DEPARTMENT OF CHEMISTRY

Course Structure for Four Semester M.Sc Programme in Chemistry under Choice-Based Credit system (CBCS)

Syllabi up to 3rd semester

Course Structure
Total Credit -90

YEAR-1				
First Semester				
Code	**Course**	**Category of Course**	**L-T-P**	**Total Credit**
	Inorganic Chemistry -I	CORE	3-0-0	3
	Organic Chemistry -I	CORE	3-0-0	3
	Physical Chemistry -I	CORE	3-0-0	3
	Bioinorganic and Biochemistry	CORE	4-0-0	4
	*OEC	OPEN ELECTIVE	3-0-0	3
	Laboratory Course -I	CORE	0-0-12	6
Total Contact Hours per week: 28			**TOTAL**	**22**

Open Elective course (OEC) to be offered by Chemistry Department

a) Exploration of Everyday Chemistry.

This course is also intended to be studied by the students from other departments.

Second Semester				
Code	**Course**	**Category of Course**	**L-T-P**	**Total Credit**
	Inorganic Chemistry -II	CORE	3-0-0	3
	Organic Chemistry -II	CORE	3-0-0	3
	Physical Chemistry -II	CORE	4-0-0	4
	Modern Methods of Analysis	CORE	3-0-0	3
	Spectroscopy 1	CORE	3-0-0	3
	Laboratory Course-II	CORE	0-0-12	6
Total Contact Hours per week: 28			**TOTAL**	**22**

YEAR-2				
Third Semester				
Code	**Course**	**Category of Course**	**L-T-P**	**Total Credit**
	Inorganic Chemistry -III	CORE	3-0-0	3
	Organic Chemistry -III	CORE	4-0-0	4
	DSE-1	DSE	4-0-0	4
	SEC	SEC	3-0-0	3
	*Internship/Summer Research Project	Internship/Research Project	0-0-6	3
	Laboratory Course -III	CORE	0-0-12	6
Total Contact Hours per week: 32			**TOTAL**	23

***Internship/ summer research project has to be done during summer vacation.**

Fourth Semester				
Code	**Course**	**Category of Course**	**L-T-P**	**Total Credit**
	Quantum Chemistry	CORE	3-0-0	3
	DSE-2	DSE	4-0-0	4
	DSE-3	DSE	4-0-0	4
	DSE-4	DSE	4-0-0	4
	Project Dissertation	Project Dissertation	0-0-16	8
Total Contact Hours per week: 31			**TOTAL**	23

SEC-Skill Enhancement Course-to be offered in basket (student has to choose anyone)
SEC offered by Chemistry Department ***Advances in Energy Technology… L-T-P (3-0-0) C 3***

List of Discipline Specific Elective courses (DSE)

SL.NO	DSE (Discipline Specific Elective)	
1	**DSE-1(Choose any one)**	(a) Polymer Chemistry (b) Spectroscopy 2 (c) Swayam NPTEL Course
2	**DSE-2**	(a) Catalysis Science (b) Materials Chemistry (c) Chemistry of Natural Products
3	**DSE-3**	(a)Medicinal Chemistry (b)Organometallic Chemistry (c)Supramolecular Chemistry
4	**DSE-4**	(a) Heterocyclic Chemistry (b) Advanced Inorganic Chemistry (c)Advanced Chemical Kinetics and Electrochemistry

Students can Choose elective papers from any one of the Groups A, B or C for DSE-2, DSE-3 and DSE-4.

Group A- Catalysis Science, Supramolecular Chemistry, Advanced Chemical Kinetics and Electrochemistry.
Group B- Materials Chemistry, Organometallic Chemistry, Advanced Inorganic Chemistry.

Group C- Chemistry of Natural Products, Medicinal Chemistry, Heterocyclic Chemistry.

	INORGANIC CHEMISTRY – I	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of B. Sc level Chemistry

Course Objectives:

1. To provide an understanding of basic principles of chemical bonding in polyatomic molecules, bonding theories, shapes of molecules.
2. To enhance the knowledge of acids-bases and redox chemistry.
3. To know about the bonding in coordination compounds, understanding of magnetic properties of transition metal complexes with different geometries.
4. To make students aware of chemistry of transition metals.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To predict the nature of boding, shapes of molecules.
CO2: To explain the theory behind acids and bases and redox chemistry.
CO3: To explain the nature of bonding in coordination compounds and magnetic properties of transition metal complexes with different geometries.
CO4: To explain different aspects of transition metal chemistry.

Module 1: CHEMICAL BONDING — **15hours**

Introduction to Molecular Orbital Theory, qualitative molecular orbital treatment LCAO for homonuclear and heteronuclear diatomic molecules (N_2, O_2, CO, NO, HF), Bonding in polyatomic molecules LCAO-MO (H_2O, BeH_2, H_2O, CO_2, NO_2, BF_3), Walsh diagram. Bond properties- Bond order and Bond length and Bond strength. Hybridization and shapes of molecules (VSEPR) **(ML_2, ML_3, ML_4, ML_5 and ML_6)**. Structure and bonding in polyhedral boranes, carboranes, S-N, Se-N and P-N compounds.

Module 2: ACID BASE AND REDOX CHEMISTRY — **12hours**

Hard and soft acid-base (HSAB) concept and its applications. Strength of oxo acids and halo acids, strength of inorganic bases- periodic trends in acidity and basicity of hydrides, oxides, oxyacids of non-transition elements. Super acids and super bases. Nonaqueous solvents. Standard electrode potentials, pH dependence of electrode potentials. Redox stability of metal ions in water, oxidation by atmospheric oxygen. The fundamental type of reaction. Applications of Latimer and Frost diagrams, Redox behaviour of non-transition elements based on electrode potential data.

Module 3: COORDINATION CHEMISTRY: BONDING AND MAGNETIC PROPERTIES — **12hours**

Crystal field theory of bonding in octahedral, tetrahedral and square planar transition metal complexes. d-orbital splitting in octahedral, square planar, square pyramidal, trigonal bipyramidal, and tetrahedral complexes; Factors affecting crystal field splitting, Crystal field stabilization energy, crystal filed stabilization energies in weak filed and strong field, Spectrochemical series. Jahn Teller Distortion, Ligand field theory of metal complexes. Transition metal complexes and their magnetic properties.

Module 4: CHEMISTRY OF TRANSITION METALS — **6 hours**

Chemistry of transition metals including lanthanides and actinides, coordination chemistry - coordination number and geometry, isomerism, thermodynamic stability - successive and overall stability constants, Irving-William series, chelate and macrocyclic effects.

Total Lecture hours — **45hours**

Text Book(s)	
1	J. E. Huheey, E. A. Keiter and R. L. Keiter; Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed. Pearson Education, 2006.
2	Ligand Field theory and its Applications, B. N. Figgis and M. A. Hitchman, Wiley India, 2010
3	G. L. Miessler, D Tarr; Inorganic Chemistry. 3rd Ed., Pearson Education, 2004.
4	P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed. Oxford University Press, 2010.
5	Lanthanide and Actinide Chemistry, S. A. Cotton, John Wiley,2006
6	Magnetism and Transition Metal Complexes, F. E. Mabbs and D. J. Machin, Dover Pub. Inc., 2008.
Reference Books	
1.	Fundamental Concepts of Inorganic Chemistry, Vols. 1-7, by A.K. Das and M. Das, CBS Publishers and Distributors, 2015
2.	F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann; Advanced Inorganic Chemistry, 6th ed. Wiley, 1999
3.	R. L. Dutta, A. Syamal, Elements of Magnetochemistry, 2nd Ed. Affiliated East-West Press Pvt. Ltd.-New Delhi, 2004.
4.	Inorganic Chemistry, C. E. Housecroft and A. G. Sharpe, 4th edition, Pearson, 2012.
5	J. D. Lee, Concise Inorganic Chemistry (5th edn.) John Wiley & Sons., 2008.

	ORGANIC CHEMISTRY – I	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of B.Sc level chemistry

Course Objectives:

1. To make students understand the stereochemistry of different molecules.
2. To provide an insight into the various concepts associated with the kinetics of organic reaction mechanisms.
3. To provide knowledge of the generation and application of different reaction intermediates in organic synthesis.
4. To Introduce students to various photophysical processes and their application in different photochemical reactions.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To explain the stereochemical aspects of organic molecules.

CO2: To illustrate the various concepts associated with the kinetics of organic reaction mechanism.

CO3: To explain the generation and application of different reaction intermediates in organic synthesis.

CO4: To explain the principles of photochemistry and their application in different photochemical reactions.

Module 1: STEREOCHEMISTRY — **10 hours**

Classification of organic molecules into different Point Groups, R/S, E/Z nomenclature in C, N, S, P containing compounds; absolute and relative configuration; concept of chirality, optical activity in absence of chiral carbon - allenes, spiranes and biphenyls (atropisomerism).

Stereogenic center – chirotopic and achirotopic center; homotopic and heterotopic ligands and faces (prostereoisomerism and prochirality etc); Cram's rule, Prelog's rule, optical purity and enantiomeric excess; conformational analysis of cyclohexane and decalins,

Conformational effect on reactivities and physical properties of molecules.

Module 2: Kinetics and Energetics of Reaction Mechanism — **12 hours**

TS theory of reaction rates: kinetics & thermodynamics requirements. Reaction profiles for multistep reactions, Hammond postulate, Curtin-Hammett Principle; kinetic and thermodynamic control.

