MANIPAL
ACADEMY of HIGHER EDUCATION
(Institution of Eminence Deemed to be University)

Department of Sciences
Manipal Academy of Higher Education
M.Sc. (Chemistry) Program
Choice Based Credit System - 2024 (CBCS - 2024)
(To be implemented from the academic year 2024-25)

Signature of Registrar

Signature of Deputy Registrar- Academics (Tech)

Signature of Coordinator-DoS

Signature of Head, Department of Chemistry

Course structure

Semester	Subject code	Subject	L-T-P-C	Credits
First semester	CHM	Inorganic Chemistry	4-0-0-4	4
	CHM	Organic Chemistry	4-0-0-4	4
	CHM	Physical Chemistry	4-0-0-4	4
	CHM	Spectroscopy I	4-0-0-4	4
	CHM	Chemistry Practical I	0-0-4-2	2
	CHM	Chemistry Practical II	0-0-4-2	2
Total credits				20
Second semester	CHM	Spectroscopy II	4-0-0-4	4
	CHM	Seminar	0-0-2-0	2
	Organic Chemistry Specialization			
	CHM	Advanced Organic Chemistry	4-0-0-4	4
	CHM	Heterocyclic Chemistry and Natural Products	4-0-0-4	4
	CHM	Advanced Organic Chemistry Practical I	0-0-6-3	3
	CHM	Advanced Organic Chemistry Practical II	0-0-6-3	3
	Applied Chemistry Specialization			
	CHM	Principles and Practice of Analytical Chemistry	4-0-0-4	4
	CHM	Advanced Analytical Chemistry	4-0-0-4	4
	CHM	Analytical Chemistry Practical	0-0-6-3	3
	CHM	Applied Chemistry Practical	0-0-6-3	3
Total credits				20
	CHM	RMTC	3-0-0-3	3
Third semester	CHM	Elective I	3-0-0-3	3
	CHM	Elective II	3-0-0-3	3
	CHM	Elective III	3-0-0-3	3
	CHM	Elective IV	3-0-0-3	3
	CHM	Industry/Research Lab Visit	1-0-0-1	1
Total credits				16
Fourth semester	CHM	Project		24

Total credits	24
Grand Total	80

1st Semester

CHM **: Inorganic Chemistry**
[4-0-0-4]

Course Objectives:
At the end of the course students will be able to

- Explain certain key concepts in inorganic chemistry (e.g. valence bond theory, molecular orbital theory, general structural types and bonding)
- Describe the basics of analytical chemistry
- Use these concepts in problem solving
- Describe the chemistry of main group elements and transition metals

Pre-requisites:
B.Sc. Chemistry background

Syllabus

Chemical bonding and coordination chemistry:
Introduction to Bonding, Primary and Secondary bonding types, V.S.E.P.R.T., M.O.T., Bond parameters, Lattice energy- Born-Haber cycle, Polarity in covalent bonds, Concept and scope of ligand fields, Effect of ligand field-octahedral and tetrahedral, MOT of complexes, Electronic spectra of complexes, Transition metal magneto chemistry, Spectrochemical series, Nephelauxetic effect, John-Teller theory, Stability constants of complex ions. **[12]**

Analytical chemistry:
Classification of Chemical Analysis, Uncertainty in measurement, Accuracy and precision. Statistical treatment of finite samples, Least- squares method for deriving calibration of plots, Principles of sampling. Gravimetric Analysis-Practical gravimetric procedures. Electro gravimetry, Principles, instrumentation and applications. Chromatographic techniques: Classification, Experimental techniques - thin layer chromatography, liquid chromatography, HPLC, Gas chromatography and Gel chromatography, Ion exchange chromatography, advantages, disadvantages. Solvent extraction: Principles, Extraction techniques and applications.

[12]

Chemistry of s and p block elements:
Hydrogen and its compounds, Hydrides classification, Application of crown ethers in extraction of alkali & alkaline earth metals, Boron hydrides, Metalloboranes, Carboranes, Fullerenes, Ring, Cage & Cluster compounds of P block elements, Silicates, Zeolites, Noble gases & their compounds - Synthesis, properties, uses, structure and bonding

[8]

Chemistry of Transition & Inner-transition Elements:
Transition metals- Metallic character, variable oxidations states, Stereochemistry and coordination numbers of metals, catalytic properties, comparison of 3d, 4d and 5d series. Lanthanides and actinides: Electronic structure, Oxidation states, Extraction and separation of lanthanides, stereochemistry, Spectral and magnetic properties of lanthanide and actinide complexes, application of Lanthanides and actinides. Comparison of f block with d-block ions.

[8]

Bioinorganic Chemistry:
Principles of bioinorganic chemistry, Ligands of biological interest, Metalloproteins, Iron storage and transport proteins, Dinitrogen fixation in nature and biological models, Structure and the characteristic features of Myoglobin, Hemoglobin, Carboxypeptidase, Carbonic anhydrase, Fe-S proteins , Cytochromes, Cyano-cobalamin, Chlorophyll.

[8]

References

1. J.E. Huheey, E.A. Keiter, R.L. Keiter, O. K. Medhi, Inorganic Chemistry 4th Edn., Pearson Education, Boston, 2008
2. D.F. Shriver, P.W. Atkins, C.H. Langford, Inorganic Chemistry, 3rd Edn., Oxford University Press, Oxford, 1999
3. J.D. Lee, Concise Inorganic Chemistry, 5th Edn., Blackwell Science Ltd., New Delhi, 2004
4. F.A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6th Edn., J. Wiley, New York, 1999
5. C.E. Housecraft, A.G. Sharpe, Inorganic Chemistry, 4th Edn., Prentice Hall, New Jersey , 2001
6. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, John Wiley, New York, 2000
7. R.M. Roat, Malone, Bioinorganic Chemistry. A Short Course, 2nd Edn, Wiely New Jersey, 2007
8. Skoog, Holler, Nieman, Principle of Instrumental Analysis,5th Edn, Thomas Asia ptc. Ltd, 2004.
9. G.R. Chatwal and S. Anand, Instrumental Methods of Chemical Analysis, 5th Ed., Himalaya Publishing House, 2014

CHM** : Organic Chemistry**
[4-0-0-4]

Course Objectives:

- At the end of the course students will be able to
- Demonstrate an understanding of organic chemistry, its principles, concepts and mechanism of organic reactions and types of reaction intermediates.

- Explain the basic principles and concepts in the stereochemistry of organic molecules and photochemistry.
- Demonstrate an understanding of pericyclic reactions and predicts their mechanisms using FMO and Woodward-Hoffman correlation diagram.
- Explain the synthetic utilities of various reagents for organic transformations and to describe their selectivity.

