Structure and Detailed Syllabus of the Undergraduate Course (B.Sc.) in Chemistry under CBCS

Department of Chemistry

Presidency University

(Effective from 2022)

PRESIDENCY UNIVERSITY
KOLKATA

Department of Chemistry
(Faculty of Natural and Mathematical Sciences)
Presidency University
Hindoo College (1817-1855), Presidency College (1855-2010)
86/1, College Street, Kolkata - 700 073
West Bengal, India

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Aim of the Programme / Programme Outcomes:

1. Create an amicable learning environment among students to inculcate the deep interests and knowledge in subject.

2. Provide choice-based learning to students.

3. Help students to develop the ability to use their knowledge and skills to interpret and handle the problem arises day to day.

4. Motivate students to pursue advanced studies on their subject of interest.

5. Educate and enhancing student generic skills through skill enhancement courses and value added courses, this may help them creating employment and business opportunities in academia and industries.

Programme specific learning outcomes

A graduating student of B.Sc. Chemistry degree expected to:

1. Have proficient theoretical and experimental knowledge in the broad subject area of chemistry as well as different sub-fields of chemistry such as Analytical Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry, Material Chemistry, etc.
2. Explain, integrate and apply the acquired knowledge to problems that are emerging from the interdisciplinary areas.
3. Be aware of current developments at the forefront in Chemistry and allied subjects.
4. Have hands-on training on various analytical techniques, classical qualitative and quantitative chemical analysis, which creates different types of professionals in the field of chemistry and related fields such as pharmaceuticals, chemical industry, teaching, research, environmental monitoring, product quality, consumer goods industry, food products, cosmetics industry, etc.
5. Have knowledge on hazardous chemical, safe handling of chemicals and role of chemistry on environmental issues.
6. Construct a research problem as per the social requirement.
7. Communicate the scientific work in oral, written and e- formats as per the requirements.

Structure of Chemistry Courses

Semester	Number of Course				
	Core Course	AECC (out of)	SEC (out of)	DSE (out of)	GE (out of)
1st	2	1 (3)	-	-	1
2nd	2	1 (3)	-	-	1
3rd	3	-	1 (3)	-	1 (2)
4th	3	-	1 (3)	-	1 (2)
5th	2	-	-	2 (6)	-
6th	2	-	-	2 (7)	-
Total	**14**	**2**	**2**	**4**	**4**

PRESIDENCY UNIVERSITY
KOLKATA

Credit Allocation and Marks Distribution for the Undergraduate Course in Chemistry (Major) under CBCS
Department of Chemistry, Presidency University, Kolkata

Semester	Course Type	Paper Code	Course Name	Marks					
				Theory	Practical	Total	Theory	Practical	Total
First	Core Course	CHEM01C1	INORGANIC CHEMISTRY-I	4	2	6	70	30	**100**
First	Core Course	CHEM01C2	PHYSICAL CHEMISTRY-I	4	2	6	70	30	**100**
First	Generic Elective	CHEM01GE1	Atomic Structure, Bonding, General Organic Chemistry, Aliphatic Hydrocarbons	4	2	6	70	30	**100**
First	Ability Enhancement Compulsory Course	AECC01	Environmental Science / English Communication / Modern Indian Language	4		4	100		**100**
Second	Core Course	CHEM02C3	ORGANIC CHEMISTRY-I	4	2	6	70	30	**100**
Second	Core Course	CHEM02C4	PHYSICAL CHEMISTRY-II	4	2	6	70	30	**100**
Second	Generic Elective	CHEM02GE2	Chemical Energetics, Equilibria and Functional Organic Chemistry	4	2	6	70	30	**100**
Second	Ability Enhancement Compulsory Course	AECC02	Environmental Science / English Communication / Modern Indian Language	4		4	100		**100**
Third	Core Course	CHEM03C5	INORGANIC CHEMISTRY-II	4	2	6	70	30	**100**
Third	Core Course	CHEM03C6	ORGANIC CHEMISTRY-II	4	2	6	70	30	**100**
Third	Core Course	CHEM03C7	PHYSICAL CHEMISTRY-III	4	2	6	70	30	**100**
Third	Generic Elective	CHEM03GE3.1 CHEM03GE3.2	1.Solutions, Phase Equilibria, Conductance, Electrochemistry & Functional Group Organic Chemistry*OR*2.Molecules of Life	4	2	6	70	30	**100**
Third	Skill Enhancement Course	CHEM03SEC1.1 CHEM03SEC1.2	1.IT Skills for Chemists *OR* 2.Basic Analytical and Nuclear Chemistry	4		4	100		**100**
Fourth	Core Course	CHEM04C8	INORGANIC CHEMISTRY-III	4	2	6	70	30	**100**
Fourth	Core Course	CHEM04C9	ORGANIC CHEMISTRY-III	4	2	6	70	30	**100**
Fourth	Core Course	CHEM04C10	PHYSICAL CHEMISTRY-IV	4	2	6	70	30	**100**
Fourth	Generic Elective	CHEM04GE4.1 CHEM04GE4.2	1.Transition Metal & Coordination Chemistry, States of Matter & Chemical Kinetics *OR* 2. Quantum Chemistry, Spectroscopy & Photochemistry	4	2	6	70	30	**100**
Fourth	Skill Enhancement Course	CHEM04SEC2.1 CHEM04SEC2.2	1.Green Methods in Chemistry *OR* 2. Pharmaceutical Chemistry	4		4	100		**100**
Fifth	Core Course	CHEM05C11	ORGANIC CHEMISTRY-IV	4	2	6	70	30	**100**
Fifth	Core Course	CHEM05C12	PHYSICAL CHEMISTRY-V	4	2	6	70	30	**100**
Fifth	Discipline Specific Elective	CHEM05DSE1.*	Discipline Specific Elective*	4	2	6	70	30	**100**
Fifth	Discipline Specific Elective	CHEM05DSE2.*	Discipline Specific Elective*	4	2	6	70	30	**100**
Sixth	Core Course	CHEM06C13	INORGANIC CHEMISTRY-IV	4	2	6	70	30	**100**
Sixth	Core Course	CHEM06C14	ORGANIC CHEMISTRY-V	4	2	6	70	30	**100**
Sixth	Discipline Specific Elective	CHEM06DSE3.**	Discipline Specific Elective**	4	2	6	70	30	**100**
Sixth	Discipline Specific Elective	CHEM06DSE4.**	Discipline Specific Elective**	4	2	6	70	30	**100**
			Total:	104	44	**148**	1940	660	**2600**

*** 1. Research Methodology for Chemistry, 2. Polymer Chemistry, 3. Analytical Methods in Chemistry,** 4. Applications of Computers in Chemistry, 5. Molecular Modelling & Drug Design, 6. Industrial Chemicals & Environment. **** 7. Seminar / Review / Grand Viva, 8. Fluorescence study: Theory and Applications for Macromolecules and Nanomaterials Sensing, 9. Biologically relevant molecules, Organic Photochemistry, Dyes and synthetic polymers,** 10. Inorganic Materials of Industrial Importance, 11. Green Chemistry, 12. Instrumental Methods of Analysis, 13. Novel Inorganic Solids

Semester-wise Modules of the Undergraduate Course in Chemistry (Major) under CBCS
Department of Chemistry, Presidency University, Kolkata

Semester I

CHEM01C1	INORGANIC CHEMISTRY-I
CHEM01C2	PHYSICAL CHEMISTRY-I
CHEM01GE1	Generic Elective-I
AECC01	Environmental Science / English Communication / Modern Indian Language

Semester II

CHEM02C3	ORGANIC CHEMISTRY-I
CHEM02C4	PHYSICAL CHEMISTRY-II
CHEM02GE2	Generic Elective-II
AECC02	Environmental Science / English Communication / Modern Indian Language

Semester III

CHEM03C5	INORGANIC CHEMISTRY-II
CHEM03C6	ORGANIC CHEMISTRY-II
CHEM03C7	PHYSICAL CHEMISTRY-III
CHEM03GE3	Generic Elective-III
CHEM03SEC1	Skill Enhancement Course-I

Semester IV

CHEM04C8	INORGANIC CHEMISTRY-III
CHEM04C9	ORGANIC CHEMISTRY-III
CHEM04C10	PHYSICAL CHEMISTRY-IV
CHEM04GE4	Generic Elective-IV
CHEM04SEC2	Skill Enhancement Course-II

Semester V

CHEM05C11	ORGANIC CHEMISTRY-IV
CHEM05C12	PHYSICAL CHEMISTRY-V
CHEM05DSE1	Discipline Specific Elective-I
CHEM05DSE2	Discipline Specific Elective-II

Semester VI

CHEM06C13	INORGANIC CHEMISTRY-IV
CHEM06C14	ORGANIC CHEMISTRY-V
CHEM06DSE3	Discipline Specific Elective-III
CHEM06DSE4	Discipline Specific Elective-IV

Academic Session: Each Semester shall contain at least 16 Teaching Weeks

Odd Semesters: Semesters One, Three and Five - July to December
Even Semesters: Semesters Two, Four and six - January to June

CORE COURSE (HONOURS IN CHEMISTRY)

Semester I:

1. CHEMISTRY-C1: INORGANIC CHEMISTRY-I (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL- C1 LAB: (Credits: Practicals-02, 60 Lectures)

2. CHEMISTRY-C2: PHYSICAL CHEMISTRY-I (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C2 LAB: (Credits: Practicals-02, 60 Lectures)

Semester II:

3. CHEMISTRY-C3: ORGANIC CHEMISTRY-I (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C3 LAB: (Credits: Practicals-02, 60 Lectures)

4. CHEMISTRY-C4: PHYSICAL CHEMISTRY-II (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C4 LAB: (Credits: Practicals-02, 60 Lectures)

Semester III:

5. CHEMISTRY-C5: INORGANIC CHEMISTRY-II (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C5 LAB: (Credits: Practicals-02, 60 Lectures)

6. CHEMISTRY-C6: ORGANIC CHEMISTRY-II (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C6 LAB: (Credits: Practicals-02, 60 Lectures)

7. CHEMISTRY-C7: PHYSICAL CHEMISTRY-III (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C7 LAB: (Credits: Practicals-02, 60 Lectures)

Semester IV:

8. CHEMISTRY-C8: INORGANIC CHEMISTRY-III (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C8 LAB: (Credits: Practicals-02, 60 Lectures)

9. CHEMISTRY-C9: ORGANIC CHEMISTRY-III (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C9 LAB: (Credits: Practicals-02, 60 Lectures)

10. CHEMISTRY-C10: PHYSICAL CHEMISTRY-IV (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C10 LAB: (Credits: Practicals-02, 60 Lectures)

Semester V:

11. CHEMISTRY-C11: ORGANIC CHEMISTRY-IV (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C11 LAB: (Credits: Practicals-02, 60 Lectures)

12. CHEMISTRY-C12: PHYSICAL CHEMISTRY-V (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL - C12 LAB: (Credits: Practicals-02, 60 Lectures)

Semester VI:

13. CHEMISTRY-C13: INORGANIC CHEMISTRY-IV (Credits: Theory-04,60 Lectures), CHEMISTRY PRACTICAL – C13 LAB: (Credits: Practicals-02, 60 Lectures)

14. CHEMISTRY-C14: ORGANIC CHEMISTRY-V (Credits: Theory-04, 60 Lectures), CHEMISTRY PRACTICAL – C14 LAB: (Credits: Practicals-02, 60 Lectures)

CHEMISTRY-DSE (ELECTIVES)

Credit: 5+ 1 or 4 + 2

Semester V:

1. Research Methodology for Chemistry (5) + Tutorials (1)

2. Polymer Chemistry + Lab

3. Analytical Methods in Chemistry + Lab

4. **Applications of Computers in Chemistry+ Lab**

5. Molecular Modelling & Drug Design + Lab

6. Industrial Chemicals & Environment + Lab

Semester VI:

7. Seminar / Review / Grand Viva

8. Fluorescence study: Theory and Applications for Macromolecules and Nanomaterials Sensing+ Lab

9. Biologically relevant molecules, Organic Photochemistry, Dyes and synthetic polymers + Lab

10. Inorganic Materials of Industrial Importance + Lab

11. Green Chemistry + Lab

12. Instrumental Methods of Analysis + Lab

13. Novel Inorganic Solids + Lab

SKILL ENHANCEMENT COURSES (SEC)

Credit: 4

Semester III:

1. IT Skills for Chemists
2. Basic Analytical and Nuclear Chemistry

Semester IV:

3. Green Methods in Chemistry
4. Pharmaceutical Chemistry

GENERIC ELECTIVE PAPERS (GE) MINOR CHEMISTRY

Credit: 4+2

Semester I:

1. Atomic Structure, Bonding, General Organic Chemistry, Aliphatic Hydrocarbons

Semester II:

2. Chemical Energetics, Equilibria and Functional Organic Chemistry

Semester III:

3. Solutions, Phase Equilibria, Conductance, Electrochemistry & Functional Group Organic Chemistry

OR

Molecules of Life

Semester IV:

4. Transition Metal & Coordination Chemistry, States of Matter & Chemical Kinetics

OR

Quantum Chemistry, Spectroscopy & Photochemistry

Semester I

CHEM01C1: INORGANIC CHEMISTRY-I

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: The course aims to provide the knowledge on atomic structure, periodic table, periodic properties of elements, various types of chemical bonding in molecule, elementary idea of redox chemistry. Basic idea on the laboratory instruments, and titration techniques in laboratory experiments.

Atomic Structure:

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Sommerfield modification. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation. Hydrogenic wavefunctions, Quantum numbers, introduction to the concept of atomic orbitals; shapes, radial and angular probability diagrams of s, p and d orbitals (qualitative idea). Many electron atoms and ions: Pauli's exclusion principle, Hund's rule, exchange energy, Aufbau principle and its limitations. Term symbols of atoms and ions. **(14 Lectures)**

Periodicity of Elements:

s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to *s* and *p*-block – group trend and periodic trend.

(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.

(b) Atomic radii (van der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.

(f) Electron gain enthalpy, trends of electron gain enthalpy.

(g) Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity.

(16 Lectures)

Chemical Bonding:

(i) *Ionic bond:* General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) *Covalent bond:* Lewis structure, Valence Bond theory (Heitler-London approach). Hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N_2, O_2, C_2, B_2, F_2, CO, NO, HCl, BeF_2, CO_2, (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths.

Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rule and consequences of polarization.

Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

(iii) *Metallic Bond:* Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

(iv)*Weak Chemical Forces:* van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment) Effects of chemical force, melting and boiling points.

(20 Lectures)

Oxidation-Reduction:

Elementary idea on standard redox potentials with sign convention, Nernst equation. Influence of complex formation, precipitation and change of pH on redox potentials, formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators, redox potential diagram (Latimer and Frost) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples). **(10 Lectures)**

Reference Books:

- Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
- Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970
- Rodger, G.E. Inorganic and Solid State Chemistry, Cengage Learning India Edition, 2002.
- R. L. Dutta & G.S. De, Inorganic Chemistry (Vol. 1), The New Book Stall, 1973.
- Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press, 2010.
- R. P. Sarkar, General and Inorganic Chemistry (Vol. 1), New Central Book Agency, ed. 3, 2011
- A. K. Das, Fundamental Concepts of Inorganic Chemistry (Vol. 1,2 and 3), CBS Publishers & Distributors, 2010
- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.

