UNIVERSITY OF MUMBAI
No. UG/ /56 of 2016-17

CIRCULAR:-

A reference is invited to the Syllabi relating to the B.Sc. degree course , **vide** this office Circular No. UG/98 of 2015-16, dated 13th October, 2016 and the Principals of affiliated Colleges in Science are hereby informed that the recommendation made by the Ad-hoc Board of Studies in Chemistry at its meeting held on 7th July, 2016 has been accepted by the Academic Council meeting held on 14th July, 2016 **vide** item No. 4.13 and that in accordance therewith, the revised syllabus as per the Choice Based Credit System for T.Y. B.Sc. programme in Chemistry (Sem. V & VI), which are available on the University's web site (www.mu.ac.in) and that the same has been brought into force with effect from the academic year 2016-17.

16/11/16

(Dr.M.A.Khan)
REGISTRAR

MUMBAI – 400 032
16 November, 2016

To,

The Principals of the affiliated Colleges in Science.

A.C/4.13/14.07.2016

****

No. UG/ /56A of 2016 MUMBAI-400 032 16 November, 2016

Copy forwarded with Compliments for information to:-

1) The Co-ordinator, Faculties of Science,
2) The Chairman, Board of Studies in Chemistry,
3) The Professor-cum-Director, Institute of Distance & Open Learning (IDOL)
4) The Director, Board of College and University Development,
5) The Co-Ordinator, University Computerization Centre,
6) The Controller of Examinations.

16/11/16

(Dr.M.A.Khan)
REGISTRAR

PTO..

UNIVERSITY OF MUMBAI

Syllabus for sem V & VI
Program: B.Sc.
Course: CHEMISTRY

(Credit Based Semester and Grading System with effect from the academic year 2016–2017)

T.Y.B.Sc.
CHEMISTRY
Credit Based Semester and Grading System
To be implemented from the Academic year 2016-2017

SEMESTER V
Theory

Course	UNIT	TOPICS	Credits	L / Week
USCH501	**I**	**1.1 Colligative Properties of Dilute Solutions (8L)** **1.1.1** Dilute solution, colligate properties, Raoult's law, relative lowering of vapour pressure. **1.1.2** Elevation in boiling point of a solution, thermodynamic derivation relating elevation in the boiling point of a solution and the molar mass of the non-volatile solute. **1.1.3** 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. **1.1.4** Osmotic pressure, van't Hoff's equation for osmotic pressure, (derivation is expected) and determination of molar mass of the solute. Abnormal molar masses of solutes and van't Hoff factor (calculation of Degree of Association and Degree of Dissociation.) **1.2 Phase Rule (7L)** **1.2.1** Gibb's phase rule and terms involved in the equation. **1.2.2** Application of phase rule to ONE component systems (i) water system, (ii) sulphur system **1.2.3** Application of phase rule to TWO component systems, condensed systems, condensed phase rule, eutectic systems (Lead-Silver system), desilverisation of lead. **1.2.4** Introduction to three component system, explanation of phase diagram for three liquids forming one immiscible pair.	**2.5**	**1**

	II	**2.1 Surface Chemistry & Catalysis (9L)** **2.1.1 Adsorption:** Physical and Chemical Adsorption, types of adsorption isotherms **.** Langmuir's adsorption isotherm (Postulates and derivation expected). B.E.T. equation for multilayer adsorption, (derivation not expected). significance of the terms involved in the equation is expected.),determination of surface area of an adsorbent using B.E.T. equation. Numericals on surface area determination are expected. **2.1.2 Catalysis:** Homogeneous and heterogeneous catalysis, catalytic activity and selectivity, promoters, inhibitors, catalyst poisoning and deactivation, **2.1.3 Acid-Base catalysis**, mechanism and kinetics of acid-base catalyzed reactions, effect of pH on acid-base catalyzed reactions. Mechanism and kinetics of enzyme catalyzed reaction (Michaelis-Menten equation). **2.2 Colloids (6L)** **2.2.1** Introduction to colloidal state of matter. **2.2.2** Origin of charge on colloidal particles. Concept of electrical double layer, zeta potential, Helmholtz and Stern model, Electro-kinetic phenomena:1.Electrophoresis, 2.Electrophoresis , 3. Streaming potential 4. Sedimentation potential . **2.2.3** Colloidal electrolytes. **2.2.4** Donnan Membrane Equilibrium. **2.2.5** Surfactants, micelle formation, applications of surfactants in detergents, food industry, in pesticide formulations.		
	III	**3.1 Electrochemistry – Electrochemical cells (15L)** **3.1.1** Lewis concept of Activity and Activity coefficient, Mean ionic activity and mean ionic activity coefficient γ_{+-} of an electrolyte, expression for activities of electrolytes of different valence type, ionic strength		

		3.1.2 Classification of cells: 1.chemical cells without transference 2.Concentration cells with and without transference (derivations of expression for concentration cell EMF are expected) Origin of liquid-liquid junction potential and its elimination using a salt bridge. **3.1.3** Applications of EMF .measurements in the determination of **1.** pH of a solution using quinhydrone and glass electrode. **2** solubility and solubility product of sparingly soluble salts using chemical cell and concentration cell method **3**. determination of liquid-liquid junction potential .		
	IV	**4.1 Introduction to Polymers (8L)** **4.1.1 Basic terms** : macromolecule, monomer, repeat unit, degree of polymerization. **4.1.2. Classification of polymers** based on (i) source, (ii) structure, (iii) thermal response, (iv) physical properties. **4.1.3. Molar masses of polymers**: 1. Number average molar mass, 2.Weight average molar mass, 3. Viscosity average molar mass, monodispersity, polydispersity. **4.1.4. Methods of determining molar masses of polymers** : 1. Ultrcentrifuge method (Limiting velocity method only). Viscosity method (Mark-Houwink equation). **4.1.5. Introduction to light emmiting polymers** (characteristics, method of preparation and it's application are expected). **4.2 Crystalline State (7L)** **4.2.1. Laws of Crystallography** **4.2.2**. Characteristics of simple cubic, face centered and body centered cubic system, inter planar distance in cubic lattices (only expressions for ratios of inter planar distances are expected). **4.2.3.** Use of X- rays in the study of crystal structure, Bragg's equation (derivation expected), X- ray diffraction method of studying crystal lattices, structure of NaCl and KCl,		**1**

		determination of Avagadro number. **4.2.4.** Elementary idea of defects in crystals- Frenkel defect and Schottky defect.		
USCH502	**I**	**1. Chemical Bonding And Solid State Chemistry (15L)** **1.1 Molecular Symmetry (7L)** **1.1.1** Introduction and Importance. **1.1.2** Symmetry elements and symmetry operations. **1.1.3** Concept of a Point Group with illustrations using the following point gro ups: (i) $C_{\alpha v}$ (HCl), (ii) $D_{\alpha h}$ (H_2), (iii) C2v (H_2O), (iv) C_{3v} (NH_3), (v) C_{2h} (trans – trichloroethylene), and (vi) D_{3h} (BCl_3). **1.2 Molecular Orbital Theory for Polyatomic Species (5L)** **1.2.1** Simple triatomic species: H_3^+ and H_3 (correlation between bond angle and Molecular orbitals). Term such as Walsh correlation diagram, Symmetry Adapted Linear Combinations (SALCs), Ligand Group orbitals (LGOs), transformation of atomic orbitals into appropriate symmetry types, expected to be discussed **1.3 (3L)** Other molecules (considering only σ-bonding): i) BeH_2, ii) H_2O, Explanation of terms viz.crystal lattice, lattice points, unit cells and lattice constants.	**2.5**	**1**

