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ಮಂಗಳೂರು ವಿಶ್ವವಿದ್ಯಾನಿಲಯ
MANGALORE UNIVERSITY

ಕುಲಸಚಿವರ ಕಛೇರಿ
ಮಂಗಳಗಂಗೋತ್ರಿ - 574199
Office of the Registrar
Mangalagangothri - 574199

ಕ್ರಮಾಂಕ / No.MU/ACC/CR40/2013-14/A2

ದಿನಾಂಕ / Date :21/3/2014

NOTIFICATION

Sub: Revised syllabus of Chemistry, an optional subject for B.Sc. degree programme.

Ref: Academic Council decision No. 3:19 (2013-14) dated: 10-1-2014.

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The revised syllabus of Chemistry, an optional subject for B.Sc. degree programme which approved by the Academic Council at its meeting held on 10-1-2014 is hereby notified for implementation with effect from the academic year 2014-15.

M.R. Hulls 3-4-14

REGISTRAR

To:

(1) The Principals of the colleges concerned.
(2) The Registrar (Evaluation), Mangalore University.
(3) The Chairman, UG BOS in Chemistry, Mangalore University.
(4) The Superintendent, ACC Section, O/o. the Registrar, Mangalore University.
(5) Guard file.

MANGALORE UNIVERSITY
B. Sc. CHEMISTRY REVISED SYLLABUS - 2013
FIRST SEMESTER

CH 101: Chemistry Paper I — **4 Hrs / Week (48 Hrs)**

UNIT–I

Chromatography: — **3 Hours**

Chromatographic methods for the separation, purification and identification of organic compounds-Thin layer, paper and column chromatography. R_f value and its significance. Principle and applications of Gas chromatography.

Methods of Analysis — **5 Hours**

Qualitative analysis - Sample size and techniques- macro, semimicro and micro. Type of tests- wet, dry and spot tests. Quantitative analysis - Volumetry, Gravimetry and Instrumental analytical methods. Principles of gravimetric analysis-methods of precipitation, optimum conditions for precipitation and co-precipitation. Solvent extraction-basic principles and applications. Errors in quantitative analysis, types of errors- determinate and indeterminate, methods of minimising errors. Accuracy - absolute error/ relative error. Precision -mean deviation / relative mean deviation, standard deviation, t-test, F-test and Q-test. Significant figures. Rules for computation of results.

Periodic Properties: — **4 Hours**

Methods of determination of Atomic properties -Atomic size by Lande's method, Ionization energy by Discharge tube method, Electron affinity from Born-Haber cycle and Electronegativity from Pauling and Mulliken scales. Predicting and explaining the chemical behaviour of elements on the basis of periodic properties (metallic/non metallic, ionic/covalent, reducing/oxidizing). Effective nuclear charge-shielding effect. Slater's rule and its applications.

UNIT–II

Chemical Bonding: — **12 Hours**

Nature of covalent Bond: Valence band theory. Concept of hybridization, Valence Shell Election Pair Repulsion (VSEPR) theory, Comparative study of structure and bonding between F_2O and H_2O; H_2S and H_2O; NH_3 and NF_3; ClF_3 and $XeOF_2$. Basic principle of Molecular orbital theory. Molecular orbital diagrams of homo and heteronuclear species- N_2, O_2, CO, NO and CN^-. Ionic bond-Nature, Lattice energy, Born-Lande equation, Solvation and Solubility of ionic solids. Polarising power and Polarisability of ions. Fajan's rule to explain bond character, covalent character of ionic compounds, relative covalent character, diagonal relationship. Comparative trend in properties: a) Melting point-e.g NaBr, $MgBr_2$, $AlBr_3$; LiF, LiCl, LiBr, LiI; $CaCl_2$, $HgCl_2$ b) Solubility-e.g AgF, AgCl, AgBr, AgI c) Thermal stability-e.g $BeCO_3$,$MgCO_3$,$CaCO_3$,$SrCO_3$, $BaCO_3$; $CdCO_3$, $PbCO_3$ Metallic bond-Application of Band theory for explaining the electrical and thermal conductance in Lithium, Beryllium, Silicon and Diamond.

UNIT–III

Solid state: — **6 Hours**

Laws of crystallography: Law of constancy of interfacial angle-explanation taking hexagonal crystal system as an example. Law of symmetry. Elements of symmetry- axis of symmetry, plane of symmetry and centre of symmetry-explanation taking cubic crystal system as an example. Law of rationality of indices. Miller indices-calculation of Miller indices for different planes in a cubic crystal system. Bravais lattices. X-ray diffraction by crystals. Derivation of Bragg's equation. Determination of crystal structure of NaCl and determination of Avogadro number. Cesium Chloride, Zinc blend, Wurtzite, Fluorite and rutile crystal structures.

Chemical Kinetics: — **4 Hours**

Concentration dependence of rates,differential rate laws of simple chemical reactions,Zero,First,Second , nth and pseudo first order reaction.

Derivation of rate constants for second order and n^{th} order reactions with equal initial concentrations. Determination of order of a reaction- Differential, Integration, Half life period and Isolation methods. Transition state theory-Derivation of relationship between rate constant and equilibrium constant. Thermodynamic aspects of activation.

Catalysis: **2 Hours**

Role of catalyst in altering reaction rate, Acid-base catalysis, specific and general acid base catalysis, mechanism and kinetics, Enzyme catalysis, Derivation of Michaelis- Menten equation.

UNIT–IV

Nature of bonding in organic molecules: **4 Hours**

Localized and delocalized bonding,conjugation,cross conjugation.Resonance and aromaticity- explanation for aromaticity in compounds and ions. Huckel rule. Concept of antiaromaticity with suitable examples.Hyperconjugation- explanation for relative stabilities of 1^0, 2^0 and 3^0 carbocations.Field effects like Inductive effect-Explanation with examples, relative strengths of aliphatic and aromatic carboxylic acids(Acetic acid and Chloroacetic acid, Acetic acid and Propionic acid, Acetic acid and Benzoic acid). Steric effect-Explanation with examples, Bonding weaker than covalent bond-Van der Waal's forces, Hydrogen bonding, Charge-transfer complexes.

