Devrukh Shikshan Prasarak Mandal's

Nya. Tatyasaheb Athalye Arts, Ved. S.R. Sapre Commerce and Vid. Dadasaheb Pitre Science College

(Autonomous)

Late Kakasaheb Pandit Educational Campus,

Devrukh, Dist: Ratnagiri- 415 804, Maharashtra

NAAC Accredited 'A' Grade (Third Cycle), Mumbai University Best College Award 2009-10

Syllabus

Programme: T. Y. B. Sc.

Course- Chemistry

w.e.f. Academic Year 2021-22

Choice Based Credit System
T. Y. B. Sc.
Chemistry Syllabus
To be implemented from the Academic year 2021-22

Course Content
Semester V

Course Code	Unit	Topics	Credits	L/Week
USCHT51	I	Molecular Spectroscopy		
	II	Electrochemistry		
	III	Nuclear Chemistry		
	IV	Surface Chemistry & Colloidal State		
USCHT52	I	Molecular Symmetry and Chemical Bonding		
	II	Solid State Chemistry		
	III	Chemistry of Inner Transition Elements		
	IV	Some Selected Topics		
USCHT53	I	Mechanism of Organic Reactions; Pericyclic Reactions & Photochemistry		
	II	Stereochemistry & Heterocyclic Chemistry		
	III	IUPAC & Synthesis of Organic Compounds		
	IV	Spectroscopy-I & Natural Products		
USCHT54	I	Statistical Treatment of Analytical Data-II		
	II	Classical Methods of Analysis (Titrimetry)		
	III	Optical Methods		
	IV	Methods of Separation–I		
USCHP51		Chemistry Practicals I		
USCHP52		Chemistry Practicals II		
USCHP53		Chemistry Practicals III		
USCHP54		Chemistry Practicals IV		

Semester VI

Course Code	Unit	Topics	Credits	L/Week
USCHT61	I	Chemical Thermodynamics & Chemical Kinetics		
	II	Polymers & Renewable Sources		
	III	Quantum Chemistry & Applied Electrochemistry		
	IV	NMR & ESR Spectroscopy		
USCHT62	I	Coordination Chemistry		
	II	Properties of Coordination Compounds		
	III	Organometallic Chemistry		
	IV	Some Selected Topics		
USCHT63	I	Stereochemistry & Biomolecules		
	II	Molecular Rearrangements & Carbohydrates		
	III	Spectroscopy-II		
	IV	Polymers; Catalysts & Reagents		
USCHT64	I	Electro Analytical Techniques		
	II	Methods of Separation-II & Introduction to Quality		
	III	Food and Cosmetics Analysis		
	IV	Thermal Methods and Analytical Method Validation		
USCHP61		Chemistry Practicals I		
USCHP62		Chemistry Practicals II		
USCHP63		Chemistry Practicals III		
USCHP64		Chemistry Practicals IV		

T.Y.B.Sc. Syllabus Chemistry Paper-I
Physical Chemistry

Semester V

Unit I: MOLECULAR SPECTROSCOPY (15L)

1.1 Rotational Spectrum: Introduction to dipole moment, polarization of a bond, bond moment, molecular structure, Rotational spectrum of a diatomic molecule, rigid rotor, moment of inertia, energy levels, conditions for obtaining pure rotational spectrum, selection rule, nature of spectrum, determination of internuclear distance and isotopic shift.

1.2 Vibrational spectrum: Vibrational motion, degrees of freedom, modes of vibration, vibrational spectrum of a diatomic molecule, simple harmonic oscillator, energy levels, zero-point energy, conditions for obtaining vibrational spectrum, selection rule, nature of spectrum.

1.3 Vibrational-Rotational spectrum of diatomic molecule: Energy levels, selection rule, nature of spectrum, P and R branch lines. Anharmonic oscillator - energy levels, selection rule, fundamental band, overtones. Application of vibrational-rotational spectrum in determination of force constant and its significance. Infrared spectra of simple molecules like H_2O and CO_2.

1.4 Raman Spectroscopy: Scattering of electromagnetic radiation, Rayleigh scattering, Raman scattering, nature of Raman spectrum, Stoke's lines, Anti-Stoke's lines, Raman shift, quantum theory of Raman spectrum, comparative study of IR and Raman spectra, rule of mutual exclusion- CO2 molecule. Number of modes of vibrations for linear and non-linear molecules.

Unit-II: ELECTROCHEMISTRY (15L)

2.1 Activity and Activity Coefficient: Lewis concept, Ionic Strength, Mean Ionic Activity and Mean Ionic Activity Coefficient of an electrolyte, expression for activities of electrolytes. Debye-Huckel limiting law (No derivation).
2.2 Classification of Galvanic cells: Chemical cells and Concentration cells, Chemical cells with and without transference, Electrode Concentration cells, Electrolyte concentration cells with and without transference (Derivations are expected)
2.3 Origin of Liquid Junction Potential and its elimination.
2.4 Determination of solubility product and solubility of a sparingly soluble salt: By Chemical cell and By Concentration cell.
2.5 Determination of Liquid Junction Potential

Unit III: NUCLEAR CHEMISTRY (15L)

3.1. Introduction: Basic terms-radioactive constants (decay constant, half-life and average life) and units of radioactivity
3.2 Detection and Measurement of Radioactivity: Types and characteristics of nuclear radiations, behavior of ion pairs in electric field, detection and measurement of nuclear radiations using G. M. Counter and Scintillation Counter.
3.3 Application of use of radioisotopes as Tracers: Chemical reaction mechanism, Age Determination - Dating by C_{14}.
3.4 Nuclear reactions: nuclear transmutation (one example for each projectile), artificial radioactivity, Q - value of nuclear
reaction, threshold energy.

3.5 Fission Process: Fissile and fertile material, nuclear fission, chain reaction, factor controlling fission process, multiplication factor and critical size or mass of fissionable material, nuclear power reactor and breeder reactor.

Unit IV: SURFACE CHEMISTRY & COLLOIDAL STATE (15L)

4.1 Surface Chemistry (6L)

4.1.1 Adsorption: Physical and Chemical Adsorption, types of adsorption isotherms. Langmuir's adsorption isotherm (Postulates and Derivation expected).

4.2.2 B.E.T. equation for multilayer adsorption (Derivation not expected), Determination of surface area of an adsorbent using B.E.T. equation.

4.2 Colloidal State (9L)

4.2.1 Introduction to colloids: Emulsions, Gels and Sols

4.2.2 Electrical Properties: Origin of charges on colloidal particles, Concept of electrical double layer, zeta potential, Helmholtz and Stern model.