	II	**2. Solid Materials (15L)** **2.1 Structures of Solids (10L)** **2.1.1** Importance of solid state chemistry. **2.1.2** Classification of solids on the basis of bonding. **2.1.3** Closest packing of rigid spheres (hcp, ccp), packing density in simple cubic, bcc, fcc and hcp lattices (numerical problems expected). Point defects with respect to Frenkel and Schottky defects expected. **2.1.4** Structure metallic solids. **2.1.5** Tetrahedral and octahedral interstitial voids in ccp lattice, tetrahedral holes,limiting radius ratios for different coordination numbers and their significance, calculation of limiting radius ratio for coordination number 4. **2.1.7** Structures of sodium chloride and cesium chloride. **2.2 Superconductivity (05L)** **2.2.1** Superconductivity, Meissner effect. **2.2.2** Different superconducting materials viz,convential superconductors, organic superconductors, alkali metal fullerides (A_3C_{60}) and high temperature Superconductors. **2.2.3** Applications of superconducting materials.		**1**
	III	**3. Chemistry of elements (15L)** **3.1 Inner transition elements (3L)** **3.1.1** Introduction: position of f-block elements and comparison between lanthanides and actinides **3.1.2** The shapes of *f*-orbitals. **3.1 Lanthanides Series (10L)** **3.2.1** Chemistry of lanthanides with reference to (i) lanthanide contraction, (ii) Oxidation states (iii) magnetic and spectral properties, **3.2.2** Occurrence, extraction and separation of lanthanides by Solvent extraction. **3.2.3** Applications of lanthanides.		**1**

		3.3 Actinides Series (2L) **3.3.1 Chemistry** of Uranium and with reference to occurrence, extraction (solvent extraction method), **3.3.2** Properties and applications.		
	IV	**4. Solution Chemistry** **4.1 Acid-base Chemistry in Aqueous Medium (8L)** **4.1.1 Acidity** of mono- and polyatomic cations. **4.1.2** Basicity of mono- and polyatomic anions (discussion for 4.1.1 as well as 4.1.2 to Include Latimer equation and predominance diagrams). **4.2 Chemistry in Non-aqueous Solvents (7L)** **4.2.1** Classification of solvents and importance of non-aqueous solvents. **4.2.2** Characteristics and study of liquid ammonia, dinitrogen tetraoxide and acetic acid as non-aqueous solvents with respect to (i) acid-base reactions and (ii) redox reactions.		**1**
USCH503	**I**	**1.1. Mechanism of Organic Reactions (15L)** 1.1.1 Thermodynamic and Kinetic control of organic reactions: Concept with mechanisms of the following reactions: addition of HX to butadiene; sulfonation of naphthalene. Nucleophilicity/ electrophilicity vs Basicity/acidity. 1.1.2 Mechanism of elimination reactions, with stereochemistry: E1 and E2 reactions: regioselectivity (Saytzeff and Hofmann rules). 1.1.3 Mechanism of reactions of carbonyl compounds with nucleophiles: 1.1.3.1 Formation of acetals/ketals from aldehydes and ketones. 1.1.3.2 Reaction of aldehydes and ketones with primary and secondary amines. 1.1.3.3 Acyl nucleophilic substitution (tetrahedral mechanism): Acid catalysed esterification of Carboxylic acids and base promoted hydrolysis of esters. 1.1.4 Mechanism of rearrangements with examples and stereochemistry wherever applicable. 1.1.4.1 Migration to electron deficient carbon: Pinacol,	**2.5**	**1**

		Benzylic acid. 1.1.4.2 Migration to electron deficient nitrogen: Beckmann, Hofmann. 1.1.5 Mechanism of the following reactons with synthetic application: Claisen condensation, Michael addition.		
	II	**2. Stereochemistry (15L)** 2.1.1 Molecular chirality and element of symmetry: Mirror Plane symmetry (inversion centre), rotation-reflection (alternating) axis, Chirality of compounds without stereogenic centre: cummulenes, spirans and biphenyls. 2.1.2 Stability ofcycloalkanes: Strains in cycloalkanes-angle,eclipising, transannular (3 to 8 membered). Conformations of cyclohexane, mono- and di- alkyl cyclohexanes and their relative stabilities. 2.1.3 Stereo selectivity and Stereo specificity: Idea of enantioselectivity (ee) and diastereoselectivity (de).Topicity-enantiotopic and diastereotopic atoms, groups and faces. **Stereochemistry of-** (1) Substitution reactions- S_N1, S_N2, S_Ni (reaction of alcohol with thionyl chloride). (2) E_2-anti-elimination-Base induced dehydrohalogenation of 1-bromo-1,2- diphenylpropane. (3) Addition reactions to olefins-i) catalytic hydrogenation ii) bromination (electrophilic anti addition) (iii)syn-hydroxylation (molecular addition) with OsO_4 and $KMnO_4$.		**1**
	III	**3.1 Carbohydrates (10L)** 3.1.1 Introduction: Classification, Sources, Reducing and non-reducing sugars DL notation. 3.1.2 Structures of monosaccharides: Fischer projection (4-6 carbon monosaccharides and Haworth formula-Furanose and pyranose forms of pentoses and hexoses. Interconversion :open and Haworth forms of monosaccharides with 5 and 6 carbons. Chair conformation with stereochemistry of D-glucose and D-fructose. Stability of chair forms of D-		**1**

