Cotton University, Guwahati
Department of Chemistry

UG (B. Sc.) CBCS LOCF Syllabus
for
Core, Laboratory and Elective Courses

Programme Learning Objectives (PLOs):

PLO-1: To provide broad and balanced knowledge in chemistry in addition to understanding of key chemical concepts, principles and theories.

PLO-2: To develop students' ability and skill to acquire expertise over solving both theoretical and applied chemistry problems.

PLO-3: To provide knowledge and skill to the students' thus enabling them to undertake further studies in chemistry in related areas or multidisciplinary areas that can be helpful also for self-employment/entrepreneurship.

PLO-4: To provide an environment that ensures cognitive development of students in a holistic manner. A complete dialogue about chemistry, chemical knowledge and their significance is fostered in this framework, rather than being mere theoretical aspects.

PLO-5: To provide the latest subject matter, both theoretical as well as practical, in such a way so as to foster their core competency and learning discovery. A chemistry graduate as envisioned in this framework would be sufficiently competent in the field to undertake further discipline-specific studies, as well as to begin domain-related employment.

PLO-6: To mould a responsible citizen who is aware of the most basic domain-independent knowledge, including of critical thinking and communication.

PLO-7: To enable the graduate, prepare for national as well as international competitive examinations, especially UGC-CSIR NET, GATE and UPSC Civil Services Examination.

PROGRAMME SPECIFIC OUTCOMES (PSOs)

The student graduating with the Degree B.Sc. (Chemistry Core) will be able to acquire:

PSO-1: Systematic and coherent understanding of the fundamental concepts in Physical Chemistry, Organic Chemistry, Inorganic Chemistry, Analytical Chemistry and all other related allied chemistry subjects.

PSO-2: Students will be able to use the evidence-based comparative chemistry approach to explain the chemical synthesis and analysis.

PSO-3: Students will be able to understand the characterisation of materials.

PSO-4: Students will be able to understand the basic principles of equipments/instruments used in the chemistry laboratory.

PSO-5: Students will be able to demonstrate the experimental techniques and methods encountered in their course in chemistry.

PSO-6: Discipline's Knowledge and Skills – A graduate student is expected to be capable of demonstrating comprehensive understanding of both theoretical and experimental/applied chemistry knowledge in various fields of interest like Analytical Chemistry, Physical Chemistry, Inorganic Chemistry, Organic Chemistry, Material Chemistry, etc. Further, the student will be capable of using of advanced instruments and related software for in-depth characterisation of materials/chemical analysis and separation technology.

PSO-7: Skilled Communicator – The course curriculum incorporates basics and advanced training in order to make a graduate student capable of expressing the subject through technical writing as well as through oral presentation.

PSO-8: Critical Thinker and Problem Solver – The course curriculum also includes components that is helpful for graduate students to develop critical thinking ability by way of solving numerical/non-numerical problems using basic chemistry knowledge and concepts.

PSO-9: Sense of Inquiry – It is expected that the course curriculum will develop an inquisitive characteristic among the students through appropriate questions, planning and reporting experimental investigation.

PSO-10: Team Player – The course curriculum has been designed to provide opportunity to act as team player by collaborating in laboratory, field-based situations and industry.

PSO-11: Skilled Project Manager – The course curriculum has been designed in such a manner as to enable a graduate student to become a skilled project manager by acquiring knowledge about chemistry project management, writing, planning, study of ethical standards, and rules and regulations pertaining to scientific project operation.

PSO-12: Digitally Literate – The course curriculum has been so designed to impart a good working knowledge in understanding and carrying out data analysis, use of online library search tools, and use of chemical simulation software and related computational work.

PSO-13: Ethical Awareness – A graduate student requires to understand and to develop ethical awareness which the course curriculum adequately provides.

PSO-14: Lifelong Learner – The course curriculum is designed to inculcate a habit of learning continuously through use of advanced ICT techniques and other available techniques/books/journals for personal academic growth as well as for increasing employability opportunity.

Mapping of PSO and Chemistry Courses

Table-1

	Inorganic Chemistry I	Physical Chemistry I		English/ EVS/ MILcommunication	Organic Chemistry I	Physical Chemistry II		English/ EVS/ MILcommunication	Inorganic Chemistry II	Organic Chemistry II	Physical Chemistry III		
	Core-1	Core-2	GE1	AECC 1	Core-3	Core-4	GE-2	AECC-2	Core-5	Core-6	Core-7	SEC-1	GE-3
PSO1	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
PSO2	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓
PSO3	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓
PSO4	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓
PSO5	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓
PSO6	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
PSO7	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓
PSO8	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
PSO9	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
PSO10	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓
PSO11			✓	✓			✓	✓				✓	✓
PSO12				✓				✓				✓	✓
PSO13	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table-2

	Core-8	Core-9	Core-10	SEC- 2	GE-4	Core-11	Core-12	DSE-1	DSE-2	Core-13	Core-14	DSE-3	DSE-4
	Inorganic Chemistry III	Organic Chemistry III	Physical Chemistry IV			Organic Chemistry IV	Physical Chemistry V			Inorganic Chemistry IV	Organic Chemistry V		
PSO1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO2	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO3	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO4	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO5	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO7	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO10	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO11				✓	✓			✓	✓			✓	✓
PSO12				✓	✓			✓	✓			✓	✓
PSO13	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PSO14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Course Structure (Chemistry-Major)
Details of courses under B.Sc. (Honours)

Course	*Credits	
	Theory+ Practical	Theory + Tutorial
(I) Core Course (14 Papers)	14×4=56	14×5=70
Core Course /Practical / Tutorial* (14 papers)	14×2=28	14×1=14
(II) Elective Course (8 Papers)		
A.1 Discipline Specific Elective **(4 Papers)**	4×4=16	4×5=20
A.2 Discipline Specific Elective Practical/Tutorial* **(4 Papers)**	4×2=8	4×1=4
B.1 Generic Elective/Interdisciplinary **(4 Papers)**	4×4=16	4×5=20
B.2 Generic Elective Practical/ Tutorial* **(4 Papers)**	4×2=8	4×1=4
III Ability Enhancement Courses		
1. Ability Enhancement Compulsory **(2 Papers of 2 credit each)** Environmental Science English/MIL Communication	2×2=4	2×2=4
2. Ability Enhancement Elective (Skill Based) (Minimum 2) **(2 Papers of 2 credit each)**	2×2=4	2×2=4
Total credits	**140**	**140**

• Optional Dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 6th Semester

*** Wherever there is a practical there will be no tutorial and vice-versa**

PROPOSED SCHEME FOR CHOICE BASED CREDIT SYSTEM
IN
B. Sc. Honours (Chemistry)

	CORE COURSE (14)	**Ability Enhancement Compulsory Course (AECC) (2)**	**Ability Enhancement Elective Course (AEEC) (2) (Skill Based)**	**Elective: Discipline Specific DSE (4)**	**Elective: Generic (GE) (4)**
I	Inorganic I:Atomic Structure& Chemical Bonding-I (4+2)	(English Communication/MIL) /Environmental Science			GE-1
	Physical I: States of Matter & Ionic Equilibrium (4+2)				
II	Organic I: Basics & Hydrocarbons (4+2)	Environmental Science/ (English/MIL Communication)			GE-2
	Physical II: Chemical Thermodynamics & its Applications (4+2)				
III	Inorganic II: s-and p-Block Elements (4+2)		SEC -1		GE-3
	Organic II: Oxygen Containing Functional Groups (4+2)				
	Physical III: Phase Equilibria & Chemical Kinetics (4+2)				
IV	Inorganic III: Coordination Chemistry (4+2)		SEC -2		GE-4
	Organic III: Heterocyclic Chemistry (4+2)				
	Physical IV: Electrochemistry (4+4)				
V	Organic IV: Biomolecules (4+2)			DSE -1	
	Physical V: Quantum Chemistry & Spectroscopy (4+2)			DSE-2	
VI	Inorganic IV: Organometallic Chemistry (4+2)			DSE-3	
	Organic Chemistry V: Spectroscopy (4+2)			DSE-4	

SEMESTER	COURSE OPTED	COURSE NAME	Credits
I	Ability Enhancement Compulsory Course-I	English Communications/ Environmental Science	2
	Core Course-I	Inorganic Chemistry-I	4
	Core Course-I Practical	Inorganic Chemistry-I Lab	2
	Core Course-II	Physical Chemistry-I	4
	Core Course-II Practical	Physical Chemistry-I Lab	2
	Generic Elective -1	GE-1	4/5
	Generic Elective -1 Practical/Tutorial	GE-1 Lab	2/1
II	Ability Enhancement Compulsory Course-II	English Communications/ Environmental Science	2
	Core Course-III	Organic Chemistry-I	4
	Core Course-III Practical	Organic Chemistry-I Lab	2
	Core Course-IV	Physical Chemistry-II	4
	Core Course-IV Practical	Physical Chemistry-II Lab	2
	Generic Elective -2	GE-2	4/5
	Generic Elective -2 Practical/Tutorial	GE-2 Lab	2/1
III	Core Course-V	Inorganic Chemistry-II	4
	Core Course-V Practical	Inorganic Chemistry-II Lab	2
	Core Course-VI	Organic Chemistry-II	4
	Core Course-VI Practical	Organic Chemistry-II Lab	2
	Core Course-VII	Physical Chemistry-III	4
	Core Course-VII Practical	Physical Chemistry-III Lab	2
	Skill Enhancement Course - 1	SEC-1	2
	Generic Elective -3	GE-3	4/5
	Generic Elective -3 Practical/Tutorial		2/1
IV	Core Course-VIII	Inorganic Chemistry-III	4
	Core Course-VIII Practical	Inorganic Chemistry-III Lab	2
	Core Course-IX	Organic Chemistry-III	4
	Core Course-IX Practical	Organic Chemistry-III Lab	2
	Core Course-X	Physical Chemistry-IV	4
	Core Course-X Practical	Physical Chemistry-IV Lab	2
	Skill Enhancement Course - 2	SEC -2	2
	Generic Elective -4	GE-4	4/5
	Generic Elective -4 Practical	GE-4 Lab	2/1
V	Core Course-XI	Organic Chemistry-IV	4
	Core Course-XI Practical	Organic Chemistry-IV Lab	
	Core Course-XII	Physical Chemistry-V	4
	Core Course-XII Practical	Physical Chemistry-V Lab	2
	Discipline Specific Elective - 1	DSE-1	4/5
	Discipline Specific Elective -1 Practical/Tutorial	DSE-1 Lab/Tutorial	2/1

	Discipline Specific Elective -2	**DSE-2**	**4/5**
	Discipline Specific Elective- 2 Practical/Tutorial	**DSE-2 Lab**	**2/1**
VI	**Core Course-XIII**	**Inorganic Chemistry-IV**	**4**
	Core Course-XIII Practical	**Inorganic Chemistry-IV Lab**	**2**
	Core Course-XIV	**Organic Chemistry-V**	**4**
	Core Course-XIV Practical	**Organic Chemistry-V Lab 2**	
	Discipline Specific Elective -3	**DSE-3**	**4/5**
	Discipline Specific Elective -3 Practical/Tutorial	**DSE-3 Lab/Tutorial**	**2/1**
	Discipline Specific Elective-4	**DSE-4**	**4/5**
	Discipline Specific Elective -4 Practical/Tutorial	**DSE-4 Lab/Tutorial**	**2/1**
Total Credits			**140**

Core Papers (C): (Credit: 06 each) (1 period/week for tutorials or 4 periods/week for practical)

1. Inorganic Chemistry I: Atomic Structure & Chemical Bonding (4 + 4)
2. Physical Chemistry I: States of Matter & Ionic Equilibrium (4 + 4)
3. Organic Chemistry I: Basics and Hydrocarbons (4 + 4)
4. Physical Chemistry II: Chemical Thermodynamics and its Applications (4 + 4)
5. Inorganic Chemistry II: s- and p-Block Elements (4 + 4)
6. Organic Chemistry II: Oxygen Containing Functional Groups (4 + 4)
7. Physical Chemistry III: Phase Equilibria and Chemical Kinetics (4 + 4)
8. Inorganic Chemistry III: Coordination Chemistry (4 + 4)
9. Organic Chemistry III: Heterocyclic Chemistry (4 + 4)
10. Physical Chemistry IV: Electrochemistry (4 + 4)
11. Organic Chemistry IV: Biomolecules (4 + 4)
12. Physical Chemistry V: Quantum Chemistry & Spectroscopy (4 + 4)
13. Inorganic Chemistry IV: Organometallic Chemistry (4 + 4)
14. Organic Chemistry V: Spectroscopy (4 + 4)

Discipline Specific Elective Papers: (Credit: 06 each) (4 papers to be selected)- DSE 1-4

1. Analytical Methods in Chemistry (4) + Lab (4)
2. Novel Inorganic Solids (4) + Lab (4)
3. Polymer Chemistry (4) + Lab (4)
4. Research Methodology for Chemistry (5) + Tutorials (1)
5. Green Chemistry (4) + Lab (4)
6. Industrial Chemicals and Environment (4) + Lab (4)

Skill Enhancement Courses (Credit: 02 each) (2 papers to be selected) – SEC-1 & SEC-2

1. Chemical Technology and Society
2. Green Methods in Chemistry
3. Pharmaceutical Chemistry
4. Chemistry of Cosmetics & Perfumes
5. Fuel Chemistry

Generic Elective Papers (GE) (Minor-Chemistry) (any four) for other Departments/Disciplines: (Credit: 06 each)

1. Atomic Structure, Bonding, General Organic Chemistry & Aliphatic Hydrocarbons (4) + Lab (4)
2. Chemical Energetics, Equilibria & Functional Group Organic Chemistry-I (4) + Lab(4)
3. Solutions, Phase Equilibrium, Conductance, Electrochemistry & Functional Group Organic Chemistry-II (4) + Lab (4)
4. Chemistry of s- and p- block elements, States of matter and Chemical kinetics (4)+ Lab (4).

