S. Y. B.Sc. Chemistry
SEMESTER III
Paper I
CHEM 2301: Physical and Analytical Chemistry (48 L, 3 Credits)

Section I: Physical Chemistry

I) Chemical Kinetics (10 L)

Introduction of chemical kinetics. The concept of reaction rate. Effects of various factors like temperature, pressure, presence of catalyst on the reaction rate. Order and Molecularity of a chemical reaction. Derivation of integrated reaction rate equation for zero, first, second order (both for equal and unequal initial concentrations of reactants) reactions and third order reaction (no derivation). Half-life period of reaction. General methods for determination of order of a reaction. Concept of activation energy and its determination from Arhenius equation. Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular reactions Comparison of the two theories. Numerical problems.

II) Chemical Thermodynamics (6 L)

Second Law of Thermodynamics: Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change (Δ S) for reversible and irreversible processes under different conditions. Numerical problems.

Third Law of Thermodynamics: Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules.

III). Free energy and Chemical Equilibrium (8 L)

Introduction, Helmholtz free energy, variation of it with volume and temperature, Gibbs free energy, variation of it with pressure and temperature, Gibbs free energy change for chemical reaction, Free energy change for an ideal gas. Free Energy and equilibrium - Concept, Definition and significance
The reaction Gibbs Energy. Exergonic and endergonic reaction. The perfect gas equilibrium, the general case of equilibrium, the relation between equilibrium constants, molecular interpretation of equilibrium constant. The response of equilibria to conditions- response to pressure, response to temperature, Vant Haff equation, Value of K at different temperature, Problems

Reference books:

1. Principles of Physical Chemistry, S. H. Marron and C. F. Pruton, 6th edn.
2. Essentials of Physical Chemistry, Bahl, Tuli, Revised multicolour edn. 2009
3. Physical Chemistry, G. M. Barrow, Tata McGraw-Hill (2007)
4. University Chemistry, B. H. Mahan, 3rd edn. Narosa (1998)
5. Chemical Thermodynamics, R. P. Rastogi and R.P. Misera

Section II: Analytical Chemistry

1. Analytical Chemistry and Essentials (10 L)

A brief introduction of analytical chemistry, the analytical perspectives, Common analytical problems.

Some important units of measurements-SI units, distinction between mass and weight, mole, millimole and related calculations, significant figures

Solution and their concentrations- Molar concentrations, Molar analytical Concentrations, Molar equilibrium concentration, percent Concentration, part per million, part per billion, part per thousand, density and specific gravity of solutions, Numerical problems

Chemical Stoichiometry – empirical and molecular formulas, Stoichiometric calculations, Numerical problems.

2. Volumetric Analysis (14 L)

Introduction to volumetric analysis Calibration of apparatus, Standard solutions, Equivalent weights in different type of reactions, Classification of volumetric analysis,

1. Neutralization titration: Acid base indicators, Ostwald's theory of indicators, neutralization curves for strong acid- strong base, weak acid- strong base, weak base- strong acid, Determination of equivalence point and calculations.Problems.

2. Complexometric titration: Principle, Mg- EDTA titration, metal ion indicators, choice of indicators. Applications,

3. Redox titration: Principle, detection of equivalence point using suitable indicators. Titration between oxalic acid and $KMnO_4$. Applications.

4. Precipitation titration: Principle, titration between $AgNO_3$ and halide ions by Volhard's method and Fajan's method. Detection of end point of the titration. Applications.

5. Iodometric titration: Principle, detection of end point, difference between iodometry and iodimetry, standardization of $Na_2S_2O_3$ solution using $K_2Cr_2O_7$ and estimation of iodine. Applications.

Reference books:

1. Basic concept of Analytical Chemistry, S. M. Khopkar
2. Instrumental methods of chemical analysis, Willard, Merritt, Dean
3. Analytical Chemistry, G. D. Christian
4. Introduction to Instrumental analysis, R. D. Brown
5. Fundamentals of Analytical Chemistry, Skoog
6. Instrumental methods of chemical analysis, Chatwal Anand

Paper II

CHEM 2302: ORGANIC AND INORGANIC CHEMISTRY (48 L, 3 Credits)

Section I: Organic Chemistry

1. Stereoisomerism (10 L)

i) Introduction to optical isomerism - Optical Activity and polarimetry- Ordinary light, mono chromatic light, plane polarized light, optical activity, dextro rotatory, leavo rotatory, specific rotation, causes of optical activity, chirality, asymmetric carbon atom, Enantiomerism, Diastereomerism.

ii) Stereoisomerism - Baeye'rs strain theory, heat of combustion, cycloalkanes, factors affecting the stability of conformation, Conformation of cyclohexane - equatorial and axial bonds, Monosubstituted cyclohexane stability with -CH_3 and-$C(CH_3)_3$ substitutes. Structures of geometrical isomers of dimetylcyclohexane only.