		glucose. 3.1.3 Determination of open chain configuration- of D-glucose assuming the configuration of D-arabinose; and of D-fructose assuming the configuration of D-glucose. 3.1.4 Anomers and epimers of monosaccharides. Enantiomers and diastereomers of glucose. Mutarotation (with mechanism) in D-glucose. 3.1.5 Chain lengthening and shortening reaction: Modified kiliani-fischer synthesis. Wohl method. 3.1.6 Reactions of D-glucose and D-fructose: (a) osazone formation (b) reduction- H_2/Ni, $NaBH_4$ c)oxidation- bromine water, HNO_3, HIO_4. D) interconversion of D-glucose and D-fructose e) acetylation f) methylation [e and f with cyclic pyranose form]. 3.1.7 Commercial importance of carbohydrates in pharmaceutical, paper,food and Textile industries. **3.2. IUPAC Nomenclature (5L)** IUPAC systematic and accepted trivial nomenclature of the following classes of compounds, including substituted ones (up to 2 substituents/ functional groups): **3.2.1** (a)Bicyclic compounds- spiro-,fused, and bridged (upto 11carbon atoms)-saturated and unsaturated compounds. **3.2.2** (b) Biphenyls. **3.2.3** (c) Cummulenes upto 3 double bonds (d) Monocyclic (5 and 6 membered) aromatic and non-aromatic heterocyclic compounds containing a maximum of two hetero atoms among N,O,S. **3.1.1**Introduction:Classification, Sources, Reducing and non-reducing sugars DL notation. **3.1.2** Structures of monosaccharides: Fischer projection (4- 6 carbon monosaccharides and Haworth formula-Furanose and pyranose forms of pentoses and hexoses. Interconversion :open and Haworth forms of monosaccharides with 5 and 6 carbons. Chair conformation with		

		stereochemistry of D-glucose and D-fructose. Stability of chair forms of D-glucose. **3.1.3** Determination of open chain configuration- of D-glucose assuming the configuration of D-arabinose; and of D-fructose assuming the configuration of D-glucose. **3.1.4** Anomers and epimers of monosaccharides. Enantiomers and diastereomers glucose. Mutarotation (with mechanism) in D-glucose. **3.1.5** Chain lengthening and shortening reaction: Modified kiliani-fischer synthesis. Wohl method. **3.1.6** Reactions of D-glucose and D-fructose: (a) osazone formation (b) reduction- H_2/Ni, $NaBH_4$ c)oxidation-bromine water, HNO_3, HIO_4. D) interconversion of D-glucose and D-fructose e) acetylation f) methylation [e and f with cyclic pyranose form]. **3.2. IUPAC Nomenclature (5L)** IUPAC systematic and accepted trivial nomenclature of the following classes of compounds, including substituted ones (up to 2 substituents/functional groups): **3.2.1** (a)Bicyclic compounds- spiro-,fused, and bridged (upto 11carbon atoms)-saturated and unsaturated compounds. **3.2.2** (b) Biphenyls. **3.2.3** (c) Cummulenes upto 3 double bonds (d) Monocyclic (5 and 6 membered) aromatic and non-aromatic heterocyclic compounds containing a maximum of two hetero atoms among N,O,S.		
	IV	**4.1. Heterocyclic Chemistry (8L)** **4.1.1** Introduction: Electronic structure and aromaticity of furan, pyrrole,thiophene and pyridine. **4.1.2** Synthesis: Synthesis of furans, pyrroles, and thiophenes by Paal-Knor synthesis. Pyridines by Hantzsch synthesis and from 1,5-diketones. **4.1.3** Reactivity: Reactivity towards electrophilic substitution reactions- of furan, pyrrole and thiophene on basis		**1**

		of stability of intermediate; and of pyridine on the basis of electron distribution.Nucleophilic substitution reaction of pyridine on the basis of electron distribution. **4.1.4** Reactions of heterocycles: The following reactions of furan, pyrrole and thiophene: Halogenation , Nitration, Sulphonation, Vilsmeir formylation reaction, Friedel-Crafts reaction. Furan: Diels-Alder reaction. Ring opening of furan. Pyrrole: Acidity and basicity of pyrrole -Comparison of basicity of pyrrole and pyrrolidine, Acid catalyzed polymerization of pyrrole. Pyridine: Basicity. Comparison of basicity of pyridine, pyrrole and piperidine. Sulphonation of pyridine, with and without catalyst. Reduction.Oxidation of alkyl pyridines and action of sodamide (Chichibabin reaction).N-methylation of pyridine. Quaternization of piperdine, pyrrolidine and Hofmann elimination of the quaternary salts. **4.2. Organic Synthesis (7L)** **4.2.1** Introduction: Criteria for ideal organic synthesis. Yield and selectivity. Multi- component synthesis – with examples, Mannich reaction, Hanztsch synthesis of pyridines (without mechanism). **4.2.2** Illustrative synthesis of industrially important compounds: Ibuprofen (chiral synthesis), paracetamol (green synthesis), L-ascorbic acid (from D-glucose), norfloxacin, thyroxine, vanillin, methyl dihydrojasmonate (Hedione), Bifenox-I, pigment red 242, indigo, 2-hydroxy-3-amino-5-nitrobenzene sulphonic acid. **4.2.3** Newer methods of organic synthesis: Introduction to the use of the following in organic synthesis: Ultrasound, microwaves, PTC. **4.1.1** Introduction: aromaticity of furan,pyrrole,thiophene and pyridine. **4.1.2** Synthesis: Synthesis of furans, pyrroles, and thiophenes by Paal-Knor synthesis. Pyridines by Hantzsch		

		synthesis and from 1,5-diketones. **4.1.3** Reactivity: Reactivity towards electrophilic substitution reactions- of furan, pyrrole and thiophene on basis of stability of intermediate; and of pyridine on the basis of electron distribution. Nucleophilic substitution reaction of pyridine on the basis of electron distribution. **4.1.4** Reactions of heterocycles: The following reactions of furan, pyrrole and thiophene: Vilsmeir formylation reaction, Friedel-Crafts reaction. Furan: Diels-Alder reaction. Ring opening of furan. Pyrrole: Acidity and basicity of pyrrole-Comparison of basicity of pyrrole and pyrrolidine, Acid catalyzed polymerization of pyrrole. Pyridine: Basicity. Comparison of basicity of pyridine, pyrrole and piperidine. Sulphonation of pyridine, with and without catalyst. Reduction.Oxidation of alkyl pyridines and action of sodamide (Chichibabin reaction). N-methylation of pyridine.Quaternization of piperdine, pyrrolidine and Hofmann elimination of the quaternary salts. **4.2. Organic Synthesis (7L)** **4.2.1** Introduction: Criteria for ideal organic synthesis. Yield and selectivity. Multi- component synthesis – with examples, Mannich reaction, Hanztsch synthesis of pyridines (without mechanism). **4.2.2** Illustrative synthesis of industrially important compounds: Ibuprofen (chiral synthesis), paracetamol (green synthesis), L-ascorbic acid (from D-glucose), norfloxacin, nalidixic acid, vanillin, methyl dihydrojasmonate (Hedione), Bifenox-I, pigment red 242, 2-hydroxy-3-amino-5-nitrobenzene sulphonic acid. **4.2.3** Newer methods of organic synthesis: Introduction to the use of the following in organic synthesis: Ultrasound, microwaves, PTC.		