Syllabus

Fundamental Aspects

Concept of aromaticity, Huckel's rule, Polygon rule, homo-aromatic, non-aromatic and anti-aromatic systems. Aromaticity in benzenoid and non-benzenoid compounds.
Acids and Bases: Strength of aliphatic and aromatic acids and bases, Factors affecting strength of acids and bases, Effect of solvents on acid and base strength.
Organic Reaction mechanism: Organic reaction mechanisms involving nucleophilic substitution at saturated carbon, aromatic electrophilic, nucleophilic substitution reactions, addition reactions, elimination reactions.

[10]

Stereochemistry

Introduction to Stereochemistry: Conformation and configuration of molecules, projection formulae,Fischer, Saw-horse, Newman and Flying wedge representations and their Interconversion. Absolute configuration (D,L) and (R,S) systems. Elements of symmetry, Psedoassymmetric centres, chirality, molecules with more than one chiral centre, threo and erythro isomers, methods of resolution, stereospecific and stereoselective synthesis, asymmetric synthesis, Cram's and Prelog's rules. Optical activity in the absence of chiral carbon-biphenyls, allenes and spiranes. Conformational analysis of cycloalkanes and decalins. Effect of conformation on reactivity. Acyclic & cyclic systems-Substituted cyclohexanes, cyclohexanones, cyclohexanols, Curtain-Hammet Principle. Stereochemistry of compounds containing nitrogen, sulphur, and phosphorus.

[10]

Photochemistry

Bonding and antibonding orbital, Chemistry of excited states of organic molecules, Jablonski diagram and quantum yield, Photo dissociation, Photo reduction, Photochemical isomerisation, Norrish Type-I and Type-II reactions, Barton reaction and Photo Fries rearrangement, Paterno-Buchi reaction, Yang cyclization, photo oxidation and photo catalysis. Applications of organic dyes.

[06]

Reduction and Oxidation reactions

Reduction reactions of industrial importance, catalytic hydrogenation, metal hydride reduction, Mechanism, reduction by hydride transfer reagents. Electroreduction and reductions with metals (Na, Li, Zn, Fe, Al, Mg, Sn), reductions with metal compounds, reductions with non-metal compoundsWolf-Kishner reduction, reduction with diimide and

trialkysilanes. Introduction to oxidation reactions, oxidation of hydrocarbons, alcohols and ketones, oxidation with chromium and manganese compounds, per acids, periodic acids, ozone, lead tetra acetate, osmium tetroxide**.**

[08]

Pericyclic Reactions

Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl systems, Classification, Woodward-Hoffmann correlation diagram and FMO approach, Electrocyclic reactions: Introduction, Con-rotatory and dis-rotatory process, 4n and 4n+2 systems, Cycloaddition reaction: Suprafacial and antarafacial addition using 4n and 4n+2 systems, Sigmatropic reactions: Suprafacial and antarafacial shift of H and methyl group during [1,3] & [1,5] - sigmatropic shifts, Claisen, Cope, Oxy-Cope and Aza-Cope rearrangements

[08]

Reagents in Organic Synthesis

Sharpless asymmetric epoxidation, DDQ, Dioxiranes, Selenium dioxide, DMSO with either Ac_2O or oxalyl chloride, Dess-Martin reagent. Synthesis involving phase transfer catalysis (PTC), Baylis-Hillman reaction, Henry reaction, Nef reaction, Kulinkovich reaction, Ritter reaction, Sakurai reaction, Tishchenko reaction and Ugi reaction. Brook rearrangement; Tebbe olefination. Metal mediated C-C and C-X coupling reactions: Palladium catalyzed cross coupling reactions, Ullmann coupling reactions, directed ortho metalation. **[06]**

CHM **: Physical Chemistry**

[4-0-0-4]

Course Objectives:

At the end of the course students will be able to

- Describe electrochemical principles and applications
- Demonstrate an understanding of basic kinetic concepts, surface chemistry and catalysis
- Explain thermodynamic laws and phase rule
- Explain the quantum mechanical treatment of simple molecules

Pre-requisites:

B.Sc. Chemistry background

Electrochemistry

Activity and Concentration; Activity Coefficients of Electrolytes, Variation of mean activity Coefficient with concentration- Debye- Huckel Theory of mean activity coefficients of strong electrolytes, Debye- Huckel limiting law, Bjerrum's Theory of Ion Association in Electrolyte Solutions- an expression for association constant, Electro Capillary action and Electro capillary Curve, Derivation of Lippmann equation, Determination of Interfacial

tension of Mercury – HCl interface by capillary rise method. The Structure of Electrified Interfaces, Concept of outer Helmholtz Plane, Quantitative thermodynamic treatment of electrified interfaces, Mathematical models for Electrified Interfaces: The Helmholtz – Perrin Model, Gouy Chapman Diffuse Charge Model and the Stern Model. **[8]**

Chemical and electrochemical cells

Brief account on classification, working and applications. Corrosion- Polarisation, overvoltage, Butler- Volmer equation, Tafel equation, Corrosion classification, Electrochemical, kinetic and thermodynamic aspects of corrosion, Corrosion rate measurement (weight loss, Tafel polarization) and monitoring. Electroplating: need and factors affecting electro-deposit. Brief discussion on electroplating of Cr. electro-less plating of Cu.

Lithium-ion secondary cells, Fuel cells: classification, construction, and working of the alkaline fuel cell. **[4]**

Chemical Kinetics

Arrhenius equation, Activation energy- potential energy surfaces. Theories of reaction rates: kinetic theory of collision, Conventional transition state theory: (CTST)- equilibrium hypothesis, Derivation of the rate equations by the methods CTST, Thermodynamic formulation of CTST- Eyring Equation, Elementary gas phase reactions; The Lindemann Theory, Composite reactions; Rate equations for consecutive reactions- steady state treatment and rate determining step, Parallel reactions, Chain reactions with examples- Bodenstein-Lind Mechanism. Organic decompositions- thermal decomposition of ethane, Transition state theory in solutions, Reactions between ions- influence of dielectric constant, Ionic strength- primary and secondary salt effect, Effect of substitutes – Hammett and Taft equation. **[6]**

Surface Chemistry and Catalysis

Uni-and bi-molecular surface reactions, Multilayer adsorption-BET equation and its application in surface area determination. Adsorption from solutions: The Gibbs adsorption isotherm. Homogeneous catalysis; General catalytic mechanisms, Equilibrium treatment Arrhenius intermediate, Steady state treatment - van't Hoff intermediate, general acid base catalysis, Enzyme catalysis- Michaelis-Menton equation, Influence of temperature and pH on enzyme catalysis **[6]**