Ref. 3

2. Aliphatic and Aromatic amines (6 L)

a) Structure b) Classification c) nomenclature d) physical Properties – salt of amine

e) preparation of amine from – reduction of nitro compounds, reductive amination, reduction of nitriles, Hoffmann degradation of amides f) Reactions of amines - basicity, salt formation, alkylation, conversion into amides, ring substitution in aromatic amines, Hoffmann elimination, reactions with nitrous acid g) Diazonimum salts – preparation and reactions h) Sandmeyer reaction i) Replacement of nuclear 'H' by – I, -OH and H- j) Analysis of amines.

Ref. 1

3. Organic reaction Mechanism (8 L)

Introduction, types of reagents–electrophile, nucleophile and free radical. Types of organic reactions: Addition, Elimination (β-elimination and Hofmann elimination), substitution (aliphatic electrophilic and nucleophilic, aromatic electrophilic) and rearrangement. Mechanism: (i) Benzion condensation (ii) Markovnikov and anti-Markovnikov addition reaction (iii) Saytzeff and Hoffmann elimination (iv) SN 1 and SN 2 reactions (v) Pinacol-Pinacolone rearrangement (vi) Beckmann rearrangement.

Ref. 1 & 5

Reference Books:

1. Organic Chemistry. Morrison and Boyd, 6th Ed Prentice Hall of Indi Prt.Ltd, New Delhi-2001.
2. Outline of Biochemistry 5th Edn, Conn, Stumpf Bruening and Roy Doi John Wiley 1987.
3. Stereochemistry of carbon compounds, E. L. Eliel
4. Reactions, rearrangements and reagents, S N Sanyal
5. A guide book to Mechanism in Organic Chemistry, Peter Sykes, 6th Edn.

Section II: Inorganic Chemistry

1. Molecular Orbital Theory of diatomic molecules (14 L)

Limitations of Valence Bond theory(VBT), Need of Molecular orbital theory (MOT), Features of MOT, Sigma and pi bond, Molecular orbital Method, LCAO principle and method, s-s combinations of orbitals, s-p combinations of orbitals, p-p combinations of orbitals, p-d combinations of orbitals, d-d combinations, Non-bonding combinations of orbitals, Rules for linear combination of atomic orbitals.

Examples of molecular orbital treatment for homo-nuclear diatomic molecules: (Explain each molecule with respect to MO energy level diagram, bond order and magnetic behaviour) H_2^+ molecule ion, H_2 molecule, He_2^+ molecule ion, He_2 molecule, Li_2 molecule, Be_2 molecule, B_2 molecule, C_2 molecule, N_2 molecule, O_2 molecule, O_2^+, O_2^- and O_2^{2-} molecule ion, F_2 molecule, Ne_2 molecule.

Heteronuclear diatomic molecules: Examples of molecular orbital treatment for hetero- nuclear diatomic molecules, NO molecule, CO molecule, HF molecule.

2. Chemistry d-block (4 L)

Introduction, electronic configuration, size of atoms and ions, density, melting points and boiling points, reactivity, oxidation state, catalytic properties, colour and magnetic properties of complexes.

3. Acid, base and solvents (6 L)

Properties of solvents, Arrhenius theory, Lowry-Brownsted theory, Solvent system, Lux-Flood concept, Lewis concept, Hydracids and Oxyacids.

Reference Books:

1. Concise Inorganic Chemistry, Lee, J.D. ELBS, 1991.

2. Basic Inorganic Chemistry, Cotton, F.A., Wilkinson, G. & Gaus, P.L. 3rd ed., Wiley.

3. Concepts and Models in Inorganic Chemistry, Douglas, B.E., McDaniel, D.H. & Alexander, J.J. John Wiley & Sons.

4. Inorganic Chemistry: Principles of Structure and Reactivity, Huheey, J. E., Keiter, E.A., Keiter, R.L. &Medhi, O.K. Pearson(2006)

Paper III

CHEM 2303: PRACTICAL COURSE – III (2 credit)

Section I: Physical Chemistry Practical (Any five experiments)