CHEMISTRY PRACTICAL- C1 LAB:

(Credits: Practicals-02, 60 Lectures, Full marks: 30)

Elementary idea of redox titration using $KMnO_4$ and $K_2Cr_2O_7$ (theory)

A. Acid-Base Titrations

1. Estimation of carbonate and hydroxide present together in mixture.
2. Estimation of carbonate and bicarbonate present together in a mixture.

B. Redox Titrations

B-1. **Redox Titrimetric Estimations Based on Permanganometry**

1. Estimation of Fe(III) and Fe(II) mixture.
2. Estimation of Fe (III) and Ca (II) in a mixture

B-2. **Redox Titrimetric Estimations with standard $K_2Cr_2O_7$ solution**

1. Estimation of Fe(III) and Fe(II) mixture.
2. Estimation of Fe (III) and Cu (II) in a mixture

Reference Book:

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
- G. N. Mukherjee, Hand Book of Inorganic Analysis, U. N. Dhar & sons (P) LTD, 2014

Course Learning Outcomes:

On completion of the course, the students should be able to

1. Explain dual nature of subatomic particles. They will also gain preliminary notion about quantum mechanical model of the atom and shape of s, p, d, and f-orbitals.
2. Distinguish the types of bonding in a molecule and rationalize qualitative idea of valence bond and band theories.
3. Demonstrate the underlying concepts of periodic table developments and various periodic properties such as atomic size, ionization energy, electronegativity, electron affinity, etc… Changes of these periodic properties across the period and down the group.
4. Unravel the various weak inter- & intra molecular forces involved in chemical bonds.
5. Draw the molecular orbital energy diagram for some selected homo- & hetero nuclear diatomic molecules.
6. Predict structure and geometries of inorganic compounds; assign electrons to respective orbitals and shells to determine the electronic configuration of a particular element. They will be able to determine the redox potential of a given redox couple to predict the feasibility of a reaction.

7. learn about the safety protocols inside a chemistry lab. They will be able to prepare solutions with desired strength and can to analyse the concentration of unknown samples using titrations.

CHEM01C2: PHYSICAL CHEMISTRY-I

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on the kinetic theory of gas, behaviour of real gas, viscosity of gas and liquid, solid state chemistry and fundamentals of thermodynamics.

Gaseous state: Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; The Barometric distribution law; Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, idea about gamma function and related integral, error function, Maxwell distribution for kinetic energy, Maxwell –Boltzmann distribution law; law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Kinetic theory of gas in interpreting Fick's law of diffusion and Fourier law of heat conduction.

Behaviour of real gases: Deviations from ideal gas behaviour, Andrew's and Amagat's plots); compressibility factor, *Z*, and its variation with pressure for different gases. Causes of deviation from ideal behaviour. Van der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dieterici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states;

Intermolecular forces and potentials (Keesom, Debye and London), estimation of van der Waals constants, Lennard-Jones potential. **(20 Lectures)**

Viscosity of liquid: Qualitative treatment of the structure of the liquid state; physical properties of liquids; vapour pressure. General features of fluid flow (streamline and turbulent flows, Reynold's number); nature of viscous drag for streamline motion, Newton's equation, viscosity coefficient, Poisuille equation (with derivation), coefficient of viscosity. Stokes' law and terminal velocity; experimental determination of viscosity coefficient of liquids. Stokes'-Einstein relation for diffusivity, Effect of addition of various solutes viscosity. Temperature

variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of structure of water (qualitative idea). **(8 Lectures)**

Chemical Thermodynamics:

Importance and scope, intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics.

First law: Concept of heat, *q*, work, *w*, internal energy, *U*, and statement of first law; enthalpy, *H*, heat changes at constant volume and constant pressure; relation between C_p and C_v using ideal gas and van der Waals equations; joule's experiment and its consequence; explanation of term $(\delta U/\delta V)_T$, calculations of *q*, *w*, ΔU and ΔH for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions.

Thermochemistry: Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations) and pressure on enthalpy of reactions. Adiabatic flame temperature, explosion temperature.

Second Law: Second law of thermodynamics: need for a second law, Clausius and Kelvin-Planck statements and their equivalence; Carnot's theorem, thermodynamic scale of temperature, concept of heat engine, Carnot cycle and refrigerator; Concept of entropy; Clausius inequality, entropy as a state function, second law in terms of entropy, molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

(24 Lectures)

Systems of Variable Composition:

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs- Duhem equation, Eulers theorem. Non-ideal system: Excess thermodynamic functions, idea of fugacity and activity; standard states. chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases. Activity coefficient for electrolytes, Debye Huckel theory (preliminary idea).

(8 Lectures)

Reference Books:

- Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 10th Ed., Oxford University

Press (2014).
- Ball, D. W. Physical Chemistry Thomson Press, India (2007).
- Castellan, G. W. Physical Chemistry 4th Ed. Narosa (2004).
- Mortimer, R. G. Physical Chemistry 3rd Ed. Elsevier: NOIDA, UP (2009).
- Engel, T. & Reid, P. Physical Chemistry 3rd Ed. Pearson (2013).

CHEMISTRY PRACTICAL-C2 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Viscosity measurement using Ostwald's viscometer.

(a) Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.

(b) Study the variation of viscosity of sucrose solution with the concentration of solute.

2. Thermochemistry

(a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).

(b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

(c) Calculation of the enthalpy of ionization of ethanoic acid.

(d) Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.

(e) Determination of enthalpy of hydration of copper sulphate.

(f) Study of the solubility of benzoic acid in water and determination of ΔH.

Reference Books

- Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
- Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
- Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Explain the kinetic molecular model of gas, viscosity of gas and liquids.
2. Manipulate the gas laws to describe real and ideal gas behaviour.
3. Describe the Three Laws of Thermodynamics and their development.
4. Perform the experiments to measure the heat of reaction

5. Demonstrate the basic idea about the direction of physical and chemical processes in terms of thermodynamic parameters
6. Use the Maxwell equations and other thermodynamic relations to compute thermodynamic quantities from thermodynamic data tables.
7. Apply the concept of chemical potential to explain the Gibbs free energy change due to mixing and calculate partial molar quantities.

CHEM01GE1

Theory: Atomic Structure, Bonding, General Organic Chemistry, Aliphatic Hydrocarbons

(Credits: 04, 60 Lectures, Full Marks: 70)

Course Objectives: The course aims to provide the knowledge on atomic structure, and various types of chemical bonding in molecule to general science students, basic idea on titration techniques in laboratory experiments.

Section A: Inorganic Chemistry

Atomic Structure:

Extra-nuclear Structure of atoms Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen, quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many- electron atoms, Aufbau principle and its limitations.

Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations. **(14 Lectures)**

Chemical Bonding and Molecular Structure:

*Ionic bonding:*General characteristics of ionic compounds, sizes of ions, radius ratio rule and its limitation. Lattice energy, Born Haber cycle.

Covalent bonding: General characteristics of covalent compounds, valence-bond approach, hybridization involving s, p, d orbitals. Valence Shell Electron Pair Repulsion (VSEPR) concept, shapes of simple molecules and ions of main group elements, bond moment and dipole moment, partial ionic character of covalent bonds, Fajan's rules, hydrogen bonding and its effect on physical and chemical properties.

MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s-p mixing) and heteronuclear diatomic molecules such as CO and NO. Comparison of VB and MO approaches. **(16 Lectures)**

Section B: Organic Chemistry

Course Objectives: To impart knowledge on fundamentals of organic chemistry, stereochemistry of organic compounds and aliphatic hydrocarbons

Fundamentals of Organic Chemistry

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis. Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals.

Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Hückel's rule. **(8 Lectures)**

Stereochemistry

Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threo and erythro; D and L; *cis - trans* nomenclature; CIP Rules: *R/ S* (for upto 2 chiral carbon atoms) and *E / Z* Nomenclature (for upto two C=C systems). **(10 Lectures)**

Aliphatic Hydrocarbons

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure. **Alkanes**: (Upto 5 Carbons). Preparation: Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: Free radical Substitution: Halogenation. **Alkenes**: (Upto 5 Carbons) Preparation: Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule); *cis* alkenes (catalytic hydrogenation) and *trans* alkenes (Birch reduction). Reactions: *cis*-addition (alk. $KMnO_4$) and *trans*-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, Oxymecuration-demercuration, Hydroboration-oxidation. **Alkynes**: (Upto 5 Carbons) Preparation: Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides. Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alk. $KMnO_4$.

(12 Lectures)

Reference Books:

• Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
• R. L. Dutta & G.S. De, Inorganic Chemistry (Vol. 1), The New Book Stall, 1973.
• R. P. Sarkar, General and Inorganic Chemistry (Vol. 1), New Central Book Agency, ed. 3, 2011
• Graham Solomon, T.W., Fryhle, C.B. &Dnyder, S.A. *Organic Chemistry*, John Wiley & Sons (2014).
• McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
• Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
• Eliel, E.L. *Stereochemistry of Carbon Compounds*, Tata McGraw Hill education, 2000.
• Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
• Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.
• Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.

GE1-Lab: (Credits: 02, 60 Lectures, Full Marks: 30)

Section A: Inorganic Chemistry - Volumetric Analysis (any four)

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titration with $KMnO_4$.
3. Estimation of water of crystallization in Mohr's salt by titration with $KMnO_4$.
4. Estimation of Fe(II) ions by titration with $K_2Cr_2O_7$.
5. Estimation of Cu(II) ions iodometrically using $Na_2S_2O_3$.

Section B: Organic Chemistry

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing upto two extra elements)
2. Separation of mixtures by Chromatography: Measurement of R_f value in each case (combination of two compounds to be given)

(a) Identify and separate the components of a given mixture of two amino acids (glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography

(b) Identify and separate the sugars present in the given mixture by paper chromatography.

Reference Books:

- Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
- Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
- Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
- Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

Course Learning Outcomes: On completion of the course, the students should be able to

1. Explain the dual nature of subatomic particles. They will also gain a preliminary notion about the quantum mechanical model of the atom and the shape of s, p, d, and f-orbitals.
2. Distinguish the types of bonding in a molecule and rationalize the qualitative idea of valence bond and band theories.
3. Prepare solutions with the desired strength and analyse the concentration of unknown samples using titrations.
4. Interpret the physical and chemical properties of organic molecules to predict their reactivity, nature of reactive intermediates, and various reaction mechanisms.
5. Explain the geometrical and optical isomerism; execute interconversion of different 3D- and 2D-projections of saturated organic molecules along with their stereochemical nomenclature.
6. Elucidate several preparative routes and reactions of aliphatic hydrocarbons.
7. Carry out comparative studies on the reactivities of saturated and unsaturated hydrocarbons and their interconversion.

Semester II:

CHEM02C3: ORGANIC CHEMISTRY- I

(Credits: Theory-04, Theory: 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on fundamentals of organic chemistry, Chemical bonding& Reaction Mechanism, Reaction thermodynamics, stereochemistry of organic compounds and chemistry of aliphatic and aromatic hydrocarbons and cycloalkanes and their conformational analysis

Basics of Organic Chemistry, Chemical bonding& Reaction Mechanism

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties (VBT) and Treatment of MOT.

Electronic Effects: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids, bases and their relative strengths.

Homolytic and Heterolytic fission with suitable examples. Reaction Mechanism: ionic, radical and pericyclic; representation of mechanistic steps using arrow formalism, formal charges.

Reactive intermediates: carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes, nitrenes - structure using orbital picture, electrophilic / nucleophilic reactivity, stability, generation and fate. Electrophiles and Nucleophiles; Nucleophlicity and basicity;

Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

(8 Lectures)

Reaction thermodynamics

Free energy and equilibrium, enthalpy and entropy factor, intermolecular & intramolecular reactions. Application of thermodynamic principles in tautomeric equilibria (keto-enol tautomerism). Composition of the equilibrium in different systems such as simple carbonyl, 1,3- and 1,2- dicarbonyl systems, phenols and related system; substituent and solvent effect *etc*. **(6 Lectures)**

Stereochemistry:

Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: *cis–trans* and, *syn-anti* isomerism *E*/*Z* notations with C.I.P rules.

Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, *meso*-structures, Racemic mixture and resolution. Relative and absolute configuration: D/L and *R*/*S* designations. **(12 Lectures)**

Aromatic Hydrocarbons

*Aromaticity:*Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and

Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups.

(10 Lectures)

Chemistry of Aliphatic Hydrocarbons

A. Carbon-Carbon sigma bonds

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation relative reactivity and selectivity.

B. Carbon-Carbon pi bonds:

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations.

Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroborationoxidation, ozonolysis, reduction (catalytic and chemical), *syn* and *anti*-hydroxylation (oxidation). 1,2-and 1,4-addition reactions in conjugated dienes, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, *e.g.* propene, 1-butene, toluene, ethyl benzene. *Reactions of alkynes:* Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

C. Cycloalkanes and Conformational Analysis

Types of cycloalkanes and their relative stability, Baeyer strain theory, Conformation analysis of alkanes: Relative stability: Energy diagrams of cyclohexane and substituted cyclohexanes: Chair, Boat and Twist boat forms; Relative stability with energy diagrams. **(24 Lectures)**

Reference Books:

- Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt.Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
- Kalsi, P. S. Stereochemistry Conformation and Mechanism, New Age International, 2005.
- McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013.

CHEMISTRY PRACTICAL - C3 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Checking the calibration of the thermometer

2. Purification of organic compounds by crystallization using the following solvents:

   a. Water

   b. Alcohol

   c. Alcohol-Water

3. Determination of the melting points of above compounds and unknown organic compounds (Kjeldahl method and electrically heated melting point apparatus)

4. Effect of impurities on the melting point – mixed melting point of two unknown organic compounds

5. Determination of boiling point of liquid compounds (boiling point lower than and more than 100 °C by distillation and capillary method).

6. Chromatography

a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

b. Separation of a mixture of two sugars by ascending paper chromatography

c. Separation of a mixture of *o*- and *p*-nitrophenol or *o*- and *p*-aminophenol by thin layer chromatography (TLC).

Reference Books

· Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
· Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012)

Course Learning Outcomes: After completion of the course, the student should be able to

1. Analyze different physical and chemical properties of organic molecules to realize their reactivity, nature of reactive intermediates, and various types of reaction mechanisms: Addition, Elimination and Substitution reactions.
2. Quantify reaction parameters through real instances.
3. Interpret geometrical and stereoisomerism: their role in physical and chemical properties of organic compounds; describe 3D-structures of saturated organic molecules and their projections on 2D-plane and concept of chirality; explain conformational analysis of cyclic and acyclic systems.
4. Predict aromatic, anti-aromatic and non-aromatic character of cyclic, conjugated polyenes via MOT and apply this concept to rationalize the reactions of aromatic species with various electrophiles.
5. Explain the reactivities of saturated and unsaturated hydrocarbons and their interconversion.
6. Purify organic solids and liquids by simple laboratory apparatus.

CHEM02C4: PHYSICAL CHEMISTRY- II

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on the application of classical thermodynamics and to build concepts on the solution properties, reaction kinetics, surface reaction, adsorption, catalysis and solid state chemistry.