4.2.3 Electro-kinetic Phenomena: Electrophoresis, Electro-Osmosis, Streaming Potential, Sedimentation Potential, Donnan Membrane Equilibrium.

4.2.3 Colloidal Electrolytes: Introduction, micelle formation,

4.2.4 Surfactants: Classification and applications of surfactants in detergents and food industry.

(Numericals are expected from All Units)

Semester VI

Unit I: CHEMICAL THERMODYNAMICS & CHEMICAL KINETICS (15L)

1.1 Chemical Thermodynamics (10L)

1.1.1 Colligative Properties: Vapour pressure and relative lowering of vapour pressure. Measurement of lowering of vapour pressure- Static and Dynamic method.

1.1.2 Solutions of Solid in Liquid

1.1.3 Elevation in boiling point of a solution, thermodynamic derivation relating elevation in boiling point of the solution and molar mass of non-volatile solute. Depression in freezing point of a solution, thermodynamic, derivation relating the depression in the freezing point of a solution and the molar mass of the non-volatile solute. Beckmann Method and Rast Method.

1.1.4 Osmotic Pressure: Introduction, thermodynamic derivation of Van't Hoff equation, Van't Hoff Factor. Measurement of Osmotic Pressure - Berkeley and Hartley's Method, Reverse Osmosis.

1.2 Chemical Kinetics (5L)

1.2.1 Classification of reactions Collision theory of reaction rates: Application of collision theory to Unimolecular reaction (Lindemann theory) and Bimolecular reaction (Derivations expected)

1.2.2 Third law of Thermodynamics

1.2.3 Classification as slow, fast and ultra-fast. Study of kinetics of fast reactions by Stop Flow Method and Flash Photolysis (Derivation not expected).

Unit II: POLYMERS & RENEWABLE SOURCES (15L)

2.1 Polymers (10L)

2.1.1 Basic terms: macromolecule, monomer, repeat unit, degree of polymerization.

2.1.2. Classification of polymers: Classification based on source, structure, thermal response and physical properties.

2.1.3 Molar masses of polymers: Number average, Weight average, Viscosity average molar mass, Monodispersity and Polydispersity

2.1.4 Method of determining molar masses of polymers: Viscosity method using Ostwald Viscometer (Derivation expected)

2.1.5 Light Emitting Polymers: Introduction, Characteristics, Method of preparation and applications.

2.1.6 Antioxidants and Stabilizers: Antioxidants, Ultraviolet stabilizers, Colorants, Antistatic agents and Curing agents.

2.2 Renewable Sources (5L)

2.2.1 Renewable energy resources: Introduction.

2.2.2 Solar energy: Solar cells, Photovoltaic effect, Differences between conductors, semiconductors, insulators and its band gap, Semiconductors as solar energy converters, Silicon solar cell

2.2.3 Hydrogen: Fuel of the future, production of hydrogen by direct electrolysis of water, advantages of hydrogen as a universal energy medium.

Unit III: QUANTUM CHEMISTRY & APPLIED ELECTROCHEMISTRY (15L)

3.1 Basics of Quantum Chemistry (10L)

3.1.1 Classical mechanics: Introduction, limitations of classical mechanics, Black body radiation, photoelectric effect, Compton effect.

3.1.2 Quantum mechanics: Introduction, Planck's theory of quantization, wave particle duality, de –Broglie's equation, Heisenberg's uncertainty principle.

3.1.3 Progressive and standing waves- Introduction, boundary conditions, Schrodinger's time independent wave equation (Derivation not expected), interpretation and properties of wave function.

3.1.4 Quantum mechanics: State function and its significance, Concept of operators - definition, addition, subtraction and multiplication of operators, commutative and non - commutative operators, linear operator, Hamiltonian operator, Eigen function and Eigen value.

3.2 Applied Electrochemistry (5L)

3.2.1 Polarization: concentration polarization and it's elimination

3.2.2 Decomposition Potential and Overvoltage: Introduction, experimental determination of decomposition potential, factors affecting decomposition potential. Tafel's equation for hydrogen overvoltage, experimental determination of over –voltage.

Unit IV: NMR & ESR SPECTROSCOPY (15L)

4.1 NMR -Nuclear Magnetic Resonance Spectroscopy (7L)

4.1.1 Principle: Nuclear spin, magnetic moment, nuclear 'g' factor, energy levels, Larmor precession, Relaxation processes in NMR (spin -spin relaxation and spin - lattice relaxation). Instrumentation: NMR Spectrometer

4.2 Electron Spin Resonance Spectroscopy (8L)

4.2.1 Principle: fundamental equation, g-value -dimensionless constant or electron g-factor, hyperfine splitting. Instrumentation: ESR spectrometer, ESR spectrum of hydrogen and deuterium.

(Numericals are expected from All Units)

T.Y.B.Sc. Syllabus Chemistry Paper-II
Inorganic Chemistry

Semester V

Unit I: MOLECULAR SYMMETRY AND CHEMICAL BONDING (15L)

1.1 Molecular Symmetry (6L)

1.1.1 Introduction and Importance of Symmetry in Chemistry.

1.1.2 Symmetry elements and Symmetry operations.

1.1.3 Concept of a Point Group with illustrations using the following point groups: (i) $C_{\infty v}$ (ii) $D_{\infty h}$ (iii) C_{2v} (iv) C_{3v} (v) C_{2h} and (vi) D_{3h}

1.2 Molecular Orbital Theory for heteronuclear diatomic molecules and polyatomic species (9L)

1.2.1 Comparison between homonuclear and heteronuclear diatomic molecules.

1.2.2. Heteronuclear diatomic molecules like CO, NO and HCl, application of modified MO diagram for CO.

1.2.3 Molecular orbital theory for H_3 and H_3^+ (correlation diagram expected).

1.2.4. Molecular shape to molecular orbital approach in AB_2 molecules. Application of symmetry concepts for linear and angular species considering σ- bonding only. (Examples like: i) BeH_2, ii) H_2O).

Unit-II: SOLID STATE CHEMISTRY (15L)

2.1 Structures of Solids (11L)

2.1.1 Explanation of terms viz. crystal lattice, lattice point, unit cell and lattice constants.

2.1.2 Closest packing of rigid spheres (hcp, ccp), packing density in simple cubic, bcc and fcc lattices. Relationship between density, radius of unit cell and lattice parameters. (Numerical problems expected).