Thermodynamics and Phase Rule

Helmholtz Free Energy (Work Function), Gibbs free energy, Fundamental property relations, Maxwell's equations – thermodynamic derivation, Gibbs Helmoltz equation, Partial molar properties; Concept of chemical potential, Gibbs – Duhem equation, Duhem –Merguleus equation, Variation of chemical potential with pressure and temperature, Clapeyron –Clausius equation and its applications, Fugacity; its significance, Third law of thermodynamics, Experimental verification of third law of thermodynamics, Phase rule, Application of phase rule for three component systems. **[6]**

Quantum Chemistry

Review of basic mathematics, Origin and development of quantum chemistry: black body radiation, dual nature of light, de-Broglie hypothesis, dual nature of particles, Heisenberg's uncertainty principle, Concept of particle wave: Schrodinger wave function and its physical significance, conditions for acceptable wave function, conditions for normalization and orthogonality, Quantum mechanical formalization; Operators, Eigen values and Eigen functions, Basic postulates of quantum mechanics, Derivation of time independent Schrodinger wave equation, Solution of Schrodinger wave equation for exactly solvable problems such as particle in a box (1D and 3D), Harmonic oscillator (comparison between classical and quantum mechanical treatment), Quantum mechanical tunneling effect, Particle rotating in a ring, sphere, Rigid rotor (solutions for q,f equations) Circular harmonics

Atomic Structure: Structure of hydrogen and hydrogen like atoms (separation of r,q,f equations and their solutions), Quantum numbers and their characteristics, Orbital diagram. Spherical harmonics Need of approximation methods, Method of variation and perturbation, Empirical method: Huckel molecular orbital theory of linear conjugated systems (ethene, allyl & butadiene systems) **[18]**

References

1. G. M. Barrow, Physical Chemistry, 7th Edn, Tata McGraw Hill, New Delhi, 2002
2. S. Glasstone, An Introduction to Electrochemistry, East West Press, New Delhi, 2005
3. A.W. Atkins, Physical Chemistry ELBS, 5th Edn, Oxford University Press, Oxford, 2000
4. K. J. Laidler, Chemical Kinetics, Pearson Education, 4th Edn, New Delhi, 2007
5. D.R. Crow, Principles and applications of Electrochemistry, 6th Edn, Chapman and Hall CRC, 2000
6. I. N. Levine, Quantum Chemistry, 5th Edn, Allwyn and Bacon, Boston, 2000
7. P.W. Atkins, Molecular Quantum Chemistry Mechanics, 3rd Edn, Oxford University Press, Oxford, 2001
8. A.K. Chandra, Introductory Quantum Chemistry, Tata McGraw Hill, New Delhi, 2000
9. R.K. Prasad, Quantum Chemistry, New Age International Publication, New Delhi, 4th Edn., 2010
10. A. Skoog, D.M.West, F.J. Holler, S.R.Crouch, Fundamentals of Analytical Chemistry, 8th Edn, Thomson Brooks Cole, Belmont, 2008

CHM **: Spectroscopy I**

[4-0-0-4]

Course Objectives:

At the end of the course students will be able to

- Identify the symmetry elements and represent the point groups.
- Describe the principles and instrumentation involved in MW, IR, Raman and UV/visible spectroscopic methods.
- Apply the general principles to analyze and interpret spectral data.

Pre-requisites:
B.Sc. Chemistry background

Syllabus

Symmetry and Group Theory
Importance of molecular symmetry, Symmetry elements and operations - Symmetry planes, reflections, inversion center, proper/ improper axes of rotation, Products of symmetry operations- matrix representation, Classes of symmetry operations, classification of molecular point groups. Representations of groups- Representation of point groups-reducible and irreducible representation, Classification of molecules into point groups. Great orthogonality theorem (No mathematical part.). Character table. Applications of group theory. Molecular vibrations, group theoretical selection rules for electronic transitions, infra-red and Raman spectra. **[10]**

Introduction to Spectroscopy
Properties of electromagnetic radiation, Electromagnetic spectrum, interaction of electromagnetic radiation with matter, Components of spectrophotometer, Absorption and emission spectra of molecules. **[4]**

Atomic Spectroscopy
Theory of atomic spectroscopy - Origin of spectral transitions, population of energy levels, Spectral line widths, Background interferences and their correction, Instrumentation-hollow cathode lamp, atomization, flame characteristics, signal modulation, non-flame atomization techniques, double beam atomic absorption spectrophotometer.
Flame atomic emission spectroscopy - flame photometer, non-flame emission sources, comparative study & applications of AAS and AES. **[10]**

Microwave Spectroscopy
Theory of microwave spectroscopy - rotational spectra of rigid and non-rigid diatomic molecules and polyatomic molecules, intensity of spectral lines, isotope effects, Stark effect, instrumentation and applications. **[4]**

IR Spectroscopy
Theory of IR spectroscopy - Vibrational & vibrational-rotational spectra of diatomic molecules, modes of vibration in poly atomic molecules, Factors influencing vibrational frequencies, instrumentation, Solid, liquid and gaseous sampling techniques, double beam IR spectrophotometer, FTIR. Identification of functional groups of organic compounds, correlation charts, other applications in organic chemistry. **[10]**

Raman Spectroscopy

Principles of Raman effect, Quantum & classical theories of Raman effect, Rotational & Vibrational Raman spectra, Instrumentation, laser Raman spectrometer. Applications in organic chemistry, difference between IR & Raman spectra, advantages & disadvantages Of Raman spectroscopy over IR spectroscopy. **[4]**

UV- Visible Spectroscopy

Laws of absorption of light- Beer's &Lambert's law, limitations of Beer's law, Types of electronic transitions in organic molecules, Chromophores & oxochromes, Bathochromic & hypsochromic shifts, Charge transfer transitions, Instrumentation & sampling, Solvent effects, Applications of electronic spectroscopy in the elucidation of structure of organic compounds- Woodward Feiser rules, Quantitative analysis, Photoelectron spectroscopy-basic principles, measurement techniques and applications. **[6]**

References

1. C.N. Banwell, E.M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw Hill,
2. New Delhi, 2001
3. R.M. Silverstein, *Spectrometric Identification of Organic Compounds*, John Wiley & Sons, New York, 1981
4. W. Kemp, *Organic Spectroscopy*, 3rd Edn, ELBS, Hampshire, 1991
5. R.S. Drago, *Physical Methods for Chemists,* 2nd Edn., Saunders College Publishing, New York, 1992
6. G. Aruldhas, *Molecular Structure and Spectroscopy*, Prentice Hall, New Delhi, 2001