Chemical Equilibrium:

Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Coupling of exoergic and endoergic reactions. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants *Kp, Kc* and *Kx*. Le Chatelier principle (quantitative treatment); equilibrium between ideal gases and a pure condensed phase.

(6 Lectures)

Solutions and Colligative Properties:

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications.

Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution. **(8 Lectures)**

Solid state

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Defects in crystals. Glasses and liquid crystals. **(10 Lectures)**

Chemical Kinetics

Phenomenological kinetics: degree of advancement of a reaction, reaction rate, rate constant, order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental

methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions. Differential rate law for complex reactions following reaction mechanism.

Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates, primary and secondary kinetic salt effect, kinetic isotope effect. (**18 Lectures)**

Catalysis:

Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts. Enzyme catalysis, Michaelis-Menten mechanism, turnover

number, Lineweaver-Burk plot; influence of temperature and pH acid-base catalysis. Heterogeneous catalysis (single reactant). **(6 Lectures)**

Surface Tension and Surface Phenomena:

Surface tension, surface energy (thermodynamic treatment), excess pressure, capillary rise and measurement of surface tension, work of cohesion and adhesion, spreading of liquid over other surface, vapour pressure over curved surface, temperature dependence of surface tension. Effect of addition of various solutes on surface tension. Surfactants and micelles and reverse micelles: applications, size and solubility.

Physical adsorption, chemisorption, adsorption isotherms. nature of adsorbed state. Freundlich and Langmuir adsorption isotherm, multilayer and BET isotherm (without derivation) and applications, Gibbs adsorption isotherm and surface excess. **(12 Lectures)**

Reference Books

- Peter, A. & Paula, J. de. Physical Chemistry 10th Ed., Oxford University Press (2014).
- Castellan, G. W. Physical Chemistry 4th Ed., Narosa (2004).
- Engel, T. & Reid, P. Physical Chemistry 3rd Ed., Prentice-Hall (2012).
- McQuarrie, D. A. & Simon, J. D. Molecular Thermodynamics Viva Books Pvt. Ltd.:New Delhi (2004).
- Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S.Commonly Asked Questions in Thermodynamics. CRC Press: NY (2011).
- Levine, I .N. Physical Chemistry 6th Ed., Tata Mc Graw Hill (2010).
- Metz, C.R. 2000 solved problems in chemistry, Schaum Series (2006).
- Wolfson, M. M., An Introduction to X-Ray Crystallography, 2nd Ed., Cambridge University Press (1997).

CHEMISTRY PRACTICAL - C4 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Study the kinetics of the following reactions

i) Initial rate method:

(a) Iodide-persulphate reaction

ii) Integrated rate method:

(a) Acid hydrolysis of methyl acetate with hydrochloric acid.

(b) Saponification of ethyl acetate.

2. Adsorption

a) Verification of the Freundlich isotherms for adsorption of acetic acid on activated charcoal.

3. Surface tension measurements

(a) Determine the surface tension.

(b) Study the variation of surface tension of detergent solutions with concentration.

4. Indexing of a given powder diffraction pattern of a cubic crystalline system.

Reference Books

- Khosla, B. D.; Garg, V. C. & Gulati, A., Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
- Athawale, V. D. & Mathur, P. Experimental Physical Chemistry New Age International: New Delhi (2001).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Explain the origin of equilibrium constant and its relation to fugacity and activity and apply these concepts to ideal and real solutions of electrolytes and non-electrolytes and to colligative properties.
2. Analyse the powder X-ray diffraction data of cubic systems
3. List the methods for arriving at rate law based on kinetic information.
4. Apply the steady-state hypothesis to obtain rate equations and explain the effect of temperature, addition of salt, isotopic substitution and catalyst on the rate constant.
5. Demonstrate the various surface phenomena, such as surface tension, adsorption and explain the effect of temperature, addition of various solutes and surfactants on the surface tension.

CHEM02GE2

Theory: CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Section A: Physical Chemistry

Course Objectives: To impart knowledge on the basic concepts of classical thermodynamics and its application on chemical equilibrium and ionic equilibrium.

Chemical Energetics:

Review of thermodynamics and the Laws of Thermodynamics. Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchhoff's equation. Statement of Third Law of thermodynamics and calculation of absolute entropies of substances.

(10 Lectures)

Chemical Equilibrium:

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ΔG and ΔG^{o}, Le Chatelier's principle. Relationships between Kp, Kc and Kx for reactions involving ideal gases.

(8 Lectures)

Ionic Equilibria:

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.

(12 Lecture)

Section B: Organic Chemistry

Course Objectives: To impart knowledge on chemistry of Aromatic hydrocarbons, Alkyl, aryl halides, chemistry of alcohol, phenol, ethers, carbonyl compounds

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Aromatic hydrocarbons:

Preparation of benzene: from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid. Reactions of benzene: Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene). **(8 Lectures)**

Alkyl and Aryl Halides

Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (S_N1, S_N2 and S_Ni) reactions.

Preparation: from alkenes and alcohols.

Reactions: hydrolysis, nitrite & nitro formation, nitrile &isonitrile formation. Williamson's ether synthesis: Elimination *vs* substitution.

Aryl Halides Preparation: (Chloro, bromo and iodo-benzene): from phenol, Sandmeyer & Gattermann reactions.

Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/ liq.NH_3 (or $NaNH_2$/liq.NH_3).

Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

(8 Lectures)

Alcohols, Phenols and Ethers (Upto 5 Carbons)

Alcohols: Preparation: Preparation of 1°, 2° and 3° alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acids and esters. Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation, Diols: (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols: Preparation - Cumenehydroperoxide method, from diazonium salts. Reactions: Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-Tiemann Reaction, Gattermann-Koch Reaction, Houben–Höesch Condensation, Schötten – Baümann Reaction.

Ethers (aliphatic and aromatic): Cleavage of ethers by HI.

Aldehydes and ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde)

Preparation: from acid chlorides and nitriles.

Reactions – Reaction with HCN, ROH, $NaHSO_3$, NH_2-G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Pondorff-Verley reduction. **(14 Lectures)**

Reference Books:

- Graham Solomon, T.W., Fryhle, C.B. &Dnyder, S.A. *Organic Chemistry*, John Wiley & Sons (2014).
- McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
- Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
- Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
- Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.
- Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
- Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
- Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
- Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
- Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
- Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).

GE2-Lab: (Credits: 02, 60 Lectures, Full Marks: 30)

Section A: Physical Chemistry

Thermochemistry

1. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

2. Determination of enthalpy of ionization of acetic acid.

3. Study of the solubility of benzoic acid in water and determination of ΔH.

Ionic equilibria

pH measurements Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter.

Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Section B: Organic Chemistry

1. Purification of organic compounds by crystallization (from water and alcohol) and distillation.

2. Criteria of Purity: Determination of melting and boiling points.

3. Preparations: Mechanism of various reactions involved to be discussed. Recrystallisation, determination of melting point and calculation of quantitative yields to be done.

(a) Bromination of Phenol/Aniline

(b) Benzoylation of amines/phenols

(c) Oxime and 2,4-dinitrophenylhydrazone of aldehyde/ketone

Reference Books

• Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
• Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
• Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).

Course Learning Outcomes: After completion of the course, the student should be able to

1. Describe the Three Laws of Thermodynamics and their development.
2. Perform the experiments to measure the heat of reaction
3. Demonstrate the basic idea about the direction of physical and chemical processes in terms of thermodynamic parameters.
4. Measure the pH of different solutions like aerated drinks, fruit juices, shampoos and soaps
5. Explain the concepts of buffer solution and prepare buffer solution
6. Describe differential behaviour of electron-rich and electron-deficient benzene rings toward electrophiles and nucleophiles.
7. Discuss on preparative routes and reactions of alkyl and aryl halides.
8. Perform comparative studies between substitution and elimination pathways in substituted alkanes.
9. Acquaint with different functionalities like alcohols, phenols, ethers, and carbonyls in aliphatic and aromatic systems, and their reactions.
10. Preparation of simple organic molecules in one step and their purification.

Semester III

CHEM03C5: INORGANIC CHEMISTRY-II

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: This course is designed to convey knowledge on Acid –base theory of Inorganic compounds, general chemistry of the elements and their periodic properties, and also some **industrial applications** of different compounds of some important elements eg Silicones. **Environmental** hazards like CFCs are also included to create awareness. Introduce the concept of nuclear chemistry

Acids and Bases

Bronsted and Lowry's concept, solvent system concept, Lewis concept, Lux-Flood concept, relative strength of acids, hydracids and oxyacids, Pauling's rules, amphoterism, and super acids, HSAB principle, acid-base equilibria in aqueous solution, pH, buffer solutions and buffer actions, acid-base neutralization curves, acid-base indicators, choice of indicators, acid-base titrations. **(12 Lectures)**

Non-aqueous Solvents

Physical properties of a solvent, types of solvents and their general characteristics, reactions in non-aqueous solvents such as HF, H_2SO_4, NH_3, CH_3COOH, etc… **(3 Lectures)**

Chemistry of *s* and *p* Block Elements:

Inert pair effect, relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Complex formation tendency of *s* and *p* block elements. Basic properties of halogens. Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses.

Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, oxides and oxoacids of nitrogen, phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogens. **(26 Lectures)**

Noble Gases:

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of fluorides and oxofluorides; structure and bonding of noble gas fluoro, oxo and fluoro-oxo compounds.

(4 Lectures)

Inorganic Polymers:

Borazines, silicones, siloxanes silicates, phosphazenes and polysulphates, $(SN)_n$. **(3 Lectures)**

Nuclear Chemistry:

Composition of Nucleus; Classification of nuclides based on the number of nucleons- Isotopes, Isobars, Isotones; Nuclear Isomer and isomeric transition; Radius and Density of Nucleus; Nuclear Spin; Shape of Nucleus; Nuclear Stability; The Neutron to Proton Ratio and Different Modes of Decay; Fajans & Soddy's Group Displacement Law; Artificial Radioactivity; Nuclear Reactions; Nuclear Reaction Cross-Section; The Disintegration Series; Packing Fraction, Nuclear Binding Energy and Nuclear Stability; Radioactive Decay Kinetics; Application of Radioactivity in Age Determination; Nuclear Forces; Nuclear Models-Fermi Gas Model, Liquid Drop Model, Nuclear and Shell Model **(12 Lectures)**

Reference Books:

- Lee, J.D. Concise Inorganic Chemistry, ELBS, 1991.
- Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. Concepts & Models of Inorganic Chemistry 3rd Ed., John Wiley Sons, N.Y. 1994.
- Greenwood, N.N. & Earnshaw. Chemistry of the Elements, Butterworth-Heinemann. 1997.
- Rodger, G.E. Inorganic and Solid State Chemistry, Cengage Learning India Edition, 2002.
- Miessler, G. L. & Donald, A. Tarr. Inorganic Chemistry 4th Ed., Pearson, 2010. 19
- Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
- R. P. Sarkar, General and Inorganic Chemistry (Vol. 1), New Central Book Agency, ed. 3, 2011
- Essentials of Nuclear Chemistry by H. J. Arnikar
- Fundamental Concepts of Inorganic Chemistry, Vol-1, 2 and 3 by Asim K. Das
- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.

CHEMISTRY PRACTICAL - C5 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

A. Inorganic preparations (Any Five)

1. Cuprous Chloride
2. Preparation of Manganese (III) phosphate
3. Preparation of Aluminium potassium sulphate (Potash alum) or Chrome alum.
4. Tetraamminecopper(II) sulphate
5. *Cis*- and *trans*- Potassium dioxalatodiaquachromate(III)
6. Tetraamminecarbonatocobalt(III) ion
7. Potassium tris(oxalate)ferrate(III)

B. Paper Chromatography

1. Ni(II) and Co(II)
2. Fe(III) and Al(III)
3. Ni(II), Mn(II), Co(II) and Zn(II)

Reference Book:

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
- S. Gulati, J. L. Sharma, S. Manocha, Practical Inorganic Chemistry, CBS Publishers distributers, 2017.

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Use the Periodic Table to rationalize similarities and differences of elements, including physical and chemical properties and reactivity.
2. Have good knowledge of some industrial applications of some elements.
3. Have good knowledge of Periodicity of the group elements
4. Have good knowledge of special properties like relativistic effects of rare elements.
5. Acid base property, hard soft acid base etc are taught. pH calculation of solutions, buffers, indicators are taught which have good **industrial applications.**
6. Familiar with elementary idea of nuclear chemistry, nuclear reactions and kinetics
7. They may also have handful of experience on handling the various apparatus involved on synthesis of inorganic compounds as well as some redox titration

CHEM03C6: ORGANIC CHEMISTRY-II

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on Chemistry of Halogenated Hydrocarbons and the Reaction Kinetics, chemistry of alcohol, phenol, ethers, epoxides, carbonyl compounds, carboxylic acid and sulphur containing compounds

Chemistry of Halogenated Hydrocarbons & Reaction Kinetics:

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_Ni mechanisms, substrate structure, leaving group, nuc1eophiles including ambident nucleophiles, substitution involving NGP; relative rate & stereochemical features, nucleophilic substitution *vs*. elimination.

Aryl halides: Preparation, including preparation from diazonium salts, nucleophilic aromatic substitution; S_NAr, Benzyne mechanism.

Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

Reaction kinetics: rate const and free energy of activation, free energy profiles for one step and multistep reactions, catalyzed reactions, kinetic control and thermodynamic control, kinetic isotopic effect, principle of microscopic reversibility, Hammond postulate.

(18 Lectures)

Alcohols, Phenols, Ethers and Epoxides:

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouveault-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement;

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe–Schmidt Reactions, Fries and Claisen rearrangements with mechanism;

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$. **(14 Lectures)**

Carbonyl Compounds:

Structure, reactivity and preparation:

Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Reformatsky, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α- substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, PDC and PGC);

Addition reactions of unsaturated carbonyl compounds: Michael addition. Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

(14 Lectures)

Carboxylic Acids and their Derivatives:

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids;

Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic sustitution of acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

(10 Lectures)

Sulphur containing compounds and Chemistry of Ylides:

Preparation and reactions of thiols, thioethers and sulphonic acids. **(4 Lectures)**

Reference Books:

- Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Graham Solomons, T.W. Organic Chemistry, John Wiley & Sons, Inc.
- McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013.

CHEMISTRY PRACTICAL - C6 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group.

2. Organic preparations:

i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*- anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method:

a. Using conventional method.

b. Using green approach

ii. Benzolyation of one of the following amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the following phenols (β-naphthol, resorcinol, pcresol) by Schötten-Baümann reaction.

iii. Oxidation of ethanol/ isopropanol (Iodoform reaction).

iv. Bromination of any one of the following:

a. Acetanilide by conventional methods

b. Acetanilide using green approach (Bromate-bromide method)

v. Nitration of any one of the following:

a. Acetanilide/nitrobenzene by conventional method

b. Salicylic acid by green approach (using ceric ammonium nitrate).

vi. Selective reduction of *meta*- dinitrobenzene to *m*-nitroaniline.

vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.

viii. Hydrolysis of amides and esters.

ix. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.

x. *S*-Benzylisothiouronium salt of one each of water soluble and water insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

xi. Aldol condensation using either conventional or green method.

xii. Benzil-Benzilic acid rearrangement.

The above derivatives should be prepared using 0.5-1g of the organic compound. The solid samples must be collected and may be used for recrystallization, melting point and TLC.