2.1.3 Stoichiometric Point defects in solids (discussion on Frenkel and Schottky defects expected).

2.2 Superconductivity (4L)

2.2.1 Discovery of superconductivity.

2.2.2 Explanation of terms like superconductivity, transition temperature, Meissner effect.

2.2.3 Different types of super conductors viz. conventional superconductors, alkali metal fullerides, high temperature super conductors.

2.2.4 Brief application of superconductors.

Unit III: CHEMISTRY OF INNER TRANSITION ELEMENTS (15L)

3.1 Introduction (1L)
Position in periodic table and electronic configuration of lanthanides and actinides.

3.2 Chemistry of Lanthanides (11L)
3.2.1 Lanthanide contraction and its consequences.
3.2.2 Oxidation states.
3.2.3 Ability to form complexes
3.2.4 Magnetic and spectral properties.
3.2.5 Occurrence, extraction and separation of lanthanides by Solvent extraction.
3.2.6 Applications of lanthanides.

3.3 Chemistry of Actinides (3L)
3.3.1 Comparison between lanthanides and actinides.
3.3.2 Chemistry of Uranium with reference to occurrence and isolation (solvent extraction method)
3.3.2 Properties and applications of Uranium.)

Unit IV: SOME SELECTED TOPICS (15L)

4.1 Chemistry of Non-aqueous Solvents (5L)
4.1.1 Classification of solvents and importance of non-aqueous solvents.
4.1.2 Characteristics and study of liquid ammonia, dinitrogen tetra oxide as non-aqueous solvents with respect to: (i) acid-base reactions and (ii) redox reactions.

4.2 Comparative Chemistry of Group 16 (5L)
4.2.1 Electronic configurations, trends in physical properties, allotropy
4.2.2 Manufacture of sulphuric acid by Contact process.

4.3 Comparative Chemistry of Group 17 (5L)
4.3.1 Electronic configuration, General characteristics, anomalous properties of fluorine, comparative study of acidity of oxyacids of chlorine w.r.t acidity, oxidizing properties and structures (on the basis of VSEPR theory)
4.3.2 Chemistry of interhalogens with reference to preparations, properties and structures (on the basis of VSEPR theory).

Semester VI

Unit I: COORDINATION CHEMISTRY (15L)

1.1 Theories of metal-ligand bond (11L)

1.1.1 Recapitulation of VBT and its limitations.

1.1.2 Crystal Field Theory and effect of crystal field on central metal valence orbitals in various geometries from linear to Octahedral (from coordination number 2 to coordination number 6)

1.1.3 Splitting of d orbitals in octahedral, square planar and tetrahedral crystal fields.

1.1.4 Distortions from the octahedral geometry:

(i) effect of ligand field (ii) Jahn-Teller distortions.

1.1.5 Crystal field splitting parameters Δ; its calculation and factors affecting it in octahedral complexes, Spectrochemical series.

1.1.6 Crystal field stabilization energy (CFSE), calculation of CFSE for octahedral complexes with d^0 to d^{10} metal ion configurations.

1.1.7 Consequences of crystal field splitting on various properties such as ionic radii, hydration energy and enthalpies of formation of metal complexes of the first transition series.

1.1.8 Limitations of CFT

1.1.9 Evidences for covalence in metal complexes

(i) intensities of d-d transitions (ii) ESR spectrum of $[IrCl_6]^{2-}$ (iii) Nephelauxetic effect.

1.2 Molecular orbital Theory for coordination compounds (4L)

2.1.1 Identification of the central metal orbitals and their symmetry suitable for formation of σ bonds with ligand orbitals.

2.1.2 Construction of ligand group orbitals.

2.1.3 Construction of σ-molecular orbitals for an ML_6 complex.

2.1.4 Effect of π-bonding on complexes.

2.1.5 Examples like $[FeF_6]^{-4}$, $[Fe(CN)_6]^{-4}$, $[FeF_6]^{-3}$, $[Fe(CN)_6]^{-3}$**,** $[CoF_6]^{-3}$, $[Co(NH_3)_6]^{+3}$

Unit II: PROPERTIES OF COORDINATION COMPOUNDS (15L)

2.1 Stability of Metal-Complexes (4L)

2.1.1 Thermodynamic and kinetic stability of metal complexes with examples.

2.1.2 Stability constants: stepwise and overall stability constants and their interrelationship.

2.1.3 Factors affecting thermodynamic stability. (Factors related to nature of central metal atom, nature of ligand, chelate effect to be discussed).

2.2 Reactivity of metal complexes (4L)

2.2.1 Comparison between Inorganic and organic reactions.

2.2.2 Types of reactions in metal complexes.

2.2.3 Inert and labile complexes: correlation between electronic configurations and lability of complexes.

2.2.4 Ligand substitution reactions: Associative and Dissociative mechanisms.

2.2.5 Acid hydrolysis, base hydrolysis and Anation reactions.

2.3 Electronic Spectra (7L)

2.3.1 Origin of electronic spectra

2.3.2 Types of electronic transitions in coordination compounds: Intra-ligand, Charge transfer and Intra-metal transitions.

2.3.3 Selection rules for electronic transitions.

2.3.4 Electronic configuration and electronic micro states, coupling of spin momenta (M_s), orbital momenta (M_l) and Spin-Orbit coupling or Russell-Saunders coupling.
2.3.5 Terms and Term symbols, Determination of Terms for p^2 and d^2 electronic configuration
2.3.6 Terms and micro-states for transition metal atoms/ions.

Unit III: ORGANOMETALLIC CHEMISTRY (15L)

3.1 Organometallic Compounds of main group metal (6L)
3.1.1 General characteristics of various types of organometallic compounds, viz. ionic, σ-bonded and electron deficient compounds.
3.1.2 General synthetic methods of organometallic compounds:
(i) Oxidative-addition (ii) Metal-metal exchange(transmetallation) (iii) Carbanion-halide exchange (iv) Metal-hydrogen exchange (Metallation) (v) Methylene insertion reactions.
3.1.3 Some chemical reactions of organometallic compounds:
(i) Reactions with oxygen and halogens (ii) Alkylation and arylation reactions (iii) Reactions with protic reagents (iv) Redistribution reactions (v) Complex formation reactions.

3.2 Metallocenes (5L)
Introduction, Ferrocene: Synthesis, properties, structure and bonding on the basis of VBT.

3.3 Catalysis (4L)
3.3.1 Comparison between homogeneous and heterogeneous catalysis
3.3.2 Basic steps involved in homogeneous catalysis
3.3.3 Mechanism of Wilkinson's catalyst in hydrogenation of alkenes.