Reactive intermediates: **8 Hours**

Generation, stability and reactions of-i) carbocations ii) carbanions iii) Free radicals iv) Nitrenes v) Carbenes. Reactions involving these intermediates:Dienone-Phenol, Demajnov, Hofmann, Curtius, Reimer-Tieman and Wolf rearrangement, Perkin & Claisen Condensation, Sandmeyers reaction. vi) Arynes- Benzyne mechanism for the conversion of Bromobenzene to aniline.

Methods of determination of reaction mechanism-Product analysis, Identification of intermediates, Cross over experiments,Stereochemical evidences, isotope effects, kinetic isotopic studies.

CH 102: CHEMISTRY PRACTICAL I — 4 Hrs/Week (12x4 Hrs)

I. Systematic qualitative analysis of mono and bifunctional organic compounds- determination of melting point/boiling point, preparation of suitable solid derivative and identification by referring to the literature. The following compounds may be given -Resorcinol, oxalic acid, urea, thiourea, cinnamic acid, benzoic acid, salicylic acid, phenol, p-cresol, aniline, p-nitroaniline, p-toluidine, benzaldehyde, ethyl methyl ketone, acetophenone, benzophenone, chlorobenzene, bromobenzene, nitrobenzene and benzamide,Ethyl benzoate,Benzyl alcohol. **8 weeks**

II. Thin Layer Chromatography **2 weeks**

Determination of R_f values and identification of organic compounds,

a) Separation of green leaf pigments(Spinach leaves may be used),

b) Preparation and separation of 2,4-dinitrophenylhydrazones of acetone, 2-butanone, hexan-2- and 3-one, using toluene and light petroleum (40:60)

c) Separation of a mixture of dyes using cyclohexane and ethyl acetate (8.5: 1.5)

III. Paper Chromatography: Ascending and Circular **2 weeks**

Determination of Rf values and identification of organic compounds,

Separation of a mixture of phenylalanine and glycine, Alanine and aspartic acid, Leucine and glutamic acid. Spray reagent-ninhydrin.

Separation of a mixture of D, L-alanine, glycine and L-Leucine using n-butanol, acetic acid-water (4:1:5). Spray reagent-ninnydrin,

Separation of monosaccharides-mixture of D-galactose and D- fructose using n-butanol:acetone: water (4:5:1), Spray reagent-aniline hydrogen phthalate.

IV. Column Chromatography:

a) Separation of fluorescein and methylene blue.

b) Separation of leaf pigments from spinach leaves.

SECOND SEMESTER

CH 151: Chemistry Paper II — **4 Hrs / Week (48 Hrs)**

UNIT I

Gaseous State: **4 Hours**

Maxwell's distribution of molecular velocities- explanation with graph. Most probable, average and RMS velocities. Relation between RMS, average and most probable velocity. Qualitative discussion of the collision number, mean free path and collision diameter. Critical phenomena: P-V isotherms of real gases – Andrews isotherms of carbon dioxide. Continuity of states-principles. Isotherms of van der Waals equation. Relationship between critical constants and van der Waals constants-derivation of the expressions for a, b, T_c, P_c and V_c. Law of corresponding states- statement, reduced equation of state- derivation of the equation.

Liquid state: **4 Hours**

Structure of liquids-qualitative description. Structural differences between solids, liquids and gases. Liquid crystals- Explanation, classification with examples - smectic, nematic, cholesteric, disc shaped and polymeric. Structures of nematic and cholestric phases- molecular arrangements in nematic and cholestric liquid crystals. Application of liquid crystals in LCDs and thermal sensing.

Solvents: **4 Hours**

Physical properties of a solvent - density, dipole moment, specific conductance, dielectric constant, heats of fusion and vaporisation, Types of solvents - classification into protic - aprotic, acidic - basic - amphiprotic, ionising – non ionizing (examples), Characteristics-liquid range, auto-ionisation and solvating properties. Reactions in aqueous and non-aqueous solvents (two examples in each case). Water-hydration, hydrolysis, acid-base, reduction-oxidation, complex formation and precipitation. Ammonia-ammoniation, ammonolysis, acid-base, reduction-oxidation, complex formation, precipitation, alkali metals in ammonia, levelling effect-examples.

UNIT II

s-Block Elements : **4 Hours**

Hydrogen-position of hydrogen in the periodic table. Hydrides-types, preparation, properties and applications. Structure of BeH_2 and NaH. Complex hydrides-$LiAlH_4$, $NaBH_4$-Preparation and applications. Comparative study of Li and Be with other members of the same group. Comparative study of lattice energy, enthalpy of formation, enthalpy of hydration and solubility's of alkali metal and alkaline earth metal halides, hydroxides and sulphates. Comparison of standard reduction potentials and reducing properties of alkali metals and alkaline earth metals. Complexation tendencies of alkali metals with crown ether, Cryptates. BeF_4^{2-} and Basic beryllium acetate-preparation, properties and structure.

p-Block Elements: **8 Hours**

Comparative study of p-Block elements and their compounds-comparison between Boron and other members of the group. Boranes: Diborane- Preparation, properties, structure and bonding, chemical evidences to bridge hydrogen. B_4H_{10}, B_5H_9, $B_6H_6^{2-}$ - Preparation and structure, styx number, Wade's rule. Silicates-types, basic units, structure and applications. Hydrazine and hydroxylamine-structure and reducing property. Hypo phosphorus acid, phosphorus acid, phosphoric acid, orthophosphoric acid, meta phosphoric acid and pyrophosphoric acid- structure, evidence in favour of structure. Halogens in positive oxidation state. Inter halogen compounds-ICl, BrF_3, IF_5 and IF_7-preperation, properties, structure and uses. Noble gases-Clathrates, XeF_2, XeF_4, XeF_6 and XeO_3 - structure and bonding.

UNIT III

Industrial Chemistry: **12 Hours**

Inorganic polymers: Silicones- structure and applications; Fluorocarbons- structure and applications; Phosphonitrile halides- basic unit of the polymer, applications.

Fuels: Composition, production and applications of natural gas, water gas, producer gas, LPG and bio gas. Propellants: characteristics and applications.

Glasses: Types, composition and uses of glasses- hard, soft, pyrex, jena, flint, safety, optical, fibre, coloured and Crooke's glasses. Raw materials, manufacture- tank furnace, steps in manufacture and annealing of glass.

Cement: Raw materials, manufacture of cement, mechanism of setting of cement.

Ceramics: Raw materials used in modern ceramics, stages in ceramic making, glazing, applications of porcelain.

Insulators: Classification and applications, superconductors: examples and applications.