1. Study of variation of mutual solubility temperature with concentration for the phenol water system and determination of the critical solubility temperature.
2. Determination of solubility of Benzoic acid at different temperature and to calculate ΔH of solution.
3. To determine the first order rate constant of acid catalysed ester hydrolysis.
4. To compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate.
5. To determine the rate constant of base catalysed ester hydrolysis.
6. To study the standardization and working of potentiometer and determine the potential and pH of two buffer solutions.
7. To study the standardization and working of pH meter and determine the equivalence point for pH metric titration between strong acid and strong base.
8. To determine the molecular weight of organic liquid by steam distillation.
9. Study of the equilibrium of the reaction by the distribution method.(any one)

   a) $I_{2\,(aq)} + I^-_{(aq)} \rightarrow I_{2\,(aq)}$

   b) $Cu^{2+}_{(aq)} + x\ NH_{3\,(aq)} \rightarrow [Cu(NH_3)_x]^{2+}$

10. Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.

Reference Book:

1 A Senior Practical Physical Chemistry, B. D. Khosla, V. C. Garg & Gulati , R, Chand & Co.: New Delhi (2011)

2. Practical Physical Chemistry, A M. Jemes, F. E. Prichard, 3rd edn, Longman.

3. Advanced Practical Physical Chemistry, J. B. Yadav, Goel Publishing house.

Section II: Organic Chemistry Practical

1) Organic Qualitative Analysis (Six Single compounds)

Two compounds per practical.

Identification of organic compounds through –

a) Type determination of organic compound b) preliminary tests c) detection of elements (Sodium fusion tests) d) detection of functional groups e) melting point / Boiling point

i) Acids (any two): benzoic, salicylic, phthalic, cinnamic, oxalic, salicylic acid

ii) Phenols (any two): α-naphthol, β-naphthol, resorcinol, o-nitrophenol, p-nitrophenol

iii) Base (any two): Aniline, p-toludine, diphenylamine, N, N-dimethylaniline, o-nitroaniline m-nitroaniline, p-nitroaniline

iv) Neutral (any two): Benzaldehyde, glucose, fructose, acetone, ethylmethyl ketone, acetophenone, methyl acetate, ethyl acetate, naphthalene, Anthracene, Nitrobenzene, mdinitrobenzene, Acetamide, Urea, Acetanilide, Chloroform, Carbon tetrachloride, Thiourea.

2) Organic Preparation (any two) (With crystallisation, M. P. and TLC)

i) Aspirin from salicylic acid

ii) P-Nitro Benzoic acid from P- Nitro Toluene

iii) phthalic anhydride from phthalic acid by sublimation method

iv) Osazone form glucose

v) Quinone form Hydro Quinone

3) Purification of organic liquids by distillation (any two mixtures)

one volatile and one non volatile liquid with boiling point determination.

Reference Book:

1 Organic Qualitative Analysis – A. I. Vogel

S. Y. B.Sc. Chemistry
SEMESTER IV
Paper I
CHEM 2401: Physical and Analytical Chemistry (48 L, 3 Credits)

Section I: Physical Chemistry

1. SOLUTIONS (8 L)

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law - non-ideal solutions. Vapour pressure-composition and temperature- composition curves of ideal and non-ideal solutions. Distillation of solutions, Lever rule. Azeotropes. Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Immiscibility of liquids- Principle of steam distillation. Nernst distribution law and its applications, solvent extraction.

2. Ionic Equilibrium (10 L)

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, Common ion effect. Salt hydrolysis- calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts, applications of solubility product principle.

3) Phase Equilibrium (6 L)

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius - Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, FeCl3-H2O and Na-K only).

Reference books:

1. Principles of Physical Chemistry, S. H. Marron and C. F. Pruton, 6th edn.
2. Essentials of Physical Chemistry, Bahl, Tuli, Revised multicolour edn. 2009
3. Physical Chemistry, G. M. Barrow, Tata McGraw-Hill (2007)
4. University Chemistry, B. H. Mahan, 3rd edn. Narosa (1998)
5. Chemical Thermodynamics, R. P. Rastogi and R.P. Misera

Section II: Analytical Chemistry

1. Errors in Quantitative Analysis (6 L)

Introduction to Error, Accuracy, Precision, Methods of expressing accuracy and precision, Classifications of errors, Significant figures, Distribution of random errors, Mean and Standard deviations, Reliability of results, Numerical.

2. Introduction to Instrumental applications

A) **pH meter (6 L)**

Introduction, pH meter, Glass pH electrode, combination of pH electrode-Complete Cell, Standard Buffer –reference for pH measurement, Accuracy of pH measurement, Using pH meter –How does it works? pH metric titrations Applications of pH meter. Numerical based on pH metry.