Linear free energy relationships (LFER): Hammett equation, Taft equation, kinetic isotope effects in organic reactions.

Effects of conformation on reactivity: anomeric effect, stereoelectronic effects, neighbouring group participation.

Module 3: Reaction Mechanisms & Intermediates: Structure & Reactivity I — **12 hours**

Carbanions: enolates and enamines, Kinetic and thermodynamic enolates, lithium and boron enolates in aldol and Michael reactions, alkylation and acylation of enolates; name reactions under carbanion chemistry - Claisen, Dieckmann, Stobbe, Darzen, Shapiro reaction, Brook rearrangement, Sakurai reaction, Henry reaction, Kulinkovich reaction, Nef reaction, Baylis-Hillman reaction.

Ylids: Chemistry of phosphorous and sulfur ylids - Wittig and related reactions, Peterson olefination.

Carbocation: classical and non-classical carbocations, neighbouring group participation and

rearrangements including Wagner-Meerwein, pinacol-pinacolone, semi-pinacol rearrangement, C-C bond formation involving carbocations, oxymercuration, halo-lactonisation, Prins reaction.	
Module 4: PHOTOCHEMISTRY	**11 hours**
Frank-Condon principle, Jabolonski diagram, fluorescence and phosphorescence, singlet and triplet states, photosensitization. Photochemistry of carbonyl compounds, Norrish Type-I and Norrish Type-II, Paterno-Buchi reaction; Photochemistry of olefins - photostereomutation of cis-trans isomers, optical pumping, cycloaddition, photochemistry of conjugated polyenes. Photochemistry of enones; Photo-rearrangement reactions viz di-π-methane rearrangement, Photo-rearrangement of cyclohexadienones, Barton rearrangement. Fluorescence sensing.	
Total Lecture hours	**45 hours**

Text Book(s)	
1.	F. A. Cary and R. I. Sundberg, Advanced Organic Chemistry, Part A and B, 5th Edition, Springer, 2009.
2.	T. H. Lowry, K. S. Richardson, Mechanism and Theory in Organic Chemistry, Pearson; 3rd edition, 1997.
3.	J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd edition, OUP 2012
4.	Stereochemistry of Organic Compounds – D. Nasipuri, Wiley Eastern, 1991.
5	A Guidebook to Mechanism in Organic Chemistry, P. Sykes, Pearson Education, 2003.
6	A Gilbert & J.E. Baggott, Essentials of Molecular Photochemistry, Blackwell Scientific Oxford, 1991.
7	Basic stereo chemistry of organic molecules by Subrata Sengupta, Oxford University Press, 2014
Reference Books	
1.	Strategies and Tactics in Organic Synthesis 4 & 5, M. Harmata, Academic Press, 2004.
2.	W. Carruthers and I. Coldham, Modern Methods of Organic Synthesis, First South Asian Edition, Cambridge University Press, 2005
3	Organic Chemistry, T. W. G. Solomons, John Wiley and Sons, Wiley, 2017.
4	Organic Chemistry, R. T. Morrison and R. N. Boyd, Pearson India, 2016.
5	E.L. Eliel, S. H. Wilen, Stereochemistry of Organic Compounds, Wiley, 2008.

	PHYSICAL CHEMISTRY – I	L	T	P	C
		3	0	0	3

Pre-requisite: B.Sc knowledge in Chemistry

Course Objectives:

1. To introduce the student with the basic concepts of equilibrium thermodynamics.
2. To introduce students with statistical thermodynamics and its various concepts.
3. To give an insight into phase rule and its applications.
4. To make students familiar with different concepts of surface chemistry.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To understand the fundamentals of equilibrium thermodynamics.

CO2: To learn the concepts and theories of statistical thermodynamics.

CO3: To apply phase rule in various systems.

CO4: To explain the fundamentals aspects of surface chemistry.

Module 1: EQUILIBRIUM THERMODYNAMICS — **12 hours**

Concept of fugacity and it determination. Ideal solution and non ideal solutions, Activity and activity coefficient, Determination of activity coefficient, excess function for non-ideal solutions. Partial molar quantities: chemical potential, Determination of partial molar volume, Thermodynamics of mixing. Third law of thermodynamics, its experimental verification, determination of absolute entropy.

Module 2: STATI STICAL THERMODYNAMICS — **15 hours**

Statistical mechanics of systems independent particles: Maxwell Boltzmann distribution, entropy and probability. Calculation of thermodynamic properties for independent particles,- molecular partition functions- evaluation of translational, rotational and vibrational and nuclear partition functions.

Thermodynamic properties of monatomic and diatomic gases (Suckur-Tetrode equation)- calculation of partition functions, thermodynamic function, principles of equipartition, heat capacities (Einstein model and Debye modification), residual entropy, equilibrium constant.

Module 3: PHASE EQUILIBRIUM — **6 hours**

Thermodynamic criteria of phase equilibrium, Gibbs phase rule and its application to three component systems- triangular plots-, ammonium chloride-ammonium sulphate-water system, water- acetic acid –chloroform system.

Module 4: SURFACE CHEMISTRY AND CATALYSIS — **12 hours**

Adsorption and free energy changes at interfaces-Solid-gas interface-Langmuir, BET isotherms-Surface area determination-soluble and insoluble film-Solid - liquid interfaces Gibbs adsorption isotherm-contact angle and wetting-applications of adsorption. Role of surface in catalysis-semiconductor catalysis-n and p-type surfaces. Specific and general acid base catalysis: Bronsted catalysis law-Hammett acidity functions. Enzyme catalysis: Michaelis Menten Law- Influence of pH and temperature on enzyme catalysis. Heterogeneous catalysis: Kinetics of bimolecular surface reactions-Langmuir-Hinshelwood mechanism, Langmuir Rideal mechanism and Rideal-Eley mechanism.

Total Lecture hours — **45 hours**

Text Book(s)

1. Levine I. R., Physical chemistry 6 th Edition, Mcgraw Hill Education, 2011.
2. Atkins P., Paula J., Physical Chemistry, 9th Edition, Oxford University Press, Oxford 2010.
3. McQuarrie D. A., Simon J. D., Physical Chemistry: A Molecular Approach, Viva Student Edition, 1st Edition, 2011.

4.	Thermodynamics: Statistical Thermodynamics and Kinetics by Thomas Engel and Philip Reid, Pearson
5.	McQuarrie, D. A. Statistical Mechanics, Viva Books Pvt. Ltd.: New Delhi (2003).
Reference Books	
1.	Physical Chemistry: Thomas Engel and Philip Reid
2.	Bagchi B. Statistical Mechanics for Chemistry and Material Science, CRC Press (2018).
3.	Landau L. D. and Lifshitz E. M., Statistical Mechanics, Part I, Butterworth- Heinemann, 3rd ed. (2005).
4.	Berry R. S., Rice S. A. and Ross J., Physical Chemistry, 2nd Edition, Oxford University Press, Oxford 2007.
5.	Puri B. R.; Sharma L. R., Pathania M. S., Principles of Physical Chemistry; 47th Ed, Vishal Publishing, New Delhi (2017).
6.	Adamson A. W., Gast A. P., Physical Chemistry of Surfaces, 6 th Ed, Wiley India, New Delhi (2011).
7.	Moudgil H. K., Textbook of Physical Chemistry, PHI Learning, New Delhi (2010).

	BIO-INORGANIC AND BIO-CHEMISTRY	L	T	P	C
		4	0	0	4

Pre-requisite: B.Sc knowledge in Chemistry

Course Objectives:

1. To provide knowledge about role of metal ions in biological systems.
2. To give an insight into biochemistry of iron.
3. To discuss chemistry of different metallo – enzymes.
4. To provide knowledge of different biochemical systems involved in the life process.
5. To make students familiar with structures, functions and physicochemical properties of bio molecules.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To know the importance of metal ions in biological systems.

CO2: To learn structure and functions of iron – containing proteins and enzymes.

CO3: To understand the chemistry of meallo - enzymes.

CO4: To describe and interpret the chemical processes of living organisms.

CO5: To acquire knowledge of structures, functions and physicochemical properties of various bio molecules.

Module 1: METAL IONS IN BIOLOGICAL SYSTEMS — **10 hours**

Inorganic elements in biological system. Mechanism of ion transport across membrane: Energetics of transport, kinetics and mechanism of transport, ionophores, valinomycin; ATP mediated active transport, Na^+ /K^+ pump. Ca^{2+} transport. Role of calcium in muscle contraction, blood-clotting mechanism. Photosynthesis: Chlorophyll-structural features, role of Mg^{2+} , Z-scheme of photosynthesis, Water Oxidation Centre (WOC) and model studies.

Module 2: IRON – CONTAINING PROTEINS AND ENZYMES — **12 hours**

Heme proteins and oxygen uptake, structure and functions of hemoglobin and myoglobin, dioxygen binding, cooperativity effect, Bohr effect' Model complexes for dioxygen binding; Non-heme systems: hemerythrin and hemocyanin. Cytochromes: cytochrome c, cytochrome P-450. Iron sulfur proteins: rubredoxin and ferredoxin. Iron enzymes: peroxidase, catalase. Iron storage and transport: siderophores, ferritin and transferrins.