Paints: Constituents of paints and their functions with examples. Manufacture of white lead and lithopone.

Refractories: Characteristics, classification with examples and applications, Abrasives: natural abrasives, synthetic abrasives, characteristics and applications. Silicon carbide and boron nitride- structure and production.
Cane sugar: Outline of production and composition,molasses,its composition.
Paper: Production of wood pulp and preparation of paper.
Chemical fertilizers: Different types of fertilizers, importance, production of urea, CAN and superphosphate of lime.

UNIT IV

Reagents and their synthetic utility: **10 Hours**

Reagents used for the synthesis of organic compounds and the reactions with mechanism-$KMnO_4$-Oxidation of alkenes to vicinal diols; SeO_2-Conversion of benzyl phenyl ketone into benzyl; Ozone-Synthesis of carbonyl compounds from alkenes; Periodic acid-Oxidation of vicinal diols into carbonyl compounds; Lead tetra acetate-Oxidative cleavage of vicinal diamines; Osmium tetroxide-Synthesis of cis-1,2-diols; Per acids-Baeyer Villiger Oxidation; CrO_3–Sarett oxidation; Aluminium iso propoxide-Meerwein-Pondorf-Verley reduction, $LiAlH_4$ Reduction of carbonyl compounds into alcohols; $NaBH_4$ Reduction of carbonyl compounds into alcohols; Sodamide-Chichibabin reaction; N-Bromo succinimide-Allylic bromination ; Diazomethane-Methylation of carboxylic acids/phenols; Na/ethyl alcohol-Reduction of ester to alcohol; H_2O_2-Dakin reaction. CrO_2Cl_2-Etard's reaction; Hydrazine-Wolf-Kishner reduction.

Electrophilic addition to carbon-carbon multiple bonds: **2 Hours**

Electrophilic addition to carbon-carbon double and triple bonds- Mechanism, relative reactivity, regioselectivity and stereoselectivity. Reactions- halogenation, hydrohalogenation and ozonolysis. electrophiilic addition to conjugated dienes,Radical addition,Addition of HBr in presence of light and in dark,Pericyclic addition, Diels-Alder reaction and1,3-dipolar addition.

CH 152: Chemistry Practical II — 4Hrs/ Week (12x4 Hrs)

Volumetric Analysis

1. Microscale experiment-Two butette titration and beral pipette titration.
2. Preparation of standard sodium carbonate solution, standardization of hydrochloric acid and estimation of sodium hydroxide in solution.
3. Preparation of standard solution of potassium biphthalate, standardization of sodium hydroxide solution and estimation of hydrochloric acid in solution.
4. Preparation of standard solution of oxalic acid, standardization of potassium permanganate solution and estimation of Mohr's salt in solution.
5. Preparation of standard ferrous ammonium sulphate solution, standardization of Potassium dichromate solution and estimation of ferric chloride in solution.
6. Preparation of standard potassium dichromate solution, standardization of sodiumthiosulphate solution and estimation of copper sulphate in solution.
7. Estimation of a mixture of oxalic acid and sulphuric acid in a solution using standard Potassium permanganate solution and standard sodium hydroxide solution.
8. Estimation of calcium content in lime stone as calcium oxalate by permanganometry.
9. Estimation of hardness of water by EDTA method.
10. Estimation of manganese in pyrolusite by volumetric method.
11. Determination of acetic acid in commercial vinegar using NaOH.
12. Determination of alkali content in antacid tablet using HCl.
13. Estimation of glucose using iodine and sodium thiosulphate.
14. Estimation of Vitamin C.

THIRD SEMESTER

CH 201: Chemistry Paper III

4 Hrs / Week (48 Hrs)

UNIT I

12 Hours

Thermodynamics

First law of thermodynamics, Joule-Thomson effect-isoenthalpic nature. Joule-Thomson coefficient-derivation of mathematical expression. Inversion temperature- explanation in terms of Joule-Thomson coefficient. Bond dissociation energy and its calculation from thermo chemical data. Temperature dependence of enthalpy-Kirchhoff's equation. Second law of thermodynamics- Need for the law, different statements of the law. Carnot's cycle. Efficiency of Carnot's cycle, Carnot's theorem. Thermodynamic scale of temperature. Concept of entropy from Carnot's cycle, Entropy as a state function. Entropy change for an ideal gas as a function of V and T, entropy change for an ideal gas as a function of P and T. Entropy change in mixing of ideal gases. Entropy change in physical change-fusion, evaporation, sublimation and transition. Clausius inequality, Entropy as a criterion for spontaneity and equilibrium. Third Law of thermodynamics-its significance, unattainability of absolute zero. Gibbs function (G) and Helmholtz function (A) as thermodyanamic quantities. A and G as criterion for thermodynamic equilibrium and spontaneity, their advantage over entropy change. Variation of G with P, V and T (Illustrative problems to be worked out).

UNIT II

7 Hours

Chemistry of d- and f-block elements:

General electronic configuration, stabilities of oxidation states and complexing ability. Magnetic property-dia, para and ferromagnetism. Expression for magnetic moment-spin only formula, μ_S and Lande's calculation of theoretical magnetic moment, μ_{S+L} and comparison with experimental value, reasons for observed trend. Comparative treatment of 4d and 5d series with their 3d analogues in respect of ionic radii, oxidation states, magnetic behaviour and stereochemistry. Lanthanide contraction-causes and consequences. Occurrence and isolation of lanthanides by ion-exchange method. Comparison between lanthanides and actinides. Separation of Neptunium , Plutonium and Americium from Uranium.

2 Hours

Alloy :

Manufacture of steel by L.D Process. Principles and purpose of alloying, effect of alloying -carbide formation, solid solution formation and deoxidation. Presence of impurity elements-Cr, Mn, Ni, V, Mo, W, S, P, Si. Special steel-Alnico, Stainless steel and inverse steel- constituents, properties and applications.

3 Hours

Nano Chemistry : Introduction,general methods of synthesis,characterization techniques,preparation of nano particle by chemical method,application of nanomaterials.

UNIT III

5 Hours

Binary mixtures:

Liquid – liquid mixtures, completely miscible liquids, ideal liquid mixtures, Raoult's law, non-ideal systems showing positive and negative deviation from Raoult's law, Vapour pressure – composition and boiling point – composition curves, Azeotropes, HCl–H_2O and ethanol–H_2O systems. Partially miscible liquids, Miscibility temperature and critical solution temperature(CST), Phenol water system, Trimethylamine–water system and Nicotine – water system. Effect of impurity on CST. Immiscible liquids, Steam distillation-principle and experimental details, Nernst Distribution law- statement and applications.