B) **Potentiometer (6 L)**

Introduction, General Principal, Electrochemical Cell, Reference Electrodes, Liquid Junctions & Potentials, Determination of Concentration from potential measurement, Potentiometric titrations, Numerical based on potentiometry.

3. Chromatography (6 L)

Introduction to chromatography, IUPAC definition of chromatography. Descriptions about different types like, Paper chromatography, Thin Layer Chromatography, Ion exchange Chromatography, Gas permeation Chromatography, Affinity chromatography, Gas chromatography, Supercritical fluid chromatography, High Performance Liquid Chromatography, Capillary electrophoresis, Classification of chromatographic methods based on separation methods and development procedures.

Reference books:

1. Basic concept of Analytical Chemistry, S. M. Khopkar
2. Instrumental methods of chemical analysis, Willard, Merritt, Dean
3. Analytical Chemistry, G. D. Christian
4. Introduction to Instrumental analysis, R. D. Brown
5. Fundamentals of Analytical Chemistry, Skoog
6. Instrumental methods of chemical analysis, Chatwal Anand

Paper II

CHEM 2402: ORGANIC AND INORGANIC CHEMISTRY
(48 L, 3 Credits)

Section I: Organic Chemistry

1. Chemistry of Aldehydes and Ketones (6 L))

a) Structure of carbonyl groups. b) Nomenclature of Aldehyde and ketones c) Physical properties of aldehydes and ketones d) Preparations of aldehydes from primary alcohol, methyl benzenes, acid chlorides, phenols e) Preparation of ketones from – secondary alcohols, Friedel Craft acylation, nitriles f) Reaction of aldehydes and ketones – (i) Oxidation (ii) reduction – catalytic reduction, metal hydrides – $LiAlH_4$, $NaBH_4$. Clemmenson's reduction, Wolf kishner, Thioketal reduction, (iii) Addition of cyanides (iv) Addition of derivatives of ammonia (v) Addition of alcohols (vi) Cannizzaro reaction (vii) Addition or Grignard reagent (viii) Aldol condensation (ix) Perkins reaction (x) haloform reactions g) Analysis of aldehyde and ketones.

Ref. 1

2. Chemistry of Homocyclic and Heterocyclic compounds (6 L))

a) **Naphthalene and Anthracene -** Numbering of carbon atoms, nomenclature of derivatives, preparation and reactions of naphthalene and anthracene.

b) **Heterocyclic compounds** - Definition, classification, nomenclature of heterocyclic compounds.

c) **Five membered heterocyclic compounds -** furan, pyrrole, Thiophene, nomenclature, preparation dorm 1, 4-diketones, reactions sulphonation, F. C. Acylation, Diazocoupling, Riemer-Tiemann reaction, catalytic hydrogenations.

d) **Six membered heterocyclic compounds -** Pyridine, structure, preparation from picoline, acetylene, acrolein, reactions nitration, sulphonation, bromination, catalytic hydrogenation.

e) **Structure and synthesis of quinoline and Isoquinoline.**

Ref. 1

3. Introduction of Bio-molecules (12 L)

a) Introduction: What are different Bio molecules found in and associated with living system? How is biochemistry directly concern to life i.e. What is the scope and impact of biochemistry on living system? Importance of biochemistry.

Ref. 2 Relevant pages.

b) Carbohydrates : Definition, classification, reactions of carbohydrates – oxidation, reduction osazone formation, ester formation, isomerization, Killiani Fischer synthesis, Ruff degradation, D/L configuration, configuration of D(+) Glucose, Fischer proof and mutarotation, cyclic structure of glucose-Fischer Haworth and chair configuration. Brief account of maltose, sucrose, lactose, cellobiose, polysaccharides - starch, cellobiose

Ref. 1 section: 34.2–34.4, 34.6–34.9, 34.11, 34.16, 35.1 to 35.9 Pages : 1185 – 1195, 1200

c) Amino acids, proteins, enzymes: i) α-amino acids: Fischer projection, relative configuration, classification, structure of amino acid, properties and reactions of α-amino acids. ii) Proteins : Formation of peptide linkage, feature of peptide linkage, α-helical conformation, β-plated structure, primary, secondary, tertiary and quaternary structure of proteins. iii) Enzymes : General information, co-enzymes, and vitamins hormones, prosthetic groups and their role, enzymes specificity, classification of enzymes with examples.

d) Lipids : General introduction, classification with examples.

Ref. 2

Reference Books:

1. Organic Chemistry – 6^{th} Edn. Morrison and Boyd Prentice Hall (2001)
2. Outline of Biochemistry 5^{th} Edn., Conn, Sumpf, Bruening and Roy Doi John wiley 1987.