CHM**: Chemistry Practical I**

[0-0-4-2]

Course Objectives:

At the end of the course students will be able to

- Explain the principles of gravimetric and volumetric analysis
- Use the skills developed in the lab course in inorganic quantitative analysis
- Demonstrate quantitative analysis skill of certain ores, alloys and pigments
- Discuss some key introductory concepts of inorganic chemistry in quantitative analysis
- Describe basic procedures and techniques used in physical chemistry in acquiring data
- Perform experiments in physical chemistry involving conductometry, potentiometry, refractometry and kinetics

Pre-requisites:

B.Sc. Chemistry background

List of experiments

1. Analysis of pyrolusite-insoluble residue gravimetrically and manganese content by oxalate method.
2. Determination of manganese by gravimetric analysis and Colorimetric determination of Copper.
3. Analysis of Dolomite-insoluble residue gravimetrically and Ca, Mg by complexometric method.
4. Analysis of stainless steel-insoluble residue gravimetrically and determination of Ni by gravimetric and Fe by volumetric methods.
5. Semi-micro qualitative inorganic analysis of mixtures of inorganic salts containing four cations and two anions (two less common cations like Tl, W, Mo, V, Zr, Th, U, Ce, Ti and Li and anions such as phosphate, borate and fluoride to be included). (4 mixtures to be given)
6. Conductometric titrations: i) Weak acid vs strong base ii) Mixture of strong and weak acid vs strong base./ Determination of percentage composition of binary mixture by using refractometer.
7. Determination of formal potential of Fe^{2+}/Fe^{3+} system using three different oxidants by potentiometric method. / Determination of distribution coefficient of iodine in carbon tetrachloride and water system.
8. Determination of pH of buffer and pKa of acids- using pH meter. / Verification of Nernst equation.
9. Verification of Freundlich's and Langmuir adsorption isotherms. / Determination of molecular weight of the polymer by viscosity measurements

References

1. Svehla and Sivasankar, Vogel's Qualitative Inorganic Analysis, 7th Edn., Pearson Education India, 2012
2. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, Vogel's textbook of quantitative chemical analysis, 6th Edn., Prentice Hall, 2000.
3. J.B. Yadav, Advanced Practical Physical Chemsitry, Goel Publishing House, 27th Edn., 2008
4. V.B. Athawale, P. Mathur, Experimental Physical Chemisty, New Age International, 2008

CHM **: Chemistry Practical II**

[0-0-4-2]

Course Objectives:

At the end of this course students should be able to

- Perform synthetic reactions, work-ups and purifications
- Measure and report relevant physical properties of prepared compounds
- Preform physiochemical measures including solubility product, stability constant, rate constant and molecular weight

- Interpret scientific information and experimental data in the determination of several parameters and physical constants

Pre-requisites:
B.Sc. Chemistry background

List of experiments

1. Synthesis of benzopinacol and benzohydrol from benzophenone.
2. Preparation of diazoaminobenzene from aniline.
3. Preparation of coumarin derivative from resorcinol.
4. Nitration of acetanilide to p-nitroacetanilide and Hydrolysis of p-nitroacetanilide to p-nitroaniline.
5. Separation of binary and ternary mixtures of organic compounds, Organic mixtures containing aromatic hydrocarbons, carboxylic acids, phenols, amines, nitro compounds, amides, carbonyl compounds and halogenated compounds. (4 mixtures to be given)
6. Determination of energy of activation and thermodynamic parameters for the acid catalyzed hydrolysis of methyl acetate.
7. Influence of ionic strength on the rate constant of the reaction between potassium persulfate and potassium iodide.
8. Determination of stability constant of complex formed between Fe(III) and salicylic acid by Job's method.
9. Determination of rate constant of the reaction between potassium persulfate and potassium iodide by colorimetric measurements. / Determination of the solubility product of silver chloride using a galvanic cell and a concentration cell.

References:

1. A.I. Vogel, A Text Book of Practical Organic Chemistry, Pearson Education; 5 edition (2003).
2. F.G. Mann, B.C. Saunders, Practical Organic Chemistry, Pearson Education India; 4th edition (2009).
3. B. Yadav, Advanced Practical Physical Chemistry, Krishna Prakashan Media (P) Ltd, 2015
4. V.D. Athawala, P. Mathur, Experimental Physical Chemistry, New Age International, 2001
5. B. Viswanathan, P.S. Raghavan, Practical Physical Chemistry, Viva Books Pvt. Ltd, 2014
6. B.P. Levitt, Findlay's Practical Physical Chemistry, 9th Edn, Longman, 2000

2nd Semester

CHM **: Spectroscopy II**
[4-0-0-4]

Course Objectives:
At the end of the course students will be able to

- Explain the principles, concepts and applications of 1H and 13C NMR spectroscopic techniques
- Explain the principles, concepts and applications of NQR, ESR, Mossbauer spectroscopic techniques
- Explain the principles, concepts and applications of Mass spectrometry
- Apply these analytical methods in elucidating the structure of organic molecules

Pre-requisites:
Spectroscopy I

Syllabus

Proton NMR Spectroscopy:
General principles, Quantum & Classical theories, NMR spectrum- number & intensity of peaks, Chemical shift & its measurements, Factors affecting chemical shifts, Solvents used in NMR, Spin-spin coupling, Coupling constant, Chemical & magnetic equivalence in NMR, chemical exchange, factors affecting coupling constant, Karplus relationships, non- first order spectra, simplification of complex proton NMR spectra, Instrumentation- Continuous wave NMR spectrometer, FT-NMR, applications- correlation tables, Elucidation of structure of organic molecules. **[14]**

^{13}C NMR Spectroscopy:
^{13}C nucleus, recording of spectra, general aspects of ^{13}C NMR spectrum- resolution, Proton decoupling, off resonance proton decoupling, line intensity, chemical shifts equivalence, correlation data, factors affecting carbon chemical shifts and its corrections, spin-spin coupling and double irradiation, INDOR, SPI, NOE, variable temperature NMR, DEPT spectra, 2D NMR, COSY, MRI, CIDNP, Heteronuclear coupling.
^{19}F, ^{31}P, ^{14} N, ^{15}N, and ^{17}O NMR –general aspects and examples. **[10]**

NQR Spectroscopy:
Quadrupole nucleus, Principle of NQR, Transitions for axially & non-axially symmetric symmetric systems, Instrumentation and applications. **[4]**

ESR Spectroscopy:
Basic principles, Total Hamiltonian, Hyperfine structure, ESR spectra of molecules and free radicals, The ‘g’ factor, systems in triplet states, ESR of transition metal ions, Techniques and instrumentation of ESR, applications, ENDOR, ELDOR.