CORE COURSES

SEMESTER (I)

CHEMISTRY CC-I: Inorganic Chemistry – I
(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. To understand about atomic theory and its evolution.
2. Learning scientific theory of atoms, concept of wave function.
3. To know about elements in periodic table; physical and chemical characteristics, periodicity.
4. To predict the atomic structure, chemical bonding, and molecular geometry based on accepted models.
5. To understand atomic theory of matter, composition of atom.
6. Identity of given element, relative size, charges of proton, neutron and electrons, and their assembly to form different atoms.
7. Defining isotopes, isobar and isotone.
8. Physical and chemical characteristics of elements in various groups and periods according to ionic size, charge, etc. and position in periodic table.
9. Characterize bonding between atoms, molecules, interaction and energetics (ii) hybridization and shapes of atomic, molecular orbitals, bond parameters, bond- distances and energies.
10. Valence bond theory incorporating concepts of hybridization predicting geometry of molecules.
11. Importance of hydrogen bonding, metallic bonding.

Theory: 60 Lectures

Atomic Structure: (14 lectures)

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and $|\psi|^2$. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Contour boundary and probability diagrams. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau principle and its limitations, Variation of orbital energy with atomic number.

Periodicity of Elements: **(14 lectures)**

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.

(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, Mullikan, Allred Rachow scales, electronegativity and bond order, partial charge, hybridization, group electronegativity. Sanderson electron density ratio.

Chemical Bonding: **(18 lectures)**

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, expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

Covalent bond: Lewis structure, Valence Shell Electron Pair Repulsion Theory (VSEPR), Shapes of simple molecules and ions containing lone-and bond-pairs of electrons multiple bonding, sigma and pi-bond approach, Valence Bond theory, (Heitler-London approach). Hybridization containing s, p and s, p, d atomic orbitals, shapes of hybrid orbitals, Bents rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of simple homonuclear and heteronuclear diatomic molecules, MO diagrams of simple tri and tetra-atomic molecules, e.g., N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, HCHO, (idea of s-p mixing and orbital interaction to be given). Covalent character in ionic compounds, polarizing power and polarizability. Fajan rules, polarization. Ionic character in covalent compounds: Bond moment and dipole moment. ionic character from dipole moment and electronegativities.

Metallic bonding and weak chemical forces: **(10 lectures)**

Metallic Bond: Qualitative idea of free electron model, Semiconductors, Insulators.

Weak Chemical Forces: van der Waals, ion-dipole, dipole-dipole, induced dipole dipole-induced dipole interactions, Lenard-Jones 6-12 formula, hydrogen bond, effects of hydrogen bonding on melting and boiling points, solubility, dissolution.

Oxidation-Reduction: (4 lectures)

Redox equations, Standard Electrode Potential and its application to inorganic reactions. [Principles involved in volumetric analysis to be carried out in class.].

Recommended Books/References:

1.Lee, J. D. *Concise Inorganic Chemistry,* Wiley, 5th Edition.

2.Douglas, B.E., McDaniel, D.H., Alexander J.J., *Concepts & Models of Inorganic Chemistry, (Third Edition)* John Wiley & Sons,1999.

3.Atkins, P. W. and DePaula, J. *Physical Chemistry*, Tenth Edition, Oxford University Press, 2014.

4. Rodger, G. E. *Inorganic and Solid-State Chemistry*, Cengage Learning, 2002.

LAB CC-I: Inorganic Chemistry – I Lab: (60 Classes)

(A) Titrimetric Analysis

(i) Calibration and use of apparatus.

(ii) Preparation of solutions of different Molarity/Normality of titrants.

(iii) Use of primary and secondary standard solutions.

(B) Acid-Base Titrations

(i) Estimation of carbonate and hydroxide present together in mixture.

(ii) Estimation of carbonate and bicarbonate present together in a mixture.

(iii) Estimation of free alkali present in different soaps/detergents

(C) Oxidation-Reduction Titrimetry

(i) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.

(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.

(iii) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books/References:

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis* Sixth Edition, Pearson, 2009.
2. Svehala G. and Sivasankar I. B, Vogel's Qualitative Inorganic Analysis, Pearson, India, 2012.

Course Outcomes:

On completion of this course, the students will be able to:

1. Know the basic aspects of atoms and molecules.
2. They will follow basic concepts like electronic configuration, atomic orbitals, periodic properties, structure, composition, chemical bonding, physical/chemical properties etc.
3. They will also have hands-on experience at learning titrimetric techniques used in inorganic chemistry.

CHEMISTRY CC-II: Physical Chemistry – I
(Credits: Theory-04, Practicals-02)

Learning objectives:

1. Familiarization with various states of matter.
2. Physical properties of each state of matter and laws related to describe the states.
3. Understanding kinetic model of gas, Maxwell distribution, collisions, mean-free path, kinetic energies.
4. Behaviour of real gases, its deviation from ideal behaviour, equation of state, isotherm, and law of corresponding states.
5. Liquid state and its physical properties, in relation to temperature variation.
6. Solids, lattice parameters – its calculation, application of symmetry, solid characteristics of simple salts.
7. Electrolytes and electrolytic dissociation, salt hydrolysis and acid-base equilibria. Acids and bases – acid-base titrations.

Theory: 60 Lectures

Gaseous state: (**20 lectures**)

Behavior of real gases: Deviations from ideal gas behavior, compressibility factor, and its variation with pressure for different gases. Causes of deviation from ideal behavior. van der Waals equation of state, its derivation and application in explaining real gas behaviour; van der Waals equation expressed in virial form, Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, critical constants and van der Waals constants, law of corresponding states.

Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation. 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.

Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom (with lack in expression of vibrational ones at RT), molecular basis of heat capacities.

Liquid state: (8 lectures)

Structure and physical properties of liquids; vapour pressure, surface tension, viscosity, their dependence on temperature and their determinations. Effect of addition of various solutes on surface tension, cleansing action of detergents. Structure of water.

Ionic equilibria: (20 lectures)

Strong, moderate and weak electrolytes, degree of ionisation, factors affecting degree of ionisation, ionisation constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di- and tri-protic acids.

Salt hydrolysis, hydrolysis constants, degree of hydrolysis and pH for different salts. Buffer solutions; Henderson equation, buffer capacity, buffer range, buffer action, applications of buffers in analytical chemistry, solubility and solubility product.

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB), Application of HSAB principle.

Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolytes.

Solid state: (12 lectures)

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. Various types of defects in crystals, Glasses and liquid crystals.

Recommended Text books/references:

1. Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 8th Ed., Oxford University Press (2006).

2. Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).

3. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).

4. Mortimer, R. G. *Physical Chemistry* 3rd Ed. Elsevier: NOIDA, UP (2009).

5. G. M. Barrow, Tata McGraw Hill (Fifth Edition) (2007)

LAB CC-II: Physical Chemistry – I Lab
(60 Classes)

1. Surface tension measurements.

a. Determine the surface tension by (i) drop number (ii) drop weight method.

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

2. Viscosity measurements using Ostwald's viscometer.

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

b. Viscosity of sucrose solution with the concentration of solute.

3. pH metry

a. Effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.

b. Preparation of buffer solutions of different pH
   i. Sodium acetate-acetic acid
   ii. Ammonium chloride-ammonium hydroxide

c. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.

d. Determination of dissociation constant of a weak acid.

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).

Course Outcomes

On completion of the course the students will be able to:

1. Know about real gas behaviour as different from ideal behaviour.

2. Know about kinetic molecular theory, collisions, mean free path, gas viscosity and their interrelations. Perform numerical calculations on these topics.

3. Understand the distribution of molecular speeds and energies in gases along with the idea of equipartition of energies, along with the numerical aspects.

4. Know about the structure and various physical properties of liquids, along with how the surface tension depends on solutes.

5. Understand the crystal structure and symmetry in crystalline solids and perform numerical calculations on these. Also, have some introductory knowledge about glasses and liquid crystals.

CHEMISTRY CC-III: Organic Chemistry – I
(Credits: Theory-04, Practicals-02)

Learning objectives:

1. Understanding basic of organic molecules, structure, bonding, reactivity and reaction mechanisms.
2. Stereochemistry of organic molecules – conformation and configuration, asymmetric molecules and nomenclature.
3. Aromatic compounds and aromaticity, mechanism of aromatic reactions.
4. Understanding hybridization and geometry of atoms, 3-D structure of organic molecules, identifying chiral centres.
5. Reactivity, stability of organic molecules, structure, stereochemistry.
6. Electrophile, nucleophiles, free radicals, electronegativity, resonance, and intermediates along the reaction pathways.
7. Mechanism of organic reactions (effect of nucleophile/leaving group, solvent), substitution *vs*. elimination.

Theory: 60 Lectures

Basics of Organic Chemistry: (10 lectures)

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals and Carbenes).

Organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

Stereochemistry: (12 lectures)

Concept of asymmetry, 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 mixtures, Relative and absolute configuration: D/L and R/S designations.

Chemistry of Aliphatic Hydrocarbons: (30 lectures)

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, hydroboration- oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation). 1, 2- and 1, 4- addition reactions in conjugated dienes and, 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.

C. Cycloalkanes and Conformational Analysis

Cycloalkanes and stability, Baeyer strain theory, Conformation analysis, Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms.

Aromatic Hydrocarbons (8 lectures)

Aromaticity: Huckel'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 substituent groups.

Recommended Books/References:

1. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, 6th Edn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Pine S. H. Organic Chemistry, Fifth Edition, McGraw Hill, (2007)
3. F. A. Carey, Organic Chemistry, Seventh Edition, Tata McGraw Hill (2008).

4. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed., (2012), Oxford University Press.
5. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, Part A: Structure and mechanism, Kluwer Academic Publisher, (2000).

LAB CC-III: Organic Chemistry – I Lab
(60 Classes)

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 given organic compounds and unknown organic compounds (using 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).

Recommended Books/Reference:

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

Course Outcomes:

On completion of this course, the students will be able to understand:

1. The role played by various electronic factors (such as inductive, electromeric, resonance and mesomeric effects) in governing the physical and chemical properties like stability, polarity, acidity, basicity etc. of different organic species.

2. Various reactive intermediates and their role in depicting the course of an organic reaction.

3. Different types of organic reaction mechanisms and simple stereochemistry involved therein.

4. The representation of three-dimensional molecules in two-dimensional plane using different projection formulae.

5. The concept of chirality and optical properties of such molecules.

6. The properties, methods of syntheses and reactions of various classes of aliphatic and aromatic hydrocarbons.

7. The concept of aromaticity and its influence in stabilizing conjugated cyclic compounds and as well as on their special reactivity.

8. The role of simple crystallization techniques in purification organic compounds using suitable solvents via hands on experience.

9. The primary technique of investigation of purity of organic compounds - checking m.p and b.p.

10. The application of chromatographic technique in determination of purity and the number of components present in a supplied organic sample.

CHEMISTRY CC-IV: Physical Chemistry – II
(Credits: Theory-04, racticals-02)

Learning Objectives:

1. The basic concepts of thermodynamics and its various laws. Understanding the concept of system, variables, heat, work, and laws of thermodynamics.

2. Knowing about partial molar quantities and its attributes.

3. Understanding the concept of heat of reactions and use of equations in calculations of bond energy, enthalpy, etc.

4. Understanding the concept of entropy; reversible, irreversible processes. Calculation of entropy using 3rd law of thermodynamics.

5. Understanding the application of thermodynamics: Joule Thomson effects, partial molar quantities.

6. Understanding thermodynamic theories of dilute solutions.

Theory: 60 Lectures

Introduction to thermodynamics: (12 lectures)

Systems and surroundings; isolated, closed and open systems; intensive and extensive properties; thermodynamic state, state functions and path functions; processes: irreversible and reversible processes. Zeroth law of thermodynamics and the concept of temperature. *First law:* Concept of heat q, work w, internal energy U, and statement of first law; enthalpy H, relation between heat capacities, calculations of q, w, ΔU and ΔH for reversible, irreversible and free expansion of ideal gases under isothermal and adiabatic conditions.

Thermochemistry: (8 lectures)

Heat of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; estimation of bond enthalpy, bond dissociation enthalpy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equation) and pressure on enthalpy of reactions.