USCH504	**I**	**1. Treatment of analytical data-I and sampling (15 L)** **1.1 Treatment of Analytical Data (7L)** Types of errors, determinate and indeterminate errors, minimization of errors, constant and proportionate errors, accuracy and precision, measures of dispersion and central tendency: mean, median, average deviation, relative average deviation, standard deviation, variance, coefficient of variation.[Numerical problems expected] **1.2 Sampling (8L)** Terms involved, importance of sampling, sampling techniques, sampling of gases, ambient and stack sampling, equipment used, sampling of homogeneous and heterogeneous liquids, sampling of static and flowing liquids, methods and equipments used, sampling of solids, importance of particle size and sample size, samples used, need for the reduction in the sample size, methods of reduction in sample size, collection, preservation and dissolution of the sample.	**2.5**	**1**
	II	**2. Titrimetric analysis-I and UV-Visible spectroscopy. (15L)** **2.1 Acid-base Titrations (5L)** Construction of titration curves and choice of indicators in the titration of [1] strong acid and strong base, [2] strong acid and weak base, [3] weak acid and strong base, [4] weak acid and weak base. **2.2 Precipitation titrations (4L)** Argentimetric titrations, construction of the titration curve, Volhard's method, Mohr's method, adsorption indicators, theory and applications**.** **2.3 U.V. Visible Spectroscopy (4L)** Photometers and spectrophotometers, Instrumentation in the case of single and double beam spectrophotometers, Qualitative and quantitative analysis, calibration cure method.		**1**

	III	**3. Methods of separation-I (15L)** **3.1 Solvent Extraction (8L)** Partition coefficient and distribution ratio, extraction efficiency, separation factor, role of complexing agents in solvent extraction, chelation, ion pair formation, solvation, types of solvent extraction: batch, continuous. [Numerical problems expected] **3.2 Chromatography (2L)** Introduction to chromatographic techniques, classification of chromatographic techniques. **3.3 Planar Chromatography (5L)** Principle, techniques and applications of [1] Paper chromatography [2] Thin layer chromatography		**1**
	IV	**4. Optical methods (15L)** **4.1 Atomic Spectroscopy (7L)** Absorption and emission spectra, energy level diagrams, process involved in atomization, flame photometry, flame atomizer, types of burners, monochromators and detectors, atomic absorption spectroscopy; flame and electrothermal atomizer, sources, instrumentation, quantitative applications of atomic absorption and flame photometry, calibration curve method, standard addition and internal standard method. **4.2 Molecular Fluorescence and Phosphorescence Spectroscopy (4L)** Theory, instrumentation and applications **4.3 Turbidimetry and Nephelometry (4L)** Scattering of light, effect of concentration, particle size and wavelength on light scattering, instrumentation and applications.		**1**

Practicals

USCHP05	**Practicals of Course USCH501** **<u>Physical Practicals</u>** **Chemical Kinetics –** To determine the order between $K_2S_2O_8$ & KI by fractional change method. **Viscosity** – To determine the molecular weight of high polymer polyvinyl alcohol (PVA) by viscosity measurement. **OR** To determine the radius of a glycerol molecule by viscosity measurement. **Potentiometry** – 1. To determine the amount of Fe(II) in the given solution by titration with a standard $K_2Cr_2O_7$ solution and hence to find the formal redox potential of Fe^{3+}/Fe^{2+} 2. To determine the solubility product and solubility of AgCl potentiometrically using chemical cell. **OR** 3. To determine the solubility product and solubility of AgCl potentiometrically using concentration cell. **Colorimetry –** To determine the amount of Fe(III) present in the given solution by using salicylic acid by colorimetric titration.(static method) (=525 nm) **pH –Metry –** To determine acidic and basic dissociation constants of amino acid hence to calculate isoelectric point. **Course USCH502** **<u>Inorganic Practicals</u>** **Inorganic preparations** 1. Potassium diaquo bis-(oxalate)cuprate (II)$K_2[Cu(C_2O_4)_2.(H_2O]$	**3**	**8**

	2. CuCl2-2DMSO 3. Bis(ethylene diamine)iron(II)sulphate[$C_2H_4(NH_2)_2FeSO_4.4H_2O$]. 4. Skill based Qualitative preparation of Chromium (II)acetate $Cr(OAc)_2$ so that the following outcomes are achieved: • Setting up reactor for Cr(II) ions • Identification of oxidation states of Chromium • Preparation of chromium(II)acetate • Isolation of the product		

	Volumetric analysis 1. Determination of magnesium from the supplied commercial sample of Milk of magnesia tablet 2. Estimation of Nickel(II)complexometrically using murexide indicator (Students are expected to standardize supplied EDTA solution using $ZnSO_4.7H_20$)		
USCHP06	**Practicals of Course USCH503** **Organic Practicals** i. Separation of binary (solid-slid) mixture.(Weights and physical constant of both crude components of the mixture are to be reported. (Minimum 4 mixtures) ii. Identification of an organic compound of known chemical type. (Minimum 4 mixtures) Syllabus for Organic Chemistry Sem-VI **Organic preparations** i. Acetylation of hydroquinone. ii. Nitration of nitrobenzene. iii. Hydrolysis of ethyl benzoate. iv. Bromination of acetanilide. **Course USCH504** **Analytical Practicals** 1. Estimation of persulphate in the given sample by the method of back titration. 2. Determination of the calcium and the magnesium content of a dolomite sample. 3. Determination of glucose content of a honey sample by Wilstater's method. 4. Determination of the amount of fluoride in the given solution colorimetrically. 5. Determination of Vitamin C content of a given tablet by titration with sodium hydroxide pH metrically	**3**	**8**

T.Y.B.Sc.
Chemistry
Credit Based Semester and Grading System
To be implemented from the Academic year 2016-2017

SEMESTER VI
Theory

Course	UNIT		Credits	L / Week
USCH601	I	**1.1 Molecular Spectroscopy –I (15L)** **1.1.1** Dipole moment: Dipole moment, polarization of a bond, bond moment, dipole moment and molecular structure. **1.1.2 Rotational Spectrum:** 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 inter nuclear distance and isotopic shift. **1.1.3 Vibration (IR) 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. **1.1.4 Vibration-Rotation spectrum of diatomic molecule v**ibrating rotor, energy levels, selection rule, nature of spectrum, R and P branches, anharmonic oscillator : energy levels, selection rule, fundamental band, overtones . Application of vibration-rotation spectrum in determining Force constant, determination and significance. Introduction to infrared spectra of simple molecules like H_2O and CO_2 **1.1.5 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.(example of CO_2molecule).	**2.5**	**1**
	II	**2.1 Basics of Quantum Chemistry (10L)** **2.1.1** Classical mechanics, limitations of classical mechanics, Black body radiation, photoelectric effect, Compton effect. **2.1.2** Introduction to quantum mechanics,		**1**

