COURSE CURRICULUM UNDER CHOICE BASED CREDIT SYSTEM (CBCS)

B.Sc. in CHEMISTRY(HONS.)

DEPARTMENT OF CHEMISTRY

PANSKURA BANAMALI COLLEGE

(AN AUTONOMOUSCOLLEGE UNDER VIDYASAGAR UNIVERSITY)

PANSKURA R.S., MIDNAPORE (EAST) – 721152

WEST BENGAL

Education in India is largely based on a basic foundation for understanding and realization in everyone's life. Through this, a society can achieve a pioneering model of education in the universe. Rationalization and interpretation of the natural phenomena through the model subject are accounted for by chemical science. The theories have contributed most to the understanding of the subject chemistry and qualitative models of bonding/reactivity clarify and systematize the subject. The ultimate authority consists of observations and measurements, such as identities of the product(s) of a reaction, structure, thermodynamic properties, spectroscopic signature, and measurement of reaction rates.

The curriculum framework for the bachelor-level of chemistry course specifically covers the understanding of knowledge, enhancement of skill, and practices. The value addition in the course structure is primarily considered. The curriculum is more leaned towards self-discovery of concepts.The motivation to lead the global scenario has been met by the course structure. The beneficiaries enhance the universal outlook through the subject. The augmentation of practical of the theoretical concepts is visualized with substantial coverage of laboratory works and field works. The gathering of knowledge followed by practicing the earned knowledge is the key component in the chemistry course. To meet the curiosity of the students, the practicals/projects are constituted in the final year of the course. The curriculum helps the graduate students to build chemistry-related careers, and higher education in Chemistry and allied subjects. The DSE and SEC courses in the higher class were adopted to include the aptitude of chemistry knowledge in everyday life. The furnished students can move to other disciplines with vast knowledge in chemistry. The student-centric pedagogy is maintained in the B. Sc course in Chemistry. After completing the Honours course in Chemistry, a student becomes a very potential of a critical thinker, psychologist, environmentalist, and moral-ethical scientist.

Aims of the Bachelor Degree Courses provide the followings:

(i) A broad spectrum of balanced knowledge in chemistry following the key components of chemical concepts, principles and theories which relate the natural phenomena.
(ii) The ability and skill in solving both theoretical and practical chemistry problems of the students.

(iii) The elevation of the self-confidence to undertake furtherstudies in chemistry in related areas or multidisciplinary areas that will be helpful for self-employment/entrepreneurship.

(iv) The cognitive development of students in a holisticmanner.

(v) A complete dialogue about chemistry, chemical equations, and its significance isfostered in this framework, rather than mere theoretical aspects.

(vi) The successful candidates for the national level competitive examinations.

Course Structure B.Sc. (Honours)

Course component	**No. of Papers**	**Credit per paper**	**Total credit**
Core Course(**CC**)	14	6	84
Discipline Specific Elective (**DSE**) Course	4	6	24
Generic Elective (**GE**) Course	4 (from other discipline)	6	24
Ability Enhancement Compulsory Course (**AECC**)(English, ENVS)	2	2+4	6
Skill Enhancement Course (**SEC**)	2	2	4
Total	26		142

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

SEM	Core Course**(14)**	Ability Enhancement Compulsory Course **(AECC) (2)**	Skill Enhancement Course **(SEC) (2)**	Elective: Discipline Specific **(DSE) (2)**	Elective: Generic **(GE) (4)**
I	**C1**	(English/MIL Communication)/Environmental Science			**GE-1**
	C2				
II	**C3**	Environmental Science/(English/MIL Communication)			**GE-2**
	C4				

III	**C 5**		**SEC-1**		**GE-3**
	C 6				
	C 7				
IV	**C 8**		**SEC-2**		**GE-4**
	C 9				
	C 10				
V	**C 11**			**DSE-1**	
	C 12			**DSE-2**	
VI	**C 13**			**DSE-3**	
	C 14			**DSE-4**	

CORE COURSE (HONOURS IN CHEMISTRY)

SEMESTER I

COURSE STRUCTURE

Paper code	Brief Description	Credit	Marks	Lectures Hours
CEMHCC1	INORGANIC CHEMISTRY-1	4	50	60
	PRACTICAL	2	25	60
CEMHCC2	PHYSICAL CHEMISTRY-1	4	50	60
	PRACTICAL	2	25	60
CEMEGE1	SECTION I: INORGANIC CHEMISTRY-1 SECTION II: ORGANIC CHEMISTRY -1	4	50	30 30
	PRACTICAL	2	25	60
Total		**18**	**225**	**360**

PAPER CEMHCC1 (INORGANIC CHEMISTRY-1)

COURSE OUTCOMES:

Theory

- **Knowledge of the shape of orbital and term symbols, and fundamental atomic rules**
- **Methodical study of elements through the periodic table**
- **Knowledge of various acid-base theories and acid-base titration curves**
- **Concept of redox and formal potential, the feasibility of reactions**
- **The idea of solubility product and precipitation**
- **Concept of radioelements and their properties**

Practical

- **Practical knowledge of instrument calibration**
- **Practical on acidimetric and alkalimetric titration**
- **Practical knowledge on oxidation and reduction process**

SYLLABUS OF INORGANIC CHEMISTRY-I (PAPER CEMHCC1 THEORY)

A. Atomic Structure (14 Lectures):

Bohr's theory, its limitations and the atomic spectrum of the hydrogen atom. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, the significance of ψ and ψ^2. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for the 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's principle and its limitations, Variation of orbital energy with atomic number.