Second and Third Laws of Thermodynamics: (10 lectures)

Second Law: Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

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

Free Energy Functions: (6 lectures)

Gibbs and Helmholtz free energy; variation of G and A with T, V and P; Free energy change and spontaneity. Joule-Thomson coefficient, its relation with other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equations of state.

Partial molar quantities: (6 lectures)

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

Chemical Equilibrium: **(8 lectures)**

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 the reaction quotient. Equilibrium constants and their quantitative dependence on temperature. Free energy of mixing and spontaneity. Relations between the equilibrium constants K_p and K_c. Le Chatelier principle (quantitative treatment).

Dilute solutions: **(10 lectures)**

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions. 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 the concentration of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

Recommended Books/References

1. Atkins P. and De Paula, J. *Physical Chemistry* Tenth Ed., OUP, 2014.
2. Castellan, G. W. *Physical Chemistry 4th Ed.,* Narosa, 2004.
3. Engel, T. and Reid, P. *Physical Chemistry 3rd Ed.,* Prentice Hall, 2012.
4. McQuarrie, D. A. and Simon, J. D. *Molecular Thermodynamics* Viva Books, 2004.
5. Roy, B. N. Fundamentals of Classical and Statistical Thermodynamics Wiley, 2001
6. *Commonly Asked Questions in Thermodynamics.* CRC Press, 2011.
7. Levine, I .N. *Physical Chemistry* 6th Ed., Tata Mc Graw Hill, 2010.
8. Metz, C.R. *2000 Solved problems in chemistry,* Schaum Series, 2006.

LAB CC-IV: Physical Chemistry – II Lab
(60 Classes)

1. Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid.

2. Determination of heat capacity of a calorimeter by using hot and room-temperature water.

3. Determination of heat capacity of a calorimeter using change of enthalpy data of a known reaction (method of back calculation of heat capacity of calorimeter from known enthalpy of neutralisation, say of strong acid and strong alkali).

4. Determination of heat capacity of the calorimeter and enthalpy of neutralisation of hydrochloric acid with sodium hydroxide.

5. Determination of heat capacity of the calorimeter and enthalpy of neutralisation of acetic acid with sodium hydroxide.

6. To measure the depression of freezing point of water for aqueous solutions of urea/glucose and of sodium/potassium chloride.

Recommended Books/References:

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

2.Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry, Eighth Edition, McGraw-Hill (2003).

3. Halpern, A. M. and McBane, G. C. Experimental Physical Chemistry, Third Edition, W, H. Freeman (2003).

Course Outcomes:

On completion of the course, the students will be able to:

1. Know about the basic concepts of thermodynamics such as state and path and recognise its various laws.
2. Calculate the heat and work transfers and energy/enthalpy changes in ideal gas processes and in chemical reactions.
3. Judge the spontaneity of physical/chemical processes and their entropy and free energy changes.
4. Calculate the absolute entropy as per the third law, and estimate the residual entropy of imperfectly crystalline substances.
5. Know about, inter-relate and calculate the free energy functions, chemical potentials in solutions, equilibrium constants and colligative properties of solutions.

SEMESTER III

CHEMISTRY CC-V: Inorganic Chemistry – II

(Credits: Theory-04, Practicals-02)

Learning objectives:

1. To be familiar with oxidation-reductions in metallurgy.
2. Chemistry of s and p-block elements.
3. Chemistry of noble gases.
4. Inorganic polymers and their use.
5. Understanding redox reactions in hydrometallurgy processes.
6. Structure, bonding of s and p block materials and their oxides/compounds.
7. Understanding chemistry of boron compounds and their structures.
8. Chemistry of noble gases and their compounds; application of VSEPR theory in explaining structure and bonding.
9. Understanding chemistry of inorganic polymers, their structures and uses.

Theory: 60 Lectures

General principle of metallurgy: (20 lectures)

Occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon or carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel- de Boer process and Mond's process, Zone refining.

Chemistry of *s* and *p* Block Elements: (20 lectures)

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

Structure, bonding, preparation, properties and uses of: Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Per-oxo acids of Sulphur inter-halogen compounds, poly-halide ions, pseudo-halogens, properties of halogens.

Noble Gases: **(12 lectures)**

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Bonding in noble gas compounds (Valence bond and MO treatment for XeF_2), Shapes of noble gas compounds (VSEPR theory).

Inorganic Polymers: **(8 lectures)**

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes, and polysulphates.

Recommended books/references:

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

2 Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models of Inorganic Chemistry 3rd Ed.*, John Wiley Sons, N.Y. 1994.

3 Greenwood, N.N., Earnshaw. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.

4 Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.

5 Rodger, G.E. *Inorganic and Solid-State Chemistry*, Cengage Learning India Edition, 2002.

6 Miessler, G. L. & Donald, A. Tarr. *Inorganic Chemistry* Fourth Ed., Pearson, 2010

7 Atkins, P. W and Shriver D. N. *Atkins' Inorganic Chemistry* 5th Ed. Oxford University Press (2010).

Lab CC-V: Inorganic Chemistry – II Lab
(60 Classes)

(A) Iodo / Iodimetric Titrations

(i) Estimation of Cu (II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).

(ii) Estimation of (i) arsenite and (ii) antimony iodimetrically

(iii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic preparations

(i) Cuprous Chloride, Cu_2Cl_2

(ii) Preparation of Aluminium potassium sulphate (Potash alum) or Chrome alum.

Recommended books/references:

Mendham, J., A. I. Vogel's Quantitative Chemical Analysis Sixth Edition Pearson, 2009.

Course Outcomes:

On completion of the course, the students will be able to:

1. Know the underlying chemistry principles in the context of metallurgy.
2. Know the chemistry of s and p block elements including noble gases.
3. Get a deeper insight into the various type of compounds formed by these elements.
4. Know how to use Iodometric and Iodimetry titrations for inorganic estimations in addition to performing a few inorganic syntheses.

CHEMISTRY CC-VI: Organic Chemistry – II
(Credits: Theory-04, Practicals-02)

Learning objective:

1. Familiarization about classes of organic compounds and their methods of preparation.
2. Basic uses of reaction mechanisms.
3. Name reactions, uses of various reagents and the mechanism of their action.
4. Preparation and uses of various classes of organic compounds.
5. Organometallic compounds and their uses.
6. Organic chemistry reactions and reaction mechanisms.
7. Use of reagents in various organic transformation reactions.

Theory: 60 Lectures

Chemistry of Halogenated Hydrocarbons: (20 lectures)

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_Ni mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

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

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

Organometallic compounds of Mg and Li and their use in synthesis.

Alcohols, Phenols, Ethers and Epoxides: (10 lectures)

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-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's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism.

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$

Carbonyl Compounds: (14 lectures)

Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, 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.

Carboxylic Acids and their Derivatives: (10 lectures)

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 substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmannbromamide degradation and Curtius rearrangement.

Sulphur containing compounds: (6 lectures)

Preparation and reactions of thiols, thioethers and sulphonic acids.

Recommended Books/references:

1. Solomons, T.W G., Fryhle, B. Craig. *Organic Chemistry,* John Wiley & Sons, Inc (2009).

2. McMurry, J.E. *Fundamentals of Organic Chemistry*, Seventh edition Cengage Learning, 2013.

3. P Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition (1997), Orient Longman, New Delhi.

4. Morrison R. T. and Boyd R. N. Organic Chemistry, Sixth Edition Prentice Hall India, 2003.

Lab CC-VI: Organic Chemistry – II Lab

(60 Classes)

(List of experiments given are suggestive. One experiment from each group to be demonstrated)

1. Identification of elements (N, S, and halogen) and Functional group tests for alcohols, phenols, carbonyl, carboxylic acid and amine group of compounds.

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: (Using conventional method.and Using green chemistry approach)

(ii) Benzolyation of one of the amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the phenols (*β*-naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.

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

(iv) Bromination (any one)
   a. Acetanilide by conventional methods
   b. Acetanilide using green approach (Bromate-bromide method)

(v) Nitration: (any one)
   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/ insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

(xi) Aldol condensation with either conventional or green method.

(xii) Benzil-Benzilic acid rearrangement.

[Collected solid samples may be used for recrystallization, melting point and TLC.]

Recommended Books/References:

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)

2. Furniss, B.S., Hannaford, A.J., Smith, P.W.G. & Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.* Pearson (2012)

3. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000)

4. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).

Course Outcomes:

On completion of the course, the learner shall be able to understand:

1. Preparation, properties and reactions of various classes of organic compounds such as haloalkanes, haloarenes, oxygen and sulphur containing functional groups.
2. Fundamental mechanistic aspects such as nucleophilic substitution, elimination, nucleophilic addition elimination reactions involving these functional groups.
3. Named organic reactions related with these functional groups and their utility in creating highly functionalized organic compounds.
4. Utilizations of organic reagents in preparation and interconversions of functional group.
5. The traditional way to detect elements and identify functional group like alcohols, phenols, carbonyl, carboxylic acid and amine group in a given organic sample.
6. Application of common organic transformation in preparation of various organic compounds including conventional and green methodology.

CHEMISTRY CC-VII: Physical Chemistry – III
(Credits: Theory-04, Practicals-02)

Learning objectives:

1. Understanding phases, components, Gibb's phase rule and its applications, construction of phase diagram of different systems, the application of phase diagram.
2. Understanding the basics of chemical kinetics: determination of order, molecularity, and understanding theories of reaction rates, determination of rate of opposing/parallel/chain reactions with suitable examples, steady-state approximation and its applications.
3. Catalyst – mechanism of catalytic action, acid-base catalysis, enzyme catalysis.
4. Langmuir, Temkin and Freundlich – adsorption isotherms, their significance, multilayer adsorption – theory and significance.

Theory: 60 Lectures

Phase Equilibria: **(20 lectures)**

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 – upper and lower. Steam distillation of immiscible liquid pair.

Nernst distribution law: its derivation and applications.

Chemical Kinetics: **(16 lectures)**

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated rate laws for first, second and fractional order reactions, pseudounimolecular reactions, determination of the order, kinetics of complex reactions (limited to first order): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms). Kinetics of chain reactions.

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.

Catalysis: **(12 lectures)**

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, acid-base catalysis.

Surface chemistry: **(12 lectures)**

Physical adsorption, chemisorption, adsorption isotherms (Freundlich, Temkin, derivation of Langmuir adsorption isotherms, surface area determination), BET theory of multilayer adsorption (no derivation), Adsorption in solution.

Recommended books/References:

1. Atkins P. W. and De Paula J., *Physical Chemistry, (*tenth edition) Oxford University Press, 2014.

2 Castellan, G. W. *Physical Chemistry*, 4th Ed., Narosa , 2004.

3 McQuarrie, D. A. & Simon, J. D., *Molecular Thermodynamics*, Viva Books, 2004.

4 Engel, T. & Reid, P. *Physical Chemistry* Third Edition*,* Prentice-Hall,2012.

5. Zundhal, S.S. Chemistry concepts and applications Cengage India, 2011

6. Ball, D. W. Physical Chemistry Cengage India, 2012.

7. Mortimer, R. G. Physical Chemistry 3rd Ed., Elsevier: NOIDA, UP, 2009.

8. Levine, I. N. Physical Chemistry 6th Ed., Tata McGraw-Hill, 2011.

8. Metz, C. R. Physical Chemistry 2nd Ed., Tata McGraw-Hill, 2009.

Lab CC-VII: Physical Chemistry – III Lab

(60 Classes)

1. Determination of critical solution temperature and composition of the phenol-water system
2. Study of the effect of impurities on the CST of phenol-water system.
3. Construction of the phase diagram using cooling curves or ignition tube method for any one:
    a. simple eutectic
    b. congruently melting systems.
3. Study the distribution of ammonia between water and chloroform.
4. Study the equilibrium of one of the following reactions by the distribution method:
    (i) $I_2(aq) + I^- \rightarrow I_3^-(aq)$
    (ii) $Cu^{2+}(aq) + nNH_3 \rightarrow Cu(NH_3)_n$
5. Study the kinetics of the following reactions-
    1. Integrated rate method:
        (i) Acid hydrolysis of methyl acetate with hydrochloric acid.
        (ii) Saponification of ethyl acetate.
    2. Compare the strengths of two solutions of HCl by studying kinetics of hydrolysis of methyl acetate within those solutions.

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 3 rd Ed.; W.H. Freeman & Co.: New York (2003).

Course Outcomes:

On completion of the course, the students will be able to:

1. Know the theoretical aspects of phase equilibria such as Gibbs phase rule and Clausius-Clapeyron equation, and understand the specific cases of one-component phase equilibria, two-component solid-liquid equilibria of various types and three-component liquid-liquid ones.
2. Know phase equilibrium of partially miscible binary-liquid mixtures and liquid-vapour transition of various types of binary liquid mixtures.
3. Know and calculate the rate laws for simple reactions of various orders and about kinetics complex reactions of various types. Understand the collision theory of chemical reactions and their temperature dependence.
4. Understand the types, specificity and selectivity aspects of catalysed reactions, along with their mechanisms at solid surfaces, enzyme environments and acid-base mediums.
5. Distinguish between physical and chemical adsorptions and know about various popular monolayer adsorption isotherms and about multi-layer isotherms, along with numerical aspects.