		Planck's theory of quantization, wave particle duality, de-Broglie equation, Heisenberg's uncertainty principle. **2.1.3** Progressive and standing waves, boundary conditions, Schrodinger's time independent wave equation(derivation not expected)., interpretation and properties of wave function. **2.1.4** Postulates of quantum mechanics (following are to be considered),1. state function and it's significance2. Concept of operators : definition, addition, subtraction and multiplication of operators, commutative and non- commutative operators, linear operator, Hamiltonian operator, 3. Eigen function and eigen value, eigen value equation. **2.2 Applied Electrochemistry (5L)** **2.2.1** Polarization, concentration polarization and it's elimination **2.2.2** Decomposition potential, experimental determination of decomposition potential, factors affecting decomposition potential (nature of electrolyte, nature of electrodes and temperature) Tafel's equation for hydrogen overvoltage, Overvoltage, experimental determination of over-voltage, **2.2.3** Electroplating ---objectives and procedures		
	III	**3.1 Renewable Energy Sources (5L)** **3.1.1.** Lithium ion cell. **3.1.2**. Fuel cells; Choice of fuel and oxidant, Bacon's H_2 and O_2 fuel cell. **3.1.3**. Solar cells, solar energy, photovoltaic effect, semiconductors as solar energy converters, silicon solar cell **3.1.4**. Hydrogen : Fuel of the future, production of hydrogen by direct electrolysis of water, advantages of hydrogen as a universal energy medium. **3.2 Nuclear Magnetic Resonance Spectroscopy (6L)** **3.2.1**. Nuclear spin, magnetic moment, nuclear 'g' factor, energy levels, Larmor precession, Relaxation processes in n.m.r. (spin-spin relaxation and spin-lattice relaxation). **3.2.2**. NMR Spectrometer, chemical shift, shielding and deshielding of protons, low resolution n.m.r. spectrum of methanol and ethanol.		**1**

		3.3 Chemical Kinetics (4 L) **3.3.1** Collision theory of reaction rates, application of collision theory to 1. uni-molecular reaction and 2. bimolecular reaction (Lindemann theory, derivation expected). Merits and drawbacks of collision theory. **3.3.2** Classification of reactions as slow, fast and ultra-fast. study of kinetics of fast reactions by Stop flow method.		
	IV	**4.1 Nuclear Chemistry** **4.1.1** Types of nuclear radiations and their characteristics, behaviour of ion pairs in electric field, detecton and measurement of nuclear radiations using G. M. Counter and Scintillation Counter. **4.1.2** Kinetics of radioactive decay, units of radioactivity (Curie, Bequerel, Rutherford) **4.1.3** Radioactive equilibrium (secular and transient), determination of radioactive constants for radio-elements having 1. moderate half life, 2. long half life 3.extremely long or short half life. **4.1.4** Use of radioisotpes as tracers in 1. chemical investigations- reaction mechanism, 2. age determination- dating by carbon-14 **4.1.5** Nuclear reactions – nuclear transmutation, artificial radioactivity Q-value of nuclear reaction, threshold energy. **4.1.6** 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.		**1**
USCH602	**I**	**Coordination Chemistry (15L)** **1.1 Crystal Field Theory (CFT)** **1.1.1** Basic tenets of Crystal field theory and effect of crystal field on central metal valence orbitals. **1.1.2** Splitting of *d* orbitals in octahedral, tetrahedral and square planar complexes. **1.1.3** Crystal field splitting energy ($10Dq$ or Δ_o) for octahedral complexes and factors affecting the magnitude of Δ_o. **1.1.4** Crystal field stabilization energy (CFSE), calculation of CFSE, for octahedral and tetrahedral complexes with	**2.5**	**1**

		d^1 to d^{10} metal ion configurations. **1.1.5** Effect of crystal field splitting on i) Ionic radius and ii) Lattice energy. **1.1.6** Theoretical failure of the CFT model. **1.1.7** Experimental evidence for co-valence in co-ordination compounds.(i) ESR spectrum of $[IrCl_6]^{2-}$ (ii) NMR spectrum of tris (acetyl acetanato) vanadium complex, (iii) Intensities of *d-d* transitions, and (iv) Nephelauxetic effect. Consequences of crystal field splitting on various properties such as ionic radii, hydration energy, lattice energy, enthalpies of formation, colour and magnetic properties. **1.2 Molecular Orbital Theory (MOT) of Coordination Complexes** **1.2.1** Application to octahedral complexes in case of (i) $[Ti(H_2O)]^{3+}$, (ii) Fluoro complexes of Fe(II) and Fe (III) and (iii) Cyano complexes of Fe(II) and Fe (III). **1.2.2** Effect of pi-bonding an ligand field splitting parameter in M→L and L→M interactions. **1.3 Electronic States and Terms for Polyelectronic Atoms** **1.3.1** Introduction: electronic configuration and electronic states, Term symbols, coupling of spin momenta (M_S),orbital momenta (M_l)and spin- orbit coupling or Russell-Saunders coupling. **1.3.2** Determination of Terms for p^2 electronic configuration (as in a carbon atom). **1.3.3** Terms and micro-states for transition metal atoms/ions.		
	II	**2. Properties of Coordination compounds (15L)** **2.1 Stability of Complexes (5L)** **2.1.1** Thermodynamic stability and kinetic stability of complexes with examples. **2.1.2** Stability constants: Stepwise and overall constants and their inter-relationship. **2.1.3** Factors affecting thermodynamic stability. **2.1.4** Potentiometric method of determination of stability constants with example of silver-ammonia complex. **2.2 Substitution Reactions in Octahedral Complexes (5L)**		**1**