Unit IV: SOME SELECTED TOPICS (15L)

4.1 Metallurgy (7L)
4.1.1 Types of metallurgies.
4.1.2 General steps of metallurgy; Concentration of ore, calcinations, roasting, reduction and refining.
4.1.3 Metallurgy of copper: occurrence, physicochemical principles, Extraction of copper from pyrites & refining by electrolysis.

4.2 Chemistry of Group 18 (5L)
4.2.1 Historical perspectives
4.2.2 General characteristics and trends in physical and chemical properties
4.2.3 Isolation of noble gases
4.2.4 Compounds of Xenon (oxides and fluorides) with respect to preparation and structure (VSEPR)
4.2.5 Uses of noble gases

4.3 Introduction to Bioinorganic Chemistry (3L)
4.3.1 Essential and non-essential elements in biological systems.
4.3.2 Biological importance of metal ions such as Na^+, K^+, Fe^{+2}/Fe^{+3} and Cu^{+2} (Role of Na^+ and K^+ w.r.t ion pump

T.Y.B.Sc. Syllabus Chemistry Paper-III
Organic Chemistry

Semester V

Unit I: MECHANISM OF ORGANIC REACTIONS; PERICYCLIC REACTIONS & PHOTOCHEMISTRY (15L)

1.1 Mechanism of organic reactions (8L)

1.1.1 The basic terms & concepts: bond fission, reaction intermediates, electrophiles & nucleophiles, ligand, base, electrophilicity vs. acidity & nucleophilicity vs basicity.

1.1.2 Neighbouring group participation in nucleophilic substitution reactions: participation of lone pair of electrons, kinetics and stereochemical outcome.

1.1.3 Acyl nucleophilic substitution (Tetrahedral mechanism): Acid catalysed esterification of carboxylic acids (AAC2) and base promoted hydrolysis of esters (BAC2).

1.2 Pericyclic reactions and Photochemistry (7L)

1.2.1. Pericyclic reactions:

1.2.1.1. classification and nomenclature

1.2.1.2. Electro cyclic reactions (ring opening and ring closing), cycloaddition, sigma tropic Rearrangement, group transfer reactions, cheletropic reaction (definition and one example of each type)

1.2.2. Photochemistry:

1.2.2.1. Difference between thermal and photochemical reactions. Jablonski diagram, singlet and triplet states, allowed and forbidden transitions, fate of excited molecules, photosensitization.

1.2.2.2. Photochemical reactions of olefins: photoisomerization, photochemical rearrangement of 1,4- dienes (di- π methane)

1.2.2.3. Photochemistry of carbonyl compounds: Norrish I, Norrish II cleavages. Photo reduction (e.g. benzophenone to benzpinacol)

Unit II: STEREOCHEMISTRY & HETEROCYCLIC CHEMISTRY (15L)

2.1 Stereochemistry-I (7L)

2.1.1 Molecular chirality and elements of symmetry: Mirror plane symmetry, inversion center, rotation -reflection (alternating) axis.

2.1.2. Chirality of compounds without a stereo genic center: cummulenes, spiranes, and biphenyls.

2.1.3. R/S nomenclature to cummulenes, spiranes, and biphenyls

2.2 Heterocyclic chemistry (8L)

2.2.1 Reactivity of pyridine-N-oxide, quinoline and iso-quinoline.

2.2.2 Preparation of pyridine-N-oxide, quinoline (Skraup synthesis) and iso-quinoline (Bischler-Napieralski synthesis).

2.2.3 Reactions of pyridine-N-oxide: halogenation, nitration and reaction with $NaNH_2$/liq.NH_3, n-BuLi.

2.2.4 Reactions of quinoline and isoquinoline; oxidation, reduction, nitration, halogenation and reaction with $NaNH_2$/liq.NH_3, n-BuLi.

Unit III: IUPAC & SYNTHESIS OF ORGANIC COMPOUNDS (15L)

3.1 IUPAC (5L)

IUPAC Systematic nomenclature of the following classes of compounds (including compounds upto two substituents / functional groups):

3.1.1 Bicyclic compounds – spiro, fused and bridged (upto 11 carbon atoms) – saturated and unsaturated compounds. 3.1.2 Biphenyls

3.1.3 Cummulenes with upto 3 double bonds

3.1.4 Quinolines and isoquinolines

3.2 Synthesis of organic compounds (10L)

3.2.1 Introduction: Linear and convergent synthesis, criteria for an ideal synthesis, concept of chemo selectivity and regioselectivity with examples, calculation of yields.

3.2.2 Multicomponent Synthesis: Mannich reaction and Biginelli reaction. Synthesis with examples (no mechanism)

3.2.3 Green chemistry and synthesis: Introduction: Twelve principles of green chemistry, concept of atom economy and E-factor, calculations and their significance, numerical examples. i) Green reagents: dimethyl carbonate. ii) Green starting materials: D-glucose iii) Green solvents: supercritical CO2 iv) Green catalysts: Bio catalysts.

3.2.4 Planning of organic synthesis i) synthesis of nitroanilines. (o&p) ii) synthesis of halobenzoic acid.(o&p) iii) Alcohols (primary / secondary / tertiary) using Grignard reagents. iv) Alkanes (using organo lithium compounds)

Unit IV: SPECTROSCOPY-I & NATURAL PRODUCTS (15L)

4.1 Spectroscopy-I (5L)

4.1.1 Introduction: Electromagnetic spectrum, units of wavelength and frequency

4.1.2 UV–Visible spectroscopy: Basic theory, solvents, nature of UV-Visible spectrum, concept of chromophore, auxochrome, bathochromic and hypsochromic shifts, hyperchromic and hypochromic effects, chromophore-chromophore and chromophore-auxochrome interactions.

4.1.3 Mass spectrometry: Basic theory. Nature of mass spectrum. General rules of fragmentation. Importance of molecular ion peak, isotopic peaks, base peak, nitrogen rule, rule of 13 for determination of empirical formula and molecular formula. Fragmentation of alkanes and aliphatic carbonyl compounds.

4.2 Natural Products (10L)

4.2.1. Terpenoids: Introduction, Isoprene rule, special isoprene rule and the gem-dialkyl rule.

4.2.2 Citral: a) Structural determination of citral. b) Synthesis of citral from methyl heptenone c) Isomerism in citral. (cis and trans form).

4.2.3. Alkaloids Introduction and occurrence. Hofmann's exhaustive methylation and degradation in: simple open chain and N – substituted monocyclic amines.

4.2.4 Nicotine: a) Structural determination of nicotine. (Pinner's work included) b) Synthesis of nicotine from nicotinic acid c) Harmful effects of nicotine.