CHEMISTRY CC-VIII: Inorganic Chemistry – III
(Credits: Theory-04, Practicals-02)

Learning objectives:

1. To understand coordination compounds – its nomenclature, theories, d-orbital splitting in complexes, chelate.
2. Transition metals, its stability, colour, oxidation states and complexes.
3. Lanthanides, Actinides – separation, colour, spectra and magnetic behaviour
4. Bioinorganic chemistry – metal ions in biological system, its toxicity; haemoglobin.
5. Understanding the nomenclature of coordination compounds/complexes, Molecular orbital theory, d-orbital splitting in tetrahedral, octahedral, square planar complexes, chelate effects.
6. Understanding the transition metals stability in reactions, origin of colour and magnetic properties.
7. Understanding the separation of Lanthanoids and Actinoids, its colour, spectra and magnetic behaviour.
8. Understanding the bioinorganic chemistry of metals in biological systems.
9. Haemoglobin and its importance in biological systems.

Theory: 60 Lectures

Coordination Chemistry: (20 lectures)

Werner's theory, valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of 10 Dq (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δ_o, Δ_t). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry. Jahn-Teller theorem, square planar geometry. Qualitative aspects of Ligand Field and MO Theory.

IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with the coordination number 4 and 6. Chelate effect, polynuclear complexes, labile and inert complexes

Transition Elements: (13 lectures)

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Bsworth diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy).

Lanthanoids and Actinides: **(12 lectures)**

Electronic configuration, oxidation states, color, spectra and magnetic behavior, lanthanide contraction, separation of lanthanides (ion-exchange method only).

Bioinorganic Chemistry: **(15 lectures)**

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd and As), toxicity, chelating agents in medicine. Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

Recommended text books/References:

1. Purcell, K.F & Kotz, J.C. Inorganic Chemistry W.B. Saunders Co, 1977.
2. Huheey, J.E., Inorganic Chemistry, Prentice Hall, 1993.
3. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry. Panima Publishing Company 1994.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry Wiley-VCH, 1999
5. Basolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
6. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.

LAB CC-VIII: Inorganic Chemistry – III Lab
(60 Classes)

Gravimetric Analysis:

i. Estimation of nickel (II) using Dimethylglyoxime (DMG).
ii. Estimation of copper as CuSCN
iii. Estimation of iron as Fe_2O_3 by precipitating iron as $Fe(OH)_3$.
iv. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminiumoxinate).

Inorganic Preparations:

(i) Tetraamminecopper (II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$
(ii) Cis and trans $K[Cr(C_2O_4)_2(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)
(iii)Tetraamminecarbonatocobalt (III) ion
(iv) Potassium tris(oxalate)ferrate(III)

Chromatography of metal ions

Principles involved in chromatographic separations.
Paper chromatographic separation of the following metal ions-
i. Ni(II) and Co (II)
ii. Fe (III) and Al (III)

Reference Book:

- 1. Vogel, A.I. A text book of Quantitative Analysis, ELBS 1986.

Course Outcomes:

On completion of the course, the students will be able to:

1. Know about chemistry of transition metals and their complexes, organometallic chemistry of some transition metals and key concepts associated with them like, preparation, bonding, structure, reactivity, spectroscopy, applications etc.

2. Get introduced to the role of some metals in biological processes. Some laboratory experiments dealing with synthetic inorganic chemistry will also be learnt by the students of this course.

CHEMISTRY CC-IX: Organic Chemistry – III
(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Understanding Nitrogen containing functional groups and their reactions.

2. Familiarization with polynuclear hydrocarbons and their reactions.

3. Heterocyclic compounds and their reactions.

4. Alkaloids and Terpenes

5. Understanding reactions and reaction mechanism of nitrogen containing functional groups.

6. Understanding the reactions and mechanisms of diazonium compounds.

7. Understanding structure and mechanism of reactions of selected polynuclear hydrocarbons.

8. Understanding the structure, mechanism of reactions of selected heterocyclic compounds.

9. Classification, structure, mechanism of reactions of few selected alkaloids and terpenes.

Theory: 60 Lectures

Nitrogen Containing Functional Groups (15 lectures)

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 synthetic applications.

Polynuclear Hydrocarbons: (12 lectures)

Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

Heterocyclic Compounds: (15 lectures)

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's synthesis, Knorr quinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction Derivatives of furan: Furfural and furoic acid.

Alkaloids (10 lectures)

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.

Terpenes (8 lectures)

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

Recommended Text Books/references:

1.Morrison, R. T., Boyd, R. N., Bhattacharjee, S.K., Organic Chemistry, 7th Edn., Pearson.

2 Acheson, R.M. *Introduction to the Chemistry of Heterocyclic compounds,* John Welly & Sons (1976).

3. Solomons, T.W., Fryhle Craig, *Organic Chemistry,* John Wiley & Sons, Inc (2009).

4. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.

5. Kalsi, P. S. *Organic reactions and their mechanisms*, New Age Science (2010).

6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry,* Oxford University Press Inc., New York (2001).

7. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Parakashan (2010).

8. Bansal R. K. *Heterocyclic Chemistry: Syntheses, Reactions and Mechanisms*, New Age, Third Edition (1999).

9.Clayden J., Greeves N., Warren S., Organic Chemistry, (2nd Ed)., (2012), Oxford University Press.

LAB CC-IX: Organic Chemistry – III Lab
(60 Classes)

1. Detection of extra 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)

Recommended Books/References:

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)

2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012)

3. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).

4. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).

Course Outcomes:

After completion of the course, the learner shall be able to:

1. Understand the chemistry of compounds having nitrogen containing functional groups, heterocyclics, polynuclear hydrocarbons, alkaloids and terpenes.
2. Learn named organic reactions involved in preparation of aromatic heterocycles as well as other functional molecules.
3. Understand the aspects of aromaticity and reactivity related to heterocyclic compounds.
4. Have insight about natural product chemistry such as alkaloids and terpenes; and structural elucidation of such compounds.
5. Have practical experience on qualitative analysis of unknown organic compounds containing nitrogen, oxygen and halogen containing functional group.
6. Acquire knowledge on application of spectroscopic method in determination of functional group in organic compounds.
7. Learn simple extraction technique of natural products.

CHEMISTRY CC-X: Physical Chemistry – IV
(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Familiarization with ionic conduction of electricity: Conductance, conductivity and molar/equivalent conductivity and their variation with solution concentration, along with Kohlrausch's and Debye-Huckel etc. relations.

2. Understanding concepts of ionic velocities, mobilities, and transference numbers in ionic conduction along with their determinations. Knowing various applications of conductance measurements and electrolysis along with their numerical aspects.

3. Knowing about various types of Galvanic cells and their quantitative properties – cell EMF, variation of EMF, electrode potentials; free energy, enthalpy and entropy changes.

4. Application of EMF measurements including determination of pH and potentiometric titrations.

5. Knowing about electrostatics of dielectric media, dipole moment and molecular polarisability, magnetic susceptibility, diamagnetism and paramagnestism.

Theory: 60 Lectures

Conductance: (26 Lectures)

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivityand their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules.

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.

Electrochemistry: (22 Lectures)

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).

Electrical & Magnetic Properties of Atoms and Molecules: (12 Lectures)

Basic ideas of electrostatics, Electrostatics of dielectric media, Clausius-Mosotti equation, Lorenz-Laurentz equation, Dipole moment and molecular polarizabilities and their measurements. Diamagnetism, paramagnetism, magnetic susceptibility and its measurement, molecular interpretation.

Reference Books:

• Atkins, P.W & Paula, J.D. Physical Chemistry, 9 th Ed., Oxford University Press (2011).

• Castellan, G. W. Physical Chemistry 4 th Ed., Narosa (2004).

• Mortimer, R. G. Physical Chemistry 3 rd Ed., Elsevier: NOIDA, UP (2009).

• Barrow, G. M., Physical Chemistry 5 th Ed., Tata McGraw Hill: New Delhi (2006).

• Engel, T. & Reid, P. Physical Chemistry 3 rd Ed., Prentice-Hall (2012).

• Rogers, D. W. Concise Physical Chemistry Wiley (2010).

• Silbey, R. J.; Alberty, R. A. & Bawendi, M. G. Physical Chemistry 4 th Ed., John Wiley & Sons, Inc. (2005).

LAB CC-X: Physical Chemistry – IV Lab
(60 Classes)

Conductometry:

1. Determination of cell constant of the conductometer.
2. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid (say, acetic acid).
3. Perform the following conductometric titrations:
    (i) Strong acid vs. strong base
    (ii) Weak acid vs. strong base
    (iii) Mixture of strong acid and weak acid vs. strong base
    (iv) Weak base vs. strong acid

Potentiometry:

1. Perform the following potentiometric titrations (may use the mV function of a pH-meter):
    (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

2. Construct a calomel electrode and a quinhydrone electrode and measure the potential difference using a voltmeter or a potentiometric assembly.

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 Outcomes:

After completion of the course the students will be able to:

1. Understand the conductance, conductivity and molar conductivity behaviour of ionic conductor systems such as molten salts and solutions, along with the quantitative aspects.
2. Know how the ionic conductors carry current, and in what proportion by each ion – and understand how these characteristics can be measured.
3. Understand about the various forms of electrochemical cells that produce electric energy, and quantify their electrical and chemical parameters such as EMF and free energy change.
4. Know various uses of EMF measurements of such electrochemical cells.
5. Visualise and quantify the electrostatics of dielectric substances and the magnetic properties of various types.

SEMESTER V

CHEMISTRY CC-XI: Organic Chemistry – IV
(Credits: Theory-04, Practicals-02)

Learning objectives:

1. This course aims to introduce students to biochemistry and pharmaceutical compounds.
2. Student will learn about the structure and properties of nucleic acid, amino acids, peptides, proteins, lipids.
3. Types of enzymes and their role in biological catalysis.
4. Mechanism of energy production in Biosystems.
5. Structure, properties of common therapeutics and medicinal properties of traditional plants (haldi, neem)

Theory: 60 Lectures

Nucleic Acids **(9 Lectures)**

Components of nucleic acids, Nucleosides and nucleotides.

Structure, synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine; Structure of polynucleotides.

Amino Acids, Peptides and Proteins **(16 Lectures)**

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

Enzymes **(8 Lectures)**

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).

Lipids **(7 Lectures)**

Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Saponification value, acid value, iodine number. Reversion and rancidity.

Concept of Energy in Biosystems **(8 Lectures)**

Cells obtaining 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.

Interrelationship in the metabolic pathways of protein, fat and carbohydrate. Caloric value of food, standard caloric content of food types.

Pharmaceutical Compounds: Structure and Importance **(12 Lectures)**

Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis), Antimalarials: Chloroquine (with synthesis). An elementary treatment of Antibiotics and detailed study of chloramphenicol, Medicinal values of curcumin (haldi), azadirachtin (neem), vitamin C and antacid (ranitidine).

Reference Books:

• Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. VIth Edition. W.H. Freeman and Co.

• Nelson, D.L., Cox, M.M. and Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.

• Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.

LAB CC-XI: Organic Chemistry – IV Lab
(60 Classes)

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.
3. Estimation of proteins by Lowry's method.
4. Study of the action of salivary amylase on starch at optimum conditions.

5. Effect of temperature on the action of salivary amylase.
6. Saponification value of an oil or a fat.
7. Determination of Iodine number of an oil/ fat.
8. Isolation and characterization of DNA from onion/ cauliflower/peas.

Reference Books:

• Manual of Biochemistry Workshop, 2012, Department of Chemistry, University of Delhi.
• Arthur, I. V. Quantitative Organic Analysis, Pearson.

Course outcomes:

On completion of this course, the students will be able to:

1. Have primary knowledge of structure, synthesis and properties of various biomolecules such as nucleic acid, proteins etc.
2. Acquire knowledge on active site of enzymes and its specificity, mechanism of enzyme action, coenzymes and cofactors and their roles in biological reactions.
3. Understand the various pathways involved in oxidation of food thereby producing energy.
4. Learn elementary examples of a few pharmaceutical compounds and their structures, importance and synthetic procedures.
5. Determine experientially saponification value and iodine number of fat and estimate amino acid and protein
6. Isolate and characterize DNA from vegetables.

CHEMISTRY CC–XII: Physical Chemistry – V
(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Familiarization with basic ideas of quantum mechanics – its postulates, operators, wave functions, probability distributions, Schrodinger equation and its simple examples such as particle in a box, SHO model, rigid rotor model.
2. Introduction to quantum mechanical treatment of hydrogen-like systems with electron-nuclear distance quantification, extension to many-electron atoms with introduction to variation theory.
3. Introduction to quantitative MO and VB treatments of simple molecules.
4. Idea of interaction of electromagnetic radiation with molecules to generate spectra, knowing about characteristics of rotational, vibrational and Raman spectra of molecules.
5. Introduction to electronic transitions, Frank-Condon principle, dissociation and electronic spectra of molecules.
6. Principles, characteristic parameters and characterising features of NMR and ESR spectroscopy.
7. Concepts and laws of photochemistry, photochemical and photosensitised reactions and their importance.