Mossbauer Spectroscopy:
Theory - recoilless absorption & emission, isomer shift, Quadrupole interaction, Magnetic hyperfine interaction, Experimental techniques, Applications. **[6]**

Mass Spectrometry:
Basic principles, Instrumentation-Ion source, Mass analyzer, Detector, Isotopic abundance, Molecular ion, Meta stable ion, Calculation of meta stable ion m/z values, Fragmentation patterns. Fragmentation associated with functional groups, Chemical ionization, Electrospray ionization, Field ionization and field desorption. Desorption by lasers, plasmas, atoms and ions- LD, LIMA, PD, SIMS and FAB, GC-MS & LC-MS techniques, Isotope substitution, Time-of-flight MS, Quadrupole MS, FTMS, Applications, Mass spectra of organic compounds, Trace gas analysis, Problems based on joint application of several spectroscopic techniques. **[14]**

References:
1. C.N. Banwell, E.M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw Hill, New Delhi, 5th Edition, 2013
2. R.M. Silverstein, *Spectrometric Identification of Organic Compounds*, John Wiley & Sons, New York, 8th Edition, Wiley, 2014.
3. W. Kemp, *Organic Spectroscopy*, 3rd Edn, ELBS, Hampshire, 2017

G. Aruldhas, *Molecular Structure and Spectroscopy*, Prentice Hall, New Delhi, 2001

CHM **: Seminar**
[1-0-0-1]

The student must present a topic of interest (not covered in the syllabus). All other students must attend the seminar and get benefit. The seminar will be conducted on a specific date, as notified by the seminar coordinator.

Organic Chemistry Specialization

CHM **: Advanced Organic Chemistry I**
[4-0-0-4]

Course Objectives:
At the end of the course students will be able to
- Explain the organic chemistry concepts and principles in rearrangement and named reactions
- Write the mechanism of various organic reactions
- Describe the synthetic methods of certain organic compounds
- Explain the disconnection approach, principles and techniques used in retrosynthetic analysis
- Apply organometallic chemistry to synthesize simple organic molecules and polymers

Pre-requisites:
Organic Chemistry

Syllabus

Rearrangement Reactions and reactive intermediates

Molecular rearrangements: Nucleophilic, electrophilic, free radical rearrangements. Intermolecular and intramolecular migrations. Wagner-Meerwein, Pinacol-pinacolone, Benzyl-benzilic acid, Fries, Wolf, Fevorsky, Neber, Sommlet-Hauser, Hoffmann, Beckmann, Losen, Curtis, Schmidt and Benzedine rearrangements. Mechanistic classification, Nucleophiles and electrophiles, movement of electrons and rate of reaction. Generation stability and reactivity of classical and non-classical carbonium ions, carbanions, carbenes, free radicals, nitrenes, benzynes and arynes **[10]**

Named Reactions

Mechanism, stereochemistry and applications of named reactions, Aldol, Perkin, Reimer-Tiemann, Reformatsky, Diels-Alder, Friedal-Crafts, Wittig reactions, Michael addition, Oppenaur oxidation, Clemenson, Wolf-Kishner, Meerwein-Varley-Pondorf and Birch reductions, Mannich reactions, Ene reaction, Bayer-Villiger oxidation reaction Suzuki coupling reaction Grignard reaction. **[10]**

Retrosynthetic Analysis

Introduction to disconnection approach, principles and techniques used for disconnections, Synthons and synthetic equivalents, Interconversion of functional groups, One group C-X disconnections, and two group C-X disconnections, Chemoselectivity. Disconnection strategies in 1,1 1,2 1,3 1,4 1,5 and 1,6-difunctionalised compounds, Natural and reversed polarity (umpolung), umpolung strategies, donor and acceptor synthons.

Protecting groups: Principle of protection of hydroxyl, amino, carboxylic and carbonyl groups. Amine and alcohol synthesis. Approach to cyclic systems and reconnection strategies. Alkene synthesis. General strategies of disconnection. Stereo and regio selectivity, D-A reactions. Heterocyclic synthesis: 3, 4, 5, 6-membered heterocycles, fused heterocycles, Rearrangement in synthesis. Retrosynthetic analysis of industrially important compounds. **[16]**

Applications of Organometalics in Organic Chemistry:

16- and 18-electron rules, Unique reactions in organometallic chemistry-oxidative addition, reductive elimination, migratory insertion and elimination reactions, ligand substitution reactions, activation of ligands for external attack, carbonylation and decarbonylation, nucleophilic attack on coordinated ligands, ligand coordination and dissociation reductive coupling, Homogeneous catalysis; hydrogenation, hydrosilation, hydrocyanation, isomerization of olefins, Immobilisation of homogeneous hydrogenation catalysts, Hydroformylation mechanism, Monsanto acetic acid process. Wacker process, Olefin metathesis, Ziegler-Natta polymerization, Fischer -Tropsch reaction, Water Gas shift reactions, fluxionality in organometallic compounds, Organometallic compounds as drugs, radiopharmaceuticals, tracers, ionophores and sensors. **[12]**

References:

1. S. Warren, P. Wyatt, *Organic Synthesis: The Disconnection Approach*, John Wiley & Sons, New York, 2008.
2. J. Clayden, *Organic Chemistry,* Oxford University Press*,* 2000.
3. V.K. Ahluwalia and R.K. Parashar, *Organic Reaction Mechanisms*, 2nd Edn., Narosa publishing house, New Delhi, 2009.
4. R. Bruckner, *Advanced Organic Chemistry- Reaction Mechanisms*, Academic press, San Diego, 2005.
5. D. Astruc, Organometallic Chemistry and Catalysis, Springer, Berlin, 2007.

CHM **: Hetrocyclic Chemistry and Natural Products**

[4-0-0-4]

Course Objectives:

At the end of the course students will be able to

- Describe the syntheses and reactions of non-aromatic heterocyclic compounds, heterocyclic compounds having one or more hetero atoms
- Demonstrate an understanding of different types of natural products such as alkaloids, terpenoids, carotenoids and steroids
- Describe the examples and chemical properties of natural products
- Explain the synthesis of some natural products and their structure-activity relationships.