4.2.5 Hormones: Introduction, structure of adrenaline (epinephrine), physiological action of adrenaline. Synthesis of adrenaline from a) Catechol b) p-hydroxybenzaldehyde (Ott's synthesis)

Semester VI

Unit I: STEREOCHEMISTRY & BIOMOLECULES (15L)

1.1 Stereochemistry II (8L)

1.1.1 Stereoselectivity and stereospecificity: Idea of enantioselectivity (ee) and diastereoselectivity (de), Topicity: enantiotopic and diasterotopic atoms, groups and faces.

1.1.2 Stereochemistry of– i) Elimination reactions: E2–Base induced dehydrohalogenation of 1-bromo-1,2- diphenylpropane. ii) Addition reactions to olefins: a) bromination (electrophilic anti addition) b) syn hydroxylation with $KMnO_4$ c) epoxidation followed by hydrolysis.

1.2 Amino acids, Proteins & Nucleic Acids (7L)

1.2.1 α-Amino acids: General Structure, configuration, and classification based on structure and nutrition. Properties: pH dependency of ionic structure, isoelectric point and zwitter ion. Methods of preparations: Strecker synthesis, Gabriel phthalamide synthesis.

1.2.2 Polypeptides and Proteins: nature of peptide bond. Nomenclature and representation of polypeptides (di-and tri-peptides) with examples Merrifield solid phase polypeptide synthesis.

Proteins: general idea of primary, secondary, tertiary & quaternary structure

1.2.3. Nucleic acids: Controlled hydrolysis of nucleic acids, Sugars and bases in nucleic acids. Structures of nucleosides and nucleotides in DNA and RNA. Structures of nucleic acids (DNA and RNA) including base pairing.

Unit II: MOLECULAR REARRANGEMENTS & CARBOHYDRATES (15L)

2.1 Molecular Rearrangements (5L)

Mechanism of the following rearrangements with examples and stereochemistry wherever applicable.

2.1.1 Migration to the electron deficient carbon: Pinacol-pinacolone rearrangement.

2.1.2 Migration to the electron deficient nitrogen: Beckmann rearrangement.

2.1.3 Migration involving a carbanion: Favorski rearrangement.

2.1.4 Name reactions: Michael addition, Wittig reaction.

2.2 Carbohydrates (10L)

2.2.1 Introduction: classification, reducing and non-reducing sugars, DL notation

2.2.2 Structures of monosaccharides: Fischer projection (4-6 carbon monosaccharides) and Haworth formula (furanose and pyranose forms of pentoses and hexoses) Interconversion: open chain and Haworth forms of monosaccharides with 5 and 6 carbons. Chair conformation with stereochemistry of D-glucose, Stability of chair form of D-glucose

2.2.3 Stereoisomers of D-glucose: enantiomer, diastereomers, anomers, epimers.

2.2.4 Mutarotation in D-glucose with mechanism

2.2.5 Chain lengthening & shortening reactions: Modified Kiliani-Fischer synthesis (D-arabinose to D-glucose and D-mannose), Wohl method (D-glucose to D-arabinose)

2.2.6 Reactions of D-glucose and D-fructose: (a) Osazone formation (b) reduction: Hi/Ni, $NaBH_4$ (c) oxidation: bromine water, HNO_3, HIO_4 (d) acetylation (e) methylation:(d) and (e) with cyclic pyranose forms

Unit III: SPECTRIOSCOPY-II (15L)

3.1.1 IR Spectroscopy: Basic theory, nature of IR spectrum, selection rule, fingerprint region.
3.1.2 PMR Spectroscopy: Basic theory of PMR, nature of PMR spectrum, chemical shift (δ unit), standard for PMR, solvents used. Factors affecting chemical shift: (1) inductive effect (2) anisotropic effect (with reference to C=C, C≡C, C=O and benzene ring). Spin- spin coupling and coupling constant, application of deuterium exchange technique, application of PMR in structure determination.
3.1.3 Spectral characteristics of following classes of organic compounds, including benzene and monosubstituted benzenes, with respect to IR and PMR:
(1) alkanes (2) alkenes (3) alkynes (4) haloalkanes (5) alcohols (6) carbonyl compounds (7) ethers (8) amines (broad regions characteristic of different groups are expected). Problems of structure elucidation of simple organic compounds using individual or combined use of UV-Vis, IR, Mass and NMR spectroscopic technique are expected. (Index of hydrogen deficiency should be the first step in solving the problems).

Unit IV: POLYMERS; CATALYSTS & REAGENTS (15L)

4.1 Polymer (8L)
4.1.1 Introduction: terms monomer, polymer, homopolymer, copolymer, thermo plastics and thermosets.
4.1.2 Addition polymers: polyethylene, polypropylene, Teflon, polystyrene, PVC, Uses.
4.1.3 Condensation polymers: polyesters, polyamides, polyurethanes, polycarbonates, phenol formaldehyde resins. Uses
4.1.4 Stereochemistry of polymers: Tacticity, mechanism of stereochemical control of polymerization using Ziegler Natta catalysts.
4.1.5 Natural and synthetic rubbers: Polymerization of isoprene: 1,2 and 1,4 addition (cis and trans), Styrene butadiene copolymer.
4.1.6 Additives to polymers: Plasticizers, stabilizers and fillers.
4.1.7 Biodegradable polymers: Classification and uses. polylactic acid structure, properties and use for packaging and medical purposes.
(Note: Identification of monomer in a given polymer & structure of polymer for a given monomer is expected. condition for polymerization is not expected)

4.2 Catalysts and Reagents (7L)
Study of the following catalysts and reagents with respect to functional group transformations and selectivity (no mechanism).
4.2.1 Catalysts: Catalysts for hydrogenation: a. Raney Nickel b. Pt and PtO_2 (C=C, CN, NO_2, aromatic ring) c. Pd/C : C=C, COCl→CHO (Rosenmund) d. Lindlar catalyst: alkynes
4.2.2 Reagents: a. $LiAlH_4$ (reduction of CO, COOR, CN,NO_2) b. $NaBH_4$ (reduction of CO) c. SeO_2 (Oxidation of CH_2 alpha to CO) d. mCPBA (epoxidation of C=C) e. NBS (allylic and benzylic bromination)

T.Y.B.Sc. Syllabus Chemistry Paper-IV
Analytical Chemistry

Semester V

UNIT I: STATISTICAL TREATMENT OF ANALYTICAL DATA-II (15L)