2.2.1 Introduction, types of reactions in complexes.
2.2.2 Ligand substitution reactions: basic mechanisms.
2.2.3 Inert and labile complexes and

		electronic configurations and lability of complexes. **2.2.4** Acid hydrolysis, base hydrolysis and anation reactions. **2.3 Electronic Spectra (5L)** **2.3.1** Types of electronic transitions like intra –ligand transitions, charge transfer transitions and intra-metal transitions and (*d-d* or ligand field transitions for transition metals). **2.3.2** Rules for electronic transitions: Spin and Orbital or Laporte selection rules. Orgel Diagrams for D Terms (i.e,d^1 , d^4 and d^6 .d^9 electronic configurations) and its use in interpretation of visible electronic absorption spectra of these configurations.		
	III	**Organometallic Chemistry (15L)** **3.1 Organometallic Compounds of main group metals (6L)** **3.1.1** Introduction: General synthetic methods: (i) Oxidative addition, (ii) Metal-Metal exchange (Transmetallation), (iii) Carbanion-Halide exchange, (iv) Metal Hydrogen exchange and (v) Methylene insertion reactions. **3.1.2** Chemical rections: (i) Reactions with oxygen, (ii) Alkylation and arylation reactions (iii) Reactions with protic reagents and (iv) Complex formation reactions. **3.2 Organometallic compounds of transition metals (9L)** **3.2.1** Synthesis , structure, reactions and of ferrocene. **3.2.2** Bonding in ferrocene on the basis of VBT. **3.2.3** Bonding in Re and Mo halide complexes.		**1**
	IV	**Some Selected Topics (15L)** **4.1 Inorganic Polymers (3L)** 4.1.1Various methods of classification with examples. **4.1.2** Chemistry of borazine with reference to preparation , properties, structures, bonding and applications. **4.2 Characteristics and Treatment**		**1**

		of Liquid Effluent (06L) **4.2.2** Characterization of waste: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), aerobic and anaerobic processes. **4.2.3** Removing of solid contaminants, physical and chemical principles such as coagulation, flocculation and sedimentation. **4.2.4** Primary,secondary and tertiary of liquid effluents. **4.3 Nanomaterials(04L)** **4.3.2** Introduction and importance of nanomaterials. **4.3.3** Properties (Comparison between bulk and nanomaterials): (i) Optical properties, (ii) Electrical conductivity, and (iii) Mechanical properties. **4.3.4** Forms of nanomaterials: nanofilms, nanolayers, nanotubes, nanowires, and nanoparticles. **4.3.5** Chemical methods of preparation: (i) Colloidal route, and (ii) Sol-gel method. **4.5 Inorganic Pharmaceuticals (2L)** **4.4.2** Gastrointestinal agents viz., (i) antacids (aluminium hydroxide, milk of magnesia, sodium bicarbonate and (ii) cathartics (magnesium sulphate and sodium phosphate). Topical agents viz., (i) protectives and adsorbents (talc, calamine), (ii) antimicrobial agents (potassium permanganate, tincture iodine, boric acid) and astringents (alum).		
USCH603	**I**	**1.1 Spectroscopy** (15L) 1.1.1 Introduction : Electromagnetic spectrum, units of wavelength and frequency. 1.1.2 UV- Visible Spectroscopy: Basic theory, solvents, nature of UV-VIS spectrum, concept of Chromophore, auxochrome,bathochromic shift,Hypsochromic shift hyperchromic	**2.5**	**1**

		effect and chromophore-auxochrome interactions. 1.1.3 IR Spectrocopy: Basic theory, nature of IR spectrum, selection rule , fingerprint region. 1.1.4 PMR Spectroscopy: Basic theory of NMR, nature of PMR spectrum, chemical shift (∂ unit), standard for PMR, solvents used. Factors affecting chemical shift: (1) inductive effect (2) anisotropic effect (with reference to C=C, CΞC, C=O and benzene ring). Spin- spin coupling and coupling constant. Proton exchange-application of deuterium exchange ,Application of PMR in structure determination. 1.1.5 Spectral characteristics of following classes of organic compounds, including benzene and monosubstituted benzenes, with respect to UV-VIS, IR,PMR: (1)alkanes (2)alkenes and polyenes (3) alkynes (4) haloalkanes (5) alcohols (6) carbonyl compounds (7) ethers (8) carboxylic acids (9) esters (10)amines (11) amides (broad regions characteristic of different groups are expected). 1.1.6 Mass Spectrometry: Basic theory.Nature of mass spectrum. General rules of fragmentation. Importance of - molecular ion peak, isotopic peaks, basepeak, Nitrogen rule.Illustrative fragmentation of alkanes and aliphatic carbonyl compounds (No Mclafferty rearrangement). 1.1.7 Problems of structure elucidation of simple organic compounds using individual or combined use of the above spectroscopic technique are expected.(index of hydrogen deficiency should be the first step in solving the problems).		
	II	**2.1 Polymers (11L)** 2.1.1 Introduction: General idea of monomers, polymers, and polymerization, natural and synthetic polymers. Homoplymers and copolymers. Classification of polymers- Plastic, fibres, resins, elastomers. Thermoplastics and thermosets. Copolymers-alternating, block, random, graft. 2.1.2 Mechanism of free radical addition		**1**

		polymerization. 2.1.3 Elastomers: Natural and synthetic rubbers. Diene polymerization: 1,2- and 1,4- addition (cis and trans) polymerization of isoprene. 1,3-Butadiene-styrene copolymer. 2.1.4 Stereochemistry of polymers: Tacticity. Role of Ziegler-Natta catalyst (co- ordination polymerization) in directing the tacticity in polypropylene (no mechanism). 2.1.5 Preparation & use of polymers: (1) Addition polymers: (a) polyethylene (b)polypropylene (c) PVC (d) polystyrene (e) polyacrylonitrile (f) polyvinylalcohol (g) Teflon. (2) Condensation Polymers: (a) Polyesters (b) polyamides (c) polyurethans (d)phenol-formaldehyde resin (e) epoxy resin (f) polycarbonates. 2.1.6 Recyclable polymers. Biodegradable polymers and their uses. Biomedical use of polymers. 2.1.7 Additives to polymers: Plasticizers ,stabilizers and fillers.(The students are expected to identify monomers in a given polymer and draw the structure of a polymer from a given set of monomers). **2.2 Photochemistry** 2.2.1 Introduction: Difference between thermal and photochemical reactions. Jablonski diagram, singlet and triple states, allowed and forbidden transitions, fate of excited molecules, photosensitization. 2.2.2 Photochemical reactions of olefins: photoisomerisation, photochemical rearrangement of 1,4-dienes (di π methane) 2.2.3 Photochemistry of carbonyl compounds: Norrish I, Norrish II cleavages, Photo reduction (e.g. benzophenone to benzpinacol).		
	III	**3.1 Catalysts and Reagents (5L)** Study of the following catalysts and reagents with respect to functional group transformations and selectivity (no mechanism). 3.1.1 **Catalysts** : Catalysts for **1** hydrogenation: Raney Ni,Pt and PtO_2: C=C, CN, NO_2, aromatic ring; Pd/C: C=C, COCl→CHO (Rosenmund); Lindlar catalyst: alkynes; Wilkinson's catalyst for		