Module 3: METALLO – ENZYMES — **10 hours**

Introduction,Molybdenum-containing enzyme: xanthine oxidase; nitrate reductase, nitrogenase, Biological fixation of N_2. Copper containing enzymes: superoxide dismutase, cytochrome c oxidase, plastocyanin and ceruloplasmin. Zinc-containing enzymes:carbonic anhydrase, carboxypeptidase, alcohol dehydrogenase, interchangeability of zinc and cobalt in enzymes. Cobalt-containing enzymes: Vitamin B_{12} and B_{12} coenzymes and cyanocobalamin.

Module 4: NUCLEIC ACIDS — **10 hours**

Nucleic acid chemistry- structure and functions of DNA and RNA, the double helical structure of DNA; unusual DNA structure- DNA hairpins, triple helix, G-quadruplex; stability of the double helix- thermal denaturation and renaturation of DNA double helix; chemical and enzymatic hydrolysis of nucleic acids; DNA replication, RNA transcription and translation of genetic information; chemical basis of heredity.

Module 5: CARBOHYDRATES AND LIPIDS — **8 hours**

Carbohydrate metabolism- glycolysis, gluconeogenesis and Kreb's cycle.
Biochemistry of lipids- biosynthesis of fatty acids, triglycerols, phospholipids, cholesterol and related steroids; prostaglandins.

Module 6: PROTEINS — **10 hours**

Protein biochemistry- amino acids, biosynthesis of amino acids, activation of amino acids,

sequencing of amino acids in polypeptides; protein structure- primary, secondary tertiary and quaternary structure of proteins, post-translational modifications and protein folding.	
Total Lecture hours	**60 hours**
Text Book(s)	
1.	Lippard S. J., Berg J. M., Principle of Bioinorganic Chemistry, University Science Books (1994)
2.	Kaim, W.; Schwederski, B.; Klein, A., Bioinorganic Chemistry-Inorganic Elements in the Chemistry of Life: An Introduction and Guide, 2nd Ed., John Wiley & Sons, West Sussex (2013).
3.	Bertini, I.; Gray, H. B.; Lippard, S. J.; Valentine, J. S., Bioinorganic Chemistry, Viva Books, New Delhi (2007).
4.	Housecroft, C. E; Sharpe, A. G., Inorganic Chemistry, 5 th Ed., Pearson Education, Essex (2018).
5.	Berg, J. M.; Tymoczko, J. L.; Gatto Jr., G. J.; Stryer, L., Biochemistry, 9 th Ed., W. H. Freeman, New York (2019).
6.	Abeles R. H, Frey P. A., Jencks W. P., Biochemistry, Jones and Bartlett Publishers, Boston, 1992.
Reference Books	
1.	Bioinorganic Chemistry: A chemical Approach to enzyme action, Hermann Dugas and C. Penny, Springer Verlag.
2.	Rehder, D., Bioinorganic Chemistry, Oxford University Press, London (2014)
3.	Roat-Malone, R. M., Bioinorganic Chemistry: A Short Course, 2nd Ed., Wiley Blackwell, New York (2007).
4.	Reddy, K. H., Bioinorganic Chemistry, New Age International Publishing, New Delhi (2009).
5.	Campbell, M. K.; Farrell, S. O., Biochemistry, 8 th Ed., Brooks/Cole, Belmont (2015)
6.	Nelson, D. L.; Cox, M. M., Lehninger Principles of Biochemistry, 7 th Ed., W. H. Freeman, New York (2017).
7.	Voet D., Voet J. G., Pratt C. W., Fundamentals of Biochemistry: Life at the Molecular Level, 4th Edition, 2012.

	EXPLORATION OF EVERYDAY CHEMISTRY	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of Basic Science

Course Objectives:

1. To make students aware of different pollutants and their effects on the environments.
2. To make students identify different food additives, adulterants and contaminants.
3. To provide an insight into different paints and dyes.
4. To make students familiar with different types of petroleum and non – petroleum based fuels and their properties.
5. To give knowledge about composition and applications of fertilizers, ceramics and glasses.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To learn about the sources and effects of different types of pollutants.

CO2: To identify different food additives, adulterants and contaminants.

CO3: To know different types of paints and dyes.

CO4: To acquire knowledge of various petroleum and non – petroleum based fuels and their properties.

CO5: To understand the composition and uses of fertilizers, ceramics and glasses.

Module 1: POLLUTION **10 hours**

Air pollution: Major sources of air pollution, effect on eco – system, prevention and control, some important pollutants of air, green house gases, acid rain, ozone hole and CFC's, photochemical smog and PAN, catalytic converters for mobile sources.

Water pollution: Types of water pollution, sources of water pollution, water pollution control, criteria and standards of water quality-safe drinking water, public health significance and measurement of water quality parameters- (colour, turbidity, total solids, acidity, alkalinity, hardness, sulphate, fluoride, phosphate, nitrite, nitrate, BOD and COD), water purification for drinking and industrial purposes.

Toxic chemicals in the environment. Detergents- pollution aspects, eutrophication. Pesticides and insecticides- pollution aspects, heavy metal pollution, solid pollutants -treatment and disposal, treatment of industrial liquid wastes. Sewage and industrial effluent treatment.

Module 2: CHEMISTRY OF FOOD **10 hours**

Dairy Products: Composition of milk and milk products. Principle of determination of fat content, minerals in milk and butter. Estimation of added water in milk. Beverages: Analysis of caffeine in coffee and tea, detection of chicory in coffee, chloral hydrate in toddy, estimation of methyl alcohol in alcoholic beverages.

Food additives, adulterants and contaminants- Role of food preservatives, commonly used food preservatives - benzoates, propionates, sorbates, disulphites.

Artificial sweeteners: Aspartame, saccharin, dulcin, sucralose and sodium cyclamate. Flavours: Vanillin, alkyl esters (fruit flavours) and monosodium glutamate.

Artificial food colorants: Coal tar dyes and non-permitted colours and metallic salts. Analysis of pesticide residues in food.

Module 3: PAINTS AND DYES **8 hours**

Paints & Pigments: Introduction, White pigments (white lead, ZnO, lithopone, TiO_2). Blue, red, yellow and green pigments. Paints and distempers: Requirement of a good paint. Emulsion, latex; luminescent paints. Fire retardant paints and enamels, lacquers. Solvents and thinners for paints.

Dyes: Colour and constitution (electronic concept). Classification of dyes. Methods of

applying dyes to the fabrics. A general study of azo dyes, Mordant brown, Congo red and methyl organe.	
Module 4: FUEL	**8 hours**
Composition of crude petroleum, Refining and different types of petroleum products and their applications. Fractional distillation (principle and process), Cracking (thermal and catalytic cracking), Reforming. Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels. Petrochemicals. Biomass energy and biodiesel.	
Module 5: FERTILIZERS, CERAMICS AND GLASSES	**9 hours**
Fertilizers: Classification of Fertilizers- straight fertilizers, compound/complex fertilizers, fertilizer mixtures, manufacture and general properties of fertilizer products-Urea and DAP. **Ceramics**: general properties, porous and non-porous wares, Manufacturing process, extrusion, turning, drying, decoration, Porcelain and china. **Glass**: Manufacture, properties, shaping of sheets & plate glasses. Annealing, finishing. special glasses.	
Total Lecture hours	**45 hours**

Text Book(s)	
1.	Environmental Chemistry by A. K. Dey
2.	Environmental Studies by Dr. J. P. Sharma
3.	E. Stocchi: Industrial Chemistry, Vol -I, Ellis Horwood Ltd. UK
4.	Industrial Chemistry-B. K. Sharma.
5.	Analysis of foods, H. E. Cox
6.	Handbook of Fertilizer Technology by Swaminathan and Goswamy, 6th Edition, 2001, FAI
Reference Books	
1.	Foods: Facts and Principles, N. S. Many, S. Swamy, New Age International (1998)
2.	McCully, P. 1996. Rivers no more: the environmental effects of dams (pp. 29--64). Zed Books
3.	Fuel Chemistry by Dr. Biswajit Saikia
4.	Fuel Chemistry by Debasis Mohanty
5.	Organic Chemistry by I. L. Finar, Vol. 1 & 2, Pearson Education India; 6 edition (2002).
6.	Handbook of Fertilizer Technology by Swaminathan and Goswamy, 6th Edition, 2001, FAI

	LABORATORY COURSE – I	L	T	P	C
		0	0	12	6

Pre-requisite: Knowledge of B.Sc. level chemistry

Course Objectives:

1. To expose students to various experimental skills of qualitative and quantitative analysis.
2. To develop synthesis skills among the students.
3. To introduce students with the common spectroscopic techniques and gravimetric estimation.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To do qualitative and quantitative analysis confidently.

CO2: To synthesize different compounds with proper techniques.

CO3: To do quantitative estimation by gravimetric methods and spectroscopic techniques.