Reference Books

- Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
- Furniss, B.S., Hannaford, A.J., Smith, P.W.G. & Tatchell, A.R. Practical Organic Chemistry, 5th Ed. Pearson (2012)
- Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000).
- Ahluwalia, V.K. & Dhingra, S. Comprehensive Practical Organic Chemistry: Qualitative Analysis, University Press (2000).

Course Learning Outcomes: After completion of the course, the student should be able to

1. Describe reactivities of aromatic and aliphatic halides toward nucleophiles and in organometallics.
2. Analyse various physical parameters controlling the organic transformations.
3. Incorporate different functionalities (alcohols, phenols, ethers, epoxides, carbonyls, and carboxylic acids) in aliphatic and aromatic systems, and perform their reactions.
4. Carry out synthesis and reactions of thiols, thioethers, sulphonic acid and ylides.
5. Detect various elements and functional groups in organic sample which will increase their analytical skills.

CHEM03C7: PHYSICAL CHEMISTRY-III

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on the application of classical thermodynamics on phase and ionic equilibria and build basic concepts of electrochemistry.

Phase Equilibria:

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications.

Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions.

Three component systems, water-chloroform-acetic acid system, triangular plots.

Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and nonideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation.

Nernst distribution law: its derivation and applications: solvent extraction, determination of equilibrium constant. **(26 Lectures)**

Ionic equilibria:

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; dissociation constants of mono-, di-and triprotic acids (exact treatment).

Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body.

Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations. **(14 Lectures)**

Electrochemistry

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry. Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb_2O_3 electrodes.

Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

(20 Lectures)

Reference Books:

- Peter Atkins & Julio De Paula, Physical Chemistry 10th Ed., Oxford University Press (2014).
- Castellan, G. W. Physical Chemistry, 4th Ed., Narosa (2004).
- McQuarrie, D. A. & Simon, J. D., Molecular Thermodynamics, Viva Books Pvt. Ltd.: New Delhi (2004).
- Engel, T. & Reid, P. Physical Chemistry 3rd Ed., Prentice-Hall (2012).
- Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. Commonly Asked Questions in Thermodynamics. CRC Press: NY (2011).

- Zundhal, S.S. Chemistry concepts and applications Cengage India (2011).
- Ball, D. W. Physical Chemistry Cengage India (2012).
- Mortimer, R. G. Physical Chemistry 3rd Ed., Elsevier: NOIDA, UP (2009).
- Levine, I. N. Physical Chemistry 6th Ed., Tata McGraw-Hill (2011).
- Metz, C. R. Physical Chemistry 2nd Ed., Tata McGraw-Hill (2009).
- Glasstone, S. An Introduction to Electrochemistry, Affiliated East-West Press Private Limited (2003).
- Bockris, J.O'M., Reddy, A.K.N., Modern Electrochemistry 1, 2nd Ed., Springer (2012)

CHEMISTRY PRACTICAL-C7 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.

2. Distribution of acetic/ benzoic acid between water and cyclohexane.

3. Study the equilibrium of at least one of the following reactions by the distribution method:

(a) I_2 (aq) + I^- → I_3^- (aq) (ii) Cu^{2+} (aq) + $n$$NH_3$ → $Cu(NH_3)n$

4. Potentiometry

Perform the following potentiometric titrations:

(i) Strong acid vs. strong base

(ii) Weak acid vs. strong base

(iii) Dibasic acid vs. strong base

(iv) Potassium dichromate vs. Mohr's salt

Reference Books:

- Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
- Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
- Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Interpret phase diagrams and explain phase equilibria in terms of chemical potentials.
2. Calculate the degrees of freedom for various types of systems
3. Explain how phase equilibria help in understanding the formation of various materials, allotropic forms of different substances and the formation of binary mixtures, azeotropes.
4. Explain the use of electrical energy for initiating chemical reactions and also how chemical reactions can be utilized to produce electrical energy, and the basic principle used in the formation of cells and batteries.
5. Perform potentiometric and pH-metric titrations and prepare various buffer solutions.

CHEM03GE3.1

Theory: SOLUTIONS, PHASE EQUILIBRIA, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL GROUP ORGANIC CHEMISTRY

(Credits: 04, 60 Lectures, Full Marks: 70)

Section A: Physical Chemistry

Course Objectives: To impart knowledge on the application of classical thermodynamics on phase, solutions and build basic concepts of conductance and electrochemistry.

Solutions

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. Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Nernst distribution law and its applications, solvent extraction.

(8 Lectures)

Phase Equilibria

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. GibbsPhase 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.

(8 Lectures)

Conductance

Conductivity, equivalent and molar conductivity and their variation with dilution for weakand strong electrolytes. Kohlrausch law of independent migration of ions. Transference number and its experimental determination using Hittorf and Moving boundary methods. Ionic mobility. Applications of conductance measurements: determination of degree of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid base).

(6 Lectures)

Electrochemistry

Reversible and irreversible cells. Concept of EMF of a cell. Measurement of EMF of a cell.Nernst equation and its importance. Types of electrodes. Standard electrode potential. Electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data. Calculation of equilibrium constant from EMF data. Concentration cells with transference and without transference. Liquid junction potential and salt bridge. pH determination using hydrogen electrode and quinhydrone electrode. Potentiometric titrations qualitative treatment (acid-base and oxidation-reduction only). **(8 Lectures)**

Section B: Organic Chemistry

Course Objectives: To impart knowledge on chemistry of carboxylic acids, amines, diazonium salts, amino acid, peptides, proteins and carbohydrates

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Carboxylic acids and their derivatives

Carboxylic acids (aliphatic and aromatic)

Preparation: Acidic and Alkaline hydrolysis of esters.

Reactions: Hell – Volhard - Zelinsky Reaction.

Preparation: Acid chlorides, Anhydrides, Esters and Amides from acids and their interconversion.

Reactions: Comparative study of electrophilicity of acyl derivatives. Reformatsky Reaction, Perkin condensation.

(6 Lectures)

Amines and Diazonium Salts

Amines (Aliphatic and Aromatic): (Upto 5 carbons)

Preparation: from alkyl halides, Gabriel Phthalimide synthesis, Hofmann Bromo amide reaction (Hofmann Degradation).

Reactions: Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO_2, Schötten – Baümann Reaction. Electrophilic substitution (aniline): nitration, bromination, sulphonation.

Diazonium salts:

Preparation: from aromatic amines.

Reactions: conversion to benzene, phenol, dyes.

(6 Lectures)

Amino Acids, Peptides and Proteins:

Preparation of Amino Acids: Strecker synthesis using Gabriel phthalimide synthesis. Zwitterion, Isoelectric point and Electrophoresis.

Reactions of Amino acids: ester of –COOH group, acetylation of $–NH_2$ group, complexation, ninhydrin test.

Overview of Primary, Secondary, Tertiary and Quaternary Structure of proteins.

Determination of Primary structure of Peptides by degradation: Edmann degradation (N-terminal) and C–terminal (thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (*t*-butyloxycarbonyl and phthaloyl) & C activating groups and Merrifield solid-phase synthesis.

(10 Lectures)

Carbohydrates:

Classification and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation. **(8 Lectures)**

Reference Books:

- Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
- Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
- Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry*, Cengage Learning India Pvt. Ltd.: New Delhi (2009).
- Mahan, B.H. *University Chemistry*, 3rd Ed. Narosa (1998).
- Petrucci, R.H. *General Chemistry*, 5th Ed., Macmillan Publishing Co.: New York (1985).
- Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry* (*Volume 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Nelson, D. L. & Cox, M. M. *Lehninger's Principles of Bioch*emistry *7th Ed.*, W. H. Freeman.
- Berg, J.M., Tymoczko, J.L. &Stryer, L. *Biochemistry*, W.H. Freeman, 2002.

GE3.1-Lab: (Credits: 02, 60 Lectures, Full Marks: 30)

Section A: Physical Chemistry

Distribution

Study of the equilibrium of one of the following reactions by the distribution method:

$I_2(aq) + I(aq) = I_3^-(aq)$

$Cu^{2+}(aq) + xNH_3(aq) = [Cu(NH_3)_x]^{2+}$

Phase equilibria

Determination of the critical solution temperature and composition of the phenol water system and study of the effect of impurities on it.

Conductance

1. Determination of cell constant

2. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

3. Perform the following conductometric titrations:

a. Strong acid vs. strong base

b. Weak acid vs. strong base

Potentiometry

1. Perform the following potentiometric titrations (any two):

a. Strong acid vs. strong base

b. Weak acid vs. strong base

c. Potassium dichromate vs. Mohr's salt

Section B: Organic Chemistry

I. Systematic Qualitative Organic Analysis of Organic Compounds possessing monofunctional groups (-COOH, phenolic, aldehydic, ketonic, amide, aromatic nitro, aromatic amines) and preparation of one derivative.

II.

1. Separation of amino acids by paper chromatography
2. Determination of the concentration of glycine solution by formylation method.
3. Titration curve of glycine
4. Action of salivary amylase on starch
5. Effect of temperature on the action of salivary amylase on starch.
6. Differentiation between a reducing and a nonreducing sugar.

Reference Books:

• Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
• Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
• Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
• Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry,*Universities Press.

Course Learning Outcomes: After completion of the course, the student should be able to

1. Interpret phase diagrams and explain phase equilibria in terms of chemical potentials.
2. Calculate the degrees of freedom for various types of systems
3. Explain how phase equilibria help in understanding the formation of various materials, allotropic forms of different substances and the formation of binary mixtures, azeotropes.
4. Apply the principles of electrochemistry to conductance, voltaic, and electrolytic systems.
5. Comprehend the reactivity of acyl carbon toward different nucleophiles.
6. Conduct synthesis, separation, and identification of 1°, 2°, and 3°-amines and their reactions.
7. Elucidate Primary, Secondary, Tertiary and Quaternary Structure of proteins; determine structure of peptides and carry out synthesis and reactions of amino acids.
8. Explain physical, chemical and optical properties of basic units of carbohydrates.
9. Detect nitrogenous and non-nitrogenous functional groups and separation of organic molecules.

OR

CHEM03GE3.2

Theory: MOLECULES OF LIFE (Credits: 04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on chemistry amino acid, peptides, proteins, carbohydrates, nucleic acid, lipids and enzymes correlation with drugs

Carbohydrates

Classification of carbohydrates, reducing and non-reducing sugars, General properties of glucose and fructose, their open chain structures. Epimers, mutarotation and anomers. Determination of configuration of Glucose by Fischer's method. Cyclic structure of glucose. Haworth projections. Cyclic structure of fructose. Linkage between monosachharides, structure of disacharrides (sucrose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation. **(10 Lectures)**

Amino Acids, Peptides and Proteins

Classification *of Amino Acids*, Zwitterion structure and Isoelectric point. Overview of Primary, Secondary, Tertiary and Quaternary structure of proteins. Determination of primary structure of peptides, determination of N-terminal amino acid (by DNFB and Edman method) and C–terminal amino acid (by thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (*t*-butyloxycarbonyl and phthaloyl) & C-activating groups and Merrifield solid phase synthesis. **(12 Lectures)**

Enzymes and correlation with drug action

Mechanism of enzyme action, factors affecting enzyme action, Coenzymes and cofactors and
their role in biological reactions, Specificity of enzyme action (including stereospecificity), Enzyme inhibitors and their importance, phenomenon of inhibition (Competitive and Noncompetitive inhibition including allosteric inhibition). Drug action-receptor theory. Structure–activity relationships of drug molecules, binding role of –OH group, -NH_2 group, double bond and aromatic ring. **(12 Lectures)**

Nucleic Acids

Components of nucleic acids: Adenine, Guanine, Thymine and Cytosine (Structure only), other components of nucleic acids, Nucleosides and nucleotides **(nomenclature)**, Structure of polynucleotides; Structure of DNA (Watson-Crick model) and RNA (**types of RNA**), Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation. **(10 Lectures)**

Lipids

Introduction to lipids, classification.

Oils and fats: Common fatty acids present in oils and fats, Omega fatty acids, Trans fats, Hydrogenation, Saponification value, Iodine number. Biological importance of triglycerides, phospholipids, glycolipids, and steroids (cholesterol). **(8 Lectures)**

Concept of Energy in Biosystems

Calorific value of food. Standard caloric content of carbohydrates, proteins and fats. Oxidation of foodstuff (organic molecules) as a source of energy for cells. Introduction to Metabolism (catabolism, anabolism), ATP: the universal currency of cellular energy, ATP hydrolysis and free energy change.

Conversion of food into energy. Outline of catabolic pathways of Carbohydrate- Glycolysis,

Fermentation, Krebs Cycle. Overview of catabolic pathways of Fats and Proteins. Interrelationships in the metabolic pathways of Proteins, Fats and Carbohydrates. **(8 Lectures)**

Reference Books:

- Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry* (*Volume 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Nelson, D. L. & Cox, M. M. *Lehninger's Principles of Biochemistry 7th Ed.,* W. H. Freeman.
- Berg, J.M., Tymoczko, J.L. &Stryer, L. *Biochemistry*, W.H. Freeman, 2002.

GE3.2 - LAB: (Credits: 02, 60 Lectures, Full Mars: 30)

1. Separation of amino acids by paper chromatography
2. To determine the concentration of glycine solution by formylation method.
3. Study of titration curve of glycine
4. Action of salivary amylase on starch
5. Effect of temperature on the action of salivary amylase on starch.
6. To determine the saponification value of an oil/fat.
7. To determine the iodine value of an oil/fat
8. Differentiate between a reducing/ nonreducing sugar.
9. Extraction of DNA from onion/cauliflower
10. To synthesise aspirin by acetylation of salicylic acid and compare it with the ingredient of an aspirin tablet by TLC.

Reference Books:

- Furniss, B.S.; Hannaford, A.J.; Rogers, V.; Smith, P.W.G.; Tatchell, A.R. *Vogel's Textbook of Practical Organic Chemistry*, ELBS.
- Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry,*Universities Press.

Course Learning Outcomes: After completion of the course, the student should be able to

1. Explore the fundamentals of nucleic acids, Nucleosides and nucleotides
2. Elucidate Primary, Secondary, Tertiary and Quaternary Structure of proteins; determine structure of peptides and carry out synthesis and reactions of amino acids.
3. Explain physical, chemical and optical properties of basic units of carbohydrates
4. Know the functioning of lipid, enzymes in biosystems
5. Differemtiate varieties of organic molecules by chromatographic techniques and carry out their quantitative estimation.

Skill Enhancement Course (Credit: 04 each)
CHEM03SEC1.1: IT SKILLS FOR CHEMISTS

(Credits: 04, 60 Lectures, Full Marks: 100)

Course Objectives: To acquire mathematical and computational skills that can be applied on the relevant research areas.

Mathematics

Fundamentals, mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs.

Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities.

Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).

Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms).Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

Computer programming:

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language (FORTRAN). BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

BASIC programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

HANDS ON

Introductory writing activities: Introduction to word processor and structure drawing (Chem Sketch) software. Incorporating chemical structures, chemical equations, expressions from chemistry (e.g. Maxwell-Boltzmann distribution law, Bragg's law, van der Waals equation, etc.) into word processing documents.

Handling numeric data: Spreadsheet software (Excel/Origin/Gnuplot)), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs.

Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a spreadsheet (Planck's distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory-Maxwell-Boltzmann distribution curves as function of temperature and molecular weight), spectral data, pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

Numeric modelling: Simulation of pH metric titration curves. Excel functions LINEST and Least Squares. Numerical curve fitting (Origin), linear regression (rate constants from concentration time

data, molar extinction coefficients from absorbance data), numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pKa of weak acid), integration (e.g. entropy/enthalpy change from heat capacity data).

Statistical analysis: Gaussian distribution and Errors in measurements and their effect on data sets. Descriptive statistics using Excel.

Presentation: Presentation graphics (Power Point Presentation).

Reference Books:

- McQuarrie, D. A. *Mathematics for Physical Chemistry University* Science Books (2008).
- Mortimer, R. *Mathematics for Physical Chemistry*. 3rd Ed. Elsevier (2005).
- Steiner, E. *The Chemical Maths Book* Oxford University Press (1996).
- Yates, P. *Chemical calculations.* 2nd Ed. CRC Press (2007).
- Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
- Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
- Noggle, J. H. *Physical chemistry on a Microcomputer*. Little Brown & Co. (1985).
- Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Formulate a set of calculations that can address a relevant research question.
2. Use one or several computer programs and extract useful information.
3. Write a research paper that describes methods, results, and interpretation.
4. Assess the meaning and validity of calculations that appear in the chemical literature.

OR

CHEM03SEC1.2: BASIC ANALYTICAL AND NUCLEAR CHEMISTRY

(Credits: 04, 60 Lectures, Full Marks: 100)

Course Objectives: The course aims to provide the knowledge on various analytical methods involved on chemical analysis, specially aims to water, soil analysis using instrumental techniques. Some advanced aspects of nuclear chemistry

Introduction: Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. presentation of experimental data and results, from the point of view of significant figures.

Analysis of soil: Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators

a. Determination of pH of soil samples.

b. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

Analysis of water: Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

a. Determination of pH, acidity and alkalinity of a water sample.

b. Determination of dissolved oxygen (DO) of a water sample.

Chromatography: Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

a. Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).

b. To compare paint samples by TLC method.

Ion-exchange: Column, ion-exchange chromatography etc.

Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

Suggested Applications (Any one):

a. To study the use of phenolphthalein in trap cases.

b. To analyze arson accelerants.

c. To carry out analysis of gasoline.

Suggested Instrumental demonstrations:

a. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.

b. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.

c. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drinks.

Radioactivity

Radioisotopes as Tracers and their applications; Isotopic exchange reactions; Kinetic isotope effect; Radiation Chemistry; Interaction of radiation with matter; Radiolysis of Water; Detection and Measurement of Radiation – Proportional counter, Scintillator and Detector; Radiation Dosimetry; Nuclear Reactors and Particle Accelerators; Radiation hazards

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Reference Books:

- Willard, H.H., Merritt, L.L., Dean, J. &Settoe, F.A. *Instrumental Methods of Analysis*, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA,1988.
- Skoog, D.A., Holler, F.J. & Crouch, S. *Principles of Instrumental Analysis*, Cengage Learning India Edition, 2007.
- Skoog, D.A.; West, D.M. & Holler, F.J. *Analytical Chemistry: An Introduction 6th Ed.*, Saunders College Publishing, Fort Worth, Philadelphia (1994).
- Harris, D. C. *Quantitative Chemical Analysis*, 9th ed. Macmillan Education, 2016.
- Dean, J. A. *Analytical Chemistry Handbook*, McGraw Hill, 2004.
- Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India, 1992.
- Freifelder, D.M. *Physical Biochemistry 2nd Ed.*, W.H. Freeman & Co., N.Y. USA (1982).
- Cooper, T.G. *The Tools of Biochemistry*, John Wiley & Sons, N.Y. USA. 16 (1977).
- Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7th Ed.,* Prentice Hall, 1996.
- Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009.
- Robinson, J.W. *Undergraduate Instrumental Analysis 5th Ed.*, Marcel Dekker, Inc., New York (1995).
- Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
- Nuclear Chemistry by M.G. Arora, Mandip Singh.
- Essentials of Nuclear Chemistry by Hari Jeevan Arnikar.
- Textbook of Nuclear Chemistry by A. Singh, R. Singh.
- Fundamental Concepts of Inorganic Chemistry, Vol-1 by Asim K. Das

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Course Learning Outcomes: On completion of the course, the students should be able to

1. Analyse the water and soil using chromatographic method, AAS method, pH measurement,
2. Analyse the contaminants.
3. Demonstare the various applications of radioisotopes
4. Explain the working principle of nuclear reactor

Semester IV

CHEM04C8: INORGANIC CHEMISTRY-III

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: The course aims to provide the knowledge on introduction to coordination compounds, comparison of inherent properties of transition metals in group, lanthanides and actinides and chemical elements in life, Quantitative gravimetric analysis and some elementary synthesis.

Coordination Chemistry:

Werner's theory, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of 10 Dq (Δo), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δo, Δt). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspect of Ligand field and MO Theory.

Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and ferromagnetic/antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$-$3d^9$ ions and their spectroscopic ground states; selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

Chelate effect, polynuclear complexes, Labile and inert complexes. Stability constant. **(30 Lectures)**

Transition Elements:

General comparison of 3d, 4d and 5d elements; Elemental form; Electronic configuration; Oxidation state; Redox properties; Atomic radii; Ionization potentials; Metallic nature; Atomization energy; Coordination chemistry and catalytic properties **(6 Lectures)**

f block elements and comparative studied with d block:

Lanthanides: Lanthanide contraction; Electronic configuration; Oxidation states; Atomic/Ionic radii; Ionization energy; Complex formation; Isomerization; Basicity; Hydration of Ln (III) ions; Organometallics compounds and their applications; Separation of lanthanides by ion exchange method

Actinides: Actinide contraction; Electronic configuration; Oxidation states; Atomic/Ionic radii; Ionization energy; Complex formation and Organometallics compounds **(12 Lectures)**

Bioinorganic Chemistry:

Elements of life: essential, major, trace and ultratrace elements. Basic chemical reactions in the biological systems and the role of metal ions (specially Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, $Fe^{3+/2+}$,$Cu^{2+/+}$, and Zn^{2+}). Ionophores, Sodium potassium pump. Biological functions of hemoglobin and myoglobin, cytochromes and ferredoxins, carboxypeptidase, carbonic anhydrase. Biological nitrogen fixation, Photosynthesis: Photo system-I and Photosystem-II. Toxic metal ions and their effects, chelation therapy, Pt and Au complexes as drugs (examples only), metal dependent diseases. **(12 Lectures)**

Reference Books:

- W. U. Malik, G. D. Tuli, R. D. Madan, Selected Topics in Inorganic Chemistry, S. Chand Publishers, 2001
- R. L. Dutta & G.S. De, Inorganic Chemistry (Vol. 1), The New Book Stall, 1973.
- Purcell, K.F & Kotz, J.C. Inorganic Chemistry W.B. Saunders Co, 1977.
- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
- Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.
- Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry Wiley-VCH, 1999
- Basolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
- The f Elements by Nikolas Kaltsoyannis and Peter Scott
- Bioinorganic Chemistry, Asim K Das
- Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.

CHEMISTRY PRACTICAL –C8 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

A. Inorganic preparations (Any Two)

1. Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs. thermodynamic factors.
2. Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}.
3. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

B. Gravimetric Analysis (Any One)

1. Estimation of nickel(II) using dimethylglyoxime (DMG).
2. Estimation of copper as CuSCN
3. Estimation of iron as Fe_2O_3 by precipitating iron as $Fe(OH)_3$.
4. Estimation of Al(III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminiumoxinate).

A. Titrimetric Estimations Based on complexometric EDTA Titrations.

1. Estimation of Ca(II) and Mg(II) in a mixture.
2. Estimation of permanent and temporary hardness of water

Reference Book:

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
- S. Gulati, J. L. Sharma, S. Manocha, Practical Inorganic Chemistry, CBS Publishers distributers, 2017.
- G. N. Mukherjee, Hand Book of Inorganic Analysis, U. N. Dhar & sons (P) LTD, 2014

Course Learning Outcomes: On completion of the course, the students should be able to

1. Differentiate double-salts and coordination complexes.
2. Explain the structure, spectral and magnetic properties of coordination complexes
3. Predict spectral properties using various theory of coordination chemistry
4. Demonstrate the periodic properties of d and f block elements
5. Explain functioning of important enzymes and proteins in our body.
6. Describe the metal-based drugs and their side effects.
7. Demonstrate the metal inducing pollution to environment; living system and some possible remedy.

CHEM04C9: ORGANIC CHEMISTRY-III

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on chemistry of nitrogen containing compounds, polynuclearhydrocarbons, heterocyclic compounds and synthetic strategy of organic compounds.

Nitrogen Containing Functional Groups

Preparation and important reactions of nitro and compounds, nitriles and isonitriles Amines: Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid.

Diazonium Salts: Preparation and their synthetic applications. **(18 Lectures)**

Polynuclear Hydrocarbons

Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons. **(8 Lectures)**

Heterocyclic Compounds

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of: Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander synthesis, Knorr quinoline synthesis, Doebner- Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction.

Derivatives of furan: Furfural and furoic acid. **(22 Lectures)**

Synthetic strategy:

Retrosynthetic analysis- disconnections, synthons, donor and acceptor synthons, functional group interconversion, C-C disconnections and synthesis [one group and two group (1,2 to 1,6-deoxygenated], reconnection (1,6-dicarbonyl), natural reactivity and umpolung, protection-deprotection strategy [alcohol, amine, carbonyl, acid] **(12 Lectures)**

Reference Books:

- Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India)Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry ofNatural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Acheson, R.M. Introduction to the Chemistry of Heterocyclic compounds, JohnWelly & Sons (1976).
- Graham Solomons, T.W. Organic Chemistry, John Wiley & Sons, Inc.McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage LearningIndia Edition, 2013.
- Kalsi, P. S. Textbook of Organic Chemistry 1st Ed., New Age International (P)Ltd. Pub.
- Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, OxfordUniversity Press.
- Organic Synthesis: The disconnection Approach by Stuart Warren (Wiley)

CHEMISTRY PRACTICAL-C9 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Detection of special elements.

2. Functional group test for nitro, amine and amide groups.

3. Qualitative analysis of unknown organic compounds containing simple functional groups (alcohols, carboxylic acids, phenols and carbonyl compounds)

Reference Books

- Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education(2009)
- Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical OrganicChemistry, 5th Ed., Pearson (2012)

- Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry:Preparation and Quantitative Analysis, University Press (2000).
- Ahluwalia, V.K. & Dhingra, S. Comprehensive Practical Organic Chemistry:Qualitative Analysis, University Press (2000).

Course Learning Outcomes: After completion of the course, the student should be able to

1. Explain physical and chemical properties of nitrogenousorganic molecules (amines, diazonium salts, nitro, nitriles, and isonitriles) and their effects on the reactivity; preparation, reactions and synthetic applications.
2. Elucidate structures, a variety of preparative methods and reactions of polynuclear hydrocarbons.
3. Explicate structures, classification, nomenclature and synthesis of several heterocycles: Furan, Pyrrole, Thiophene, Pyridine, Pyrimidine, Indole, Quinoline, Isoquinoline.
4. Plan retrosynthetic strategies in order to develop basic organic transformations.
5. Detect various elements and functional groups in organic sample which will increase their analytical skill.

CHEM04C10: PHYSICAL CHEMISTRY-IV

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To acquire knowledge of the quantum chemical description of various chemical systems, conductance and electrical and magnetic properties of atoms and molecules.

Quantum Chemistry-I

Breakdown of classical ideas – Line Spectra, black body (or cavity) radiation, Planck's quantization, photoelectric effect, Elementary idea of Bohr Theory, Compton scattering for relativistic (preliminary idea only); wave properties of particles: de Broglie hypothesis and the concept of matter waves, Davisson-Germer experiment, nature of matter waves: group and phase velocities and the idea of a wave packet; Heisenberg uncertainty principle and its relation to the measurement process, Differentiation of small and large particles on the basis of Uncertainty Principle, necessity of more general theory.

Time-independent form of the Schrödinger equation; probabilistic interpretation of the wave function; conditions for acceptability of wave functions.

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment), quantization of energy, zero-point energy and Heisenberg Uncertainty principle; wavefunctions, probability distribution functions, nodal properties, Extension to two- and three-dimensional boxes, separation of variables, degeneracy.

Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wavefunctions. Vibrational energy of diatomic molecules and zero-point energy. **(20 Lectures)**

Conductance

General Law for charge transfer, Comparison of conduction in solutions and metals, Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Structure of ionic solutions, Debye-Hückel law (with derivation), Debye-Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules, Temperature and viscosity dependence of conductivity, abnormal conductivity of H^+ and OH^- ions, Grotthuss mechanism, Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts. **(20 Lectures)**

Electrical & Magnetic Properties of Atoms and Molecules

Basic ideas of electrostatics, electric field, Gauss law, concept of electric potential, Poisson's equation, electric field due to point dipole, energy of a dipole in an electric field, polarizability (distortion and orientational), Electrostatics of dielectric media, relation between polarization and surface charge density, Clausius-Mosotti equation, estimation of orientational polarizability, Debye equation, Lorenz-Laurentz equation, Measurements of Dipole moment and molecular polarizabilities.

Spin and orbital contribution in magnetic moment, Diamagnetism, paramagnetism, ferromagnetism and anti-ferromagnetism; magnetic susceptibility and its measurement (Gouy's method, SQUID), Temperature dependence of magnetic susceptibility, Curie's equation. **(20 Lectures)**

Reference Books:

- Levine. I. N., Quantum Chemistry 7th Ed. Pearson (2016)
- McQuarrie. D. A., Quantum Chemistry Viva Student Ed. Pearson (2003)
- Atkins, P.W & Paula, J.D. Physical Chemistry, 10th Ed., Oxford University Press(2014).
- Castellan, G. W. Physical Chemistry 4th Ed., Narosa (2004).
- Mortimer, R. G. Physical Chemistry 3rd Ed., Elsevier: NOIDA, UP (2009).
- Barrow, G. M., Physical Chemistry 5th Ed., Tata McGraw Hill: New Delhi (2006).
- Engel, T. & Reid, P. Physical Chemistry 3rd Ed., Prentice-Hall (2012).
- Rogers, D. W. Concise Physical Chemistry Wiley (2010)
- Silbey, R. J.; Alberty, R. A. &Bawendi, M. G. Physical Chemistry 4th Ed., JohnWiley & Sons, Inc. (2005).

CHEMISTRY PRACTICAL-C10 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. pH metry

(i) Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.

(ii) Preparation of buffer solutions of different pH

(a) Sodium acetate-acetic acid

(b) Ammonium chloride-ammonium hydroxide

(iii) pH metric titration of

(a) strong acid vs. strong base

(b) weak acid vs. strong base.

(iv) Determination of dissociation constant of a weak acid.

2. Conductometry

(i) Determination of cell constant

(ii) Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

(iii) Perform the following conductometric titrations:

(a) Strong acid vs. strong base

(b) Weak acid vs. strong base

(c) Mixture of strong acid and weak acid vs. strong base

(d) Strong acid vs. weak base

Reference Books:

- Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
- Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
- Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Recognise the importance of the quantum chemistry and quantization of energy.
2. Solve the Schrodinger equation of various quantum chemical models such as particle in a box, harmonic oscillator and apply them to real systems related to chemistry.
3. Apply the principles of electrochemistry to conductance, voltaic, and electrolytic systems.

