and secondary and tertiary structures of proteins: α-helix and β- pleated sheets, Isolation, characterization, denaturation of proteins. Enzymes: Nomenclature, Characteristics (mention of Ribozymes), Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Introduction to Biocatalysis: Importance in "Green Chemistry" and Chemical Industry.
III	**Lipids:** Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications. Lipoproteins: Properties, functions and biochemical functions of steroid hormones. Biochemistry of peptide hormones.
IV	**Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA:** Replication, Transcription and Translation, Introduction to Gene therapy. Enzymes: Nomenclature, classification, effect of pH, temperature on enzyme activity, enzyme inhibition. A diagnostic approach to biochemistry.
V	**Blood:** Composition and functions of blood, blood coagulation. Blood collection and preservation of samples. Anaemia, Regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.
VI	**Urine:** Collection and preservation of samples. 6. Formation of urine. Composition and estimation of constituents of normal and pathological urine.

Learning Resources

1. Cooper, T. G. Tool of Biochemistry. Wiley-Blackwell (1977).
2. Wilson, K. & Walker, J. Practical Biochemistry. Cambridge University Press (2009).
3. Varley, H., Gowenlock, A. H. & Bell, M.: Practical Clinical Biochemistry, Heinemann, London (1980).
4. Devlin, T. M., Textbook of Biochemistry with Clinical Correlations, John Wiley & Sons, 2010. 160.
5. Berg, J. M., Tymoczko, J. L. & Stryer, L. Biochemistry, W. H. Freeman, 2002.
6. Talwar, G. P. & Srivastava, M. Textbook of Biochemistry and Human Biology, 3rd Ed. PHI Learning.
7. Nelson, D. L. & Cox, M. M. Lehninger Principles of Biochemistry, W. H. Freeman, 2013.
8. O. Mikes, R. A. Chalmers: Laboratory Handbook of Chromatographic Methods, D. Van Nostrand & Co., 1961.

Title of the Course and Course Code	Analytical Chemistry Practical - III (CHA-570)	Number of Credits: 04
Course Outcome (COs) **On completion of the course, the students will be able to:**		
CO1	Describe the theoretical principles and concepts related to experiments.	
CO2	Represent the results of scientific work in oral, written, graphical and electronic formats.	
CO3	Apply laboratory skills in organic and physical chemistry. Carry out single stage preparation along. Demonstrate software related to chemistry.	
CO4	Identify and analyse the product obtained by different techniques. Demonstrate purification technique.	
CO5	Justify the steps to standardize the methods and instruments.	
CO6	Perform experiments, analyze and interpret the experimental results.	

Unit No.	Title of Unit and Contents
I	**Organic Practicals** a. TLC b. Column Chromatography c. Distillation d. Use of chemistry software like ChemDraw, Chemsketch e. Single stage preparations: oxidation, reduction, alkylation, formylation, cycloaddition etc.
II	**Physical Practicals** a. Radioactivity: 1. To determine counting errors of Giger Muller counter. 2. To determine E_{max} of β radiation and absorption coefficients in Al by Geiger Muller counter b. Viscometry: To determine radius of glycerol molecule by viscosity. c. Conductometry: To study the hydrolysis of NH_4Cl by Conductometry. d. Spectrum Analysis: To analyze crystal structure from single crystal X-ray pattern. e. Theoretical Experiment: To study statistical treatment of experimental data. f. pH metry: To determine Hammett constant of ortho, meta, para amino / nitro benzoic acid.

Title of the Course and Course Code	Analytical Chemistry Practical - IV (CHA-571)	Number of Credits: 04
Course Outcome (CO) On completion of the course, the students will be able to:		
CO1	Describe the theoretical principles and concepts related to experiments.	
CO2	Represent the results of scientific work in oral, written, graphical and electronic formats.	
CO3	Execute chemical analysis for different samples. Implement problem solving, critical thinking and analytical reasoning as applied to scientific problems.	
CO4	Analyze data from a range of physical techniques to characterise different compounds.	
CO5	Justify the steps to prepare and standardize different solutions.	
CO6	Design and perform scientific experiments. Interpret and write the experimental results with standards.	

Unit No.	Title of Unit and Contents
I	**Inorganic Practicals:** 1. Analysis of silica and iron from hematite ore 2. Analysis of cupronickel / stainless steel alloy. 3. Synthesis and characterization of Tris (ethylene diammine) Ni(II) thiosulphate. 4. Synthesis and characterization of Tris triphenylphosphine copper nitrate 5. Synthesis and characterization of Cis and Trans dichloro bis(ethylenediamine) Co(III) chloride. 6. Synthesis and characterization of Tris acetylacetonato manganese 7. Synthesis and characterization of Postassium trioxalato chromate 8. Determination of iron by solvent extraction techniques using 8-hydroxyquinoline reagent. 9. Separation of mixture of Zn(II) and Mg(II) using Amberlite IRA 400 anion exchanger and quantitative estimation of separated ions Zn(II) and Mg(II). 10. Estimation of phosphate from waste water by calibration curve method. 11. Synthesis of Fe_2O_3 / ZnS nanoparticles.
II	**Physical Practicals:** **1. Conductometry:** a. To determine equivalent conductance at infinite dilution, dissociation constant of Acetic Acid and to study DebeyHuckel Limiting law. b. To determine critical micellar concentration (CMC) and G of micellization of sodium dodecyl sulphate (SDS). **2. Potentiometry:** a. To determine Solubility and solubility product of a sparingly soluble salt. b. To determine strength of commercial vinegar by potentiometric titration. **3. Potentiometry:** To estimate amount of halides, present in the mixture. **4. pH metry:** To determine dissociation constants of tribasic acid (phosphoric acid). **5. Spectrophometry** To study simultaneous determination of cations from binary mixture.

Learning Resources

1. Text book of Quantitative Analysis, A. I. Vogel 4th Edn. (1992).
2. Experimental Inorganic Chemistry, Mounir A. Malati, Horwood Series in Chemical Science (Horwood Publishing, Chichester) 1999.
3. Experiments in Chemistry, D. V. Jahagirdar, Himalaya Publishing House.
4. Ligand Field Theory, B. N. Figgis.