2 Hours

Acids and Bases:

Lewis concept of acids and bases. Modern concepts of acids and bases- Usanovich concept, Lux -Flood concept. Hard and Soft Acids and Bases (HSAB)- Classification of acids and bases as hard and soft-examples and comparison, Pearson's HSAB concept-acid base strengths and hardness and softness. Electro negativity and hardness and softness.

5 Hours

Oxidation and Reduction:

Use of redox potential data -thermodynamic feasibility using free energy, reducing and oxidizing tendency, Analysis of redox couple - example of Zn/Zn^{2+} couple. Redox stability in water - reaction with water, one example each for oxidation by water and reduction by water. Frost, Latimer and Pourbaix diagrams – presentation of potential data, Frost diagram for nitrogen, Latimer diagram for chlorine and Pourbaix diagram for iron.

UNIT IV

Reactions and reactivity of Phenols: **3 Hours**

Comparison of acidic properties of phenols with carboxylic acids, alcohols and carbonic acid. Mechanism of - Fries rearrangement, Claisen rearrangement, Gattermann synthesis, Mannich reaction, Ene reaction. Synthesis of aryloxy acetic acids.

Ethers and Epoxides: **3 Hours**

Chemical reactions of ethers-Cleavage and auto-oxidation with examples. Ziesel's method of estimation of methoxy/ethoxy group in ethers. Synthesis of epoxides, acid and base catalyzed ring opening of epoxides. Orientation and reactivity in epoxide ring opening .

Structure and reactivity of carbonyl compounds: **6 Hours**

Structure of carbonyl group, Nucleophilic additions to carbonyl group, relative reactivities of aldehydes and ketones-explanation, Mechanism of reactions involving Hydride shift-Tischenko reaction; C-C bond formation-Bucherer reaction, hydantoin synthesis; C=C bond formation-Wittig reaction; C=N bond formation-addition of NH_3 derivatives; C-O bond formation-Acetal formation, Michael addition and Robinson annulations. α, β-unsaturated aldehydes and ketones-preparation and their synthetic applications.

CH 202: CHEMISTRY PRACTICAL III **4 Hrs/Week (12x4 Hrs)**

Systematic semimicro qualitative analysis of mixtures of two simple inorganic salts (containing two cations and two anions).

Anions: CO_3^{2-}, HCO_3^-, SO_3^{2-}, $S_2O_3^{2-}$, S^{2-}, Cl^-, Br^-, I^-, NO_3^-, BO_3^{3-}, PO_4^{3-}, SO_4^{2-}

Cations: Pb^{2+}, Cu^{2+}, Bi^{3+}, Cd^{2+}, Co^{2+}, Ni^{2+}, Al^{3+}, Fe^{2+}, Mn^{2+}, Zn^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+

FOURTH SEMESTER

CH 251: Chemistry Paper IV **4 Hrs/Week (48 Hrs)**

UNIT I

Co-ordination Compounds: **6 Hours**

Nomenclature-order of naming ion, naming the coordination sphere, naming ligand, order of naming the ligand, ending the name, oxidation state of metal ion, naming geometrical and optical isomers, bridge ligands. Isomerism in coordination compounds-Ionisation isomerism, hydrate isomerism, coordinate isomerism, linkage isomerism. Stereoisomerism-geometrical isomerism and optical isomerism - Coordination numbers 4 and 6.

Metal-ligand Bonding in Transition Metal Complexes: **6 Hours**

Valence bond theory-examples for sp^3, dsp^2, dsp^3, d^2sp^3 and sp^3d^2 hybridisation-$Ni(CO)_4$, $[Ni(CN)_4]^{2-}$, $[Cu(NH_3)_4]^{2+}$, $Fe(CO)_5$, $[Fe(CN)_6]^{5-}$, $[Co(NH_3)_6]^{3+}$ and $[CoF_6]^{3-}$. Explanation for magnetic properties. Limitations of Valence bond theory. Crystal field theory-important concepts of CFT, Crystal field splitting in octahedral, tetrahedral and square planar complexes, crystal field stabilization energy. Calculation of CFSE, weak and strong field ligands, spectrochemical series, explanation for stability, geometry, magnetic and spectral properties. Factors affecting the crystal field splitting-nature of metal ions, charge, size, principal quantum number of d-electron , number of ligands and nature of ligands. Limitations of CFT.

UNIT II

Chemical Equilibrium **4 Hours**

Derivation of relationship between equilibrium constant and free energy $\Delta G^\circ = -RT\ln K_p$. Thermodynamic derivation of law of mass action, Le Chatelier's principle-statement and applications. Van't Hoff's reaction isotherm and reaction isochore (Van't Hoff equation) (Illustrative problems to be worked out).

Phase Equilibrium: **6 Hours**

Phase rule-Statement (mathematical expression) and meaning of the terms. Explanation for the terms phase, component and degrees of freedom-suitable examples for each term. Derivation of phase rule from thermodynamic consideration. Phase equilibria of one component system (water and sulphur systems)-phase diagram and explanation. Two component system- classification with examples, simple eutectic system (lead-silver system)-phase diagram and explanation, desilverisation of lead (Pattinson's Process). Solid solutions-

compound formation with congruent melting point (Mg-Zn system) -phase diagram and explanation. Compound formation with incongruent melting point (NaCl-water system)-phase diagram and explanation. Freezing mixtures (acetone-dry ice). Solid solution formation. Fractional crystallization.

Surface chemistry: **2 Hours**

Adsorption of gases on solids: Frandlich and Langmuir adsorption isotherm.Multilayer adsorption-BET equation. Determination of surface area and area of cross section of a molecule. Adsorptiom from solution-Gibb's Adsorption isotherm.

UNIT-III

unit I

Solutions, dilute solutions and colligative properties : **6 Hours**

Ideal and non-ideal solutions, Methods of expressing concentrations–Activity and Activity coefficients. Colligative properties: Raoult's law of relative lowering of vapour pressure. Osmosis and laws of Osmotic pressure. Elevation of boiling point and depression of freezing point. Thermodynamic derivation of the relation between elevation of boiling point/depression of freezing point and molecular mass of solute(Illustrative problems to be worked out).