Pre-requisites:

Advanced Organic Chemistry

Syllabus

Non aromatic Heterocycles

Nomenclature, Strain- bond angle and torsional strains, interactions and conformational aspects of nonaromatic heterocycles. Synthesis, reactivity and importance of the 3, and 4 membered ring systems. **[6]**

Aromatic Heterocycles

General chemical behavior of aromatic heterocycles, criteria of aromaticity Heteroaromatic reactivity and tautomerism in aromatic heterocycles. Preparation, properties and applications of pyrrole, furan, thiophene, Pyrazole, Imidazole, Oxazole, Thiazole, benzopyrroles, bezofurans and benzothiophenes. benzopyrazole, benzimidazole, benzoxazole and benzthiazole, **[12]**

Six membered ring system

Synthesis and reactions of pyridine, pyran, quinoline, isoquinoline, acridine and phenanthridine, 2-pyrones, 4-pyrones, benzopyran, benzo-2-pyrones and benzo-4-pyrone, Preparation of pyridazine, pyrimidine, pyrazine, **[6]**

Alkaloids and Terpenoids

Classification, Isolation, Methods of structural determination of alkaloids. Steriochemistry, synthesis of Adrenaline, Ephedrine, Quinine, Applications, Structure, classification and isolation of mono - and sesqui - terpenoids, isoprene rules, methods of determining structure of terpenoids, α-pinene, camphor, borneol, isoborneol, nerolidol, zingeberene.

[12]

Carotenoids and Steroids:

Geometrical isomerism of carotenes, Structure and synthesis of β-carotene, Structure and synthesis of anthocyanins, flavones, isoflavones. Introduction and Nomenclature of steroids, Blanc's rule, Barbier-Wieland degradation, Oppenauer oxidation, Diel's hydrocarbon, Chemistry of Cholesterol, Ergosterol, bile acids. oestrone, oesterdiol, oestriol, progesterone, androsterone, aldosterone, testosterone, cortisone, and cortisol.

[12]

References

1. Raj K. Bansal, *Heterocyclic chemistry,* 3rd Edn., New Age International (P) Ltd., 1999
2. J.A. Joule & K.Mills, *Heterocyclic Chemistry,* 4th Edn., Blackwell publishing, 2000
3. T. Eicher and S. Hauptmann, *The Chemistry of Heterocycles*.2nd Edn.,Wiley-VCH, 2003
4. Gurdeep R Chatwal, Organic Chemistry of Natural Products Vol 1 and 2, Himalaya Publishing House, 2011
5. O. P. Agarwal, Organic Chemistry Natural Products Vol 1 and 2, Krishna Prakashan Media (P) Ltd, 2018

CHM **: Advanced Organic Chemistry Practical I**

[0-0-4-2]

Course Objectives:

At the end of the course students will be able to

- Quantify the percentage of organic compounds in a given sample
- Develop the skill in extracting the ingredients from the plant source
- Separate the mixtures using chromatographic techniques

Pre-requisites:

B.Sc. Chemistry background

List of experiments

(Any ten experiments to be performed)

1. Estimation of Amino acid
2. Estimation of Phenol
3. Hydroxy group by acetylation

4. Aliphatic or aromatic amide
5. Ester-acid mixture
6. Percentage of keto-enol equilibrium
7. Equilibrium constant for ferric ion – salicylic acid complex (green method)
8. Extraction and analysis of coconut oil
9. Recinoleic acid and azelic acid from castor oil
10. Caffeine from tea leaves
11. Nicotine from tobacco leaves
12. Casein and lactose from milk
13. Green Soap: Extraction and saponification of avocado oil (green method)
14. Column chromatography: Separation of mixture of o and p-nitro anilines

References:

1. Brian S. Furniss, Antony J. Hannaford, Peter W. G. Smith and Austin R. Tatchell, Vogel's text book of Practical Organic Chemistry, 5th Edn. (8th impression), Pearson Education, New Delhi, 2011.
2. V. K. Ahluwalia and Renu Aggarwal, Comprehensive Practical Organic Chemistry: Quantitative Analysis, Universities Press (India) Pvt. Ltd., Hyderabad, 2013.
3. S. Warren, P. Wyatt, Organic Synthesis: The Disconnection Approach, John Wiley & Sons, New York, 2008
4. J. Clayden, Organic Chemistry, Oxford University Press, 2000
5. V.K. Ahluwalia and R.K. Parashar, Organic Reaction Mechanisms, 2nd Edn., Narosa publishing house, New Delhi, 2009
6. R. Bruckner, Advanced Organic Chemistry- Reaction Mechanisms, Academic press, San Diego, 2005
7. Jag Mohan, Organic Analytical Chemistry: Theory and Practice, Narosa publishing house Pvt. Ltd., New Delhi, 2006

CHM **: Advanced Organic Chemistry Practical II**

[0-0-4-2]

Course Objectives:

At the end of the course students will be able to

- Perform multistep synthesis
- Choose the appropriate solvents for recrystallization

Pre-requisites:

B.Sc. Chemistry background

List of experiments

(Any ten experiments to be performed)

1. 2,4-Dinitrophenylhydrazine from chlorobenzene.
2. p-Aminoazobenzene from aniline.
3. 2,5-Dihydroxy acetophenone from hydroquinone.

4. Tribromobenzene from aniline.
5. Benzanilide from benzophenone.
6. Benzylic acid from benzoin.
7. Anthranilic acid from phthalic anhydride.
8. p-bromoaniline from acetanilide.
9. Methyl orange from aniline.
10. M-nitroaniline from nitrobenzene.
11. P-Chlorotolune from p-toluidine.
12. 2-Carbethoxycyclopentanone from adipic acid.
13. Aspirin (green method)

References:

1. A.I. Vogel, A Text Book of Practical Organic Chemistry, 5th Edn., Pearson, 2005
2. F.G. Mann, B.C. Saunders, Practical Organic Chemistry, 4th Edn., Pearson, 2009
3. R.K. Bansal, Laboratory Manual of Organic Chemistry, 5th Edn, New Age Int., 2008

Applied Chemistry specialization

CHM **: Principles and Practice of Analytical Chemistry**
[4-0-0-4]

Course Objectives:

At the end of the course students will be able to

- Explain the basics of analytical chemistry
- Identify a reagent or method for decomposition and dissolution reactions
- Describe separation and electro-analytical technique Apply organometallic

Pre-requisites:

B.Sc. chemistry background

Syllabus

Introduction

Review of fundamental concepts of analytical chemistry. Statistical treatment, application of statistics to data treatment and evaluation, Hypothesis testing using statistical analysis, Using spread sheets for plotting calibration curves, Quality in analytical Chemistry, The basis and procedure of sampling, sampling statistics, sampling and physical state. **[8]**

Decomposition and dissolution

Reagents for decomposition and dissolution like HCl, H_2SO_4, HNO_3, $HClO_4$, microwave decompositions, combustion methods. **[4]**