1. Qualitative analysis of tertiary mixture, alloy, ore.
2. Quantitative analysis (binary mixture, alloy, ore) - Ca-Mg ore, Cu-Zn alloy, Pb-Sn alloy, Ni in an alloy, steel etc.
3. Synthesis of co-ordination compounds
   (i) Potassium trioxalato ferrate(III) trihydrate, $K_3[Fe(C_2O_4)_3].3H_2O$
   (ii) Cis- and trans-dichloro bis (ethylene diamine) cobalt (III) chloride $[Co(en)_2Cl_2]Cl$
   (iii) Potassium dioxalato cuprate (II) dihydrate $K_2[Cu(C_2O_4)_2(H_2O)_2]$
   (iv)Synthesis of Pentaamminechloro cobaltic(III) chloride $[Co(NH_3)_5Cl]Cl_2$
   (v) Synthesis of Pentaammine nitro cobaltic(III) chloride $[Co(NH_3)_5NO_2]Cl_2$
   (vi)Synthesis of Pentaammine nitrito cobaltic(III) chloride $[Co(NH_3)_5ONO]Cl_2$
4. Determination of concentration of components in a mixture
   (i) Estimation of Fe^{II} and Fe^{III} in a mixture.
   (ii) Estimation of Na_2CO_3 and $NaHCO_3$ in a mixture.
5. Gravimetric estimation
   (i) Estimation of Sulphate as Barium Sulphate in a given solution.
   (ii) Estimation of Nickel as Nickel Dimethyl Glyoximate in the given solution.
6. Colorimetry
   (i) To determine amount of iron (III) in solution by photometric titration (static) with EDTA.
   (ii) Estimation of Nickel as nickel dimethylglyoximate complex spectrophotometrically.
7. Spectroscopy
   (i)Identification of the Linkage isomers with Infrared spectroscopy.

   (ii)UV-Visible spectra of $K_3[Cr(C_2O_4)_3]$ complex and calculation of extinction coefficient and identification of the bands.

Textbook(s)

1.	Vogel's Qualitative Inorganic Analysis; Svehla G. and Sivasankar B.; 7th edition; Pearson.
2.	Barua, S.; A textbook of Practical Chemistry; 2th edition; 2016; Kalyani Publishers.

3.	Mendham J., Denney R.C., Barnes J.D. and. Thomas M.J.K.; Vogel's Textbook of Quantitative Chemical Analysis, 6th edition, 3rd Indian Reprint, 2003, Pearson Education Pvt. Ltd., New Delhi.

	INORGANIC CHEMISTRY – II	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of B.Sc. level Chemistry.

Course Objectives:

1. To provide the concept of Group Theory and Symmetry.
2. To provide a general idea of electronic spectra of transition metal complexes of different geometries.
3. To provide an insight into solid state chemistry.
4. To make students understand the magnetic properties of inorganic compounds of different geometries.
5. To provide knowledge about Reaction mechanism of metal complexes.

Course Outcome:

After successful completion of the course, the students will be able.

CO1: To learn the concept of Group Theory and Symmetry.

CO2: To interpret the electronic spectra of transition metal complexes of different geometries.

CO3: To explain the structure and properties of solids.

CO4: To predict magnetic properties of different inorganic compounds.

CO5: To predict the reaction mechanism of inorganic reactions.

Module 1: GROUP THEORY — **6 hours**

Concept of group theory, Symmetry elements and symmetry operations, Classes of symmetry operation, Symmetry point groups, Assignment of point groups to simple molecules, Structure and symmetry of Inorganic complexes.

Module 2: ELECTRONIC SPECTRA OF TRANSITION METAL COMPLEXES. — **10 hours**

Colour, intensity and origin of spectra, *d-d* transition, charge transfer transition, term symbols and splitting of terms in weak and strong octahedral and tetrahedral fields, selection rules for electronic transitions, correlation, Orgel and Tanabe-Sugano diagrams, Determination of Dq and Racah parameters, Nephelauxetic series

Module 3: SOLID STATE CHEMISTRY — **12 hours**

Structure of simple solids – metals, alloys and compounds; common structure types. Synthesis of solid - state compounds - ceramic method, hydrothermal synthesis, CVD and intercalation methods. Characterization of solids, XRD, free-electron and band theory of solids, optical, magnetic and electrical properties of solids.

Module 4: MAGNETIC PROPERTIES — **6 hours**

Magnetic properties of free ions, types of magnetic behaviour: dia-, para-, ferro- and antiferro-magnetism, temperature independent paramagnetism, magnetic susceptibility - Van Vleck equation, experimental measurement, magnetic moment - orbital contribution, quenching of contribution, effect of spin orbit coupling, spin crossover. Temperature dependence of magnetic susceptibility, exchange coupling effects. Magnetic properties of second and third transition series and lanthanides.

Module 5: MECHANISM OF INORGANIC REACTIONS	**11 hours**
Kinetic and thermodynamic stability, Lability and inertness, Stability Constants, Mechanistic pathways of Substitution reactions in octahedral and square planer complexes, Trans effect and its application to the synthesis of metal complexes, Inner sphere and outer sphere mechanisms of Redox Reactions, Marcus Theory.	
Total Lecture hours	**45 hours**

Text Book(s)	
1	Lee, J.D. Concise Inorganic Chemistry ELBS, 1991
2	P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed. Oxford University Press, 2010.
3	G. L. Miessler, D Tarr; Inorganic Chemistry. 3rd Ed., Pearson Education, 2004.
4	Reaction Mechanism in Inorganic Chemistry 2nd Ed. R. R. Jordan Oxford University Press, 1998
5	Mabbs, F. E. & Machin, D. J. Magnetism and Transition Metal Complexes Chapman and Hall: U.K. (1973).
Reference Books	
1.	Wulfsberg, G. Inorganic Chemistry Univ. Science books: Viva Books: New Delhi (2000)
2	Fundamental Concepts of Inorganic Chemistry, Vols. 1-7, by A.K. Das and M. Das, CBS Publishers and Distributors, 2015
3	L. Smart, E. Moore, Solid State Chemistry: An Introduction, 2nd Ed. Nelson Thorns Ltd. 2004.
4	A. R. West, Solid State Chemistry and Its Application, Wiley Student Edition, John Wiley & Sons. 1998.
5	R. L. Dutta, A. Syamal, Elements of Magnetochemistry, 2nd Ed. Affiliated East-West Press Pvt. Ltd.-New Delhi, 2004.
6	F. Basolo, R. G. Pearson, Mechanism of Inorganic Reactions 2nd Ed. Wiley Eastern Pvt. Ltd. 1973.
7	J. E. Huheey, E. A. Keiter and R. L. Keiter; Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed. Pearson Education, 2006

	ORGANIC CHEMISTRY – II	L	T	P	C
		3	0	0	3

Pre-requisite: B.Sc knowledge in Chemistry

Course Objectives:

1. To provide knowledge of the generation and application of different reaction intermediates in organic synthesis.
2. To give comprehensive idea of various oxidising agents used in organic transformations.
3. To discuss different reduction reactions.
4. To make students familiar with pericyclic reactions and their utilities.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To explain the generation and application of different reaction intermediates in organic synthesis.

CO2: To select an oxidising agent for a chemoselective organic reactions.

CO3: To understand chemistry of various reduction reactions.

CO4: To predict the substrates for a pericyclic reaction and the selectivity in such reactions.

Module 1: REACTION MECHANISMS & INTERMEDIATES : STRUCTURE & REACTIVITY – II — **12 hours**

Carbenes and Nitrenes: Structure of carbenes, generation of carbenes, addition and insertion reactions, rearrangement reactions of carbenes such as Wolff rearrangement, generation and reactions of ylids by carbenoid decomposition (existence of O and N based ylids), structure of nitrene, generation and reactions of nitrene and related electron deficient nitrogen intermediates, Curtius, Hoffmann, Schmidt, Beckmann rearrangement, Tebbeolefination reactions.

Radicals: Generation of radical intermediates and its (a) addition to alkenes, alkynes (inter &intramolecular) for C-C bond formation and Baldwin's rules (b) fragmentation and rearrangements. Name reactions involving radical intermediates such as Barton deoxygenation and decarboxylation, McMurry coupling.

Module 2: OXIDATION REACTIONS — **11 hours**

Oxidation: Metal and non-metal-based oxidations of alcohols to carbonyls (Chromium, manganese, aluminium, silver, DMSO and hypervalent iodine). Oxidation of phenols: Fremy's salt, alkenes to epoxides: via halohydrin, peroxides/per acids based, Sharpless asymmetric epoxidation; alkenes to diols (Manganese, osmium based reagents), Prevost reaction and Woodward modification; oxidation of alkyl or alkenyl fragments: selenium dioxide, ketones to ester/lactones: Baeyer-Villiger oxidation.

Module 3: REDUCTION REACTIONS — **11 hours**

Reduction: Catalytic hydrogenation (Heterogeneous: Palladium/ Platinum/ Rhodium/ Nickel etc; Homogeneous: Wilkinson catalyst); metal-liquid ammonia processes: Birch reduction, Pinacol formation etc.; stereo selection and mechanism of the following reagents: Lithium aluminium hydride, L-selectride, K-selectride, sodium borohydride, DIBAL, sodium cyanoborohydride, alkyl borane, non-metallic reducing agents: diimide.

Module 4: PERICYCLIC REACTIONS — **11 hours**

Introduction, general orbital symmetry rules, types: electrocyclic reaction, sigmatropic rearrangement, cycloaddition reaction, 1,3 – dipolar cycloaddition, chelotropic reactions, group transfer reactions and ene reactions.