Theory: 60 Lectures

Quantum Chemistry **(24 Lectures)**

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and the 'particle-in-a-box' (rigorous treatment), quantization of energy 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).

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 and heteronuclear diatomic molecules (HF, LiH). Localised and non-localised molecular orbitals treatment of triatomic (BeH_2, H_2O) molecules. Qualitative MO theory and its application to AH_2 type molecules.

Molecular Spectroscopy: **(24 Lectures)**

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

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.

Photochemistry **(12 Lectures)**

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. Role of photochemical reactions in biochemical processes, photo stationary states, chemiluminescence.

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 2 nd Ed. Elsevier: USA (2004).
• Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).
• Kakkar, R. Atomic & Molecular Spectroscopy, Cambridge University Press (2015).

LAB CC-XII: Physical Chemistry – V Lab
(60 Classes)

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. Comment on the effect of structure on the UV spectra of organic compounds.

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

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

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 Outcomes:

On completion of the course, the students will be able to:

1. Understand and internalise the basic concepts of quantum mechanics such as postulates, operators, wave functions, probability aspects, Schrodinger equation and its application in simple model systems.
2. Follow the quantum mechanics treatment of one-electron atoms with quantifications, and its extension to many-electron atoms using approximation theory.
3. Appreciate the quantitative aspects of MO and VB treatments for molecules, already theoretically familiar to them.
4. Know how electromagnetic radiation interacts with molecules to generate spectra, with illustration of molecular rotational, vibrational and Raman spectra. Understand how electronic transitions happen, leading sometimes to dissociation and generally to spectra.
5. Understand the principles, characteristic parameters and characterising features of NMR and ESR spectroscopy.
6. Know the concepts and laws of photochemistry and photochemical reactions.

SEMESTER VI

CHEMISTRY CC-XIII: Inorganic Chemistry – IV
(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Basic principles involved in qualitative chemical analysis
2. Preparation, properties and bonding in organometallic compounds
3. Reaction kinetics and mechanism involved in reactions of complexes
4. Catalytic reactions by organometallic complexes.

Theory: 60 Lectures

Theoretical Principles in Qualitative Analysis (H_2S Scheme) (10 Lectures)

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 the need to remove them after Group II.

Organometallic Compounds (22 Lectures)

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. Pi-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 that of benzene.

Reaction Kinetics and Mechanism (18 Lectures)

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.

Catalysis by Organometallic Compounds (10 Lectures)

Study of the following industrial processes and their mechanisms:
1. Alkene hydrogenation (Wilkinsons Catalyst)
2. Hydroformylation (Co salts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes

Reference Books:

• Vogel, A.I. Qualitative Inorganic Analysis, Longman, 1972
• Svehla, G. Vogel's Qualitative Inorganic Analysis, 7th Edition, Prentice Hall, 1996-03-07.
• Cotton, F.A. G.; Wilkinson & Gaus, P.L. Basic Inorganic Chemistry 3 rd Ed.; Wiley India,
• 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, 4 th 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.
• Greenwood, N.N. & Earnshaw, A. Chemistry of the Elements, Elsevier 2nd Ed, 1997 (Ziegler Natta Catalyst and Equilibria in Grignard Solution).
• Lee, J.D. Concise Inorganic Chemistry 5 th Ed., John Wiley and sons 2008.
• Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988.
• Shriver, D.D. & P. Atkins, Inorganic Chemistry 2 nd Ed., Oxford University Press, 1994.
• Basolo, F. & Person, 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. & Donald, A. Tarr, Inorganic Chemistry 4 th Ed., Pearson, 2010.
• Collman, James P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987.
• Crabtree, Robert H. The Organometallic Chemistry of the Transition Metals. j New York, NY: John Wiley, 2000.
• Spessard, Gary O., &Gary L. Miessler. Organometallic Chemistry. Upper Saddle River, NJ: Prentice-Hall, 1996.

LAB CC-XIII: Inorganic Chemistry – IV Lab
(60 Classes)

I. Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations:
Emphasis should be given to the understanding of the chemistry of different reactions.
The following radicals are suggested:
CO_3^{2-}, NO_2^-, S^{2-}, SO_3^{2-},$S_2O_3^{2-}$, CH_3COO^-, F^-,Cl^-, Br^-, I^-, NO_3^-, SO_4^-, BO_3^{3-}, $C_2O_4^{2-}$, PO_4^{3-}, NH_4^+, K^+, Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+},, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ba^{2+},Sr^{2+}, Ca^{2+}, Mg^{2+}
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, e.g., CO_3^{2-} and SO_3^{2-}, NO_2^- and NO_3^-, Cl^- and Br^-, Cl^- and I^-, Br^- and I^-, NO_3^- and Br^-, NO_3^- and I^-.

[Spot tests should be done whenever possible.]

II. Other Miscellaneous Experiments:

(i) Measurement of 10 Dq by spectrophotometric method
(ii) Verification of spectrochemical series.
(iii) Controlled synthesis of two copper oxalate hydrate complexes:kinetic vs thermodynamic factors.
(iv) Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}. Find the λ_{max} of the complex.
(v) Synthesis of ammine complexes of Ni (II) and its ligand exchange reactions (e.g., bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

Reference Books:

- Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla.
- Marr & Rockett Inorganic Preparations.

Course Outcomes:

On completion of the course:
1. The students will be familiarized with the theoretical and experimental aspects of qualitative Inorganic Analysis of salt mixtures.
2. In addition, they will learn about aspects like structure, bonding, reactivity and applications of a variety of organometallic compounds. Moreover, they will learn about inorganic reaction mechanisms.
3. They will also get opportunity to verify some important spectrochemical properties of inorganic compounds in the laboratory.

CHEMISTRY CC-XIV: Organic Chemistry – V
(Credits: Theory-04, Practicals-02)

Learning objectives:

1. This course will introduce basics of various spectroscopic techniques used for analysis of organic molecules.
2. Student will learn about structure, synthesis and properties of carbohydrates.
3. This course will introduce industrially important compounds such as dyes and polymers

Theory: 60 Lectures

Organic Spectroscopy **(24 Lectures)**

General principles – revision of absorption and emission spectroscopy

UV Spectroscopy: Types of electronic transitions, λ_{max}, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Application of Woodward Rules for calculation of λmax 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, Interpetation of NMR spectra of simple compounds.

Applications of IR, UV and NMR for identification of simple organic molecules.

Carbohydrates **(16 Lectures)**

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; Killiani- Fischer synthesis and Ruff degradation;

Disaccharides – Structure elucidation of maltose, lactose and sucrose. Polysaccharides – Elementary treatment of starch, cellulose and glycogen.

Dyes **(8 Lectures)**

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.

Polymers **(12 Lectures)**

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.

Reference Books:

• Kalsi, P. S. Textbook o*f* 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).
• Billmeyer, F. W. Textbook o*f* Polymer Science, John Wiley & Sons, Inc.
• Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. Polymer Science, New Age International (P) Ltd. Pub.
• Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry o*f* Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
• Graham Solomons, T.W. Organic Chemistry, John Wiley & Sons, Inc.
• Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press.
• Singh, J.; Ali, S.M. & Singh, J. Natural Product Chemistry, Prajati Prakashan (2010).
• Kemp, W. Organic Spectroscopy, Palgrave

LAB CC-XIV: Organic Chemistry – V Lab (60 Classes)

1. Extraction of caffeine from tea leaves.
2. Preparation of sodium polyacrylate.
3. Preparation of urea formaldehyde.

4. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars.

5. 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.

6. Identification of simple organic compounds by IR spectroscopy and NMR spectroscopy (Spectra to be provided).

7. Preparation of methyl orange.

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).

Course outcomes:

On completion of this course, the students will be able to:

1. Assign the peaks of various spectra (UV-Vis, IR, NMR)
2. Identify small organic molecules based on given spectral information.
3. Write structures of carbohydrates with proper stereochemistry.
4. Work out reactions of carbohydrates.
5. Understand structure and properties of dyes, and their industrial applications.
6. Understand different polymerisation techniques, properties of polymers and their uses.

CHEMISTRY DSEs (Department Specific Electives)

CHEMISTRY DSE: Analytical Methods in Chemistry

(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Understanding sampling, evaluation of analytical data, errors, accuracy and precision
2. Normal law of distribution if indeterminate errors
3. UV-Visible Spectrometry, Infrared Spectrometry, Flame Atomic Absorption and Emission Spectrometry
4. Theory of thermogravimetry (TG), basic principle of instrumentation
5. Classification of electroanalytical methods, potentiometric and conductometric titrations
6. Techniques used for the determination of pK_a values
7. Separation techniques: Solvent extraction, Chromatography, Development of chromatograms, Stereoisomeric separation and analysis
8. Application of Spectrophotometry, ion exchange etc.

Theory: 60 Lectures

Qualitative and quantitative aspects of analysis (8 Lectures)

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

Optical methods of analysis (22 lectures)

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

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 samples.

Thermal methods of analysis (5 lectures)

Theory of thermogravimetry (TG), basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

Electroanalytical methods (10 lectures)

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 pK_a values.

Separation techniques (15 Lectures)

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, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of enantiomeric composition using NMR, Chiral solvents and chiral shift reagents.

Chiral chromatographic techniques using chiral columns (GC and HPLC). Role of computers in instrumental methods of analysis.

Reference Books:

- Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5th Ed. The English Language Book Society of Longman .
- Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7 th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
- Christian, Gary D; Analytical Chemistry, 6 th Ed. John Wiley & Sons, New York, 2004.
- Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
- 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, Thomson Asia Pvt. Ltd. Singapore.
- Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
- Ditts, R.V. Analytical Chemistry – Methods of separation.

DSE LAB: Analytical Methods in Chemistry Lab

(60 Classes)

I. **Separation Techniques**

1. Chromatography:

(a) Separation of mixtures

(i) Paper chromatographic separation of Fe^{3+}, Al^{3+}, and Cr^{3+}.

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

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

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

2. Solvent Extractions:

(i) To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry.

(ii) Solvent extraction of zisconium with amberliti LA-1, separation from a mixture of irons and gallium.

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

4. Determination of Na, Ca, Li in cola drinks and fruit juices using fame photometric techniques.

5. Analysis of soil:

   (i) Determination of pH of soil.

   (ii) Total soluble salt

   (iii) Estimation of calcium, magnesium, phosphate, nitrate

6. Ion exchange:

   (i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

   (ii) Separation of metal ions from their binary mixture.

   (iii) Separation of amino acids from organic acids by ion exchange chromatography.

II Spectrophotometry

1. Determination of pK_a values of indicator using spectrophotometry.
2. Structural characterization of compounds by infrared spectroscopy.
3. Determination of dissolved oxygen in water.
4. Determination of chemical oxygen demand (COD).
5. Determination of Biological oxygen demand (BOD).
6. Determine the composition of the Ferric-salicylate/ferric-thiocyanate complex by Job's method.

Reference Books:

• Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5th Ed. Longman.

• Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7 th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.

• Christian, Gary D; Analytical Chemistry, 6 th Ed. John Wiley & Sons, New York, 2004.

• Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.

• 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, Thomson Asia Pvt. Ltd. Singapore.

• Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.

• Ditts, R.V. Analytical Chemistry – Methods of separation.

Course outcomes:

On completion of this course:

1. The students will able to understand how to evaluate analytical data with accuracy and precision.

2. They also acquire knowledge on basics of spectrophotometry and its different techniques. Basics and instrumentation of thermal analysis as well as different separation techniques like ion exchange, solvent extraction, chromatography will be well understood by the students by completion of this course.

CHEMISTRY DSE: Novel Inorganic Solids

(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Synthesis of Inorganic Solids: Co-precipitation method, Sol-gel methods, Hydrothermal method, Ion-exchange methods
2. Material Properties of Inorganic Solids: Molecular material and fullerides, molecular magnets, inorganic liquid crystals
3. Classification of nanostructures and nanomaterials, Bio-inorganic nanomaterials, DNA and nanomaterials
4. Introduction to Composite materials: matrix materials, reinforcements, metal-matrix composites
5. Introduction to engineering materials: super alloys thermoplastics,
6. Applications of various types of cast irons, plain carbon and alloy steels, copper, aluminum and their alloys like duralumin
7. Conducting polymers - Introduction, conduction mechanism, manufacture and applications.

Theory: 60 Lectures

Synthesis and modification of inorganic solids: (10 Lectures)

Conventional heat and beat methods, Co-precipitation method, Sol-gel methods, Hydrothermal method, Ion-exchange and Intercalation methods.

Inorganic solids of technological importance: (10 lectures)

Solid electrolytes – Cationic, anionic, mixed Inorganic pigments – coloured solids, white and black pigments.

Molecular material and fullerides, molecular materials & chemistry – one-dimensional metals, molecular magnets, inorganic liquid crystals.

Nanomaterials: (10 Lectures)

Overview of nanostructures and nanomaterials: classification, Preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-control of nanoarchitecture-one dimensional control. Carbon nanotubes and inorganic nanowires. Bio-inorganic nanomaterials, DNA and nanomaterials, natural and antisical nanomaterials, bionano composites.