		stereo selective reduction of olefins. 3.1.2 **Reagents**: (1)$LiAlH_4$ and Red-Al: reduction of CO,COOR, CN, NO_2. (2) $NaBH_4$: reduction of CO (3) SeO_2: hydroxylation of allylic and benzylic positions,oxidation of CH_2, alpha to CO to CO.(5)mCPBA and R-OOH/H_2O_2 for epoxidation of C=C. (6) NBS: allylic and benzylic bromination of position alpha to CO. **3.2 Natural Products (10L)** 3.2.1 Introduction: Primary and secondary metabolites. Introduction to the following natural products with respect to the sources and classes. (Structures of the compounds specified below are expected). (a) Terpene: Isoprene and special isoprene rule.α-terpeniol, citral,camphor, α-pinene. (b) Alkaloids: nicotine,atropine. (c) Vitamins: Vitamins A and C. (d) Hormones: adrenaline, thyroxine. (e) Steroids: cholesterol, progesterone. 3.2.2 Structure determination of natural products: 3.2.2.1 Ozonolysis in terpenoids-Examples of open chain and monocyclic monoterpenes. 3.2.2.2 Hofmann exhaustive methylation and degradation in alkaloids – simple open chain and monocyclic amines.3.2.2.3 Structure determination of citral and nicotine through degradation studies. Total synthesis of degradation studies. Total synthesis of (i) Citral from 3-methylbutan-1-ol (ii) Nicotine from nicotinic acid. 3.2.4 Commercial importance of terpenoids and alkaloids: Synthesis of camphor from α-pinene, α and β ionones, geraniol and nerol from citral. 3.2.5		
	IV	**4.1 Organometallic Chemistry (5L)** 4.1.1 Intoduction: Carbon-metal bond-Nature, types reactivity. 4.1.2 **Organo magnesium Compounds**: Grignard reagent :Preparation, structure, and stability, Reaction with compounds containing acidic hydrogen,carbonyl compounds, cyanides and CO_2. 4.1.3 **Organolithium Compounds** : Preparation using alkyl/aryl halides. Reactions with compounds containing		**1**

		acidic hydrogen, alkyl halides, carbonyl compounds, cyanides and CO_2. Lithium dialkyl cuprates: Preparation and reactions with aliphatic /aromatic/vinylic halides. 4.1.4 **Organozinc compounds**: Preparation of dialkyl zinc. Reaction with water, acid chlorides and alkyl halides. Reformatsky reaction (with mechanism). **4.2 Chemistry of some Important Biomolecules: (10L)** 4.2.1 α-Amino acids: Structure,configuration,Essential amino acids and their abbreviations, classification, Properties: pH dependency of ionic structure and isoelectric point. Methods of preparations: Strecker synthesis, amidomalonate synthesis, Erlenmeyer azalactone synthesis. 4.2.2 Polypeptides and Proteins: Polypeptides: Peptide bond. Nomenclature and representation of polypeptides. Merrifields solid phase peptide synthesis (example of di- and tri- peptides for nomenclature and synthesis). Proteins: Sources, types,functions,colloidal nature, separation based on isoelectric point, denaturation and functions. Partial and total hydrolysis. General idea of primary, secondary, tertiary and quartenary structures. 4.2.3 Nucleic acids: Selective hydrolysis of nucleic acids.Sugars and bases in nucleic acids. Stuctures of nucleosides an nucleotides in DNA and RNA. Structure of nucleic acids (DNA and RNA): Base pairing in nucleic acids. Importance of nucleic acids-self duplication, protein synthesis.		
USCH604	**I**	**Electroanalytical methods. (15L)** **1.1** D.C. Polaroghraphy (11L): Polarizable and nonpolarizable electrodes, basic principles, residual current, diffusion current, limiting current, dropping mercury electrode, supporting electrolyte half wave potential, derivation of the polarographic wave equation for a reversible reaction. Ilkovic equation, oxygen interference and its removal, maxima and maxima suppressors, polarographic cell, qualitative	**2.5**	**1**

		and quantitativeanalysis, calibration curve and standard addition method, applications. [Numerical problems expected] **1.2** Amperometric Titrations: Basic principles, rotating platinum electrode and nature of the titration curves, applications, advantages and limitations.		
	II	**Methods of separation-II (15L)** **2.1** Gas chromatography (6L): Gas liquid chromatography, basic principles retention time, retention volume, resolution, peak width theoretical plates. HETP, instrumentation, columns, detectors, applications. **2.2** High Performance Liquid Chromatography (4L): Instrumentation, types of elution, U.V. and I.R. detector and applications **2.3** Ion Exchange Chromatography (5L): Types of ion exchangers, mechanism of ion exchange, selectivity coefficients and separation factors, capacity and its determination, factors affecting the separation of ions, applications.		**1**
	III	**Treatment of analytical data-II and Titrimetric analysis-II (15L)** **3.1** Treatment of Analytical Data (6L): Distribution of random errors, Gaussian curve, students' t, confidence limits and confidence interval, criteria for rejection of result: 2.5d rule,4.0 rule and Q test, F teset, testing for significance, null hypothesis, method of averages, least squares method. Numerical problems expected] **3.2** Complexometric Titrations (5L): General introduction, EDTA titrations, advantages and limitations of EDTA as the titrant, absolute and conditional formation constants of metal EDTA complexes, construction of titration curves, types of EDTA titrations,methods of increasing the selectivity of EDTA as a titrant, metallochromic indicators, theory and applications. **3.3** Redox Titrations (4L): General introduction, theory of redox indicators, criterion for choosing an indicator for a redox titration, construction of the titration curves in the case of (1) Fe (II) Vs. Ce(IV)		**1**

		(2) Fe (II) Vs. dichromate, use of diphenyl amine and ferroin as redox indicators.		
	IV	**Concepts in Quality and miscellaneous methods (15L)** **4.1** Total quality management (5L) : concept of quality, quality control, quality assurance total quality management, ISO series, Good laboratory practices **4.2** Mass Spectrometry (2L): Basic principles, introduction of components only **4.3** Thermal Methods (5L): Classification of thermal methods, thermogravimetric analysis,basic principles, instrumentation factors affecting the TG curve, applications **4.4** Introduction to Radio Analytical Techniques (3L): Classification of the techniques, introduction to neutron activation analysis and its applications.		**1**