Physical properties and molecular structure : **4 Hours**

Optical activity, polarization (Clausius-Mosotti equation), orientation of dipoles in an electric field, dipole moment, measurement of dipole moment-temperature method and refractivity method, dipole moment and structure of molecules, magnetic properties-paramagnetism and ferromagnetism.

Refractometry: **2 Hours**

Introduction, Abbe's Refractometer, applications of Refractometry.

UNIT IV

Reactive methylene compounds: **3 Hours**

Keto-enol tautomerism in ethylacetoacetate , diethyl malonate and acetylacetone. Reactions supporting keto and enol forms. Synthetic applications of reactive methylene compounds-Synthesis of alkyl and dialkyl acetic acids, succinic acid, keto acids, α-β unsaturated acids(crotonic acid), 4- Methyl uracil and antipyrine.

Nucleophilic substitution at saturated carbon: 3 Hrs

Mechanism of nucleophilic substitutions : S_N1 and S_N2 reactions with energy profile diagrams. Stereochemistry and factors affecting S_N1 and S_N2 reactions.

Elimination reactions: **2 Hours**

E1 and E2 mechanisms, evidences, orientation and stereochemistry. Hofmann and Saytzeff rules.

Aromatic electrophilic and nucleophilic substitutions: **4 Hours**

Aromatic electrophilic substitution-general pattern of the mechanism with energy profile diagram. Role of σ and Л complexes. Activating and de-activating substituents, Orienting influence, ortho/ para ratio. Nucleophilic aromatic substitution reactions- Bimolecular displacement mechanism and Elimination-addition mechanism (Benzyne mechanism).Vilsmeier-Haack reaction,Sommelet rearrangement .Stevens rearrangement.

CH 252: Chemistry Practical IV — 4 Hrs/ Week (12x4 Hrs)

Determination or study of the following:

1. The specific reaction rate for the acid catalysed hydrolysis of methyl acetate at room temperature using 0.5N HCl or 0.5N H_2SO_4.
2. Effect of acid strength on the hydrolysis of an ester.
3. Comparison of the catalytic strengths of HCl and H_2SO_4 by studying the kinetics of hydrolysis of methyl acetate.
4. The rate of decomposition of iodide by H_2O_2
5. The distribution of iodine between water and CCl_4.
6. The distribution of benzoic acid between benzene and water.
7. Preparation of arsenious sulphide sol and comparison of the precipitating power of mono-, bi- and trivalent anions.
8. Density and viscosity of the given liquid (using specific gravity bottle and viscometer).
9. The percentage composition of a given mixture of glycerol and water by viscometry.
10. The density and surface tension of a liquid.
11. Composition of binary liquid mixture (Alcohol & toluene) by Refractometry.

12.Cystallization and decolorisation of impure naphthalene(100g of naphthalene mixed with 0.3g of Congo Red using 1g decolourising carbon from ethanol).
13. Critical Solution Temperature of phenol – water system.
14. The percentage of NaCl present in water - phenol system.
15. The molecular weight of a non-volatile solute by Walker - Lumsden method.

FIFTH SEMESTER 357

CH 301: Chemistry Paper V — 3 Hrs/Week (40 Hrs)

UNIT I

Application of metal complexes and complexation: **3 Hours**

Applications of complexes and complex formation in metallurgy – Ag, Au, Al, Ni extractions. Volumetric analysis – Complexiometry, masking, demasking, external indicator.
Qualitative analysis – tests for ferrous and ferric ions, separation of copper from cadmium.
Gravimetric analysis – precipitation of nickel, magnesium and aluminium ions.

Thermodynamic and Kinetic Aspects of Metal Complexes: **3 Hours**

Thermodynamic stability of metal complexes(brief outline), stepwise formation of complexes, stepwise formation and overall formation constants. Relation between K and β, $\Delta G = -2.303\ RT \log \beta$
Factors affecting the stability – chelate effect, account for high ΔS values. Labile and inert nature of complexes. Substitution reactions of square planar complexes – Pt(II) complexes, synthesis of cis and trans $[Pt(NH_3)_2Cl_2$ complexes, trans effect.

Magnetic Properties of Transition Metal Complexes: **4 Hours**

Origin of magnetism, magnetic induction, magnetic flux density, magnetic moment per unit volume, χ_M, χ_{Mcor}. Types of magnetic behaviour – dia, para and ferromagnetic properties- examples, cause (origin), magnetic susceptibility-data, sign, magnitude, temperature and field dependence.
Factors determining para-magnetisum, study of magnetic behaviour of first row transition elements. Methods of determining magnetic susceptibility- Gouy method, expressions for μ_{eff} and $\chi_M$cor (no derivation). Correlation of and μ_s and μ_{eff} values, $\mu_{eff} = \mu_s (1 - \alpha . \lambda/D)$. Orbital contribution to magnetic moments, L-S coupling – Russell-Saunder coupling, quenching of orbital angular moment. Application of magnetic moment data tor 3d-metal complexes – predicting geometry of complexes.

UNIT II

Electrochemistry: **10 Hours**

Transport number-Definition, determination of transport number by Hittorf's method using attackable and unattackable electrodes and Moving Boundary method. Equivalent conductance and its determination. Strong and weak electrolytes, Debye- Huckel- Onsager equation for strong electrolytes (no derivation). Applications of conductivity measurements: Determination of (a) Degree of dissociation, (b) Ka of weak acids (c) Solubility product of sparingly soluble salt. Conductometric titrations, calculations. Reference electrodes, Calomel, Quinhydrone, Ag-AgCl and glass electrode(Construction, Electrode reaction, Nernst equation), E.M.F of cells and its measurements by potentiometric method, calculation of electrode potential, computation of cell EMF, relation between ΔG^0 and K for a cell reaction, calculations. Concentration cells: Electrolyte concentration cells with and without transport, liquid junction potential, calculations. Applications of concentration cells: Determination of a) valency of ions, b) solubility product and c) activity coefficient. Applications of E.M.F measurements: a) Potentiometric titrations (acid- base and redox), b) Determination of pH using hydrogen electrode, Quinhydrone electrode and Glass electrode by potentiometric methods. Decomposition potential, polarization and over voltage. Applications of hydrogen over voltage.