Introduction to engineering materials for mechanical construction: (10 Lectures)

Composition, mechanical and fabricating characteristics and applications of various types of cast irons, plain carbon and alloy steels, copper, aluminum and their alloys like duralumin, brasses and bronzes cutting tool materials, super alloys thermoplastics, thermosets and composite materials.

Composite materials: (10 Lectures)

Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

Speciality polymers: (10 Lectures)

Conducting polymers - Introduction, conduction mechanism, polyacetylene, polyparaphenylene and polypyrole, applications of conducting polymers, Ion-exchange resins and their applications. Ceramic & Refractory: Introduction, classification, properties, raw materials, manufacturing and applications.

Reference Books:

• Shriver & Atkins. Inorganic Chemistry, Peter Alkins, Tina Overton, Jonathan Rourke, Mark Weller and Fraser Armstrong, 5th Edition, Oxford University Press (2011-2012)

• Adam, D.M. Inorganic Solids: An introduction to concepts in solid-state structural chemistry.

• Frank J. Ovens, Introduction to Nanotechnology

DSE LAB: Novel Inorganic Solids Lab

(60 Classes)

1. Determination of cation exchange method
2. Determination of total difference of solids.
3. Synthesis of hydrogel by co-precipitation method.
4. Synthesis of silver and gold metal nanoparticles.

Reference Book:

• Fahan, Materials Chemistry, Springer (2004).

Course Outcomes:

On completion of this course:

1. The students will learn various synthetic method for inorganic solid and their applications in material chemistry.

2. The students will also be benefited by gaining knowledge on different aspects of nanomaterials like classification and properties.

3. Basics of Composite materials, engineered materials as well as polymers specially conducting polymers are also part of the course. Students will gain knowledge on recent updates on material chemistry after completion of this course.

CHEMISTRY DSE: Polymer Chemistry

(Credits: Theory-06, Practicals-02)

Learning Objectives:

1. Familiarization with the concept of polymers, their common types and the mechanism of polymer formation.

2. Knowing the different structures of polymers, various average molecular weights of polymer and the structure property relationship of polymers.

3. Learning various polymerization processes and use of polymerization catalyst therein.

4. Characterization of polymers using molecular weight determination and spectroscopy.

Theory: 60 Lectures

Introduction **(8 Lectures)**

Polymer, monomer, examples of polymers, biopolymers, classification, polymerization process, degree of polymerization, condensation, addition polymers, kinetics of addition polymerization process.

Polymer Structure and Structure-Property Relationship **(15 Lectures)**

Structure of polymers - Linear, branched, cross linked, and network polymers, molecular weight (number average, weight average, viscosity average) and distribution of molecular weight, polydispersity index, crystallinity in polymer, melting temperature and glass transition temperature, Volumetric properties - molar volume, density, Van der Waals volume - Coefficient of linear thermal expansion and volumetric thermal expansion - Pressure volume temperature (PVT) relationship.

Polymerisation Chemistry **(10 Lectures)**

Industrial methods of polymerisation such as a bulk, solution, emulsion and suspension. Stereochemistry of polymers and stereo-specific polymerisation, Catalysts – their utility in polymers and stereo-specific polymerisations, Zieglar-Natta, Metallocene and others.

Polymer Solutions **(7 Lectures)**

Criteria for polymer solubility, solubility parameter, thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory.

Characterization of Polymers **(8 Lectures)**

Molecular Weight Determination by Light Scattering, Osmometry, End-Group Analysis, Viscosity, Gel Permeation Chromatography; Application of FTIR, UV-visible, NMR, and Mass Spectroscopy for Identification of polymers.

Polymers of Industrial Importance **(12 Lectures)**

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, polyesters, polyamides and related polymers. Phenol formaldehyde resins (bakelite, novalac), polyurethanes, silicone polymers, polydienes, polycarbonates, conducting polymers – polyanilines.

Reference Books:

• Seymour's Polymer Chemistry, Marcel Dekker, Inc.

• G. Odian: Principles of Polymerization, John Wiley.

• F.W. Billmeyer: Text Book of Polymer Science, John Wiley.

• P. Ghosh: Polymer Science & Technology, Tata Mcgraw-Hill.

• R.W. Lenz: Organic Chemistry of Synthetic High Polymers.

DSE LAB: Polymer Chemistry Lab

(60 Classes)

Polymer Synthesis (any three):

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

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 (any three)

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 (any two):

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

Reference Books:

- Malcohm P. Stevens, Polymer Chemistry: An Introduction, 3 rd Ed.
- Harry R. Allcock, Frederick W. Lampe and James E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003)
- Fred W. Billmeyer, Textbook of Polymer Science, 3 rd ed. Wiley-Interscience (1984)
- Joel R. Fried, Polymer Science and Technology, 2 nd ed. Prentice-Hall (2003)
- Petr Munk and Tejraj M. Aminabhavi, Introduction to Macromolecular Science, 2 nd ed. John Wiley & Sons (2002)
- L. H. Sperling, Introduction to Physical Polymer Science, 4 th ed. John Wiley & Sons (2005)
- Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3 rd ed. Oxford University Press (2005)
- Seymour/ Carraher's Polymer Chemistry, 9 th ed. by Charles E. Carraher, Jr. (2013).

Course Outcomes:

After completion of the course the students will be able to

1. Know about polymers, their classification and mechanism of polymer synthesis.

2. Understand the various possible internal structures of polymers, visualise different averaging calculations of polymer molecular weight.

3. Recognise the structure-property relation in polymers.

4. Know the different possible polymerization processes and use of certain polymerization catalysts in some of those processes.

5. Recognise how polymers are characterized using various molecular weight determination procedures and various spectroscopic techniques.

CHEMISTRY DSE: Research Methodology for Chemistry

(Credits: Theory-05, Tutorials-01)

Learning Objectives:

1. To understand about different print and digital sources for literature survey on a research topic.

2. Learning how to write a scientific paper.

3. Knowing different aspects of chemical safety and ethical handling of chemicals.

Theory: 75 Lectures (Corresponding to 5 credits)

Literature Survey: **(45 Lectures)**

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples

Digital: Web resources, E-journals, Journal access, TOC alerts, Hot articles, Citation index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and communities, Blogs, Preprint servers, Search engines, Scirus, Google Scholar, ChemIndustry, Wiki- Databases, ChemSpider, Science Direct, SciFinder, Scopus.

Information Technology and Library Resources: The Internet and World Wide Web. Internet resources for chemistry. Finding and citing published information.

Methods of Scientific Research and Writing Scientific Papers:

Reporting practical and project work. Writing literature surveys and reviews. Organizing a poster display. Giving an oral presentation.

Writing scientific papers – justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work. Writing ethics. Avoiding plagiarism.

Chemical Safety and Ethical Handling of Chemicals: (20 Lectures)

Safe working procedure and protective environment, protective apparel, emergency procedure and first aid, laboratory ventilation. Safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric – safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals.

Data Analysis (10 Lectures)

The Investigative Approach: Making and Recording Measurements. SI Units and their use. Scientific method and design of experiments.

Analysis and Presentation of Data: Descriptive statistics. Choosing and using statistical tests. Chemometrics. Analysis of variance (ANOVA), Correlation and regression, Curve fitting, fitting of linear equations, simple linear cases.

Reference Books:

• Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J. & Jones, A. (2011)

Practical skills in chemistry. 2nd Ed. Prentice-Hall, Harlow.

• Hibbert, D. B. & Gooding, J. J. (2006) Data analysis *f*or chemistry. Oxford University Press.

• Topping, J. (1984) Errors o*f* observation and their treatment. Fourth Ed., Chapman Hall, London.

• Harris, D. C. Quantitative chemical analysis. 6 th Ed., Freeman (2007) Chapters 3-5.

• Levie, R. de, How to use Excel in analytical chemistry and in general scienti*f*ic data analysis. Cambridge Univ. Press (2001) 487 pages.

• Chemical safety matters – IUPAC – IPCS, Cambridge University Press, 1992.

• OSU safety manual 1.01.

Course Outcomes:

After studying this course, students will acquire thorough knowledge about

1. How to do literature survey on a topic from different print and digital sources.

2. Reporting project work, making oral presentations and writing scientific papers.

3. How to handle chemicals safely and ethically.

4. How to analyse the quantitative and qualitative data obtained in research.

CHEMISTRY DSE: Green Chemistry

(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. To learn about the meaning, principles and importance of Green Chemistry

2. To understand how green synthetic processes may be designed for different chemicals

3. To know about the future trends in Green Chemistry

Theory: 60 Lectures

Introduction to Green Chemistry (4 Lectures)

Meaning of Green Chemistry. Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.

Principles of Green Chemistry and Designing a Chemical synthesis (24 Lectures)

Twelve principles of Green Chemistry with their explanations and examples; Designing a Green Synthesis using these principles; Prevention of Waste/byproducts; maximum incorporation of the materials used in the process into the final products (Atom Economy); prevention/ minimization of hazardous/ toxic products; designing safer chemicals – different basic approaches to do so; selection of appropriate auxiliary substances (solvents, separation agents), green solvents, solventless processes, immobilized solvents and ionic liquids; energy requirements for reactions - use of microwaves, ultrasonic energy; selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups; use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; designing of biodegradable products; prevention of chemical accidents; strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

Examples of Green Synthesis/ Reactions (24 Lectures)

1. *Green Synthesis of the following compounds:* adipic acid, catechol, BHT, methyl methacrylate, urethane, aromatic amines (4-aminodiphenylamine), benzyl bromide, acetaldehyde, disodium iminodiacetate (alternative to Strecker synthesis), citral, ibuprofen, paracetamol, furfural.

2. *Microwave assisted reactions in water:* Hofmann Elimination, Hydrolysis (of benzyl chloride, benzamide, n-phenyl benzamide, methylbenzoate to benzole acid), Oxidation (of toluene, alcohols).

Microwave assisted reactions in organic solvents: Esterification, Fries rearrangement, Orthoester Claisen Rearrangement, Diels-Alder Reaction, Decarboxylation.

Microwave assisted solid state reactions: Deacetylation, Deprotection. Saponification of esters, Alkylation of reactive methylene compounds, reductions, synthesis of nitriles from aldehydes; anhydrides from dicarboxylic acid; pyrimidine and pyridine derivatives; 1,2- dihydrotriazine derivatives; benzimidazoles.

3. *Ultrasound assisted reactions:* Esterification, saponification, substitution reactions, Alkylations, oxidation, reduction, coupling reaction, Cannizaro reaction, Strecker synthesis, Reformatsky reaction.

4. *Selective methylation of active methylene group using dimethylcarbonate*: Solid-state polymerization of amorphous polymers using diphenylcarbonate; Use of "Clayan", a nonmetallic oxidative reagent for various reactions; Free Radical Bromination; Role of Tellurium in organic syntheses; Biocatalysis in organic syntheses.

Future Trends in Green Chemistry (8 Lectures)

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; oncovalent derivatization; Green chemistry in sustainable development.

Reference Books:

• V.K. Ahluwalia & M.R. Kidwai: New Trends in Green Chemistry,

• Anamalaya Publishers (2005).

• P.T. Anastas & J.K. Warner: Oxford Green Chemistry- Theory and Practical, University Press (1998).

• A.S. Matlack: Introduction to Green Chemistry, Marcel Dekker (2001).

• M.C. Cann & M.E. Connely: Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).

• M.A. Ryan & M. Tinnesand, Introduction to Green Chemistry, American Chemical Society, Washington (2002).

DSE LAB: Green Chemistry Lab

(60 Classes)

1. Safer starting materials

The Vitamin C clock reaction using Vitamin C tablets, tincture of iodine, hydrogen peroxide and liquid laundry starch.

a. Effect of concentration on clock reaction

b. Effect of temperature on clock reaction. (if possible)

2. Using renewable resources

Preparation of biodiesel from vegetable oil.

3. Avoiding waste

Principle of atom economy.

Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.

Preparation of propene by two methods can be studied

(I) Triethylamine ion + OH^- → propene + trimethylpropene + water

(II) 1-propanol ⟶ propene + water

The other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.

4. Use of enzymes as catalysts

Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide

Alternative Green solvents

5. Diels Alder reaction in water

Reaction between furan and maleic acid in water and at room temperature rather than in benzene and reflux.

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

7. Mechanochemical solvent free synthesis of azomethines

8. Co-crystal controlled solid state synthesis (C3S3) of N-organophthalimide using phthalic anhydride and 3-aminobenzoic acid.

Alternative sources of energy

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

10. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Reference Books:

• Anastas, P.T & Warner, J.C. Green Chemistry: Theory and Practice, Oxford University Press (1998).

• Kirchoff, M. & Ryan, M.A. Greener approaches to undergraduate chemistry experiment. American Chemical Society, Washington DC (2002).

• Ryan, M.A. Introduction to Green Chemistry, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).

• Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. I.K. Green Chemistry Experiment: A monograph International Publishing House Pvt Ltd. New Delhi. Bangalore CISBN 978-93-81141-55-7 (2013).

• Cann, M.C. & Connelly, M. E. Real world cases in Green Chemistry, American Chemical Society (2008).

• Cann, M. C. & Thomas, P. Real world cases in Green Chemistry, American Chemical Society (2008).