Practicals

USCHP07	**Practicals of Course USCH601** **<u>Physical Practicals</u>** **Chemical Kinetics –** To determine the energy of activation for the acid catalysed hydrolysis of methyl acetate. **Partition coefficient** To determine the equilibrium constant for the reaction$KI + I_2 \rightleftharpoons KI_3$ by partition method. (Partion coefficient of I_2 between CCl_4 and water is to be given) **Potentiometry –** 1. To determine the strength of the given strong acid (HCl) by potentiometric titration using quinhydrone electrode (Calculation of pH from E_{cell} and the plot of (a) $\frac{\Delta E}{\Delta V}$ against V (b) pH against V graphs are expected). **OR** To determine pKa value of the given weak monobasic acid (CH_3COOH) by e.m.f. measurements. 2. To determine E_{cal} at room temperature	**3**	**8**

	and using this value, determine standard reduction potential of Ag/Ag^+ electrode at room temperature. **Conductometry –** To determine the amount of dibasic acid (Oxalic acid) by conductometric titration against strong base. **OR** To determine the relative strength of monochloroacetic acid and acetic acid conductometrically. **Course USCH602** **<u>Inorganic Practicals</u>** **Inorganic preparations** 1. Mercury tetrathiocyanato Cobaltate (II) $Hg[Co(SCN)_4]$ 2. Magnesium oxinate$[Mg(Ox)_2]$ 3. Tris-acetyl acetonato iron(III) $[Fe(AcAc)_3]$ 4. Tetrammine copper(II) sulphate. $[Cu(NH_3)_4]SO_4.H_2O$ **Inorganic estimations/ Analysis** 1. Estimation of copper iodometrically using sodium thiosulphate. (Students are expected to standardize supplied sodium thiosulphate solution using potassium dichromate) 2. Estimation of lead by complexomety using EDTA solution. (Students are expected to standardize the supplied EDTA solution. Suggested standard for standardization: $ZnSO_4.7H_2O$)		
USCHP08	**Practicals of Course USCH603** **<u>Organic Practicals</u>** **Binary Mixture Separation** Seperation of mixture containing (VL + NVL) & (S + VL) components. **Organic Preparations** 1. Aniline/p-toluidine → N-Acetyl derivative 2. Salicylic acid/nitrobenzene/ Acetanilide → Nitro derivative	**3**	**8**

	3. β- naphthol → Methyl Ether derivative (Using dimethyl sulphate) 4. Acetanilide → p-bromoacetanilide derivative 5. Aniline/ p-toluidine → Schiff base with benzaldehyde 6. Hydroquinone/beta naphthol → Acetyl derivative 7. Methyl salicylate/ethyl benzoate → Acid derivative (Hydrolysis) 8. Benzaldehyde/p-nitrobenzaldehyde → Acid (Oxidation) **Course USCH604** **<u>Analytical Practicals</u>** 1. Determination of chemical oxygen demand of a water sample. 2. Determination of percentage purity of a sample of common salt using a cation exchanger. 3. Determination of potassium content of a commercial salt sample by flame photometry. 4. Determination of acetic acid content of a vinegar sample by potentiometric titration with sodium hydroxide using quinhydrone. **5.** Determination of Cr (VI) in the given solution as dichromate by the method of least squares, spectrophotometrically		

Reference List for Paper-I (Physical Chemistry)

1. Physical Chemistry, Ira Levine, 5th Edition, 2002 Tata McGraw Hill Publishing Co.Ltd.
2. Physical Chemistry, P.C. Rakshit, 6th Edition, 2001, Sarat Book Distributors, Kolkota.
3. Physical Chemistry, R.J. Silbey, & R.A. Alberty, 3rd edition , John Wiley & Sons, Inc [part 1]
4. Physical Chemistry, G. Castellan, 3rd edition, 5th Reprint, 1995 Narosa Publishing House.
5. Modern Electrochemistry, J.O.M Bockris & A.K.N. Reddy, Maria Gamboa – Aldeco 2nd Edition, 1st Indian reprint,2006 Springer
6. Visible & U.V. Spectroscopy, Analytical Chemsitry by Open Learning R. Demny and R. Sinclair M 1991 John Wiley & Sons
7. Classical Methods , Vol 1 Analytical Chemistry by Open Learning D. Cooper & C. Devan,1991 John Wiley & Sons
8. Physical Chemistry, G.M. Barrow, 6th Edition, Tata McGraw Hill Publishing Co. Ltd. New Delhi.
9. The Elements of Physical Chemistry, P.W. Atkins, 2nd Edition, Oxford Universtity Press Oxford
10. Physical Chemistry, G.K. Vemullapallie, 1997, Prentice Hall of India, Pvt.Ltd. New Delhi.

References for Paper-II.(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. K. F. Purcell and J. C. Kotz, *Inorganic chemistry*, Saunders, Hongkong, (1977).
4. N. N. Greenwood and E. Earnshaw, *Chemistry of elements*,Pergamon Press, Singapore, (1989).
5. W. L. Jolly, *Modern inorganic chemistry*, 2nd Ed. McGraw Hill Book Co., (1991).
6. B. E. Douglas and H. McDaniel, *Concepts and models in inorganic chemistry*, 3rd Ed., John Wiley & Sons, Inc., New York, (1994).
7. G. N. Mukherjee and A. Das, *Elements of bioinorganic chemistry*, Dhuri and Sons, Calcutta, (1988).
8. R. W. Hay, *Bioinorganic chemistry*, Ellis Harwood, England, (1984).

9. R. C. Mehrotra and A. Singh, *Organometallic chemistry: A unified approach*, Wiley Eastern, New Delhi, (1991).
10. For synthesis of iron ethylenediamine sulphate refer Practical Inorganic Chemistry by G. Marr and B. W. Rockett,Van Nostrand Reinhold Company London1972. P 34.
11. For preparation of $CuCl_2$.2DMSO Refer Microscale Inorganic Chemistry by Z. Szafran, Ronald M. Pike and Mono M. Singh. Pub. John Wiley and Sons1991.p.218.

References For Paper-III (Organic Chemistry)

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. A guide to mechanism in Organic Chemistry, 6th Edition, Peter Sykes, Pearson Education
5. Fundamentals of Organic Chemistry , G. Marc Loudon, 4th Edition Oxford
6. Organic Chemistry, L.G. Wade Jr and M.S. Singh, 6th Edition,2008
7. Organic Chemistry Baula Y. Bruice, Pearson Edition, 2008
8. Organic Chemistry,J.G. Smith, 2nd Editionm Special Indian Edition, Tata McGraw Hill
9. Organic Chemistry, S.H. Pine, McGraw Hill Kogakusha Ltd.
10. Stereochemistry, P.S. Kalsi, New Age International Ltd. 4th Edition,2006

Reference List for Paper-IV (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, AffiliatedEast-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 Qunatitative Chemical Analysis, Fifth edition, ELBS Publication (1996)
4. D.A. Skoog D.M. West and F.J. Holler, Fundametals of Analytical Chemistry, 7thEdition (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 etal 8th edition, Saunders college publishing.