UNIT III

Rotational Spectroscopy: **4 Hours**

Diatomic molecules (rigid Rotator), Derivation of expression for moment of inertia, energy levels of a rigid rotator, selection rules, intensity of spectral lines, Limitations of rotational spectra , applications of rotational spectra (determination of bond length), Qualitative description of non- rigid rotator, the effect of isotopic substitution(Illustrative problems to be worked out).

VibrationalSpectroscopy (Infrared spectroscopy) 6 Hours

Diatomic molecules as simple harmonic oscillators, energy levels of SHO, selection rules, pure vibrational spectrum, limitations of vibrational spectra. Applications of vibrational spectra (determination of Force constant), Qualitative relation of Force constant and Bond energies, Effect of anharmonic motion on the spectrum. Finger print region,characteristic absorption of various functional groups and interpretation of IR spectra of organic molecules

UNIT IV

Stereochemistry of Organic Compounds: **8 Hours**

Configurational isomerism-optical, geometrical and conformational isomerism. Optical isomerism-elements of symmetry, molecular chirality, stereogenic centre-chiral and achiral molecules with two stereogenic centres-Eg., Lactic acid and Tartaric acid. Enantiomers-properties. Resolution of enantiomers. Diastereomers-definition and examples, threo and erythro diastereomers, meso compounds-definition and examples. Inversion (of sugars) and racemization. Relative and absolute configuration, sequence rules, D and L, R and S systems of nomenclature.
Geometric isomerism: Determination of configuration of geometric isomers. E and Z system of nomenclature, geometric isomerism in oximes and alicyclic compounds.
Conformational isomerism-conformational analysis of ethane and 1,2-dichloroethane. Conformations of cyclohexane-Newman projection. Differences between configuration and conformation.

Vitamins and Hormones: **2 Hours**

Definition, classification with examples and their importance. Synthesis of vitamin A from β-ionone, vitamin C from D-glucose, Adrenaline form catechol and Thyroxine from p-nitroaniline.

CH 302: Chemistry Paper VI 358 3 Hrs/Week(40 Hrs)

UNIT I

Elementary Quantum Mechanics: 8 Hours

Quantum Theory of radiation (Black body radiation), Planck's radiation law, Heat capacities of solids, Photoelectric effect, Compton effect, de Broglie hypothesis, Heisenberg's uncertainity principle, Sinusoidal wave equation, Hamiltonian operator, Schrodinger wave equation (SWE) and its importance, Physical interpretation of wave function, Postulates of quantum Mechanics(statements only), Particle in one dimensional box, Setting up of SWE for H atom (no separation of variables or solution), Quantum numbers and their importance.

Raman spectroscopy : 2 Hours

Classical and quantum theories of Raman effect.Concept of polarizability and polarizability ellipsoid.Rotations and vibrational Raman spectra,Selection rules.

UNIT II

Electronic Spectra of Transition Metal Complexes: **5 Hours**

Types of electronic transitions: d-d transition or crystal field transition, charge transfer from ligand to metal and metal to ligand, intra ligand transition. Selection rules for d-d transitions-spin selection rule, Laporte selection rule, relaxation of selection rule(vibronic coupling), forbidden transition. Spin multiplicity, Term symbols and Spectroscopic ground states. Spectroscopic ground states for d^1 to d^9 systems. Orgel diagram-explanation. Orgel diagram for d^1 and d^9 systems. Discussion of electronic spectra of $[Ti(H_2O)_6]^{3+}$ and $[Cu(H_2O)_6]^{2+}$.

Flame Photometry: **2 Hours**

General principle, instrumentation , interferences and applications.

Thermoanalytical methods: **3 Hours**

Principle, instrumentation and applications of Thermogravimetric Analysis, Derivative Themogravimetry and Differential Thermal Analysis. Nature of TGA, DTG and DTA curves.

UNIT III

Bioinorganic chemistry: 3 Hours

Essential and trace elements in biological processes – biochemical roles.
Metalloporphyrins with reference to haemoglobin and myoglobin-skeletal structure, functions, brief explanation for transportation of oxygen and carbon dioxide.

Organometallic Chemistry: **5 Hours**

Definition, nomenclature and classification of organometallic compounds – ionic organometallic compounds containing metal-carbon sigma bonds, non-classically bonded organometallic compounds (multi centred bonds and interaction between π orbitals and delocalised electron clouds).

Preparation, properties, bonding and applications of alkyls and aryls of Li, Al and Hg, Mononuclear carbonyls and the nature of bonding in metal carbonyls (back bonding, synergic effect).

Wilkinson catalyst-Hydrogenation of alkenes,Hydroformylation of alkanes by cobalt carbonyl,Wacker oxidation of alkenes to acetaldehyde and Fischer Tropsch synthesis. **2 Hours**

UNIT IV

Heterocyclic compounds: **10 Hours**

Classification and nomenclature. Molecular orbital pictures and explanation for the aromatic characteristics of pyrrole, furan, thiophene, pyridine, pyrazole, oxazole and thiazole. Comparison of aromaticity of these compounds. General methods of synthesis (3 methods) and reactions of these compounds, mechanism of electrophilic substitution in furan and pyridine. Mechanism of nucleophilic substituition in pyridine. Comparison of basicity of pyridine, piperidine and pyrrole, condensed five or six membered heterocycles-explanation with examples. Preparation and reactions of indole, quinoline, isoquinoline with special reference to Fischer- Indole synthesis, Skraup synthesis and Bischler-Napieralski synthesis, Mechanism of electrophilic substitution, reactions of indole, quinoline and isoquinoline.

CH 303 Chemistry Practical V 359 **4Hrs/Week (12x4 Hrs)**

1. Inorganic gravimetric Experiments:

a) Estimation of barium as barium sulphate in barium chloride solution.

b) Estimation of copper as cuprous thiocyanate in copper sulphate solution.

c) Estimation of Ni as nickel dimethyl glyoximate in nickel ammonium sulphate solution.

d) Estimation of iron as ferric oxide in ferrous ammonium sulphate solution.

e) Estimation of chloride/ silver as AgCl.

f) Estimation of magnesium as oxinate in magnesium sulphate solution.

2. Solvent Extraction: Separation and estimation of Mg(II) and Fe(II) ions.

3. Colorimetry: Verification of Beer-Lambert Law, Job's and Mole-ratio methods.

4. Adulteration: Determination of adulteration in food stuffs.

5. Effluent analysis: Analysis of effluent water.

6. Steam Distillation: Steam distillation of Naphthalene from its suspension in water/clove oil from cloves/Separation of o-and p-nitro phenols.