• Pavia, D. L. Lamponan, G. H. &Kriz, G.S. W B Introduction to organic laboratory

Course Outcomes:

After completion of this course, students will learn about

1. Principles involved in Green Chemistry.

2. Green synthetic procedures and

3. Future trends in Green Chemistry

CHEMISTRY DSE: Industrial Chemicals and Environment

(Credits: Theory-04, Practicals-02)

Learning Objectives:

This course is designed for the students to learn about

1. Uses, storage and hazards in handling of the gases and chemicals used in Industries.
2. Metals for industrial applications
3. Air, Water and Soil pollutions and their remedy
4. Sources of Energy

Theory: 60 Lectures

Industrial Gases and Inorganic Chemicals (10 Lectures)

Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.

Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

Industrial Metallurgy (4 Lectures)

Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

Environment and its segments (30 Lectures)

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur.

Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution.

Pollution by SO_2, CO_2, CO, NO_x, H_2S and other foul-smelling gases. Methods of estimation of CO, NO_x, SO_x and control procedures.

Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.

Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems.

Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal.

Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

Energy and Environment (10 Lectures)

Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.

Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

Biocatalysis (6 Lectures)

Introduction to biocatalysis: Importance in 'Green Chemistry' and in chemical industry.

Reference Books:

• E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

• R.M. Felder, R.W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

• J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

• S. S. Dara: A Textbook of Engineering Chemistry, S. Chand & Company Ltd. New Delhi.

• K. De, Environmental Chemistry: New Age International Pvt., Ltd, New Delhi.

• S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi.

• S.E. Manahan, Environmental Chemistry, CRC Press (2005).

• G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).

• A. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).

DSE LAB: Industrial Chemicals and Environment Lab

(60 Classes)

1. Determination of dissolved oxygen in water.

2. Determination of Chemical Oxygen Demand (COD)

3. Determination of Biological Oxygen Demand (BOD)

4. Percentage of available chlorine in bleaching powder.

5. Measurement of chloride, sulphate and salinity of water samples by simple titration method ($AgNO_3$ and potassium chromate).

6. Estimation of total alkalinity of water samples (CO_3^{2-}, HCO_3^-) using double titration method.

7. Measurement of dissolved CO_2.

8. Study of some of the common bio-indicators of pollution.

9. Estimation of SPM in air samples.

10. Preparation of borax/ boric acid.

Reference Books:

- E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
- R.M. Felder, R.W. Rousseau: Elementary Principles o*f* Chemical Processes, Wiley Publishers, New Delhi.
- J. A. Kent: Riegel's Handbook o*f* Industrial Chemistry, CBS Publishers, New Delhi.
- S. S. Dara: A Textbook o*f* Engineering Chemistry, S. Chand & Company Ltd. New Delhi.
- K. De, Environmental Chemistry: New Age International Pvt., Ltd, New Delhi.
- S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi.

Course Outcomes:

On completion of this course, students will acquire knowledge about

1. Chemicals used in industries.

2. Different types of environmental pollutions and their control.

3. Various sources of energy used in industries.

CHEMISTRY SEC: Chemical Technology and Society

(Credits: 02)

Learning Objectives:

1. To understand about different chemical technologies used in industries.

2. Societal and technological issues from a chemical perspective.

Theory: 30 Lectures

Chemical Technology **(10 lectures)**

Basic principles of distillation, solvent extraction, solid-liquid leaching and liquid-liquid extraction, separation by absorption and adsorption. An introduction into the scope of different types of equipment needed in chemical technology, including reactors, distillation columns, extruders, pumps, mills, emulgators. Scaling up operations in chemical industry. Introduction to clean technology.

Social Aspects **(20 lectures)**

Exploration of societal and technological issues from a chemical perspective. Chemical and scientific literacy as a means to better understand topics like air and water (and the trace materials found in them that are referred to as pollutants); energy from natural sources (i.e. solar and renewable forms), from fossil fuels and from nuclear fission; materials like plastics and polymers and their natural analogues, proteins and nucleic acids, and molecular reactivity and interconversions from simple examples like combustion to complex instances like genetic engineering and the manufacture of drugs.

Reference Book:

John W. Hill, Terry W. McCreary & Doris K. Kolb, Chemistry for changing times. 13th Ed.

Course Outcomes:

1. This course will provide students overview of various chemical technologies presently used.

2. Would understand the different impacts of chemical technologies on the society.

CHEMISTRY SEC: Green Methods in Chemistry

(Credits: 02)

Learning Objectives:

1. Understanding the principles of Green Chemistry

2. Real-world examples of chemical synthesis by Green methods.

Theory: 30 Lectures

Tools of Green Chemistry, Twelve principles of Green Chemistry – with examples. The following real-world cases in Green Chemistry to be discussed: (30 Lectures)

(i) A green synthesis of ibuprofen which creates less waste and fewer by-products (Atom economy).

(ii) Surfactants for Carbon Dioxide – replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments.

(iii) Environmentally safe antifoulant.

(iv) CO_2 as an environmentally friendly blowing agent for the polystyrene foam sheet packaging market.

(v) Using a catalyst to improve the delignifying (bleaching) activity of hydrogen peroxide.

(vi) A new generation of environmentally advanced preservative: getting the chromium and arsenic out of pressure treated wood.

(vii) Right fit pigment: synthetic azo pigments to replace toxic organic and inorganic pigments.

(viii) Development of a fully recyclable carpet: cradle to cradle carpeting.

Reference Books:

1. Manahan S.E. (2005) Environmental Chemistry, CRC Press
2. Miller, G.T. (2006) Environmental Science 11th edition. Brooks/Cole
3. Mishra, A. (2005) Environmental Studies. Selective and Scientific Books, New

Course Outcome:

1. This course will make the students aware of advantages of using green chemical methods.

2. They will be exposed to real-life examples of advantages of green chemical methods.

CHEMISTRY SEC: Pharmaceutical Chemistry

(Credits: 02)

Learning Objectives:

1. To know about drug designing and synthesis.

2. To know about production of antibiotics and vitamins.

3. To learn synthesis of aspirin and antacids like magnesium bisilicate.

Theory: 30 Lectures

Drugs and 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); 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.

Practicals:

1. Preparation of Aspirin and its analysis.

2. Preparation of magnesium bisilicate (Antacid).

Reference Books:

• G.L. Patrick: Introduction to Medicinal Chemistry, Oxford University Press, UK.

• Harkishan, V. K. Kapoor: Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi.

• William O. Foye, Thomas L., Lemke, David A. William: Principles of Medicinal Chemistry, B.I. Waverly Pvt. Ltd. New Delhi.

Course Outcome:

Students will learn about drug designing and synthesis of some drugs by taking course.

CHEMISTRY SEC: Chemistry of Cosmetics and Perfumes

(Credits: 02)

Learning Objectives:

1. To learn the role of chemistry in cosmetic and perfume items

2. To learn experimentally the synthesis of some cosmetic products

Theory: 30 Lectures

A general study including preparation and uses of the following: hair dye, hair spray, shampoo, suntan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavours. Essential oils and their importance in cosmetic industries with reference to eugenol, geraniol, sandalwood oil, eucalyptus, rose oil, 2-phenyl ethyl alcohol, jasmone, civetone, muscone.

Practicals:

1. Preparation of talcum powder.
2. Preparation of shampoo.
3. Preparation of enamels.
4. Preparation of hair remover.
5. Preparation of face cream.
6. Preparation of nail polish and nail polish remover.

Reference Books:

• E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

• P.C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.

• B.K. Sharma: Industrial Chemistry, Goel Publishing House, Meerut.

Course Outcome:

On completing this course, students will know about application of chemistry in cosmetics and perfumes and they will also have hands on experience in synthesizing some cosmetic products.

CHEMISTRY SEC: Fuel Chemistry

(Credits: 02)

Learning Objectives:

1. To gain knowledge about different renewable and non-renewable sources of energy

2. To understand different aspects of Coal and Petroleum Industries

3. To know about petrochemicals and their uses in industries.

Theory: 30 Lectures

Review of energy sources (renewable and non-renewable). Classification of fuels and their calorific value.

Coal: Uses of coal (fuel and nonfuel) in various industries, its composition, carbonisation of coal. Coal gas, producer gas and water gas—composition and uses. Fractionation of coal tar, uses of coal tar bases chemicals, requisites of a good metallurgical coke, Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining.

Petroleum and Petrochemical Industry: Composition of crude petroleum, Refining and different types of petroleum products and their applications.

Fractional Distillation (Principle and process), Cracking (Thermal and catalytic cracking), Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels. Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives, Xylene.

Lubricants: Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semisolid lubricants, synthetic lubricants.

Properties of lubricants (viscosity index, cloud point, pore point) and their determination.

Reference Books:

• E. Stocchi: Industrial Chemistry, Vol -I, Ellis Horwood Ltd. UK.

• P.C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.

• B.K. Sharma: Industrial Chemistry, Goel Publishing House, Meerut.

Course Outcome:

On completing this course, students will acquire knowledge about the chemistry involved in fuels and about production and applications of various petrochemicals.

CHEMISTRY GEs: Chemistry Generic Elective Papers

(For Students Majoring in other Departments)

CHEMISTRY GE-I: Atomic Structure, Bonding, General Organic Chemistry and Aliphatic Hydrocarbons

(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Atomic structure, concept of quantum mechanics and electronic configurations of atoms.

2. Ionic and covalent bonding, VSEPR theory, concepts of resonance, valence bond and molecular orbital approach of bonding.

3. Physical effects and reactive intermediates in organic molecules

4. Stereochemistry of organic compounds

5. Preparation properties and reactions of hydrocarbons.

Theory: 60 Lectures

Section A: Inorganic Chemistry – I **(30 lectures)**

Atomic Structure: **(14 lectures)**

Review of: Bohr's theory and its limitations, dual behaviour of matter and radiation, de-Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a different approach to Atomic structure.

Meaning of quantum mechanics. Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and $|\psi|^2$, Schrödinger equation for hydrogen atom. Radial and angular parts of the hydrogen atom wavefunctions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (only graphical representation need be memorised). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers m_l and m_s. Shapes of s, p and d atomic orbitals, nodal planes. Discovery of spin, spin quantum number (s) and magnetic spin quantum number (m_s).

Rules for filling electrons in various orbitals, Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

Chemical Bonding and Molecular Structure **(16 lectures)**

Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridisation with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.

Concept of resonance and resonating structures in various inorganic and organic compounds.

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, NO and NO^+. Comparison of VB and MO approaches.

Section B: Organic Chemistry – I **(30 Lectures)**

Fundamentals of Organic Chemistry **(8 Lectures)**

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.

Stereochemistry **(10 Lectures)**

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 Opticalisomerism; 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 up to two C=C systems).

Aliphatic Hydrocarbons **(12 Lectures)**

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 (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alk. KMnO4) 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 alkaline $KMnO_4$.

Reference Books:

• J. D. Lee: A new Concise Inorganic Chemistry, E L. B. S.

• F. A. Cotton & G. Wilkinson: Basic Inorganic Chemistry, John Wiley.

• Douglas, McDaniel and Alexader: Concepts and Models in Inorganic Chemistry, John Wiley.

• James E. Huheey, Ellen Keiter and Richard Keiter: Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Publication.

• T. W. Graham Solomon: Organic Chemistry, John Wiley and Sons.

• Peter Sykes: A Guide Book to Mechanism in Organic Chemistry, Orient Longman.

• E. L. Eliel: Stereochemistry o*f* Carbon Compounds, Tata McGraw Hill.

• I. L. Finar: Organic Chemistry (Vol. I & II), E. L. B. S.

• R. T. Morrison & R. N. Boyd: Organic Chemistry, Prentice Hall.

• Arun Bahl and B. S. Bahl: Advanced Organic Chemistry, S. Chand

LAB GE-I: Atomic Structure, Bonding, General Organic Chemistry and Aliphatic Hydrocarbons Lab

(60 Classes)

Section A: Inorganic Chemistry - Volumetric Analysis

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.

2. Estimation of oxalic acid by titrating it with $KMnO_4$.

3. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.

4. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.

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 up to two extra elements)

2. Separation of mixtures by chromatography: Measure the R_f value in each case (combination of two compounds to be given)

(a) Identify and separate the components of a given mixture of 2 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:

• Vogel's Qualitative Inorganic Analysis, A.I. Vogel, Prentice Hall, 7th Edition.

• Vogel's Quantitative Chemical Analysis, A.I. Vogel, Prentice Hall, 6th Edition.

• Textbook of Practical Organic Chemistry, A.I. Vogel, Prentice Hall, 5th edition.

• Practical Organic Chemistry, F. G. Mann. & B. C. Saunders, Orient Longman, 1960.

Course Outcomes:

On completion of the course, the students will:

1. Have knowledge about basic aspects of inorganic and organic chemistry.

2. Master basic concepts including atomic structure, bonding and structure of molecules, fundamental concepts in organic chemistry e.g., electronic effects, bonding and reactivity, aromaticity, stereochemistry, etc.