Analytical calculations

1.1. Nature of Indeterminate Errors (5L)

1.1.1. The true and acceptable value of a result of analysis

1.1.2. Measures of central tendency: mean, median, mode, average

1.1.3. Measures of dispersion: Absolute deviation, relative deviation, relative average deviation, standard deviation, (s, sigma) variance, coefficient of variation

1.2. Distribution of random errors (2L)

1.2.1. Gaussian distribution curve.

1.2.2. Equation and salient features of Gaussian distribution curve

1.3. Concept of Confidence limits and confidence interval & its computation using (4L)

(i) Population standard deviation; (ii) Student's t test; (iii) Range (Chemical calculations)

1.4. Criteria for rejection of doubtful result (2L)

(i) 2.5 d rule (ii) 4.0 d rule (iii) Q test

1.5. Test of Significance (2L)

(i) Null hypothesis

(ii) F-test (variance ratio test)

UNIT II: CLASSICAL METHODS OF ANALYSIS (TITRIMETRY) (15L)

2.1. Redox Titrations (Numerical & word Problems are expected) (8L)

2.1.1. Introduction

2.1.2. Construction of the titration curves and calculation of E_{system} in aqueous medium in case of: (1) One electron system (2) Multielectron system

2.1.3. Theory of redox indicators, Criteria for selection of an indicator. Use of diphenyl amine and ferroin as redox indicators

2.2. Complexometric Titrations (7L)

2.2.1. Introduction, construction of titration curve

2.2.2. Use of EDTA as titrant and its standardization

2.2.3. Selectivity of EDTA as a titrant. Factors enhancing selectivity with examples. Advantages and limitations of EDTA as a titrant.

2.2.4. Types of EDTA titrations.

2.2.5. Metallochromic indicators, theory, examples and applications

UNIT III: OPTICAL METHODS (15L)

3.1. Atomic Spectroscopy: Flame Emission spectroscopy (FES) and Atomic Absorption Spectroscopy (AAS) (7L)

3.1.1. Introduction, Energy level diagrams, Atomic spectra, Absorption and Emission Spectra

3.1.2. Flame Photometry– Principle, Instrumentation (Flame atomizers, types of Burners, Wavelength selectors, Detectors)

3.1.3. Atomic Absorption Spectroscopy– Principle, Instrumentation (Source, Chopper, Flame and Electrothermal Atomizer)

3.1.4. Quantification methods of FES and AAS– Calibration curve method, Standard addition method and internal standard method.

3.1.5. Comparison between FES and AAS

3.1.6. Applications, Advantages and Limitations

3.2. Molecular Fluorescence and Phosphorescence Spectroscopy (4L)

3.2.1. Introduction and Principle

3.2.2. Relationship of Fluorescence intensity with concentration

3.2.3. Factors affecting Fluorescence and Phosphorescence

3.2.4. Instrumentation and applications

3.2.5. Comparison of Fluorimetry and Phosphorimetry

3.2.6. Comparison with Absorption methods

3.3. Turbidimetry and Nephelometry (4L)

3.3.1. Introduction and Principle

3.3.2. Factors affecting scattering of Radiation: Concentration, particle size, wavelength, refractive index

3.3.3. Instrumentation and Applications

UNIT IV: METHODS OF SEPARATION–I (15L)

4.1. Gas Chromatography (8L)

4.1.1. Introduction, Principle, Theory and terms involved

4.1.2. Instrumentation: Block diagram and components, types of columns, stationary phases in GSC and GLC, Detectors: TCD, FID, ECD

4.1.3. Qualitative, Quantitative analysis and applications

4.1.4. Comparison between GSC and GLC

4.2. High Performance Liquid chromatography (HPLC) (7L)

4.2.1. Introduction and Principle, Instrumentation- components with their significance: Solvent Reservoir, Degassing system, Pumps- (reciprocating pumps, screw driven- syringe type pumps, pneumatic pumps, advantages and disadvantages of each pump), Precolumn, Sample injection system, HPLC Columns, Detectors (UV–Visible detector, Refractive index detector)

4.2.2. Qualitative and Quantitative Applications of HPLC

Semester VI

UNIT I: ELECTRO ANALYTICAL TECHNIQUES (15L)

1.1. Polarography (10L)

1.1.1. Introduction to voltametric methods of analysis
1.1.2. Principles of polarographic analysis, Dropping Mercury Electrode, Instrument and working of polarographic apparatus,
1.1.3. Ilkovic equation and quantitative analysis, Polarogram and chemical analysis,
1.1.4. Factors affecting polarographic wave, Quantitative Applications, Numerical Problems

1.2. Amperometric Titrations (5L)

1.2.1. Principle, Rotating Platinum Electrode (Construction, advantages and limitations)
1.2.2. Titration curves with example
1.2.3. Advantages and limitations

UNIT II: METHODS OF SEPARATION-II & INTRODUCTION TO QUALITY (15L)

2.1 High Performance Thin Layer Chromatography (HPTLC) (5L)

2.1.1 Introduction and Principle, Stationary phase, Sample application and mobile phase
2.1.2 Detectors
a) Scanning densitometer- components, Types of densitometers: Single beam and Double beam,
b) Fluorometric Detector
2.1.3 Advantages, disadvantages and applications
2.1.4 Comparison of TLC and HPTLC

2.2 Ion Exchange Chromatography (6L)

2.2.1 Introduction, Principle.
2.2.2 Types of Ion Exchangers, Ideal properties of resin
2.2.3 Ion Exchange equilibria and mechanism, selectivity coefficient and separation factor
Factors affecting separation of ions
2.2.4 Ion exchange capacity and its determination for cation and anion exchangers.
2.2.5 Applications of Ion Exchange Chromatography with reference to: Preparation of demineralized water, Separation of amino acids.

2.3 Quality in Analytical Chemistry (4L)

2.3.1 Concepts of Quality, Quality Control and Quality Assurance
2.3.2 Chemical Standards and Certified Reference Materials; Importance in chemical analysis
2.3.3 Quality of material: Various grades of laboratory reagents.