8. Resolution of racemic mixture of (+) mandelic acid.

9. Stereochemical Study of organic compounds via models

a) R and S configuration of optical isomers.

b) E and Z configuration of geometrical Isomers

c) Conformational analysis of cyclohexane and substituted cyclohexanes.

SIXTH SEMESTER

CH 351: Chemistry Paper VII

3 Hrs/Week(40 Hrs)

UNIT I

4 Hours

Inorganic polymers:

Preparation, properties, structure and applications of Silicones, Flurocarbons and Phosphonitrilic halides. Production and structural features of borazine, boron nitride, sulphur nitride(SN)x and silican carbide.

2 Hours

Composites:

Introduction, role of matrix in composites, types of matrix, different matrix materials, reinforcement, classification of composites and applications of composites in industry.

Polymers:

Synthetic

4 Hours

Types of polymerization (i) radical polymerization (ii) cationic polymerization and (iii) anionic polymerization. Zeigler–Natta polymerization. Phenol formaldehyde resins-e.g. Bakelite, urea-formaldehyde resins, epoxy resins and polyurethanes-preparation and applications. Natural rubber-composition. Synthetic rubbers: Buna–S and SBR-preparation and applications, advantages of synthetic rubber over natural rubbers.

UNIT II

6 Hours

Photochemistry:

Interaction of radiation with matter, difference between thermal and photochemical processes, primary and secondary processes of a photochemical reaction, laws of photochemistry- Grothus –Draper Law, Stark's – Einstein Law (only statement), Jablonski diagram depicting various processes occurring in the excited state, qualitative description of fluorescence, phosphorescence, non- radiactive processes(internal conversion and intersystem crossing), Quantum yield- definition, reasons for low and high yield, one example for low yield (combination of H_2 and Br_2) and one example for high yield (combination of H_2 and Cl_2), Photosensitised reactions: energy transfer proceses, definition of photosensitisation, (e.g: Photosynthesis in plants, dissociation of H_2, dissociation of ethylene, Isomerisation of 2-butene).

4 Hours

Radiation and Nuclear chemistry:

Radiolysis of water, radiation dosimetry, dosimeter, applications in organic and inorganic reactions. Application of radioisotopes in the study of oganic reaction mechanism, medicine and soil fertility. Industrial applications.

UNIT III

6 Hours

Carbohydrates:

Monosaccharides: Interconversions of glucose and fructose, chain lengthening of aldoses(Kiliani-Fischer method), Chain shortening (Ruff degradation), Conversion of glucose into mannose–epimerisation, Mechanism of osazone formation-Amadori rearrangement, Formation of glycosides, ethers (methyl), esters (acetates). Configuration of glucose and fructose-deduction, Determination of ring size of monosaccharides (methylation and periodic acid method), Elucidation of cyclic structure of D(+) glucose, Mechanism of muta rotation.

4 Hours

Amino acids, Proteins and peptides:

Classification based on functional group, Essential and non essential aminoacids, structure and stereochemistry of amino acids- explanation, Acid–base behaviour, isoelectric point and electrophoresis- explanation, Preparation of α- amino acids from α- halogenated acids, Strecker synthesis and Gabriel synthesis. Reactions due to COOH and NH_2 groups, Action of heat, structure and nomenclature of di-, tri- and polypeptides, classification of proteins based on chemical composition and molecular shape. Peptide structure determination-end group analysis, selective hydrolysis of peptides, classical peptide synthesis, solid phase peptide synthesis, levels of protein structure- primary, secondary, tertiary and quaternary structures, Denaturation of proteins.

UNIT IV

Structure and reactions of Carboxylic acids and their derivatives: **5 Hours**

Structure of carboxylic acid and carboxylate ion, Effect of substituents on the acidity of aliphatic and aromatic carboxylic acids(ortho effect). Reactions of carboxylic acids, with mechanism-i) Homologation-Arndt-Eistert reaction ii) Degradation to alkyl halides-Hunsdiecker reaction iii) Conversion to primary amines-Curtius rearrangement iv) Conversion to haloacids-HVZ reaction. Derivatives of carboxylic acids- acid chlorides, amides esters, anhydrides-preparation and reactions.

5 Hours

Alkaloids:

Classification with examples–pyridine, piperidine, quinoline, isoquinoline and indole alkaloids. General properties–formation of salts and exhaustive methylation, physical properties and physiological activity.

Structural elucidation of nicotine and Ephedrine including synthesis. Structural formulae of atropine, cocaine, hygrine and morphine.

CH 352: Chemistry Paper VIII

3 Hrs/Week(40 Hrs)

UNIT I

4 Hours

Colorimetry and Spectrophotometry:
Introduction, theory of colorimetry and spectrophotometry. Beer-Lambert's law. Instrumentation and applications of colorimetry and spectrophotometry.

6 Hours

Ultraviolet absorption spectroscopy :
Absorption laws- Beer-Lambert law. Concept of molar absorptivity,energy level,types of electronic excitations,Frank-Condon principle(explanation about red shift and blue shift). presentation and analysis of UV spectra, types of electronic transitions. effect of conjugation. Concept of chromophore and auxochrome. Bathochromic, hypsochromic, hyperchromic and hypochromic shifts. UV spectra of conjugated dienes, dienonesand ,B-unsaturated carbonyl compounds.

UNIT II

8 Hours

Nuclear Magnetic Resonance Spectroscopy:
Introduction, origin of spectra, instrumentation of PMR spectrometer,solvents used,scales, nuclear shielding and desheilding, number of signals obtained from the sample, position of signals and chemical shift and molecular structure, spin –spin splitting,spin notation and coupling constants, areas of signals, interpretation of PMR spectra of simple organic molecules such as ethyl bromide, ethanol, acetaldehyde, 1,1,2- tribromoethane and ethyl acetate.

2 Hours

Photoelectron Spectroscopy:
Basic principles,valence and core binding energies,shifts in energies due to chemical forces,photoelectron spectra of simple molecules.

UNIT III

4 Hours

Mass spectrometry:
Principle and instrumentation of mass spectrometer. Applications in the determination of molecular mass and isotopic abundance. Nitrogen rule,even electron rule,Meclafferty rearrangement

Petroleum and Petrochemicals:
Composition,petroleum refining, Knocking, octane and Cetane numbers.Isomerization,reforming ,Isomerization of alkanes ,cracking,alkylation,synthetic fuels,Bergius process,Fischer-Tropsch process,Petrochemicals **6 Hrs**

UNIT IV

3 Hours

Terpenes:
Classification with examples, methods of isolation, Structural elucidation of citral and geraniol including synthesis. Structural formulae of menthol, α-pinene and camphor.