3. Also, the students will have a detailed understanding of aliphatic hydrocarbons.

4. They will know and do quantitative inorganic analysis and qualitative analysis of organic compounds.

CHEMISTRY GE-II: Chemical Energetics, Equilibria and Functional Organic Chemistry-I

(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. Understanding different concepts involved in Thermodynamics, chemical equilibrium and ionic equilibrium.

2. Preparation, properties and reactions of aromatic hydrocarbons, alkyl and aryl halides, alcohols, phenols, ethers, aldehydes and ketones.

3. Experimental physical and organic chemistry, which will include determination of pH of a solution and synthesis of some organic compounds.

Theory: 60 Lectures

Section A: Physical Chemistry-I (30 Lectures)

Chemical Energetics (10 Lectures)

Review of thermodynamics, and of the First and Second 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.

Chemical Equilibrium: (8 Lectures)

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 K_p, K_c and K_x for reactions involving ideal gases.

Ionic Equilibria: (12 Lectures)

Strong 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.

Section B: Organic Chemistry-II **(30 Lectures)**

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

Aromatic hydrocarbons **(8 Lectures)**

Preparation (taking the case of benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.

Reactions (taking the case of benzene): Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) - (up to 4 carbons on benzene). Side chain oxidation of alkyl benzenes (up to 4 carbons on benzene).

Alkyl and Aryl Halides **(8 Lectures)**

Alkyl Halides (up to 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 case): from phenol, Sandmeyer & Gattermann reactions.

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

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

Alcohols, Phenols and Ethers (Upto 5 Carbons) **(14 Lectures)**

Alcohols: Preparation: Preparation of 1°, 2° and 3° alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.

Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alkaline $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation of diols: (up to 6 carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols (taking the case of phenol): Preparation: Cumene hydroperoxide method, from diazonium salts. Reactions: Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-Tiemann Reaction, Gattermann-Koch Reaction, Houben-Hoesch Condensation, Schotten-Baumann Reaction.

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

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

Preparation: from acid chlorides and from 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.

Reference Books:

- T. W. Graham Solomons: Organic Chemistry, John Wiley and Sons.
- Peter Sykes: A Guide Book to Mechanism in Organic Chemistry, Orient Longman.
- I.L. Finar: Organic Chemistry (Vol. I & II), E. L. B. S.
- R. T. Morrison & R. N. Boyd: Organic Chemistry, Prentice Hall.
- Arun Bahl and B. S. Bahl: Advanced Organic Chemistry, S. Chand.
- G. M. Barrow: Physical Chemistry Tata McGraw--□Hill (2007).
- G. W. Castellan: Physical Chemistry 4th Edn. Narosa (2004).
- J. C. Kotz, P. M. Treichel & J. R. Townsend: General Chemistry Cengage Lening India Pvt. Ltd., New Delhi (2009).
- B. H. Mahan: University Chemistry 3rd Ed. Narosa (1998).
- R. H. Petrucci: General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).

LAB GE-II: Chemical Energetics, Equilibria and Functional Organic Chemistry-I Lab

(60 Classes)

Section A: Physical Chemistry

Thermochemistry:

1. Determination of heat capacity of a calorimeter by using hot and room-temperature water.

2. Determination of heat capacity of the calorimeter and enthalpy of neutralisation of hydrochloric acid with sodium hydroxide.

3. Determination of heat capacity of the calorimeter and enthalpy of neutralisation of acetic acid with sodium hydroxide.

Ionic equilibria (pH measurements):

4. 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.

5. Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

[Measurement of pH of the prepared 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) of the following. Recrystallisation, determination of melting point and calculation of quantitative yields be done.

(a) Bromination of Phenol/Aniline

(b) Benzoylation of amines/phenols

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

Reference Books

- A.I. Vogel: Textbook of Practical Organic Chemistry, 5th edition, Prentice-Hall.
- F. G. Mann & B. C. Saunders, Practical Organic Chemistry, Orient Longman (1960).
- B.D. Khosla, Senior Practical Physical Chemistry, R. Chand & Co.

Course Outcomes:

1. On completing this course, students will know fundamentals of physical chemistry viz., principles of thermodynamics, thermochemistry, ionic equillibria and chemical equillibria.

2. They will know about the chemistry of the important functional groups in organic chemistry like alcohols, phenols, ethers, alkyl and aryl halides etc.

3. They will also have an opportunity to verify some of these concepts experimentally in the laboratory.

CHEMISTRY GE-III: Solutions, Phase Equilibrium, Conductance, Electrochemistry and Functional Group Organic Chemistry-II

(Credits: Theory-04, Practicals-02)

Learning objectives:

1. To learn thermodynamic properties of solutions, phase equilibrium, conductance and basic concepts of electrochemistry.

2. Preparation, properties and reactions of functional groups like carboxylic acids and their derivatives, amines and diazonium salts, amino acids, peptides, proteins and carbohydrates.

3. Determination of cell constant, conductometric and potentiometric titrations.

4. Systematic qualitative analysis of organic compounds and other experiments in organic chemistry.

Section A: Physical Chemistry-2 **(30 Lectures)**

Solutions **(10 lectures)**

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions. Vapour pressure-composition and temperature- composition curves of ideal and non-ideal solutions. Distillation of solutions. Lever rule. Azeotropes.

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

Phase Equilibrium **(6 lectures)**

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius–Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, $FeCl_3$-H_2O and Na-K only).

Conductance **(6 lectures)**

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and 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. Conductometric titrations (only acid-base ones).

Electrochemistry **(8 lectures)**

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).

Section B: Organic Chemistry-3 **(30 Lectures)**

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

Carboxylic acids and their derivatives **(6 Lectures)**

Carboxylic acids (aliphatic and aromatic) Preparation: Acidic and Alkaline hydrolysis of esters. Reactions: Hell-Vohlard-Zelinsky Reaction.

Carboxylic acid derivatives (aliphatic): (Upto 5 carbons)

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

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

Amines and Diazonium Salts **(6 Lectures)**

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

Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction.

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

Diazonium salts:

Preparation: from aromatic amines.

Reactions: conversion to benzene, phenol, dyes.

Amino Acids, Peptides and Proteins: (10 Lectures)

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

Reactions of Amino acids: ester of –COOH group, acetylation of $–NH_2$ group, complexation with Cu^{2+} ions, 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) and C-activating groups and Merrifield solid-phase synthesis.

Carbohydrates: (8 Lectures)

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.

Reference Books:

• G. M. Barrow: Physical Chemistry Tata McGraw--□Hill (2007).

• G. W. Castellan: Physical Chemistry 4th Ed. Narosa (2004).

• J. C. Kotz, P. M. Treichel, J. R. Townsend, General Chemistry, Cengage Learning India Pvt. Ltd.: New Delhi (2009).

• B. H. Mahan: University Chemistry, 3rd Edn. Narosa (1998).

• R. H. Petrucci, General Chemistry, 5th Edn., 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 o*f* Biochemistry 7 th Ed., W. H. Freeman.

• Berg, J. M., Tymoczko, J. L. & Stryer, L. Biochemistry 7 th Ed., W. H. Freeman

LAB GE-III: Solutions, Phase Equilibrium, Conductance, Electrochemistry and Functional Group Organic Chemistry-II Lab

(60 Classes)

Section A: Physical Chemistry

Distribution

1. Study of the equilibrium of any one of the following reactions by the distribution method:

$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$

$Cu^{2+}(aq) + x\ NH_3(aq) \rightleftharpoons [Cu(NH_3)_x]^{2+}$

Phase equilibria

2. Study of the variation of mutual solubility temperature with concentration for the phenol water system and determination of the critical solubility temperature.

Conductance

3. Determination of cell constant of the conductometer

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

5. Perform the following conductometric titrations of strong acid vs. strong base

Potentiometry (via mV function of pH meter)

6. Perform the following potentiometric titrations:

(i) Strong acid vs. strong base

(ii) Weak acid vs. strong base

Section B: Organic Chemistry

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

2. Separation of amino acids by paper chromatography

3. Determination of the concentration of glycine solution by formylation method.

4. Action of salivary amylase on starch

5. Determination of either the saponification value or iodine value of an oil/fat.

Reference Books:

- A.I. Vogel: Textbook of Practical Organic Chemistry, Prentice Hall, 5th Edn.
- F. G. Mann & B. C. Saunders: Practical Organic Chemistry, Orient Longman, 1960.
- B.D. Khosla: Senior Practical Physical Chemistry, R. Chand & Co.
- Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry,

Universities Press.

Course Outcomes:

1. This course will enable students to learn some key concepts in physical chemistry viz., solutions, phase equillibria, conductance, electrochemistry etc.

2. They will also learn organic chemistry of carboxylic acids, amines, diazonium salts and biomolecules like carbohydrates, amino acids, peptides, etc.

3. Practical associated with this course will provide opportunity to the students to verify some important concepts learnt in this course to be verified experimentally in the laboratory

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CHEMISTRY GE-IV: Chemistry of s- and p- Block Elements, States Of Matter & Chemical Kinetics

(Credits: Theory-04, Practicals-02)

Learning Objectives:

1. To know Different aspects of metallurgy and chemistry of s and p block elements.
2. Physical properties of gases, solids and liquids.
3. Concepts in chemical kinetics.
4. Semimicro qualitative analysis of mixtures of inorganic salts.
5. Measurement of surface tension and viscosity.
6. Experimental investigation of kinetics of some chemical reactions.

Section A: Inorganic Chemistry-2 **(30 lectures)**

General Principles of Metallurgy **(5 Lectures)**

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon as reducing agent.

Hydrometallurgy, Methods of purification of metals (Al, Pb, Ti, Fe, Cu, Ni, Zn): electrolytic, oxidative refining, Kroll process, Parting process, van Arkel-de Boer process and Mond's process.

s- and p- Block Elements **(25 Lectures)**

Periodicity in s- and p-block elements with respect to electronic configuration, atomic and ionic size, ionization enthalpy, electronegativity (Pauling, Mulliken, and Alfred-Rochow scales). Allotropy in C, S, and P.

Oxidation states with reference to elements in unusual and rare oxidation states like carbides and nitrides), inert pair effect, diagonal relationship and anomalous behaviour of first member of each group.

Compounds of s- and p-Block Elements

Hydrides and their classification (ionic, covalent and interstitial), structure and properties with respect to stability of hydrides of p- block elements.

Concept of multicentre bonding (diborane).

Structure, bonding and their important properties like oxidation/reduction, acidic/basic nature of the following compounds and their applications in industrial, organic and environmental chemistry.

Hydrides of nitrogen (NH_3, N_2H_4, N_3H, NH_2OH) Oxoacids of P, S and Cl.

Halides and oxohalides: PCl_3, PCl_5, $SOCl_2$ and SO_2Cl_2

Section B: Physical Chemistry-3 **(30 Lectures)**

Kinetic Theory of Gases **(10 lectures)**

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).

Liquids **(5 lectures)**

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)

Solids **(5 lectures)**

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.

Chemical Kinetics **(10 lectures)**

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).

Reference Books:

• G. M. Barrow: Physical Chemistry Tata McGraw-Hill (2007).

• G. W. Castellan: Physical Chemistry 4th Edn. Narosa (2004).

• J. C. Kotz, P. M. Treichel & J. R. Townsend: General Chemistry Cengage Lening India Pvt. Ltd., New Delhi (2009).

• B. H. Mahan: University Chemistry 3rd Ed. Narosa (1998).

• R. H. Petrucci: General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).

• J. D. Lee: A New Concise Inorganic Chemistry, E.L.B.S.

• F.A. Cotton & G. Wilkinson: Basic Inorganic Chemistry, John Wiley.

• D. F. Shriver and P. W. Atkins: Inorganic Chemistry, Oxford University Press.

• Gary Wulfsberg: Inorganic Chemistry, Viva Books Pvt. Ltd.

LAB GE-IV: Chemistry of s- and p- Block Elements, States Of Matter & Chemical Kinetics Lab

(60 Classes)

Section A: Inorganic Chemistry

Semi-micro qualitative analysis using H_2S of mixtures – not more than four ionic species (two anions and two cations, and excluding insoluble salts) out of the following:

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

Anions : CO_3^{2-}, NO_2^-, S^{2-}, SO_3^{2-}, SO_4^{2-}, $S_2O_3^{2-}$, CH_3COO^-, F^-,Cl^-, Br^-, I^-, NO_3^-, BO_3^{3-}, $C_2O_4^{2-}$, PO_4^{3-}

(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 (any one).

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

(b) Saponification of ethyl acetate.

(c) Compare two strengths of HCl by studying kinetics of hydrolysis of methyl acetate

Reference Books:

- A.I. Vogel, Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.
- A.I. Vogel, Quantitative Chemical Analysis, Prentice Hall, 6th Edn.
- B.D. Khosla, Senior Practical Physical Chemistry, R. Chand & Co.

Course Outcomes:

1. Students of this course will know about the chemistry involved in metallurgy.
2. They will be introduced to the bonding, structure, reactivities and other basic aspects of compounds formed by s and p block elements.
3. They will also know about the physical chemistry of gases, solids and solutions. They will also be introduced to chemical kinetics.
4. Practical portion of this course will let them know and do experiments pertaining to qualitative inorganic analysis, surface tension, viscosity and chemical kinetics experiments.