Section II: Inorganic Chemistry

3. Introduction to Coordination chemistry (16 L)

General account and meaning of the terms involved in coordination chemistry: Coordinate bond, central metal atom or ions, ligand, double salt, coordination compound, coordination number, charge on the complex ion, oxidation number of central metal ion, first and second coordination sphere, Ligands: Definition, Classification, Chelate and chelating agents, IUPAC nomenclature of coordination compounds, Different geometries of coordination compounds with C. N.= 2, 4 and 6 with examples of each geometry. Stability of coordination complexes, Isomerism: Polymerization isomerism, Ionization isomerism, Hydrate isomerism, Linkage isomerism, Coordination isomerism, Coordination position isomerism, Geometric isomerism or stereoisomerism, Optical isomerism, Werner Theory of coordination compounds, Sedgwick and Pauli theory and EAN rule, Problems

4. Chemistry of Carbonyls Complexes. (8 L)

Introduction, Definition, bonding in carbonyl complexes, 18 electron rule, M-M bonds in carbonyl complexes, geometries of coordination complexes, CO π acid ligands.

synthesis of carbonyl complexes: direct reaction, reductive carboxylation, photolysis, thermolysis, homogeneous catalysis: hydro-formylation by Cobalt carbonyl complex, Wacker's process and Monsanto acetic acid process, Wilkinson catalyst.

Reference Books:

1. Concise Inorganic Chemistry, Lee, J.D. ELBS, 1991.
2. Basic Inorganic Chemistry, Cotton, F.A., Wilkinson, G. &Gaus, P.L. 3rd ed., Wiley.
3. Concepts and Models in Inorganic Chemistry, Douglas, B.E., McDaniel, D.H. & Alexander, J.J. John Wiley & Sons.
4. Inorganic Chemistry: Principles of Structure and Reactivity, Huheey, J. E., Keiter, E.A., Keiter, R.L. &Medhi, O.K. Pearson(2006)

Paper III

CHEM 2403: PRACTICAL COURSE- IV

(2 credit)

Section I: Analytical Chemistry Practical (Any five experiments)

1. Determination of Ca in presence of Mg using EDTA.
2. Determination of the strength of given H_2O_2 solution with standard 0.05 N KMnO4 solution.
3. To determine the amount of Aspirin from a given tablet. Also calculate absolute error, relative error, standard deviation and relative standard deviation with reference to the mean of analysis.
4. To determine the amount of acetic acid in commercial vinegar by titrating with approx. NaOH solution using selected best indicator.
5. Estimation of Nickel or Aluminum from the given salt solution by using Eriochrome Black T indicator (back titration method)
6. Determination of molecular weight of mono / dibasic acid volumetrically.
7. To perform the pH titration between weak acid and strong base and hence select the best indicator to locate the equivalence point graphically.
8. Verification of Beer's law using different concentrations of $KMnO_4$ and determine the unknown concentration of $KMnO_4$ by calibration curve method.
9. Identification of metal by paper chromatography in any two mixture containing two / three metal ions like- Ni, Cu, Al, Fe, Co, Mn.
10. To study formation of Fe(III)-thiocyanate complex calorimetrically and determine the effect of metal ion and ligand concentration on complex formation.
11. To determine the amount of copper from the given solution iodometrically.

Reference books:

1. Analytical Chemistry, G. D. Christian 6^{th} edn.
2. Vogel's textbook of Quantitative chemical analysis, R. C. Denney, J. D. Barnes. M. J. K. Thomas, 6^{th} edn.

Section II: Inorganic Chemistry Practical (Any five experiments)

1. Inorganic qualitative analysis any simple three mixtures without phosphate and borate.
2. Inorganic Synthesis (any two)
   A) Synthesis and purity of Sodium cobaltinitrate

   B) Green Synthesis of $[Fe(acac)_3]$ complex

   C) Synthesis and purity of $K_3[Al(OX)_3]$

   D) Preparation of coordination complex $[Cu(NH_3)_4]\ SO_4.H_2O$ and find out its purity.
   E) Preparation of coordination complex $[Ni(NH_3)_6]\ Cl_2$ and find out its purity.
   F) Preparation of coordination (Oxalato) aluminate complex and find out its purity.

Reference books:

1. Vogel's Qualitative Inorganic Analysis, Svehla G. Pearson Education, 2012
2. Vogel's Quantitative Inorganic Analysis, Mendham J. Pearson Education, 2012