Total Lecture hours — **45 hours**

Text Book(s)

1. Cary F. A., Sundberg R. I., Advanced Organic Chemistry, Part A and B, 5th Edition, Springer, 2009.

2.	Smith M. B., Organic Synthesis, 4th Ed., Academic Press, Cambridge, Massachusetts, 2016.
3.	Carruthers W. and Coldham I., Modern Methods of Organic Synthesis, First South Asian Edition, 2005, Cambridge University Press.
4.	Greeves N., Clayden J.,Warren S., Organic Chemistry, 2nd Ed., Oxford University Press, New Delhi, 2012.
5.	Anslyn E. V., Dougherty D. A., Modern Physical Organic Chemistry, University Science Books, 2005.
Reference Books	
1.	Smith M. B., March J., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th Ed., Wiley India, New Delhi, 2015.
2.	Carruthers W., Modern Methods of Organic Synthesis, 4th Ed., Cambridge University Press, New Delhi, 2005.
3.	Zweifel G. S., Nantz M. H., Somfai P., Modern Organic Synthesis: An Introduction, 2nd Ed., Wiley-Blackwell, New York, 2017.
4.	Morrison R. T., Boyd R. N., Bhattacharjee S. K., Organic Chemistry, 7th Edition, Pearson Education India, 2010.
5.	Solomons T. W. G., Fryhle C. B., Snyder S. A., Organic Chemistry, 12th Edition, Wiley, 2017.
6.	Harmata M., Strategies and Tactics in Organic Synthesis, Volume 4, Academic Press, 2004.
7.	Lowry T. H., Richardson K. S., Mechanism and Theory in Organic Chemistry, 3rd Edition , Pearson, 1997.

	PHYSICAL CHEMISTRY – II	L	T	P	C
		4	0	0	4

Pre-requisite: B.Sc. knowledge in Chemistry

Course Objectives:

1. To introduce the student with the basic concepts of chemical kinetics.
2. To give an insight into molecular reaction dynamics.
3. To introduce the students with the basic concepts of polymer chemistry.
4. To make students familiar with data analysis.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To understand the fundamentals of chemical kinetics.

CO2: To understand molecular reaction dynamics.

CO3: To learn the concepts and theories of polymer chemistry.

CO4: To explain the fundamentals aspects of data analysis.

Module 1: CHEMICAL KINETICS	**10 hours**
Rate, order, and molecularity of reactions. First order, second order, third order, zero order kinetics. Steady state approximation, straight-chain reaction, branching-chain reactions, enzyme catalyzed reactions, reactions in solutions, diffusion-controlled reactions in solutions, influence of ionic strength in reaction rates, kinetics of fast reactions, potential energy surfaces.	
Module 2: MOLECULAR REACTION DYNAMICS	**12 hours**
Collisions of real molecules- trajectory calculations, Laser techniques, reactions in molecular beam, reaction dynamics, estimation of activation energy and calculation of potential energy surface- the transition state theory (TST) of bimolecular gaseous reactions. Comparison between TST and hard sphere collision theory. Diffusion controlled reactions; kinetics of reactions in solution diffusion controlled and chemically controlled reactions, Bronsted and Bjerrum equation.	
Module 3: THEORIES OF UNIMOLECULAR REACTIONS	**10 hours**
Theory of unimolecular reactions Lindemann theory and its drawbacks, Hinselwood modification, RRK theory, slaters treatment, RRKM theory.	
Module 4: THEORIES OF ELECTRICAL INTERFACE	**10 hours**
Electrocapillary phenomena- Lippmann equation, electron transfer at interfaces, polarizable and non-polarizable and nonpolaisable interfaces, Butler-Volmer equation, Tafel plot.	
Module 5: POLYMER CHEMISTRY	**10 hours**
Molecular weight of polymers, determination of molecular weight, kinetics of polymerization reaction, copolymerization, average dimension of polymer molecules, size exclusion chromatography	
Module 6: SAMPLING AND DATA ANALYSIS	**8 hours**
Sampling of solid, liquid and gaseous samples, mean and standard deviation, absolute and relative errors, linear regression, covariance and correlation coefficient, t-test and f-test.	
Total Lecture hours	**60 hours**

Text Book(s)

1. Levine I. R., Physical chemistry 6 th Edition, Mcgraw Hill Education, 2011.
2. Atkins P., Paula J., Physical Chemistry, 9th Edition, Oxford University Press, Oxford 2010.
3. McQuarrie D. A., Simon J. D., Physical Chemistry: A Molecular Approach, Viva Student Edition, 1st Edition, 2011.
4. V. R. Gowarikar, N. V. Viwanathan, J. Sreedhar, Polymer Science, 1st Edition, New age International Publishers, 1986.

Reference Books

1.	Chemical kinetics, Keith J. Laidler, Pearson.
2.	Physical Chemistry: Thomas Engel and Philip Reid
3.	Bagchi B. Statistical Mechanics for Chemistry and Material Science, CRC Press (2018).
4.	Landau L. D. and Lifshitz E. M., Statistical Mechanics, Part I, Butterworth- Heinemann, 3rd ed. (2005).
5.	Berry R. S., Rice S. A. and Ross J., Physical Chemistry, 2nd Edition, Oxford University Press, Oxford 2007.
6.	Puri B. R.; Sharma L. R., Pathania M. S., Principles of Physical Chemistry; 47th Ed, Vishal Publishing, New Delhi (2017).
7.	Adamson A. W., Gast A. P., Physical Chemistry of Surfaces, 6 th Ed, Wiley India, New Delhi (2011).
8.	Moudgil H. K., Textbook of Physical Chemistry, PHI Learning, New Delhi (2010).

	Modern Methods of Analysis	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of B.Sc. level Chemistry.

Course Objectives:

1. To provide knowledge electronic spectroscopy.
2. To provide an insight into the different thermogravimetric analysis methods.
3. To make students understand the different diffraction techniques.
4. To develop the skill of different types of chromatographic techniques.
5. To provide knowledge on various microscopic techniques to have a clear idea of phenomenon occurring at atomic and molecular levels.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To understand the working principle and applications of electronic spectroscopy.
CO2: To understand the theory behind the different thermogravimetric analysis techniques.
CO3: To apply the knowledge of diffraction techniques in different types of analysis.
CO4: To separate components from different mixtures by chromatographic techniques.
CO5: To apply the microscopy skills for generation of qualitative and quantitative data.

Module 1: ELECTRON SPECTROSCOPY — **8 hours**

Photoelectron spectroscopy, basic principle, Koopman's theorem, XPS, UPS, photoelectron spectra of simple molecules, ESCA, chemical information from ESCA.

Module 2: THERMAL METHODS — **5 hours**

TGA, DTA, DTG, DSC: Principle, Instrumentation, Applications.

Module 3: DIFFRACTION TECHNIQUES — **8 hours**

Powder XRD: Principle, Instrumentation, Applications.
Single Crystal XRD: Principle, Instrumentation, Applications.

Module 4: CHROMATOGRAPHIC TECHNIQUES — **12 hours**

Gas Chromatography (GC), Gas Chromatography- Mass Spectrometry (GCMS), Liquid Chromatography- Mass Spectrometry (LCMS), High Performance Liquid Chromatography (HPLC), Gel permeation Chromatography (GPC): Techniques, Instrumentation and Applications.

Module 5: Microscopy — **12hours**

Electron Microscopy: Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM), Energy Dispersive X-ray Technique EDX, instrumentation, Scanning probe microscopy SPM (Atomic Force Microscopy AFM, Scanning Tunneling Microscopy STM) and applications

Total Lecture hours — **45 hours**

Text Book(s)

1. D. B. Murphy, M. W. Davidson, Fundamentals of Light Microscopy and Electronic

	Imaging, Wiley, 2013.
2.	D. B. Williams, C. B. Carter, Transmission Electron Microscopy A Textbook for Materials Science, Springer, 2009.
3.	B. D. Cullity, Elements of X-Ray Diffraction, 3rdEdition, Addison Wesley Publishing Company, Inc., 2004.
4.	J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel 's Textbook of Quantitative Chemical Analysis,6th Edition, Pearson, 2009.
5.	Jaffe, H. H. & Orchin, M. Symmetry in Chemistry Dover Publications (2002).
6.	Cotton, F. A. Chemical Applications of Group Theory Wiley Interscience: N.Y .1990.
Reference Books	
1.	Hatfield, W. E. & Parker, W. E. Symmetry in Chemical Bonding & Structure C. E. Merrill Publishing Co. USA (1974).
2.	Bishop, D. M. Group Theory and Chemistry, Clarendon Press: Oxford, U.K. 1973.
3.	Willard, H. H. Instrumental Methods of Analysis, East West Press, 1998.
4.	Bard, A. J., Faulkner, L. R. Electrochemical Methods, Fundamentals and Applications, John Wiley, 2000.
5	Cullity, B.D. & Stock, S.R. Powder X-Ray Diffraction, 3rd edition, Kindle Publisher 2001.

	SPECTROSCOPY – I	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of chemistry at B.Sc. level

Course Objectives:

The course is being offered with the following objectives:

1. To provide knowledge of fundamental principles of spectroscopy.
2. Special emphasis on the electronic, rotational, vibrational, and NMR spectroscopy.
3. To provide an insight into the applications of different spectroscopy.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To understand the theoretical basis of different spectroscopic techniques.

CO2: To characterize different compounds based on electronic, rotational and vibrational, NMR spectroscopy.

CO3: To analyze experimental data.