4. Provide a physical basis for Debye-Hückel theory.
5. Perform acid-base titration using conductometric method.
6. Explain the concepts of electrical and magnetic properties of atoms and molecules.

CHEM04GE4.1

Theory: TRANSITION METAL & COORDINATION CHEMISTRY, STATES OF MATTER & CHEMICAL KINETICS

(Credits: 04, 60 Lectures, Full Marks: 70)

Course Objectives: The course aims to provide the knowledge on introduction to coordination compounds, comparison of inherent properties of transition metals in group to general science students. Handful experience on qualitative analysis of inorganic salts.

Section A: Inorganic Chemistry

Transition Elements (3d series)

General group trends with special reference to electronic configuration, variable valency, colour, magnetic properties and ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.

Lanthanoids and actinoids: Electronic configurations, ionization energy, oxidation states, electronic spectra, magnetic properties, lanthanide contraction, separation of lanthanides (ion exchange method only).

(12 Lectures)

Coordination Chemistry

Valence Bond Theory (VBT): Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

Drawbacks of VBT. IUPAC system of nomenclature. **(8 Lectures)**

Crystal Field Theory

Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of Dq. Spectrochemical series. Comparison of CFSE for O_h and T_d complexes, Tetragonal distortion of octahedral geometry.

Jahn-Teller distortion, Square planar coordination. **(10 Lectures)**

Section B: Physical Chemistry

Course Objectives: To impart knowledge on the different states of matter and kinetics of chemical reactions

Kinetic Theory of Gases

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation.

Deviation of real gases from ideal behaviour, compressibility factor, causes of deviation. Van der Waals equation of state for real gases. Boyle temperature (derivation not required). Critical phenomena, critical constants and their calculation from van der Waals equation. Andrews isotherms of CO_2.

Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance.

Temperature dependence of these distributions. Most probable, average and root mean square velocities (no derivation). Collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only). **(8 Lectures)**

Liquids

Surface tension and its determination using stalagmometer. Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only). **(6 Lectures)**

Solids

Forms of solids. Symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices. Miller indices. X–Ray diffraction by crystals, Bragg's law. Structures of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals. Glasses and liquid crystals. **(8 Lectures)**

Chemical Kinetics

The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants). Half–life of a reaction. General methods for determination of order of a reaction. Concept of activation energy and its calculation from Arrhenius equation.

Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular reactions. Comparison of the two theories (qualitative treatment only). **(8 Lectures)**

Reference Books:

- Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
- Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
- R. P. Sarkar, General and Inorganic Chemistry (Vol. 2), New Central Book Agency, ed. 3, 2011

- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
- Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
- Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
- Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
- Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
- Cotton, F.A. & Wilkinson, G. *Basic Inorganic Chemistry*, Wiley.
- Shriver, D.F. & Atkins, P.W. *Inorganic Chemistry*, Oxford University Press.
- Wulfsberg, G. *Inorganic Chemistry*, Viva Books Pvt. Ltd.
- Rodgers, G.E. *Inorganic &Solid State Chemistry*, Cengage Learning India Ltd., 2008.

GE4.1-Lab: (Credits: 02, 60 Lectures, Full Marks: 30)

Section A: Inorganic Chemistry

Semi-micro qualitative analysis (using H_2S or other methods) of mixtures - three ionic species (two anions and one cation or one anion and two cations, excluding insoluble salts) out of the following:

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

Anions : CO_3^{2-}, S^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, NO_2^-, Cl^-, Br^-, I^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, F^-

(Spot tests should be carried out wherever feasible)

Section B: Physical Chemistry

(I) Surface tension measurement (use of organic solvents excluded).

a) Determination of the surface tension of a liquid or a dilute solution using a stalagmometer.

b) Study of the variation of surface tension of a detergent solution with concentration.

(II) Viscosity measurement (use of organic solvents excluded).

a) Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer.

b) Study of the variation of viscosity of an aqueous solution with concentration of solute.

(III) Chemical Kinetics

Study the kinetics of the following reactions.

Integrated rate method:

a. Acid hydrolysis of methyl acetate with hydrochloric acid.

b. Saponification of ethyl acetate.

c. Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of ester.

Reference Books:

- Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.

• Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
• Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).

Course Learning Outcomes: On completion of the course, the students should be able to

1. Differentiate double-salts and coordination complexes.
2. Explain the structure, spectral and magnetic properties of coordination complexes
3. Predict spectral properties using various theory of coordination chemistry
4. Explain the kinetic molecular model of gas, viscosity of gas and liquids.
5. Manipulate the gas laws to describe real and ideal gas behaviour.
6. Derive rate laws of various elementary and complex reactions

OR

CHEM04GE4.2

Theory: QUANTUM CHEMISTRY, SPECTROSCOPY & PHOTOCHEMISTRY

(Credits: 04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on the basic concepts and applications of quantum chemistry, spectroscopy and photochemistry.

Quantum Chemistry

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation andits application to free particle and "particle-in-a-box" (rigorous treatment), quantization ofenergy levels, zero-point energy and Heisenberg Uncertainty principle; wavefunctions, probability distribution functions, nodal properties, Extension to two and three dimensional boxes, separation of variables, degeneracy.Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wavefunctions. Vibrational energy of diatomic molecules and zero-point energy.

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component. Rigid rotator model of rotation of diatomic molecule. Schrödinger equation, transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution.

Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus.

Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom).

(24 Lectures)

Molecular Spectroscopy:

Interaction of electromagnetic radiation with molecules and various types of spectra.

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies.

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence.

Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and interpretation of PMR spectra of organic molecules.

Electron Spin Resonance (ESR) spectroscopy: Its principle, ESR of simple radicals. **(24 Lectures)**

Photochemistry

Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, photochemical equilibrium and the differential rate of photochemical reactions, photosensitised reactions. Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence. **(12 Lectures)**

Reference Books:

- Banwell, C. N. & McCash, E. M. *Fundamentals of Molecular Spectroscopy* 4th Ed. Tata McGraw-Hill: New Delhi (2006).
- Chandra, A. K. *Introductory Quantum Chemistry* Tata McGraw-Hill (2001).
- House, J. E. *Fundamentals of Quantum Chemistry* 2nd Ed. Elsevier: USA (2004).
- Lowe, J. P. & Peterson, K. *Quantum Chemistry,* Academic Press (2005).
- Kakkar, R. *Atomic & Molecular Spectroscopy*: *Concepts & Applications*, Cambridge University Press (2015).

GE4.2 LAB: (Credits: 02, 60 Lectures, Full Marks: 30)

UV/Visible spectroscopy

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).

2. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$.

3. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde,

2-propanol, acetic acid) in water.

Colorimetry

1. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/$K_2Cr_2O_7$ in a solution of unknown concentration.

2. Determine the concentrations of $KMnO_4$and $K_2Cr_2O_7$ in a mixture.

3. Determine the dissociation constant of an indicator (phenolphthalein).

Reference Books

• Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
• Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
• Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.;* McGraw-Hill: New York (2003).
• Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York (2003).

Course Learning Outcomes: On completion of the course, the students should be able to

1. Recognise the importance of the quantum chemistry and quantization of energy.
2. Solve the Schrodinger equation of various quantum chemical models such as particle in a box, harmonic oscillator and apply them to real systems related to chemistry.
3. Explain the structural properties of molecules on the basis of spectroscopic data
4. Calculate the quantum yield on the basis of the mechanism of photochemical reactions and explain the fates of electronically excited molecules by using Jablonski diagram

Skill Enhancement Course (Credit: 04 each)
CHEM04SEC2.1: GREEN METHODS IN CHEMISTRY

(Credits: 04, 60 Lectures, Full Marks: 100)

Course Objectives: To impart knowledge on green methods in chemistry

Theory:

Theory and Hand-on Experiments

Introduction: Definitions of Green Chemistry. Brief introduction of twelve principles of Green Chemistry, with examples, special emphasis on atom economy, reducing toxicity, green solvents, Green Chemistry and catalysis and alternative sources of energy, Green energy and sustainability

The following real world cases in Green Chemistry should be discussed:

Surfactants for carbon dioxide – Replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments.

Designing of environmentally safe marine antifoulant.

Rightfit pigment: Synthetic azo pigments to replace toxic organic and inorganic pigments.

An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.

Practical

Preparation and characterization of biodiesel from vegetable oil.

Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice.

Mechano chemical solvent free synthesis of azomethine.

Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).

Reference Books:

- Anastas, P.T. & Warner, J.K. *Green Chemistry- Theory and Practical*, Oxford University Press (1998).
- Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
- Cann, M.C. & Connely, M.E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000).
- Ryan, M.A. &Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, Washington (2002).
- Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. *Green Chemistry Experiments: A monograph* I.K. International Publishing House Pvt Ltd. New Delhi, Bangalore.
- Lancaster, M. *Green Chemistry: An introductory text* RSC publishing, 2nd Edition.
- Sidhwani, I.T., Saini, G., Chowdhury, S., Garg, D., Malovika, Garg, N. Wealth from waste: A green method to produce biodiesel from waste cooking oil and generation of useful products from waste further generated *"A Social Awareness Project", Delhi University Journal of Undergraduate Research and Innovation*, **1(1)**: 2015.

Course Learning Outcomes: After completion of this course students should be able to

1. Design green synthetic protocol utilizing alternative greener energy sources to minimize the environmental impact of chemical reactions for sustainable development.
2. Get hands on experience of extraction and characterization of natural products and their synthesis.

OR

CHEM04SEC2.2: PHARMACEUTICAL CHEMISTRY

(Credits: 04, 60 Lectures, Full Marks: 100)

Course Objectives: To impart knowledge on theory of drugs and pharmaceuticals and aerobic and anaerobic fermentation

Theory: Drugs & Pharmaceuticals

Drug discovery, design and development; Basic Retrosynthetic approach. Synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (Aspirin, paracetamol, lbuprofen); antibiotics (Chloramphenicol); Antimalarials: Chloroquine (with synthesis). Medicinal values of curcumin (haldi), azadirachtin (neem), and antacid (ranitidine). antibacterial and antifungal agents (Sulphonamides; Sulphanethoxazol, Sulphacetamide, Trimethoprim); antiviral agents (Acyclovir), Central Nervous System agents (Phenobarbital, Diazepam), Cardiovascular (Glyceryl trinitrate), antilaprosy (Dapsone), HIV-AIDS related drugs (AZT- Zidovudine).

Fermentation

Aerobic and anaerobic fermentation. Production of (i) Ethyl alcohol and citric acid, (ii) Antibiotics; Penicillin, Cephalosporin, Chloromycetin and Streptomycin, (iii) Lysine, Glutamic acid, Vitamin B2, Vitamin B12 and Vitamin C.

Practical

1. Preparation of Aspirin and its analysis.

2. Preparation of magnesium bisilicate (Antacid).

Reference Books:

• Patrick, G. L. *Introduction to Medicinal Chemistry, Oxford University* Press, UK, 2013.
• Singh, H. & Kapoor, V.K. *Medicinal and Pharmaceutical Chemistry,* Vallabh Prakashan, Pitampura, New Delhi, 2012.
• Foye, W.O., Lemke, T.L. & William, D.A.: *Principles of Medicinal Chemistry*, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.

Course Learning Outcomes: After completion of this course students should be able to

1. Design and develop synthetic routes to access various organic compounds with analgesics, antipyretic, anti-inflammatory, antibiotic, antibacterial, antifungal, antiviral and other significant pharmacological activities.
2. Explain aerobic and anaerobic fermentation and their role in the production of ethanol and citric acid.
3. Conduct preparation and reactions of important antibiotics such as, Penicillin, Cephalosporin, Chloromycetin and Streptomycin.
4. Describe the pharmaceutical activities of Lysine, Glutamic acid, Vitamin B2, Vitamin B12 and Vitamin C.
5. Synthesize simple and small drug molecules.

Semester V

CHEM05C11: ORGANIC CHEMISTRY-IV

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on organic spectroscopy, Asymmetric synthesis, Organometallic chemistry and Pericyclic reactions

Organic Spectroscopy:

General principles Introduction to absorption and emission spectroscopy.

UV Spectroscopy: Types of electronic transitions, λmax, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Application of Woodward Rules for calculation of λ_{max} for the following systems: α,β unsaturated aldehydes, ketones, carboxylic acids and esters; Conjugated dienes: alicyclic, homoannular and heteroannular; Extended conjugated systems (aldehydes, ketones and dienes); distinction between cis and trans isomers.

IR Spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O, N and S containing functional groups; Effect of H-bonding, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis.

NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin – Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds.

Applications of IR, UV and NMR for identification of simple organic molecules. **(24 Lectures)**

Asymmetric synthesis:

Stereoselective and stereospecific reactions, diastereoselectivity, and enantioselectivity (only definition), diastereoselectivity: addition of nucleophiles to C=O, adjacent to a stereogenic centre (Felkin-Anh model); addition of electrophiles to C=C (Houk model). **(10 Lectures)**

Organometallic Chemistry:

Preparation and Application of organo-Si, Cd, Se, Ti, Pd etc. **(8 Lectures)**

Pericyclic Reactions:

Electrocyclic reactions: 4e and 6e neutral systems; cycloaddition reactions: [4 + 2] and [2 + 2] reactions, cheletropic addition of carbene; sigmatropic rearrangements: [1,3] and [1,5] H shifts, [3,3] Cope and Claisen rearrangements. FMO analysis and Woodward-Hoffmann selection rules. **(18 Lectures)**

Reference Books:

- Kemp, W. Organic Spectroscopy, Palgrave.
- Pavia, D. L. et al. Introduction to Spectroscopy 5th Ed. Cengage Learning India Ed. (2015)
- The Conservation of Orbital Symmetry - R.B. Woodward and R. Hoffmann, VCH
- Organic Reactions and Orbital Symmetry - T.L. Gilchrist and R.C. Storr, CUP
- Pericyclic Chemistry - D. K. Mandal
- Pericyclic Reaction - I. Fleming, OUP
- Molecular Orbitals and Organic Chemical Reactions (John Wiley and Sons, Ltd.) - I. Fleming
- Kalsi, P. S. Textbook of Organic Chemistry 1st Ed., New Age International (P) Ltd. Pub.
- Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

CHEMISTRY PRACTICAL-C11 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Identification of simple organic compounds by IR spectroscopy and NMR spectroscopy (Spectra to be provided)
2. Preparation of organic molecules using Grignard reagent
3. Aldol condensation
4. Michael reaction
5. Esterification reaction
6. Diel-Alder reaction

. **Reference Books:**

- Organic Spectroscopy - W. Kemp, ELBS
- Introduction to Spectroscopy - Pavia, Lampman
- Applications of Absorption Spectroscopy of Organic Compounds - Dyer

Course Learning Outcomes: After completion of the course, the student should be able to

1. Explain the principle and instrumentation of UV, infrared and nuclear magnetic spectroscopy and interpret the spectra to characterize simple organic molecules.
2. Analyze stereoselective and stereospecific reactions with the aid of different models.
3. Describe preparative methods and applications of organo-Si, Cd, Se, Ti, Pd compounds.