Elimination of interference from samples

Separation by precipitation, electrolytic precipitation, extraction and ion exchange. Separation techniques based on phase equilibria: Principles of analytical separation, Craig concept of counter current distribution, process optimization, retention analysis, process optimization, Distillation: Fractional and molecular distillation. Separation technique based on rate process: dialysis, electrodialysis, electro-osmosis, reverse osmosis, electrophoresis and ultracentrifugation. **[12]**

Electro-analytical techniques

Brief review of conductometric and potentiometric titrations, High frequency titrations, Ion selective electrodes in potentiometry, Polarography and voltammetry, Cyclic voltammetry, Coulometry, Chronopotentiometry, Stripping analysis, Amperometric titrations, chronoamperometry **[14]**

Environmental Analytical chemistry

Introduction, analysis of atmospheric samples, analysis of water - Definition & estimation of Turbidity, pH, Acidity, Alkalinity, Hardness, Chlorides, DO, BOD, COD, Nitrogen, Solids, Fluorides, Sulphate, TOC, soil analysis, Thermal Methods in Environmental Analysis, Chromatography methods in Environmental Analysis. **[10]**

References

1. F.W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, Blackwell Science, 2000
2. G.D. Christian, Analytical Chemistry, 4th Edn., John Wiely, 1986
3. S.M Kopker, Basic concepts of Analytical Chemistry, 2nd Edn., New age Int. Publications, New Delhi, 2002
4. D.A. Skoog, F. J. Holler, T. A. Nieman, Principles of Instrumental Analysis, 5th Edition, Saunders College Publishing, Chicago, 1998.
5. F. W. Fifield, P. J. Haines, Environmental Analytical Chemistry, 2nd Edn, Blackwell Science, London, UK, 2000.

CHM **: Advanced Analytical Chemistry**

[4-0-0-4]

Course Objectives:

At the end of the course students will be able to

- Describe the nuclear structure, properties and decay processes
- Explain the various nuclear reactions and different types of radiation detection
- Discuss the radio isotopes and their applications in various fields
- Explain the synthesis of transuranium elements and health & safety aspects of radiation

Pre-requisites:

B.Sc. chemistry background

Syllabus

Nuclear Chemistry

The Nucleus and Nuclear structure: Nomenclature, properties of nucleus – Nuclear masses, binding energy per nucleon, Radioactive decay modes of natural and artificial nuclides, Determination of half-life, decay and growth kinetics, Conditions of equilibrium theories of α, β, and γ emissions. Definition of curie and related calculations. Production of radioisotopes and labelled compounds by bombardment. Radiochemical separation techniques- carriers, solvent extraction and ion-exchange methods. Physico chemical and analytical applications of radioisotopes- isotope dilution method, activation analysis, radiometric titrations, ^{14}C dating. Medical, agricultural and industrial applications of isotopes. Radiation sources, units (LET, Rad, Roentgen and G-value), radiation dose and radiation chemical yield. Chemical Dosimetry-Fricke and ceric sulphate dosimeters. Radiation chemistry of water. A brief introduction to radiolysis of gases, liquids and solids. Techniques for study of transient species- Pulse radiolysis. Industrial applications of radiation chemistry (radiation polymerization, food irradiation and radiation synthesis). Radiation Detectors -Principles of counting techniques such as G.M. counter, proportional, ionization and scintillation (solid and liquid) counters. Cloud chamber, nuclear track detectors, neutron detectors **[14]**

Health and Safety Aspects

Biological effects of radiation, Hazards in radiochemical work. Radiation protection, permissible exposure doses. Radioactive waste management. **[4]**

Thermoanalytical Methods

Thermo gravimetric analysis, Differential thermal analysis, Differential Scanning calorimetry, Thermo mechanical analysis and dilatometry **[6]**

Food Chemistry

Estimation of moisture/ash/food protein, fat, crude fiber, carbohydrate, calcium,potassium, sodium and phosphate in foods, analysis of common adulterants in food, milk and milk products – alcohol test, fermentation test, dye reduction test, test to distinguish between butter and margarine, phosphatase test for pasteurization, estimation of added water, beverages – caffeine and chicory in coffee, methanol in alcoholic drinks. **[8]**

Drugs and poisons

Classification of drugs; Characterization of common drugs; Analgesics, Expectorants, Sedatives and Antibiotics, Cardiovascular. Drugs of abuse: Analysis of narcotics (nicotine, morphine, heroin). Analysis of drug residues in biological samples. General discussion of poisons with special reference to mode of action of snake venom, war gases, cyanide, Estimation of cyanide, carbon monoxide **[6]**

Advanced Electrochemistry

Fundamentals, electro- organic synthesis (Kolbe's synthesis, adiponitrile, oxidation & reduction of hydrocarbons, reduction of nitro-compounds). Electroinorganic synthesis of fluorine and chlorates. Photoelectrochemistry: Introduction, photogalvanic cells, photoelectrochemical cells, types, and stability of semiconductor electrodes.

Corrosion: Introduction, Pourbaix diagrams, Tafel and Evans diagrams, Prevention of corrosion. **[10]**

References

1. Walter D. Loveland, David J. Morrissey and Glenn T. Seaborg, Modern Nuclear Chemistry, 2nd Ed., Hoboken, NJ: John Wiley & Sons, Inc., 2017.
2. C. A. Bertulani and P. Danielewicz, Introduction to Nuclear Reactions, CRC Press, 2004.
3. Choppin, Liljenzin and Rydberg, Radiochemistry and Nuclear Chemistry, 3rd ed., Butterworth=Heinemann press, 2002.
4. Robert E. Masterson, Nuclear Engineering Fundamentals: A practical perspective, 1st ed. CRC press, 2017.
5. Asim K. Das, *Environmental Chemistry with Green Chemistry,* Books and Allied (p)Ltd., 2010.
6. R.A. Day and A.L. Underwood, *Quantitative Analysis*, Pearson; 6th edition, 1991.
7. N. Shakuntala Manay, *Foods: Facts and Principles*, New Age, 2008.
8. C. H. Eckles, W.B. Combs and H. Macy, Milk *and Milk Products*, Tata McGraw Hill, 1996.
9. Gareth Thomas, *Fundamentals of Medicinal Chemistry*, Wiley, 2003.
10. R. B. Silverman, *The organic chemistry of drug design and drug action*, 3rd ed. Academic Press, 2014.
11. S. S. Pandey and J. R. Dimmock, *An introduction to drug design*. New Age International.
12. G.D. Christian, Analytical chemistry, 6th ed. John – Wiley and Sons Inc, 2004.
13. Douglas A. Skoog and F. James Holler, Timothy A. Nieman, Principles of instrumental analysis, 1998.
14. H.H. Willard, L.L. Merrit, J.A. Dean and F.A. Settle, Instrumental methods of analysis, CBS Publishers: 7th ed., 1986.
15. A.J. Bard and I.R. Faulkner, Electrochemical methods, 2nd ed., Wiley: New York, 2000.