4 Hours

Drugs and chemotherapeutic agents:
Synthesis and mode of action of antipyrine, sulphathiazole, sulphanilamide, benzocaine and aspirine.

3 Hours

Pesticides, fungicides and herbicides:
Introduction, structure,synthesis and properties of Pesticides: organochlorine compounds-DDT,BHC; Orgnophosphorus compounds-Malathion, Parathion, Endosulphan;Pyrethrin, Alethrin, Baygon.
Herbicides:2,4-dichlorophenoxy acetic acid,Synthesis and properties.
Fungicides: Bordeaux mixture, Dithoicarbamate.Method of preparation , composition and applications.

CH 353: Chemistry Practical VI

4 Hrs/week (12x4 Hrs)

Organic Preparations:

1. Preparation of acetanilide from aniline/Benzoylation of aniline.
2. Preparation of p-bromoacetanilide
3. Nitration of acetanilide to p-nitroacetanilide and hydrolysis to p-nitroaniline.
4. Preparation of iodoform from ethanol.
5. Preparation of m-dinitrobenzene.
6. Preparation of adipic acid from cyclohexanol.
7. Preparation of benzoic acid from toluene.
8. Preparation of tribromoaniline from aniline.and conversion to tribromo benzene.

Instrumental Methods

9. To determine the strength of the given acid mixture (acetic acid+ hydrochloric acid) conductometrically using standard alkali solution.
10. To determine the dissociation constant of a weak acid by potentiometric method.
11. To determine equivalent conductance of sodium chloride by conductometric method.
12. To determine the ionization constant of a weak acid.
13. Potentiometric titration of ferrous ammonium sulphate using potassium dichromate as titrant and calculation of the redox potential of Fe^{3+} /Fe^{2+} system on the hydrogen scale.
14. To study the rate of inversion of cane sugar.
15. To determine the concentration of cupric ions present in a solution using a colorimeter.

Preparation of Complexes:

16. Preparation of sodium trisoxalatoferrate(III), $Na_3[Fe(C_2O_4)_3$
17. Preparation of tetraammine copper(II) sulphate, $[Cu(NH_3)_4]SO_4$,
18. Preparation of hexaamminecobalt(III) chloride, $[Co(NH_3)_6]Cl_3$

II semester: Computers for Chemists, Laboratory Safety and Chemotherapy

UNIT I

Computers for Chemists

Basic structure and functioning of computer with a PC as an illustrative example.

Memory, Input/output devices, Secondary storage, Computer languages, Operating systems, Algorithm and Flow chart , programmes and packages, MS-word, EXCEL, PPT, CHEM SKETCH etc.

Demonstration and writing and drawing of chemical formulae and structure through chem sketch.

Plotting the various graphs such as pressure-volume (PV), pressure- temperature (PT), potentiometric, conductometric and colorimetric plots through EXCEL. 8h

LABORATORY SAFETY

Introduction. General laboratory protocols: Basic rules, Good Laboratory Practices. Chemical hazards, safety data sheets, symbols and hazard information, storage procedure, Physical hazards, Health hazards, Reaction hazards. Assessing the risks of hazards. Minimizing the risks of hazards: fume hood, ventilation, fire extinguisher, personal protective equipment's, Preparedness for emergencies from uncontrolled hazards: Importance of reporting incidents, response to common emergencies such as fires, explosions, chemical spills, chemical exposures, injuries. 4h

UNIT II

SERENDIPITY

The role of Chance in making Scientific Discoveries

What is Serendipity- Some Serendipous Inventions in Science; Guncotton, Velcro, Plastic, X-rays, Microwave, Superglue, Mauve, Teflon, Saccharin, Stainless steel, Matches. Role of Serendipity in Drug discovery; Inventions in Chemistry that enabled the modern world.

3h

CHEMOTHERAPY

Introduction. Classification – antibiotics-Chloramphenicol and Pencillin. Synthesis and Uses. Analgesics – Narcotic analgesics and Non-Narcotic analgesics-Examples and their uses. (Simple Synthesis to be included).

Sulphonamides-Preparation of sulphonamides.-Examples and their uses. Antiseptics and disinfectants-Examples and their uses. Hypoglycemic agents –Cancer treatment by Chemotherapy.

A brief account of medicinally important compounds. Compounds of aluminum as pharmaceutics; compounds of phosphorous as pharmaceutics; Compounds of iron as pharmaceutics. Examples and uses. (Only specific examples) 4h

LaboratoryReagents: Preparation of laboratory reagents and maintenance of electrodes and equipment's. Methods of expressing concentrations of solution, Preparation of reagents for qualitative analysis of organic and inorganic compounds. Precaution and safety measures during reagent preparation. 5h.

References:

1. Laboratory Safety, theory and Practice, 1st Edition, Editors: Anthony Fuscaldo and others Elsevier Publications, 1980.
2. Chemical Laboratory Safety and Security: A Guide to Developing Standard Operating Procedures. National Academies Press (2016). Board on Chemical Sciences and Technology , Division on Earth and Life Studies.
3. Chemistry Laboratory Safety Manual, Inndian Institute of Science Education and Research, Tirupati.
4. Laboratory Safety Manual, NCBS, 2016.
5. Pharmaceutical Chemistry by Thyagarajan.
6. Science and serendipity: Famous accidental discoveries, Samira Shackle, Thursday,2ndApril 2015- NEW HUMANIST.
7. The role of serendipity in drug discovery. Thomas A. Ban, MD, FRCP- Dialogues in Clinical Neuroscience, 2006 Sep; 8(3): 335–344.
8. Five Chemistry Inventions that changed the modern world-THE CONVERSATION. June 2, 2015
9. Hannan, Patrick J. (2006). Serendipity, Luck and Wisdom in Research; Universe. ISBN 0-595-36551-5.
10. Practical Chemistry- Dr. O.P.Pandey, D.N. Bajpai, Dr. S. Giri
11. Vogel's Qualitative Inorganic Analysis- G. Svehla
12. Computers and their applications to Chemistry – Ramesh Kamari
13. Computers in Modern Chemistry – A. Kumar