Topic for Self-Study:

Solvent Extraction: Introduction, Nernst Distribution law,
Factors affecting extraction: Chelation, Ion pair formation and Solvation
Craig's counter current extraction: Principle, apparatus and applications

UNIT III: FOOD AND COSMETICS ANALYSIS (15L)

3.1. Introduction to food chemistry (10L)

3.1.1. Food processing and preservation:
Introduction, need, chemical methods, action of chemicals (Sulphur dioxide, boric acid, sodium benzoate, acetic acid, sodium chloride and sugar) and pH control, Physical methods (Pasteurization and Irradiation)
3.1.2. Determination of boric acid by titrimetry and sodium benzoate by HPLC.
3.1.3. Study and analysis of food products and detection of adulterants:
1) Milk: Composition & nutrients, types of milk (fat free, organic and lactose milk), Analysis of milk for lactose by Lane Eynon's Method
2) Honey: Composition, Analysis of reducing sugars in honey by Coles Ferricyanide method
3) Tea: Composition, types (green tea and mixed tea), Analysis of Tannin by Lowenthal's method
4) Coffee: Constituents and composition, Role of Chicory, Analysis of caffeine by Bailey Andrew method

3.2. Cosmetics (5L)

Introduction and sensory properties
Study of cosmetic products:
1) Face powder: Composition, Estimation of calcium and magnesium by complexometry
2) Lipstick: Constituents, Ash analysis for water soluble salts: borates, carbonates and zinc oxide
3) Deodorants and Antiperspirants: Constituents, properties, Estimation of zinc by gravimetrically.

UNIT IV: THERMAL METHODS AND ANALYTICAL METHOD VALIDATION

4.1. Thermal Methods (12L)

4.1.1 Introduction to various thermal methods (TGA, DTA and Thermometric titration)

4.1.2. Thermogravimetric Analysis (TGA)

Instrumentation-block diagram, thermobalance (Basic components: balance, furnace, temperature measurement and control, recorder)
Thermogram (TG curve) for $CaC_2O_4.H_2O$ and $CuSO_4.5H_2O$
Factors affecting thermogram-Instrumental factors and Sample characteristics
Applications:
Determination of drying and ignition temperature range
Determination of percent composition of binary mixtures
(Estimation of Calcium and Magnesium oxalate)

4.1.3. Differential Thermal Analysis (DTA):

Principle**,** Instrumentation, and Reference material used
Differential thermogram (DTA curve) $CaC_2O_4 .H_2O$ and
$CuSO_4.5H_2O$
Applications, Comparison between TGA and DTA.

Reference Books:

Physical Chemistry

1. Physical Chemistry, Ira Levine, 5th Edition, 2002 Tata McGraw Hill Publishing Co.Ltd.
2. The Elements of Physical Chemistry, P.W. Atkins, Oxford University Press, Oxford..
3. Modern Electrochemistry, J.O.M Bockris& A.K.N. Reddy, Maria Gamboa – Aldeco 2nd Edition, 1st Indian reprint,2006 Springer
4. Physical Chemistry, G.M. Barrow, 6th Edition, Tata McGraw Hill Publishing Co. Ltd. New Delhi.
5. The Elements of Physical Chemistry, P.W. Atkins, 2nd Edition, Oxford UniverstityPress Oxford
6. Physical Chemistry, G.K. Vemullapallie, 1997, Prentice Hall of India, Pvt.Ltd. New Delhi.

Inorganic Chemistry

1. D. Banerjea, Coordination chemistry, Tata McGraw Hill, New Delhi, (1993).
2. D. F. Shriver and P. W. Atkins, Inorganic chemistry, 3rd Ed., Oxford University Press, (1999).
3. N. N. Greenwood and E. Earnshaw, Chemistry of elements,Pergamon Press, Singapore, (1989).
4. W. L. Jolly, Modern inorganic chemistry, 2nd Ed. McGraw Hill Book Co., (1991).
5. B. E. Douglas and H. McDaniel, Concepts and models in inorganic chemistry, 3rd Ed., John Wiley & Sons, Inc., New York, (1994).
6. G. N. Mukherjee and A. Das, Elements of bioinorganic chemistry, Dhuri and Sons, Calcutta, (1988).
7. R. W. Hay, Bioinorganic chemistry, Ellis Harwood, England, (1984).
8. R. C. Mehrotra and A. Singh, Organometallic chemistry: A unified approach, Wiley Eastern, New Delhi, (1991)

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1. Organic Chemistry, Francis A Carey, Pearson Education, 6th Edition, Special Indian Edition 2008.
2. Organic Chemistry, R.T. Morrison and R.N. Boyd, 6th Edition, Pearson Edition.
3. Organic Chemistry, T.W.G. Solomon and C.B. Fryhle, 8th Edition, John Wiley & Sons, 2004.
4. Organic Chemistry Baula Y. Bruice, Pearson Edition, 2008.
5. Organic Chemistry, J.G. Smith, 2nd Edition Special Indian Edition, Tata. McGraw Hill.
6. Stereochemistry, P.S. Kalsi, New Age International Ltd. 4th Edition,2006
7. Organic Spectroscopy by Jag Mohan
8. Furniss, B. S.; Hannaford, A. J.; Rogers, V.; Smith, P. W. G.; Tatchell, A. R. Vogel's Textbook of Practical Organic Chemistry, ELBS.

Analytical Chemistry

1. D. Harvey, Modern Analytical Chemistry, The McGraw-Hill Pub. 1st Edition (2000)
2. H.S. Ray, R Sridhar and K.P. Abraham, Extraction of Nonferrous Metals, Affiliated East-West Press Pvt. Ltd. New Delhi (1985) reprint 2007.
3. G.H. Jeffery, J. Bassett, J. Mendham and R.C. Denney, Vogel's Textbook of Quantitative Chemical Analysis, Fifth edition, ELBS Publication (1996)
4. D.A. Skoog D.M. West and F.J. Holler, Fundamentals of Analytical Chemistry, 7th Edition (printed in India in 2001) ISBN Publication.
5. Analytical Chemistry, J.G. Dick,1973 Tata McGraw Hill Publishing Co. Ltd. New Delhi.
6. Quantitative analysis, Dey& Underwood, Prentice Hall of India, Pvt. Ltd. New Delhi
7. Fundamentals of Analytical Chemistry, Skoog 8th edition, Saunders college publishing

Chemistry Practicals

Semester V

Paper I: Physical Chemistry

Non-Instrumental

1. Colligative Properties

To determine the molecular weight of compound by Rast Method

2. Chemical Kinetics

To determine the order between $K_2S_2O_8$ and KI by fractional change method.

3. Surface Phenomena

To investigate the adsorption of acetic acid on activated charcoal and test the validity of Freundlich adsorption isotherm.

Instrumental

1. Conductometry

To determine the velocity constant of alkaline hydrolysis of ethyl acetate by conductometric method.

2. Potentiometry

To determine the number of electrons in the redox reaction between ferrous ammonium sulphate and cerric sulphate potentiometrically.