Module 1: ELECTRONIC SPECTROSCOPY — **15 hours**

UV-Visible spectroscopy: basic principle, electronic transitions, Franck-Condon principle, selection rules. Instrumentation of UV-Visible spectrophotometer (Light sources, detectors), application in organic structure analysis.

Fluorescence and phosphorescence spectroscopy: Jablonski diagram, origin of fluorescence and phosphorescence processes, quantum yield, fluorescence quenching-static and dynamic. Instrumentation and applications.

Module 2: ROTATIONAL SPECTROSCOPY, VIBRATIONAL SPECTROSCOIPY — **15 hours**

Rotational spectroscopy. Classification of molecules based on their moment of inertia, rotational energy levels, Stark effect, molecular dipole moment. Rotational spectroscopy of symmetric and asymmetric top molecules. Stokes and anti-Stokes lines, Origin of characteristic bands, instrumentation (Light sources, detectors) and applications.

Infrared (IR) spectroscopy: Basic introductions, theory of IR spectroscopy. Analysis of IR spectra of inorganic (metal complexes with various functional groups at the coordination sites), and organic molecules. Instrumentation.

Module 3: NMR SPECTROSCOPY — **15 hours**

Basic principle, Zeeman splitting, Chemical shift tensor, factors affecting sensitivity and resolution of an NMR spectrum, ^{1}H-NMR-inductive and anisotropic effects on chemical shifts (δ), chemical and magnetic equivalence. ^{13}C-NMR and ^{13}Cδ to structural correlations. Introduction to 2D NMR (COSY, HSQC), *T*1, *T*2 and NOE.

Total Lecture hours — **45 hours**

Text Book(s)

1. C.N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Edition, Tata McGraw Hill, 1994.
2. D.L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, 4th Ed., Brooks/Cole Cengage Learning, 2015.
3. R.S. Drago, Physical Methods in Chemistry, Saunders, Thomson Learning, 1977.
4. R.M Silverstein, F. X. Webster, D. J. Kiemle, D. L. Bryce, Spectrometric Identifications of Organic Compounds, 8th Edition, Wiley India Pvt. Ltd, 2015.

Reference Books	
1.	W. Kemp, Organic Spectroscopy, 3rd Edition, Palgrave Macmillan, 2011.
2.	L. D. Field, S. Sternhell, J. R. Kalman, Organic Structures from Spectra, 5th Edition, John Wiley & Sons 2013.
3.	D.W.H. Rankin, N. Mitzel, C. Morrison, Structural Methods in Molecular Inorganic Chemistry, Wiley, 2013.

	LABORATORY COURSE – II	L	T	P	C
		0	0	12	6

Pre-requisite: Knowledge of B.Sc. level chemistry

Course Objectives:

This course is being offered with the following objectives

1. To provide knowledge about different qualitative techniques used for the identification of organic compounds.
2. To make the students familiar with various chromatographic methods for separation of organic compounds in a mixture.
3. To apprise students about the basic principles about quantitative analysis.
4. To introduce students with different methods for extraction of natural products.
5. To provide knowledge about organic synthesis.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To do qualitative analysis for identification of organic compounds.

CO2: To separate organic compounds from a mixture using different chromatographic methods.

CO3: To state the basic principles about quantitative analysis.

CO4: To learn the experimental skills to carry out extraction of natural products.

CO5: To learn the experimental skills to carry out small scale organic synthesis.

1. Qualitative Analysis of Binary organic mixtures and their identification.
2. Chromatography Experiments-
   - (i) Separation of a mixture of two amino acids by paper chromatography.
   - (ii) Separation of a mixture of two sugars by paper chromatography.
   - (iii) Separation techniques of organic compounds by column chromatography.
3. Quantitative Analysis
   - (i) Estimation of sugar using titrimetric method.
   - (ii) Estimation of amino acids using titrimetric methods.
4. Experiments on Natural products:
   - (i) Extraction of natural products - Caffeine, Lycopene, Citral.
   - (ii) Saponification of vegetable oil.
5. Synthesis (any two)-
   - (i) Preparation of *p*-bromo-acetanilide from aniline.
   - (ii) Aniline to *p*-bromo-acetanilide.
   - (iii) Cyclohexanone oxime from cyclohexanone.
   - (iv) Benzil from Benzoin.
   - (v) Cinnamic acid from Benzaldehyde and malonic acid.

Textbook(s)	
1.	Furniss B. S., Hannaford A. J., Smith P. W. G., Vogel's Textbook of Practical Organic Chemistry, Pearson, 2012.
2.	Ahluwalia V. K., Dhingra S., Comprehensive Practical Organic Chemistry, University Press
3.	Mann F. G., Saunders B. C., Practical Organic Chemistry, 3rd Edition Longman, 1978.
4.	Bansal, R. K, Laboratory Manual of Organic Chemistry 4th Edition, New Age Publishers New Delhi, 2008.
5.	Sethi A., Systematic Lab Experiments in Organic Chemistry, New Age Publisher, New Delhi, 2010.

DETAILED SYLLABUS: M.Sc 3rd Semester

	INORGANIC CHEMISTRY – III	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of B.Sc. level Chemistry.

Course Objectives:

1. To provide the generic idea of inorganic compounds and inorganic polymers.
2. To provide basic concepts of Lanthanides and Actinides.
3. To make students familiar with basic concepts and applications of Organometallic compounds.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To explain the properties of inorganic compounds, polymers, Lanthanides-Actinides and organometallic compounds.

CO2: To identify the characteristics of inorganic compounds, polymers, Lanthanides, Actinides and Organometallic compounds.

CO3: To compare the reactivities of inorganic compounds, Lanthanides-Actinides and organometallic compounds.

Module 1: DESCRIPTIVE INORGANIC CHEMISTRY **20 hours**

Structure and bonding in polyhedral boranes, carboranes and heterocarboranes, electron count in polyhedral boranes – styx numbering, Wade‘s rules – polyhedral skeletal electron pair theory (PSEPT), synthesis of polyhedral boranes. The hydroboration reaction, organoboranes such as boronic acids, tetrahydridoborates, boron nitride, borazines and borazines.

Reactivity of lithium aluminium hydride; alkyl aluminium compounds; chemistry of Al, Ga, In and Tl in +1 and +2 oxidation states.Fullerenes and fullerides, nonmolecular compounds of carbon, clays and zeolites; organo compounds of Si, Ge, Sn and Pb; phosphates, metal-oxo compounds, calixarenes, cryptands and crown ethers in complexation chemistry, metal chalcogenides.

Properties of inorganic polymers, polysilanes (Si–Si bonds), polysiloxanes (Si–O bonds, or silicones), polysilazanes (Si–N bonds), polysulfides (S–S bonds), polyphosphazenes (P–N bonds), polyborazylenes (B–N bonds), silicon rubber and resins.

Module 2: LANTHANIDES AND ACTINIDES **10 hours**

Electronic configuration, lanthanide/ actinide contraction and consequences, magnetic and spectral properties, various physical and chemical properties, stability of lanthanide/actinide complexes, occurrence and extraction of lanthanides and actinides.

Module 3: ORGANOMETALLIC CHEMISTRY **15 hours**

Synthesis, structure, bonding and reactivity of mono and polynuclear metal carbonyls. Substituted metal carbonyls. Types of M-C bonds, Calculation of M-C bonds in complexes, synthesis and reactivity of metal alkyls, carbenes, alkenes, alkynes, and arene complexes; metallocenes and bent metallocenes. Reactions of organometallic complexes: substitution, oxidative addition, reductive elimination, insertion and deinsertion; catalysis: hydrogenation, hydroformylation, Monsanto process, Wacker process, alkene polymerization, olefin metathesis, Suzuki coupling reaction.

1	Lee, J.D. Concise Inorganic Chemistry ELBS, 1991
2	P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed. Oxford University Press, 2010.
3	J. E. Huheey, E. A. Keiter and R. L. Keiter; Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed. Pearson Education, 2006
Reference Books	
1.	F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann; Advanced Inorganic Chemistry, 6th ed. Wiley, 1999
2	Fundamental Concepts of Inorganic Chemistry, Vols. 1-7, by A.K. Das and M. Das, CBS Publishers and Distributors, 2015
3	G. L. Miessler, D Tarr; Inorganic Chemistry. 3rd Ed., Pearson Education, 2004.
4	C. Elschenbroich, A. Salzer, Organometallics: A Concise Introduction, 2nd Ed. Wiley VCH, 1995.
5	R. H. Crabtree, Organometallic Chemistry of the Transition Metals 2nd Ed., John Wiley, 1993.

	ORGANIC CHEMISTRY – III	L	T	P	C
		4	0	0	4

Pre-requisite: B.Sc. knowledge in Chemistry

Course Objectives:

1. To provide a comprehensive idea of different type of bond forming strategies of C.
2. To give knowledge about protection-deprotection strategies.
3. To introduce the retro synthetic analysis and asymmetric synthesis

Course Outcome:

After successful completion of the course, the students will be able

CO1: To illustrate the different types of bond forming strategies of C and synthetic methods.

CO2: To apply the strategies of bond formation, protection, deprotection and organic synthesis.

CO3: To compare the strategies of bond formation, retro and asymmetric synthesis and protecting groups.