4. Familiarize with the preliminary idea of pericyclic reactions: Electrocyclic reactions, Sigmatropic Rearrangements and Cycloadditions and explain their feasibility in light of FMO and Woodward-Hoffmann rules.
5. Synthesize different organic compound using sensitive reactions and identify organic compounds by spectroscopic means. This will increase their analytical skill.

CHEM05C12: PHYSICAL CHEMISTRY V

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on the application of quantum chemistry for atoms and diatomic molecules, statistical concept of thermodynamics, fundamentals of rotation, vibration, Raman, electronicand NMR spectroscopy and basic ideas of Photochemistry and Photoluminescence.

Quantum Chemistry-II

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component. Rigid rotator model of rotation of diatomic molecule. Schrödinger equation, transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution.

Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus.

Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom).

Chemical bonding: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+. Bonding and antibonding orbitals. Qualitative extension to H_2. Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, detailed solution not required) and their limitations. Refinements of the two approaches (Configuration Interaction for MO, ionic terms in VB). Qualitative description of LCAO-MO treatment of homonuclear diatomic molecules. **(18 Lectures)**

Statistical Thermodynamics and Third Law

Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules

Concept of probability. Micro- and macrostates, thermodynamic probability, entropy and probability, the Boltzmann-Planck entropy formula, the Maxwell-Boltzmann distribution law for the distribution of molecular energies, partition function: molecular and molar, the translational partition function, thermodynamic quantities from partition function, vibrational partition functions, Einstein's theory of heat capacity of solids, the

characteristics temperature, its limitations and Debye's modification thereof ; Nernst heat theorem, approach to zero Kelvin, adiabatic demagnetization, Planck's formulation of third law and the concept of absolute entropies

(12 Lectures)

Molecular Spectroscopy:

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation (qualitative idea).

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.

Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and low-resolution spectra, different scales, spin-spin coupling and high-resolution spectra, interpretation of PMR spectra of organic molecules. Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals. **(24 Lectures)**

Photochemistry

Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws, of photochemistry, quantum yield, actinometry,

examples of low and high quantum yields, photochemical equilibrium and the differential rate of photochemical reactions, photosensitised reactions, quenching, chemiluminescence. Role of photochemical reactions in biochemical processes. Photochemical Reactions: kinetics of HI decomposition, H_2-Br_2 reaction, dimerization of anthracene, photo stationary state. **(6 Lectures)**

Reference Books:

- Levine. I. N., Quantum Chemistry 7th Ed. Pearson (2016)
- Engel, T. & Reid, P. Physical Chemistry 3rd Ed. Pearson (2013).
- McQuarrie D. A., Statistical Thermodynamics, Harpar & Row (1973)
- Banwell, C. N. & McCash, E. M. Fundamentals of Molecular Spectroscopy 4th Ed. TataMcGraw-Hill: New Delhi (2006).
- Chandra, A. K. Introductory Quantum Chemistry Tata McGraw-Hill (2001).
- House, J. E. Fundamentals of Quantum Chemistry 2ndEd. Elsevier: USA (2004).
- Kakkar, R. Atomic & Molecular Spectroscopy: Concepts & Applications, CambridgeUniversity Press (2015).
- Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).

CHEMISTRY PRACTICAL-C 12 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

UV/Visible spectroscopy

I. Study the 200-500 nm absorbance spectra of KMnO4 and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λmax values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).

II. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$.

III. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.

Colourimetry

I. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/$K_2Cr_2O_7$ in a solution of unknown concentration

II. Study the kinetics of iodination of propanone in acidic medium.

III. Determine the amount of iron present in a sample using 1,10-phenathroline.

IV. Determine the dissociation constant of an indicator (phenolphthalein).

V. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.

DMG, glycine) by substitution method.

Reference Books

- Khosla, B. D.; Garg, V. C. & Gulati, A., Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
- Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
- Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Explain atomic structure and the application of the concept of quantization of energy of different orbitals.
2. Apply quantum mechanical approximation methods to demonstrate chemical bonding of di-atomic systems.
3. Demonstrate the relation between microscopic and macroscopic properties of matter.
4. Explain the structural properties of molecules on the basis of spectroscopic data
5. Calculate the quantum yield on the basis of the mechanism of photochemical reactions and explain the fates of electronically excited molecules by using Jablonski diagram

CHEMISTRY-DSE 1 and 2 (ELECTIVES)

Credit: 5 + 1 and 4 + 2

CHEM05DSE:

1. RESEARCH METHODOLOGY IN CHEMISTRY

(Credits: Theory-05, Tutorial-1, 60 Lectures, Full Marks: 70)

Course Objectives: This course aims to provide knowledge on selection of research field, recent trends in research field, literature survey, lab safety, research ethics and copy right, etc.

Introduction to the concept of research: Objective of scientific research, classification of research, Identification and selection of research problem, theoretical design of methodology, diagnostic study, evaluation of research. Introduction to recent trending research topics in chemistry.

Literature survey: Need for literature survey, Sources of literature such as hardcopies and archives from university and national libraries, web sources, e-journals, e-books, search engines, identification of problem-based literature,

Basic knowledge of computer systems: writing abstract and literature-based review on word, general awareness of software packages used in research.

Basic laboratory safety protocols, Chemical safety data, chemical storage, ethical handling of chemicals, emergency procedure and first aid, concepts of drying of solvents, handling of flammable and explosive compounds disposal of laboratory chemical wastes, recovery and reuse, acquaintance of experimental setup. Use of spectroscopy and spectrometry in research.

Information about common ethical issues, copyright, intellectual property rights, citation, acknowledgement.

ReferenceBooks,

- Garg, B. L. Karadia, R. Agarwal, F, and Agarwal, U.K. 2002, An introduction to Research Methodology, RBSA Publishers.
- Chemical Safety Matters-IUPAC-IPCS, Cambridge Univ. Press.

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Select and approach the research problems
2. Perform literature survey on particular research topic
3. Write the abstract, literature survey outcomes etc.
4. Follow basic lab safety protocols and handling of hazardous chemicals, first aid
5. Analyse the spectroscopy and spectrometry data
6. Follow ethics in research, copyright and citation

2. POLYMER CHEMISTRY

(Credits: Theory-06, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on polymeric materials with reference to their functionality, crystallinity, kinetics of polymerization, structure-property relationship, molar mass determination, as well as their properties in solution and solid phase.

Introduction and history of polymeric materials:

Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers. **(4 Lectures)**

Functionality and its importance:

Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems. **(8 Lectures)**

Kinetics of Polymerization:

Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques. **(8 lectures)**

Crystallization and crystallinity:

Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point. **(4 Lectures)**

Nature and structure of polymers-Structure Property relationships. **(2 Lectures)**

Determination of molecular weight of polymers (*Mn*, *Mw*, etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index. **(8 Lectures)**

Glass transition temperature (Tg) and determination of Tg, Free volume theory, WLF equation, Factors affecting glass transition temperature (Tg). **(8 Lectures)**

Polymer Solution – Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures. **(8 Lectures)**

Properties of Polymers (Physical, thermal, Flow & Mechanical Properties). Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphide polypyrrole, polythiophene)]. **(10 Lectures)**

Reference Books:

- R.B. Seymour & C.E. Carraher: *Polymer Chemistry: An Introduction,* Marcel Dekker, Inc. New York, 1981.
- G. Odian: *Principles of Polymerization*, 4th Ed. Wiley, 2004.
- F.W. Billmeyer: *Textbook of Polymer Science*, 2nd Ed. Wiley Interscience, 1971.
- P. Ghosh: Polymer Science & Technology, Tata McGraw-Hill Education, 1991.
- R.W. Lenz: *Organic Chemistry of Synthetic High Polymers.* Interscience Publishers, New York, 1967.

DSE LAB: POLYMER CHEMISTRY

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. **Polymer synthesis**

1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).

a. Purification of monomer

b. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bis-isobutylonitrile (AIBN)

2. Preparation of nylon 66/6

1. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein

a. Preparation of IPC

b. Purification of IPC

c. Interfacial polymerization

3. Redox polymerization of acrylamide

4. Precipitation polymerization of acrylonitrile

5. Preparation of urea-formaldehyde resin

6. Preparations of novalac resin/ resold resin.

7. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry:

(a) Polyacrylamide-aq.$NaNO_2$ solution

(b) (Poly vinyl proplylidine (PVP) in water

2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.

3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).

4. Testing of mechanical properties of polymers.

5. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer analysis

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method

2. Instrumental Techniques

3. IR studies of polymers

4. DSC analysis of polymers

5. Preparation of polyacrylamide and its electrophoresis

*at least 7 experiments to be carried out.

Reference Books:

- M.P. Stevens, *Polymer Chemistry: An Introduction*, 3rd Ed., Oxford University Press, 1999.
- H.R. Allcock, F.W. Lampe & J.E. Mark, *Contemporary Polymer Chemistry*, 3rd ed. Prentice-Hall (2003)
- F.W. Billmeyer, *Textbook of Polymer Science*, 3rd ed. Wiley-Interscience (1984)
- J.R. Fried, *Polymer Science and Technology*, 2nd ed. Prentice-Hall (2003)
- P. Munk & T.M. Aminabhavi, *Introduction to Macromolecular Science*, 2nd ed. John Wiley & Sons (2002)
- L. H. Sperling, *Introduction to Physical Polymer Science*, 4th ed. John Wiley & Sons (2005)
- M.P. Stevens, *Polymer Chemistry: An Introduction* 3rd ed. Oxford University Press (2005).
- Seymour/ Carraher's Polymer Chemistry, 9th ed. by Charles E. Carraher, Jr. (2013).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Realize the history of polymeric materials.
2. Study experimentally the kinetics of polymerization.
3. Calculate the degree of crystallinity.

4. Determine the molecular weights of polymer by different methods.
5. Apply Flory-Huggins theory to polymer solutions.
6. Prepare and characterize some selected polymers.

3. ANALYTICAL METHODS IN CHEMISTRY

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: The course aims to provide the knowledge on various analytical methods involved on qualitative and quantitative analysis. Various modern spectroscopic and spectrometric methods involved on chemical analysis.

Qualitative and quantitative aspects of analysis:

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution of errors, statistical test of data; F, Q and t test, rejection of data and confidence intervals.

(6 Lectures)

Optical methods of analysis:

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, Beer-Lambert's law and its validity.

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of composition of metal complexes
using Job's method of continuous variation and mole ratio method.

Infrared Spectrometry: Basic principles of instrumentation (choice of source, monochromator & detector) for single and double beam instrument; sampling techniques. Structural illustration through interpretation of data, Effect and importance of isotope substitution.

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, detector, choice of flame and Burner designs. Techniques of atomization and sample introduction; Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water sample **(24 Lectures)**

Thermal methods of analysis:

Theory of thermogravimetry (TG), DTA & DSC principles, basic principle of TG instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture. **(4 Lectures)**

Electroanalytical methods:

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values. Linear scan voltametry (LSV), Polarography and Cyclic voltametry, Coulometry, Electrogravimetry.

(13 Lectures)

Separation techniques:

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation.

Technique of extraction: batch, continuous and counter current extractions.

Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

Chromatography: Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange.

Development of chromatograms: frontal, elution and displacement methods.

Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Stereoisomeric separation and analysis: Measurement of optical rotation. **(13 Lectures)**

Reference Books:

- Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009.
- Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
- Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
- Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.
- Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009.
- Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Ed.
- Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.
- Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

DSE LAB: ANALYTICAL METHODS IN CHEMISTRY

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

I. Separation Techniques

1.(a) Separation of mixtures

Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the Rf values.

(b) (i) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their Rf values

(ii) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:

1. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

2. Ion exchange (any one):

3. Separation of amino acids from organic acids by ion exchange chromatography.

III Spectrophotometry

1. Determination of pKa values of indicator using spectrophotometry.

2. Structural characterization of compounds by infrared spectroscopy.

3. Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job's method.

Determine the composition of the complexes by Job's method of the following systems:

(i) Fe (III)-sulphosalicylate complex

(ii) Fe (II)-phenanthroline complex

Quantitative Estimations (Real Samples) (any three)

1. Estimation of free alkali present in different soaps/detergents
2. Estimation of Cu in brass.
3. Estimation of available chlorine in bleaching powder iodometrically
4. Determination of the amount of calcium in milk powder
5. Estimation of total Mn from Pyrolusite
6. Fe^{3+} and Cr^{3+} using dichromatometric method

Reference Books:

- Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009.
- Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
- Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
- Harris, D.C. *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.
- Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009.
- Skoog, D.A. Holler F.J. and Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Edition.
- Mikes, O. &Chalmes, R.A. *Laboratory Handbook of Chromatographic & Allied Methods*, Elles Harwood Ltd. London.
- Ditts, R.V. *Analytical Chemistry: Methods of separation.* Van Nostrand, New York, 1974.

Course Learning Outcomes:

On completion of the course, the students should be able to

1. Handle, plot and analyse the data for absorption and emission spectroscopy.

2. Find complexation ratio of metal and ligand using Job's method
3. Use of AAS and AES for analysis of various water contaminant
4. Interpret the TGA and DSC data and identify the thermal stability and morphological changes of materials
5. Interpret data from modern electrochemical method such as LSV, CV and Coulometry
6. Apply separation techniques such as solvent extraction and chromatography.

4. APPLICATIONS OF COMPUTERS IN CHEMISTRY

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To provide basic understanding of the programming language, numerical methods, various computational techniques and to impart skills to apply them to solve problems related to chemistry.

Basics:

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

Numerical methods:

Roots of equations: Numerical methods for roots of equations: Quadratic formula, iterative method, Newton-Raphson method, Binary bisection and Regula-Falsi.

Differential calculus: Numerical differentiation.

Integral calculus: Numerical integration (Trapezoidal and Simpson's rule), probability distributions and mean values.

Simultaneous equations: Matrix manipulation: addition, multiplication. Gauss-Siedal method.

Interpolation, extrapolation and curve fitting: Handling of experimental data.

Conceptual background of molecular modelling: Potential energy surfaces. Elementary ideas of molecular mechanics and practical MO methods.

Reference Books:

• Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
• Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
• Noggle, J. H. *Physical chemistry on a Microcomputer*. Little Brown & Co. (1985).
• Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).

DSE LAB: APPLICATIONS OF COMPUTERS IN CHEMISTRY

(Credits: Practicals-02 60 Lectures, Full Marks: 30)

Computer programs based on numerical methods for

1. Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).

2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

3. Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values.

4. Matrix operations. Application of Gauss-Siedel method in colourimetry.

5. Simple exercises using molecular visualization software.

Reference Books:

- McQuarrie, D. A. *Mathematics for Physical Chemistry* University Science Books (2008).
- Mortimer, R. *Mathematics for Physical Chemistry*. 3rd Ed. Elsevier (2005).
- Steiner, E. *The Chemical Maths Book* Oxford University Press (1996).
- Yates, P. *Chemical Calculations*. 2nd Ed. CRC Press (2007).
- Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
- Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*,Cambridge Univ. Press (2001) 487 pages.
- Noggle, J. H. *Physical Chemistry on a Microcomputer*. Little Brown & Co. (1985).
- Venit, S.M. *Programming in BASIC: Problem solving with structure and style.* Jaico Publishing House: Delhi (1996).