CHM **: Analytical Chemistry Practical**

[0-0-4-2]

Course Objectives:

At the end of the course students will be able to

- Illustrate the theoretical principles and major applications of electroanalytical techniques
- Demonstrate the theoretical principles and typical applications of chromatographic techniques
- Correlate spectra with structure of compound and Interpret the spectral data

- Prepare and characterize the polymer
- Study the factors affecting the rate of the reaction

Pre-requisites:
B.Sc. Chemistry background

(Any ten experiments to be performed)
List of experiments

1. Verification of Beer's law a) Cu^{2+} - NH_3 system
   b) Fe^{3+} - KCNS system
2. Determination of composition and stability constant of metal complexes by (Fe^{3+} and salicylic acid, Ni (II) and 1,10 phenanthroline)
3. Determination of pKa values of maleic acid/malonic and phosphoric acid by potentiometric titration with sodium hydroxide using glass electrode
4. Preparation of Polymethylmethacrylate by suspension polymerization, polystyrene/ Polyacrylamide by solution polymerisation method
5. Preparation of 6-10 Nylon by interfacial polymerization and its characterization by m.p, inherent viscosity and IR studies
6. Separation of cations using column and paper chromatography
7. Determination of (a) COD and (b) DO in given sample of water.
8. Determination the amount of sodium or potassium present in the given sample solution by flame photometric method.
9. Prediction of the structure of unknown simple organic compound based on the given FTIR, UV-Visible, 1H and 13C NMR spectra. (About 50 compounds have to be practiced).
10. Determination of the amount of Cu present in the brass sample
11. To measure the operating voltage of GM for a radio active compound using GM Counter
12. To measure the operating voltage of GM for a radio active compound using GM Counter

References:

1. A.I. Vogel, A Text Book of Practial Organic Chemistry, 4th Edn. ELBS, 1992
2. F.J. Weicher, E. Robert, Standard methods of Chemical analysis, Krieger Publishing Co, 6th Edn, 1998
3. A.I. Vogel, A Text Book of Practial InOrganic Chemistry, 4th Edn. ELBS, 1992
4. F.G. Mann, B.C. Saunders, Practical Organic Chemistry, Pearson Education India; 4th edition (2009)

CHM **: Applied Organic Chemistry Practical**
[0-0-4-2]

Course Objectives:
At the end of the course students will be able to

- Quantify the percentage of organic compounds in a given sample
- Develop the skill in extracting the ingredients from the plant source
- Carryout organic reactions, work-up and recrystallization

Pre-requisites:
B.Sc. Chemistry background

List of experiments
(Any ten experiments to be performed)
1. Estimation of Glycine
2. Analysis of paracetamol
3. Estimation of aniline or acetone
4. Estimation of glucose
5. Analysis of amide-acid mixture
6. Lycopene from tomato
7. Extraction and analysis of groundnut oil
8. Piperine from pepper
9. Synthesis of acetylamino cinnamic acid from glycine
10. Preparation of ethyl resorcinol from resorcinol
11. Anthranilic acid from phthalic anhydride
12. Benzopinacolone from benzophenone

References:
1. A.I. Vogel, A Text Book of Practical Organic Chemistry, 5th Edn. Pearson, 2003
2. F.G. Mann, B.C. Saunders, Practical Organic Chemistry, 4th Edn. Pearson, 2009.
3. R. K. Bansal, Laboratory Manual of Organic Chemistry, 5th Edn, New age Int, 2008

3rd Semester

CHM **: Research Methodology and Technical Communication**
[3-0-0-3]

Course Objectives:
At the end of the course students will be able to
- Explain certain key concepts in research
- Use these concepts in problem solving and data analysis
- Practice these concepts in writing thesis and research communications

Pre-requisites:
B.Sc. Chemistry background

Syllabus

Introduction to Research methodology
Types of research, Significance of research, Research framework, Case study method, Experimental method, Sources of data, Data collection using questionnaire, interviewing, and experimentation. Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Criterion for hypothesis construction, Nature of hypothesis, Characteristics and Types of hypothesis, Procedure for hypothesis testing.
Introduction to Chemical research: Type of chemical research, Research framework as applied to chemical sciences, Theoretical and experimental approaches, Chemistry and interdisciplinary research. **[12]**

Experimental methods and data analysis in chemical Sciences:
Measurement and Scaling Techniques, Methods of Data Collection and analysis, standard deviation, coefficient of variation, Student t-test, Processing & Analysis of Data, Presentation of Figures and Tables, Interpretation of spectral data (Focus on presentation of data and their analysis) Thermal methods of analysis, Electroanalytical methods, Miscellaneous techniques- Illustrative examples by case study method. **[12]**

Literature Review and Journal communications:
Importance of literature review. Performance of literature review, Sources of chemical literature, identification of research gap, defining scope and objectives of the research problem, Styles of referencing.
Preparation of conference presentations (Oral and Poster) by case study method, Effective Presentation; Journal communication: Type of articles, Journal quality criteria-Impact factor and article level matrices, Importance of copyrights, Ethics in research and publishing: Plagiarism and related issues-Case studies, Criteria for authorship, Preparation of dissertation. **[12]**

References

1. R. Kumar, Research Methodology; A Step-by-Step Guide for Beginners, SAGE 2005
2. G. R. Marczyk, D. De Matteo and D. Festinger, Essentials of Research Design and Methodology, John Wiley &Sons 2004
3. S. C. Sinha, A. K. Dhiman, Research Methodology, Vedam Books 2006
4. C. R. Kothari, Research Methodology; Methods & Techniques, New age international publishers, New Delhi 2008.
5. T. Chakraborty, L. Ledwani, Research Methodology in Chemical Sciences Experimental and Theoretical Approach, CRC Press, 2016.

CHM **: Elective I /II / III/IV**
[3-0-0-3]
Electives will be selected from MOOC/Swayam/Coursera Platforms

CHM **: Industry/Research Lab Visit**
[1-0-0-1]

4th Semester

CHM **: Project Work**
The project work has to be carried out in the institution. The duration of the project work shall be of 16 weeks. The evaluation will be through mid-term presentation and end-semester presentation. The oral presentation and project report will be evaluated by the department committee for project evaluation.