Module 1: C-C bond forming reactions. **14 hours**

C-C bond formation reactions using organometallic compounds (orgnao Li, Mg, Zn, B, Sn, Si, Cu reagents). Pd catalyzed coupling reactions (Heck, Suzuki, Sonogashira, Stille and Negeshi coupling). Formation of C-C multiple bonds involving Csp2 and Csp carbon centers (with emphasis on important name reactions, e. g. Corey–Fuchs reaction, Horner– Wadsworth–Emmons reaction, Simmons−Smith Reaction), pyrolytic syn elimination reactions (Chugaev reaction and Cope reaction). Alkene from hydrazones, sulfones.

Module 2: C-heteroatom bond forming reactions. **14 hours**

Formation of carbon-hetero atom bonds: New methods for the construction of C-N, C-O, C-S and C-X bonds (including aspects related to the activation of C-H bonds), Ullmann reaction, Buchwald-Hartwig reaction, Ugi reaction, Stork-enamine reaction, hetero Diels-Alder reactions.

Module 3: Protecting Groups **8 hours**

Protection and deprotection of hydroxyl, carboxyl, carbonyl, carboxy amino groups and carbon-carbon multiple bonds; chemo- and regioselective protection and deprotection. Illustration of protection and deprotection in peptide and carbohydrate synthesis.

Module 4: Retrosynthetic Analysis **12 hours**

Basic principles and terminology of retrosynthesis, synthesis of aromatic compounds, one group and two group C-X disconnections, One group C-C and two group C-C disconnections,

Module 5: Asymmetric synthesis	**12 hours**
Enantioselective synthesis (alkylation, allylation and crotylation reactions), use of chiral reagent; Chiral catalyst and chiral auxiliary; Use of chiral auxiliaries (Evans oxazolidones, Oppolzer sultams, Myers amides, Schöllkopf Chiral Auxiliaries), use of chiral pool. Asymmetric reactions: Epoxidation (Sharpless, Jacobsen, Shi), Dihydroxylation (Sharpless), Reduction (Noyori, Corey, Pfaltz)	
Total Lecture hours	**60 hours**

Text Book(s)	
1.	Cary F. A., Sundberg R. I., Advanced Organic Chemistry, Part A and B, 5th Edition, Springer, 2009.
2.	Smith M. B., Organic Synthesis, 4th Ed., Academic Press, Cambridge, Massachusetts, 2016.
3.	Carruthers W. and Coldham I., Modern Methods of Organic Synthesis, First South Asian Edition, 2005, Cambridge University Press.
4.	Greeves N., Clayden J., Warren S., Organic Chemistry, 2nd Ed., Oxford University Press, New Delhi, 2012.
5.	Carruthers W., Modern Methods of Organic Synthesis, 4th Ed., Cambridge University Press, New Delhi, 2005.
Reference Books	
1.	Smith M. B., March J., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th Ed., Wiley India, New Delhi, 2015.
2.	R. O.C. Norman, J. M. Coxon, Principles of Organic Synthesis, 3rd Edition, CRC Press
3.	Zweifel G. S., Nantz M. H., Somfai P., Modern Organic Synthesis: An Introduction, 2nd Ed., Wiley-Blackwell, New York, 2017.
4.	Morrison R. T., Boyd R. N., Bhattacharjee S. K., Organic Chemistry, 7th Edition, Pearson Education India, 2010.
5.	Solomons T. W. G., Fryhle C. B., Snyder S. A., Organic Chemistry, 12th Edition, Wiley, 2017.
6.	Harmata M., Strategies and Tactics in Organic Synthesis, Volume 4, Academic Press, 2004.

DSE – I	Polymer Chemistry	L	T	P	C
		4	0	0	4

Pre-requisite: Knowledge of chemistry at B.Sc. level

Course Objectives:

The course is being offered with the following objectives:

1. To provide basic concept of polymer chemistry, mechanisms and techniques of polymerization.
2. To offer concept of polymer processing techniques.
3. To deliver in depth knowledge of polymer analysis and characterization.
4. To provide knowledge of commodity and engineering industrial polymers.

Course Outcome:

After successful completion of the course, the students will be able to

CO1: Learn, understand, and explain about disciplinary knowledge of polymer chemistry, mechanisms, techniques, processing, and analysis of polymers.

CO2: Develop analytical skills to synthesize, identify, analyse and evaluate commodity and engineering industrial polymers.

CO3: Develop competencies to apply the knowledge of polymers to analyze, report and evaluate polymer related projects independently and as a team respecting moral values.

To CO4: Advance proficiencies for contributing to the holistic development of society towards sustainability by applying the knowledge of polymer chemistry in real and industrial world.

Module 1: Introduction to Polymer Chemistry — **10 hours**

Introduction: Historical background of polymers, advantages and disadvantages of polymers, comparison with other materials, classification, raw materials for polymers, gas cracker, naphtha cracker, synthesis of some industrially important monomers, Glass transition temperature of polymers, Structure-property relationships.

Module 2: Mechanisms and Techniques of Polymerization — **10 hours**

Mechanisms of polymerization, Degree of polymerization and molecular weight of polymers, molecular weight distribution, control of molecular weight.

Techniques of polymerization, advantages and disadvantages of different techniques, special features of polymerization, polymerization reactors.

Module 3: Polymer Processing — **10 hours**

Plastic Molding methods, Compression molding, Transfer molding, Injection molding, Blow molding, Reaction injection molding, Extrusion, Single screw and twin screw extrusion, Calendaring, Rotational molding, Thermoforming, Rubber processing in two-roll mill, Internal mixer.

Module 4: Testing, Analysis, and Characterization of Polymers — **15 hours**

Determination of molecular weight and molecular weight distribution, GPC, light scattering, end group analysis method, Analysis involving spectroscopy, X-ray diffraction analysis – Thermogravimetric Analysis (TGA), Differential thermal analysis (DTA), Differential Scanning Calorimetry (DSC), Microscopic (Optical and Electronic) techniques.

Testing of Mechanical strength, Tensile strength, Flexural and Compressive strength, Toughness, Elastic and plastic deformation, stress-strain relationship, Testing of Abrasion, Adhesion testing, testing of Endurance, Fatigue, Hardness, Tear, Resilience, Izod and Charpy Impact tests, Ageing resistance, Environmental stress cracking resistance, testing for biodegradability.

Module 5: Synthesis and Properties of Industrially Important Polymers — **15 hours**

Commodity and Engineering Plastics, Commodity Plastics: Polyethylene (LDPE, HDPE, LLDPE), Polypropylene, Polystyrene, HIPS, Poly(vinyl chloride) etc., methods of their synthesis and properties.

Engineering plastics: Poly(acrylonitrile), nylon 6, nylon 6,6, polyesters, polyurethanes, poly(tetrafluoroethylene), etc. and their properties.

Industrial thermosetting resins: phenolic resins, amino-resins, alkyds, unsaturated polyesters, polyurethanes, epoxy resins etc. Bio-degradable polymers, recycling/reuse of waste

polymeric materials etc.	
Total Lecture hours	**60 hours**
Text Book(s)	
1.	F.W. Billmeyer, Jr.(1984) "Text Book of Polymer Science" 3rd Edition, Willey – Interscience, New York.
2.	P. Ghosh, Polymer Science and Technology: Plastics, Rubbers, Blends and Composites, Third Edition, McGraw Hill Education Private Limited (India), 2011
3.	J. A. Brydson, Plastics Materials, 4th edn., Butterworths, London, 1982
4.	1. Odian, G. Principles of Polymerization (Wiley, 2004).
Reference Books	
1.	Charrier, J. (1991) Polymeric Materials and Processing: Plastics,Elastomers and Composites. München: Carl Hanser Verlag.
2	Polymer Rheology and Processing, A.A. Collyer, Leszek A. Utracki; Springer, 1990.
3	R.F. Speyer, Thermal Analysis of Materials, Marcel Decker, 1994.
4	Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd., 2008.

DSE-1	SPECTROSCOPY – II	L	T	P	C
		4	0	0	4

Pre-requisite: Knowledge of chemistry at B.Sc. level

Course Objectives:

The course is being offered with the following objectives:

1. To discuss the applications of Nuclear Magnetic Resonance (NMR) spectroscopy and the basics of Nuclear Quadrupole Resonance (NQR) spectroscopy.
2. To provide knowledge of electron spin resonance (ESR) spectroscopy.
3. To provide basic concepts of Mass spectroscopy.
4. To provide knowledge of Mossbauer spectroscopy

Course Outcome:

After successful completion of the course, the students will be able

CO1: To understand the principles and instrumentation of various spectroscopic techniques.

CO2: To apply different spectroscopic methods for structure elucidation of compounds.

el CO3: To analyze molecules by NMR, ESR and mass spectroscopy.

CO4: To list the applications of different spectroscopy.

Module 1: NMR and NQR SPECTROSCOPY — **20 hours**

Physical basis of nuclear magnetic resonance, classic and quantum description, Relaxation mechanisms, chemical shift and anisotropy; Selection rules and relative intensities of lines; Complex spin-spin splitting, vicinal and geminal coupling and stereostructure, variable temperature spectra-geminal non-equivalence; Coupling constants and correlation with structure and stereochemistry.

Introduction to Pulse and Fourier transformation NMR.

NMR of Si, F, and P nuclei; NMR of paramagnetic metal complexes-contact and pseudo-contact shifts; magnetic moment measurement.

NQR spectroscopy: Principles and applications.