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Formulate a set of calculations that can address a relevant research question.
2. Use one or several computer programs and extract useful information.
3. Write computer programs to solve linear systems using Gaussian elimination, interpolation, numerical integration and numerical solution of differential equations.
4. Assess the meaning and validity of calculations that appear in the chemical literature.

Semester VI

CHEM06C13: INORGANIC CHEMISTRY-IV

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: The course aims to provide the knowledge on inorganic qualitative analysis, reaction kinetics, introductory, and advanced level organometallic chemistry, apply their chemical knowledge to identify the ions present in inorganic salts

Theoretical Principles in Qualitative Analysis (H_2S Scheme)

Basic principles involved in analysis of cations and anions and solubility products, common ion effect. Principles involved in separation of cations into groups and choice of group reagents. Interfering anions (fluoride, borate, oxalate and phosphate) and need to remove them after Group II.

(4 Lectures)

Organometallic Compounds

Definition and classification of organometallic compounds on the basis of bond type.

Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls. Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.

Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with thatof benzene. **(30 Lectures)**

Reaction Kinetics and Mechanism

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans- effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes. **(16 Lectures)**

Catalysis by Organometallic Compounds

Study of the following industrial processes and their mechanism:

1. Alkene hydrogenation (Wilkinson's Catalyst)
2. Hydroformylation (Co salts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes **(10 Lectures)**

Reference Books:

- Svehla, G. Vogel's Qualitative Inorganic Analysis, 7th Edition, Prentice Hall, 1996.
- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
- Sharpe, A.G. Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005
- Douglas, B. E.; McDaniel, D.H. & Alexander, J.J. Concepts and Models in Inorganic Chemistry3rd Ed., John Wiley and Sons, NY, 1994.
- A. Elias, B. D. Gupta, Basic Organometallic Chemistry, Universities Press (ed. 2), 2013.
- Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988.
- Shriver, D.D. & P. Atkins, Inorganic Chemistry 2nd Ed., Oxford University Press, 1994.
- Basolo, F. & Pearson, R. Mechanisms of Inorganic Reactions: Study of Metal Complexes in Solution 2nd Ed., John Wiley & Sons Inc; NY.
- Purcell, K.F. & Kotz, J.C., Inorganic Chemistry, W.B. Saunders Co. 1977
- Miessler, G. L. & Tarr, D.A. Inorganic Chemistry 4th Ed., Pearson, 2010.
- Collman, J. P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987.
- Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. j New York, NY: John Wiley, 2000.
- Spessard, G. O. & Miessler, G.L. Organometallic Chemistry. Upper Saddle River, NJ: Prentice-Hall, 1996.

CHEMISTRY PRACTICAL-C13 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

Cation radicals derived from:

Na, K, NH_3, Mg, Ca, Sr, Ba, Al, Pb, Bi, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd

Anion radicals:

F^-, CI^-, Br^-, I^-, NO_3^-, NO_2^-, SCN^-, S^{2-}, SO_4^{2-}, $S_2O_3^{2-}$, PO_4^{3-}, BO_3^{3-}, CrO_4^{2-}, BrO_3^-, IO_3^-, $[Fe(CN)_6]^{4-}$, $[Fe(CN)_6]^{3-}$

Detection and confirmation of four radicals by macro, semi- micro tests and assignment of probable composition of the mixtures.

Mixtures should preferably contain one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) or combination of anions

Spot tests should be done whenever possible.

Reference Books

- Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla. Pearson Education, 2002.
- G. N. Mukherjee, Hand Book of Inorganic Analysis, U. N. Dhar & sons (P) LTD, 2014
- Marr & Rockett Practical Inorganic Chemistry. John Wiley & Sons 1972.

Course Learning Outcomes: On completion of the course, the students should be able to

1. Know the theoretical and practical knowledge on separation and analysis of individual inorganic cations and anions.
2. Find the composition of unknown inorganic salt combinations.
3. Explain the inert and lability of trans ligand.
4. Explain the thermodynamic and kinetic aspects of trans effect and application of trans effect on synthesis of coordination complexes.
5. Perform electron count and calculate stability of organometallic compounds
6. Demonstrate the structure and bonding, coordination modes, geometries, fundamental reaction types of organometallic compounds and the mechanisms in the organometallic catalytic processes.

CHEM06C14: ORGANIC CHEMISTRY-V

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on nucleic acids, Aminoacids, peptides, proteins, carbohydrates, carbocycles, and natural product such as alkaloids and terpinoids.

Nucleic Acids:

Components of nucleic acids, Nucleosides and nucleotides; Structure, synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine; Structure of polynucleotides. **(9 Lectures)**

Amino Acids, Peptides and Proteins:

Amino acids, Peptides and their classification. α-Amino Acids - Synthesis, ionic properties and reactions. Zwitterions, pKa values, isoelectric point and electrophoresis; Study of peptides: determination of their primary

structures-end group analysis, methods of peptide synthesis. Synthesis of peptides using N-protecting, C-protecting and C-activating groups -Solid-phase synthesis. **(16 Lectures)**

Carbohydrates

Occurrence, classification and their biological importance.

Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, determination of ring size of glucose and fructose, Haworth projections and conformational structures; Interconversions of aldoses and ketoses; Kiliani- Fischer synthesis and Ruff degradation;

Disaccharides – Structure elucidation of maltose, lactose and sucrose.

Polysaccharides – Elementary treatment of starch, cellulose and glycogen. **(16 Lectures)**

Carbocycles

Synthesis and reactions: Thermodynamic and kinetic factors, Baldwin rules. Synthesis of carbocycles through alkylation, condensation, cycloaddition, rearrangement and their reactions. Synthesis of polycyclic aromatics.

(8 Lectures)

Alkaloids

Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Hygrine and Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

(6 Lectures)

Terpenes

Occurrence, classification, isoprene rule; Elucidation of stucture and synthesis of Citral, Neral and α-terpineol.

(5 Lectures)

Reference Books:

- Kalsi, P. S. Textbook of Organic Chemistry 1st Ed., New Age International (P) Ltd. Pub.
- Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Graham Solomons, T.W. Organic Chemistry, John Wiley & Sons, Inc.
- McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013.
- Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press.
- Singh, J.; Ali, S.M. & Singh, J. Natural Product Chemistry, PrajatiPrakashan

(2010).
- Berg, J.M., Tymoczko, J.L. &Stryer, L. (2006) Biochemistry. 6th Ed. W.H. Freeman and Co.
- Nelson, D.L., Cox, M.M. &Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.
- Murray, R.K., Granner, D.K., Mayes, P.A. & Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.

CHEMISTRY PRACTICAL-C14 LAB

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Extraction of caffeine from tea leaves.
2. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars.
3. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, for *e.g.* salicylic acid, cinnamic acid, nitrophenols, etc.
4. Estimation of glycine by Sorenson's formalin method.
5. Study of the titration curve of glycine.
6. Estimation of proteins by Lowry's method.

Reference Books:

- Vogel, A.I. Quantitative Organic Analysis, Part 3, Pearson (2012).
- Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
- Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012)
- Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000).
- Ahluwalia, V.K. & Dhingra, S. Comprehensive Practical Organic Chemistry: Qualitative Analysis, University Press (2000).
- Manual of Biochemistry Workshop, 2012, Department of Chemistry, University of Delhi.
- Arthur, I. V. Quantitative Organic Analysis, Pears

Course Learning Outcomes: After completion of the course, the student should be able to

1. Explore the fundamentals of nucleic acids, Nucleosides and nucleotides
2. Elucidate Primary, Secondary, Tertiary and Quaternary Structure of proteins; determine structure of peptides and carry out synthesis and reactions of amino acids.
3. Explain physical, chemical and optical properties of basic units of carbohydrates
4. Developed the idea of carbocycles

5. Illustrate the preliminary idea of natural products such as alkaloids and terpenoids.
6. Analyse unknown organic compounds, carbohydrates, amino acid in a qualitative manner and perform Caffein extraction which will increase their analytical skill.

CHEM06DSE:

7. Seminar / Review / Grand Viva

(Credits: Theory-04, Practicals-02, Full Marks-100)

Course Objective: To provide training on the scientific presentation and group discussion skills which will help them to prepare for job interviews in academia and industries.

Course learning Outcomes: On completion of the course, the students should be able to

1. Present scientific topics in an organized manner
2. Face the job interviews in a confident manner.

8. FLUORESCENCE STUDY: THEORY AND APPLICATIONS FOR MACROMOLECULES AND NANOMATERIALS IN SENSING

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on the theory and applications of fluorescence spectroscopy and to acquire the fundamental experimental skills on the different techniques related to fluorescence measurements

Light Matter Interaction, Absorption-Emission Kinetics, Principles of LASER and characteristic features.

Basic idea of spectral intensities: Fermi Golden rule and selection rules from quantum mechanical viewpoints. Relaxation of selection rules.

Radiative and non-radiative deactivation of excited molecules: Fluorescence - mirror-image symmetry, Phosphorescence, radiative life time, radiation less deactivation – internal conversion and intersystem crossing, delayed fluorescence.

Quenching of fluorescence, Stern-Volmer equation and plot, static and dynamic quenching, Life-time variation in presence of quencher. Fluorescence quenching study of tryptophan in protein for the sensing of organic molecules, partial accessibility of tryptophan – modified Stern Volmer plot, study of different folding states. Protein – surfactant interaction.

Excimers and exciplexes. Energy transfer: FRET, DET. Excited State Proton Transfer

Preliminary ideas of absorption and fluorescence spectrophotometer. Basic ideas of dynamics namely TCSPC, up-conversion and pump-probe techniques.

Fluorescence of nanomaterials: Concept of quantum confinement, 1D, 2D, 3D nanomaterials, Quantum dots – synthesis and optical properties, applications in sensing of biomolecules.

Reference Book:
Principles of Fluorescence Spectroscopy, 3rd edition, Joseph R. Lakowicz.

DSE LAB: FLUORESCENCE STUDY: THEORY AND APPLICATIONS FOR MACROMOLECULES AND NANOMATERIALS IN SENSING

(Credits: Practicals-02, 60 Lectures, Full Marks: 30)

1. Fluorescence quenching of organic fluorophores
2. Fluorescence quenching of tryptophan in different folding states of protein
3. Sensing of organic molecules by protein fluorescence study
4. FRET for suitable donor – acceptor pair
5. Protein fluorescence in presence of surfactants, polymers
6. Excited State Proton Transfer for Photoacids.

Course Learning Outcomes: After the completion of the course, the students should be able to

1. Analyse the possible photophysical processes for electronically excited molecules
2. Explain the mode of interaction between fluorophores and quenchers which may be useful to develop the idea of optical sensing.

9. BIOLOGICALLY RELEVANT MOLECULES, ORGANIC PHOTOCHEMISTRY, DYES AND SYNTHETIC POLYMERS

(Credits: Theory-04, 60 Lectures, Full Marks: 70)

Course Objectives: To impart knowledge on Enzymes, lipids, concept of energy in biosystems, dyes, organic photochemistry and polymers

Enzymes:

Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes. Mechanism of enzyme action (taking trypsin as example), factors affecting enzyme action, coenzymes and cofactors and their role in biological reactions, specificity of enzyme action (including stereospecificity), enzyme inhibitors and their importance, phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition). **(9 Lectures)**

Lipids:

Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenntion of fats and oils, Saponification value, acid value, iodine number. Reversion and rancidity. **(8 Lectures)**

Concept of Energy in Biosystems:

Cells obtain energy by the oxidation of foodstuff (organic molecules). Introduction to metabolism (catabolism, anabolism). ATP: The universal currency of cellular energy, ATP hydrolysis and free energy change. Agents for transfer of electrons in biological redox systems: NAD+, FAD. Conversion of food to energy: Outline of catabolic pathways of carbohydrate- glycolysis, fermentation, Krebs cycle.

Overview of catabolic pathways of fat and protein. **(8 Lectures)**

Elementary idea of Free radical and Organic Photochemistry

Free Radical Reactions: Method of generation, Stability, Radical initiators, Substitution, Addition and Rearrangement reactions involving radicals.

Photochemistry of Organic Compounds and Photochemical Reactions: Basic principles, Jablonski diagram and photoreactions of carbonyl compounds. **(10 Lectures)**

Dyes:

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing; Synthesis and applications of: Azo dyes – Methyl Orange and Congo Red (mechanism of Diazo Coupling); Triphenyl Methane Dyes - Malachite Green, Rosaniline and Crystal Violet; Phthalein Dyes – Phenolphthalein and Fluorescein; Natural dyes –structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

(10 Lectures)

Polymers:

Introduction and classification including di-block, tri-block and amphiphilic polymers; Number average molecular weight, Weight average molecular weight, Degree of polymerization, Polydispersity Index.

Polymerisation reactions -Addition and condensation -Mechanism of cationic, anionic and free radical addition polymerization; Metallocene-based Ziegler-Natta polymerisation of alkenes; Preparation and applications of plastics – thermosetting (phenol-formaldehyde, Polyurethanes) and thermosoftening (PVC, polythene).

Fabrics – natural and synthetic (acrylic, polyamido, polyester); Rubbers – natural and synthetic: Buna-S, Chloroprene and Neoprene; Vulcanization; Polymer additives; Introduction to liquid crystal polymers; Biodegradable and conducting polymers with examples. **(15 Lectures)**

Reference Book

- Nelson, D.L., Cox, M.M. &Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.
- Murray, R.K., Granner, D.K., Mayes, P.A. & Rodwell, V.W. (2009) Harper's
- Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.Organic Chemistry, Vol. I - I. L. Finar, ELBS.
- Organic Chemistry, Subrata Sen Gupta
- Billmeyer, F. W. Textbook of Polymer Science, John Wiley & Sons, Inc.
- Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. Polymer Science, New Age
- International (P) Ltd. Pub.
- Fundamentals of Polymerization - Broja Mahan Mandal
- Principles of Polymerization - George Odian

DSE LAB: Biologically relevant molecules, Organic Photochemistry and synthetic polymers

(Credits: 02, 60 Lectures, Full Marks: 30)

1. Preparation of methyl orange.
2. Saponification value of an oil or a fat.
3. Determination of Iodine number of an oil/ fat.
4. Preparation of sodium polyacrylate/poly(meth)acrylate.
5. Preparation of urea formaldehyde resin.
6. Preparation of conducting polymers.
7. Study of the action of salivary amylase on starch at optimum conditions.
8. Effect of temperature on the action of salivary amylase.
9. Isolation and characterization of DNA from onion/ cauliflower/peas.

References:

- Vogel, A.I. Quantitative Organic Analysis, Part 3, Pearson (2012).
- Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
- Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012)
- Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000).
- Ahluwalia, V.K. & Dhingra, S. Comprehensive Practical Organic Chemistry: Qualitative Analysis, University Press (2000).
- Manual of Biochemistry Workshop, 2012, Department of Chemistry, University

of Delhi.
- Arthur, I. V. Quantitative Organic Analysis, Pears

Course Learning Outcomes: After completion of the course, the student should be able to

1. Explain the functioning of lipid, enzymes in biosystems
2. Demonstrate various kinds of polymers and their uses in modern life
3. Explain the chemistry of dyes in daily life
4. Analyse oils and fats, detections of saponification value, acid value, iodine value etc. which are essential for jobs in oil industries