Paper II: Inorganic Chemistry

I. Inorganic preparations

1. Preparation of Potassium diaquobis-(oxalato)cuprate (II)
2. Preparation of Ferrous ethylene diammonium sulphate.
3. Preparation of bisacetylacetonatocopper (II)

II. Determination of percentage purity of the given water-soluble salt and qualitative detection w.r.t added cation and/or anion (qualitative analysis only by wet tests).

(Any three salts of transition metal ions)

Paper III: Organic Chemistry

Separation of Binary solid-solid mixture (2.0 gms mixture to be given).

1. Minimum Six mixtures to be completed by the students.
2. Components of the mixture should include water soluble and water insoluble acids (carboxylic acid), water insoluble phenols (2-naphthol, 1-naphthol), water insoluble bases (nitroanilines), water soluble neutral (thiourea) and water insoluble neutral compounds (anilides, amides, m-DNB, hydrocarbons) After correct determination of chemical type, the separating reagent should be decided by the student for separation.
4. Follow separation scheme with the bulk sample of binary mixture.
5. After separation into component A and component B, one component (decided by the examiner) is to be analyzed and identified with melting point.

Paper IV: Analytical Chemistry

1. Spectrophotometric estimation of fluoride
2. Estimation of magnesium content in Talcum powder by complexometry, using standardized solution of EDTA
3. Determination of COD of water sample.
4. To determine potassium content of a Fertilizer by Flame Photometry (Calibration curve method).
5. To determine the amount of persulphate in the given sample solution by back titration with standard Fe (II) ammonium sulphate solution.
6. To determine the amount of sulphate in given water sample turbidimetrically.

[Note: Calculation of percent error is expected for all the experiments.]

Semester VI

Paper I: Physical Chemistry

Non-Instrumental

1. Chemical Kinetics

To determine the energy of activation for the acid catalyzed hydrolysis of methyl acetate.

2. Viscosity

To determine the molecular weight of high polymer polyvinyl alcohol (PVA) by viscosity measurement.

Instrumental

1. Potentiometry

To determine the solubility product and solubility of AgCl potentiometrically using chemical cell.

2. Conductometry

To titrate a mixture of weak acid and strong acid against strong base and estimate the amount of each acid in the mixture conductometrically.

3. pH-metry

To determine acidic and basic dissociation constant of amino acid and hence calculate isoelectric point.

Paper II: Inorganic Chemistry

I. Inorganic preparations

1. Preparation of Tris(acetylacetonato)iron (III)
2. Green synthesis of bis(dimethylglyoximato)nickel (II) complex using nickel carbonate and sodium salt of dmg .
3. Preparation of potassium trioxalato aluminate (III)

II. Determination of percentage purity of the given water-soluble salt and qualitative detection w.r.t added cation and/or anion (qualitative analysis only by wet tests).

(Any three salts of main group metal ions)

Paper III: Organic Chemistry

Separation of Binary liquid-liquid and liquid- solid mixture.

1. Minimum Six mixtures to be completed by the students.
2. Components of the liquid-liquid mixture should include volatile liquids like acetone, methylacetate, ethylacetate, isopropylalcohol, ethyl alcohol, EMK and non-volatile liquids like chlorobenzene, bromobenzene, aniline, N,N-dimethylaniline, acetophenone, nitrobenzene, ethyl benzoate.
3. Components of the liquid-solid mixture should include volatile liquids like acetone, methylacetate, ethylacetate, ethyl alcohol, IPA, EMK and solids such as water insoluble acids, phenols, bases, neutral.
4. A sample of the mixture one ml to be given to the student for detection of the physical type of the mixture.
5. After correct determination of physical type, separation of the binary mixture to be carried out by distillation method using microscale technique.
6. After separation into component A and component B, the compound to be identified can be decided by examiner.

Paper IV: Analytical Chemistry

1. Estimation of Chromium in water sample spectrophotometrically by using Diphenyl carbazide.
2. Estimation of reducing sugar in honey by Willstatter method.
3. Estimation of Mg^{+2} and Zn^{+2} by using anion exchange resin.
4. Estimation of acetic acid in Vinegar sample by using Quinhydrone electrode potentiometrically.
5. Determination of phosphoric acid in cola sample pH metrically.

[Note: Calculation of percent error is expected for all the experiments.]

Reference Books for Practicals:

Physical Chemistry

1. Practical Physical Chemistry 3rd edition A.M.James and F.E. Prichard , Longman publication
2. Experiments in Physical Chemistry R.C. Das and B. Behra, Tata Mc Graw Hill
3. Advanced Practical Physical Chemistry J.B.Yadav, Goel Publishing House
4. Advanced Experimental Chemistry. Vol-I J.N.Gurtu and R Kapoor, S.Chand and Co.
5. Experimental Physical Chemistry By V.D.Athawale.
6. Senior Practical Physical Chemistry By: B. D. Khosla, V. C. Garg and A. Gulati, R Chand and Co. 2011

Inorganic Chemistry

1. Vogel Textbook of Quantitative Chemical Analysis G.H. Jeffery, J. Basset.
2. Advanced experiments in Inorganic Chemistry., G. N. Mukherjee., 1st Edn., 2010., U.N.Dhur & Sons Pvt Ltd .
3. Vogel's. Textbook of. Macro and Semimicro qualitative inorganic analysis. Fifth edition.
4. Practical Inorganic Chemistry by G. Marr and B. W. Rockett,VanNostrand Reinhold Company London1972. P 34. (For synthesis of iron ethylenediamine sulphate)
5. D. F. Shriver and P. W. Atkins, Inorganic chemistry, 3rd Ed., Oxford University Press, (1999).

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1. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
2. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000). Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organi chemistry, 5th Ed., Pearson (2012)
4. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996

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1. Principles of Instrumental Analysis, 5th Edition, By Skoog, Holler, Nieman.
2. Principles of Polarography by Jaroslav Heyrovský , Jaroslav Kůta, 1st Edition, Academic Press, eBook ISBN: 978148326478.
3. Solvent extraction and ion exchange, J Marcus and A. S. Kertes Wiley INC 1969. 4. D.A. Skoog D.M. West and F.J. Holler, Fundamentals of Analytical Chemistry, 7th Edition (printed in India in 2001) ISBN Publication.
4. Analytical Chemistry, J.G. Dick,1973 Tata McGraw Hill Publishing Co. Ltd. New Delhi.
5. Quantitative analysis, Dey& Underwood, Prentice Hall of India, Pvt. Ltd. New Delhi
6. Fundamentals of Analytical Chemistry, Skoog 8th edition, Saunders college publishing