Module 2: ESR SPECTROSCOPY — **15 hours**

Basic principle of ESR spectroscopy, Relaxation process and line width. Zeeman splitting, g-values, hyperfine and super hyperfine coupling constants; Factors affecting the magnitude of g values. Zero field splitting, Kramers degeneracy.

ESR spectra of organic and inorganic compounds, Determination of electronic structure, practical considerations of measurements, and instrumentation.

Module 3: MASS SPECTROSCOIPY — **15 hours**

Basic principles, ionization techniques, isotope abundance, molecular ion, fragmentation processes of organic molecules, deduction of structure through mass spectral fragmentation.

ESI-MS and MALDI- MS-applications in biomolecules, instrumentation.

Module 4: MOSSBAUER SPECTROSCOPY — **10 hours**

Principles, instrumentation, and applications.

Total Lecture hours — **60 hours**

Text Book(s)

1. C.N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Edition, Tata McGraw Hill, 1994.
2. D.L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, 4th Ed., Brooks/Cole Cengage Learning, 2015.
3. R.S. Drago, Physical Methods in Chemistry, Saunders, Thomson Learning, 1977.
4. R.M Silverstein, F. X. Webster, D. J. Kiemle, D. L. Bryce, Spectrometric Identifications of Organic Compounds, 8th Edition, Wiley India Pvt. Ltd, 2015.

Reference Books

1. W. Kemp, Organic Spectroscopy, 3rd Edition, Palgrave Macmillan, 2011.
2. L. D. Field, S. Sternhell, J. R. Kalman, Organic Structures from Spectra, 5th Edition, John Wiley & Sons 2013.
3. D.W.H. Rankin, N. Mitzel, C. Morrison, Structural Methods in Molecular Inorganic Chemistry, Wiley, 2013.

SEC	ADVANCES IN ENERGY TECHNOLOGY	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of Basic Science

Course Objectives:

1. To make students familiar with different chemical energy sources.
2. To give an insight into electrochemical energy systems.
3. To give students insight into the chemistry of fuel cells.
4. 4. To give the students' knowledge of solar energy.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To understand various energy sources.

CO2: To explain various electrochemical energy systems and chemistry of fuel cells.

CO3: To list various sources of energy and their uses.

Vv CO4: To apply the chemistry behind different energy systems.

Module 1: Chemical Energy Sources — **11 hours**

Coal: Origin, constitution of coal, coal gasification, indirect liquification, purification of synthesis gas. Water gas shift process, coal combustion, chemical obtained from coal.

Nuclear Fission: Power from nuclear fission, light water reactors (LWRs), heavy water reactor (HWRs), Gas cooled reactors (GCRs), fast breeder reactors (FBRs)

Nuclear Fusion: Cold fusion

Module 2: Electrochemical Energy System — **12 hours**

Introduction, fundamentals of batteries, choice of materials, classification of batteries, sizes of batteries.

Some common batteries: Button cells, Portable equipment batteries, SLI batteries, Vehicle traction batteries, Stationary batteries, Battery characteristic power density.

Primary batteries: Combination of materials for a primary battery, alkaline MnO_2 batteries performance and advantages, secondary batteries.

Types and classification, sealed storage batteries, metal hydride electrode

Reserve Batteries: Introduction, classification, liquid activated, water activated batteries, gas activated batteries, heat activated batteries, Lithium based conducting polymer batteries, Lithium batteries and heart pacers

Module 3: Fuel Cells — **10 hours**

Introduction, Classification, Choice of electrolyte, Electrodes and requirement of Electrocatalysis.

Biochemical Fuel cells, Characteristic, Classification, Mechanisms and Application.

Use of carbon in fuel cells, Fuel cells using Carbon nano materials

Module 4: Solar Energy — **12 hours**

Petrochemical and photogalvanic conversion

Hydrogen energy: Merits of hydrogen fuel cell, Hydrogen economy concept, Photo assisted electrolysis of water.

Biomass: Resources, Wood – a measure renewable resource and Biochemical routes, Biofuels. Gasohol, Hydrogen storage by Metal alloys Miscellaneous Sources: Tidal Energy, Geothermal Energy.	
Total Lecture hours	**45 hours**
Text Book(s)	
1.	E. Stocchi: Industrial Chemistry, Vol -I, Ellis Horwood Ltd. UK.
2.	B.K. Sharma: Industrial Chemistry, Goel Publishing House, Meerut.
Reference Books	
1.	Kent, J. A. (ed) Riegel's Handbook of Industrial Chemistry, 9 th Ed., CBS Publishers, New Delhi, 1997
2.	Solar energy technology handbook, E.W. Dickinson, CRC Press, 2018.
3.	Electrochemical energy: advanced materials and technologies, P.K. Shen, C.-Y. Wang, X. Sun, J. Zhang, CRC Press, 2018.

	LABORATORY COURSE – III	L	T	P	C
		0	0	12	6

Pre-requisite: Knowledge of B.Sc. level chemistry

Course Objectives:

1. To familiarize students with the physical chemistry experiments, errors and instrumental methods
2. To expose students to various experimental skills of physico-chemical analysis and characterization techniques.
3. To develop synthesis and analytical skills among the students.

Course Outcome:

After successful completion of the course, the students will be able

CO1: To do physical chemistry experiments pH metric titration, conductometry, spectrophotometry, kinetics and data analysis confidently.

CO2: To analyze and characterize samples by using suitable methods.

CO3: To synthesize polymers and resins by different techniques, analyse, compare and evaluate their properties.

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Experiments includes Purification of chemicals, calibration of analytical instruments through Analysis of error, primary and secondary data, accuracy and precision, averaging of data etc., Handling of basic instruments, e.g., potentiometer, conductivity meter, spectrophotometer, etc., through eight experiments chosen from below.

Synthesis and Analysis:

1. Determination of alkalinity of water sample
2. Determination of dissolved oxygen (DO) in the given water sample
3. Synthesis of Polystyrene (PS)
4. Synthesis of Polymethyl methacrylate (PMMA)
5. Preparation of Phenol – Formaldehyde resin
6. Preparation of Urea – Formaldehyde resin
7. Preparation of epoxy resin.
8. Determination of average molecular weight of a polymer by viscometry method.
9. Compositional Analysis of Coal
10. Synthesis of polymer by different techniques (bulk, solution, suspension, emulsion etc.)
11. Study the kinetics of hydrolysis of methyl acetate and determine the energy of activation.
12. Study of the autocatalytic reaction between oxalic acid and $KMnO_4$ and determination of the order of the reaction.
13. Study of the kinetics of reaction between iodine and acetone in acidic medium by half-life period method and determination of the order with respect to iodine and acetone.
14. Preparation and characterization of nanoparticles etc.
15. Defemination of physico-chemical (Acid value, Saponification value, Iodine value) properties of oil.
16. Purification by column chromatography
17. Adsorption of dye on activated carbon and analysis of result by different adsorption models.
18. Determination of adsorption kinetics of dye on activated carbon.
19. Investigation of the inversion of cane sugar in presence of acid and hence determination of the activation energy of the reaction.

Instrumental methods

20. Characterization of a given sample by using spectroscopic techniques.
21. Characterization of a given sample by using thermal analysis techniques.
22. To study the kinetics of polymerisation of styrene by dilatometric method.
23. Verify Beers law and determine concentration of (a) $K_2Cr_2O_7$ (b) Organic dyes like methylene blue, Rhodamine B (c) CuSO4
24. Determination of the concentration of chromium and manganese in a mixture of

dichromate and permanganate by spectrophotometric method.

25. Study of non-Newtonian polymer solutions by Brookfield viscometer
26. Determination of the CMC of a detergent by surface tension measurement.
27. Determination of *p*Ka by spectroscopy
28. Extraction of oils from seeds by Soxhlet extraction method.
29. pH metric titration: Determination of the dissociation constant of oxalic acid by using Hendersen 's equation.
30. Finding the amount of the components of the following mixtures using pH metric titration (a) Hydrochloric acid + Acetic acid
31. Finding the amount of the components of the following mixtures using pH metric titration (a) Hydrochloric acid + Oxalic acid
32. To determine the strength of mixture of two acids (strong acid and weak acid) by conductometric method.
33. Determination of the degree of hydrolysis and hydrolysis constant of CH_3COONa of NH_4Cl by conductance measurement.
34. Determination of the concentration of $AgNO_3$ by conductometric titration against KCl solution.

Textbook(s)

1.	Viswanathan, B., Raghavan, P. S. Practical Physical Chemistry, (Viva Books Pvt. Ltd., 2005).
2.	Barua, S.; A textbook of Practical Chemistry; 2nd edition; 2016; Kalyani Publishers.
3.	Mendham J., Denney R.C., Barnes J.D. and. Thomas M.J.K.; Vogel's Textbook of Quantitative Chemical Analysis, 6th edition, 3rd Indian Reprint, 2003, Pearson Education Pvt. Ltd., New Delhi.
4	James, A. M., Prichard, F.E. Practical Physical Chemistry, 3rd Edn., (Longman, 1974).
5	J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 27th Edison, 2008.

Reference Book(s) and journals

1	Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015).
2	Garland, G. W., Nibler, J. W., Shoemaker, D. P. Experiments in Physical Chemistry, 7th Edn., (McGraw- Hill, 2008).
3	Journal of Chemical Education, ACS Publications