B. Periodicity of Elements (16 Lectures):

A brief discussion of the followingproperties 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 the periodic table.

(b) Atomic radii (van der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

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

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

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

C. Redox Reactions and precipitation reactions (18 Lectures)

Ion-electron method of balancing equation of redox reaction. The elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential. Feasibility of a redox titration, redox potential at the equivalence point,

redox indicators. Redox potential diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples).

Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides.

D. Acids and Bases (8 Lectures)

Brönsted-Lowry concept of acid-base reactions, solvated proton, the 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.

E. Radioactivity (6 Lectures)

Natural radioactivity, units, radioactive disintegration series, group displacement law, the law of radioactive decay, half-life and the average life of radio elements. Stability of atomic nucleus: n/p ratio, nuclear binding energy, mass defect. Nuclear reactions: fission, fusion, transmutation of elements, artificial radioactivity, measurement of radioactivity (simple idea). Isobars, Isotopes, Isotones and their uses.

Reference Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry*
3. Oxford, 1970
4. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10^{th} Ed., Oxford University Press, 2014.
5. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
6. Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning India Edition, 2002.

SYLLABUS OF INORGANIC CHEMISTRY PRACTICAL-1 (PAPER CEMHCC1 PRACTICAL)

(A) Titrimetric Analysis

(i) Calibration and use of apparatus, preparation of 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 indicators.

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

Reference text:

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis 6thEd.*, Pearson, 2009.
2. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
3. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
4. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

PAPER CEMHCC2 (PHYSICAL CHEMISTRY-I)

Course outcome:

- **Description of macroscopic gas behavior including the distribution of velocities**
- **Ideal gas model, real gas models – especially van der Waals' gas model**
- **Transport behavior of fluids (liquid and gas)**
- **Fundamentals of thermodynamics with different thermodynamic processes**
- **Estimation of standard reaction enthalpy by various means**
- **Concept of chirality and stereochemistry**

SYLLABUS OF PHYSICAL CHEMISTRY-I (PAPER CEMHCC2 THEORY)

A. Gaseous state(18 Lectures):

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, the 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, the law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

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

B. **Liquid state (6 Lectures):**

Qualitative treatment of the structure of the liquid state; Radial distribution function; physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of the structure of water.

C. Solid State (16 Lectures):

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

D. Thermodynamics(20 Lectures)

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

First law: Concept of heat, *q*, work, *w*, internal energy, *U*, and statement of first law;enthalpy, *H*, relation between heat capacities, calculations of *q*, *w*, *U* and *H* for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions.

Thermochemistry: Heats of reactions: standard states; enthalpy of formation of

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

Reference Books:

1. Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 10th Ed., Oxford University Press (2014).
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. Engel, T. & Reid, P. *Physical Chemistry* 3rd Ed. Pearson (2013).

SYLLABUS OF PHYSICAL CHEMISTRY-I (PAPER CEMHCC2 PRACTICAL)

A. Surface tension measurements (15 Lectures).

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.

B. Viscosity measurement using Ostwald's viscometer(15 Lectures).

c. Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
d. Study the variation of viscosity of sucrose solution with the concentration of solute.

C. Indexing of a given powder diffraction pattern of a cubic crystalline system (10 Lectures).

D. Thermochemistry (20 Lectures).

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

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

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

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

(e) Determination of basicity/proticity of a polyprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also, calculate the enthalpy of neutralization of the first step.

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

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

Reference Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry8th Ed.*; McGraw-Hill: New York (2003).
3. Halpern, A. M. &McBane, G. C. *Experimental Physical Chemistry 3rdEd.;* W.H. Freeman & Co.: New York (2003).
4. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

PAPERCEMEGE1: ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY &ALIPHATIC HYDROCARBONS

(Credits: Theory-04, Practicals-02) **Theory: 60 Lectures**

Course outcome:

- **Concept of Atomic model and chemical forces**
- **Ionization potential, electron affinity, and various scales of electro negativity**
- **Hybridization and shape of molecules/ions**
- **Molecular orbital and bonding**
- **Inorganic quantitative analysis**
- **Fundamental of organic chemistry (theoretical and practical aspect)**
- **Concept of stereochemistry**
- **Qualitative analysis of organic compounds**

SYLLABUS OF ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS (THEORY)

Section I: Inorganic Chemistry-1 **(30 Periods)**

A. Atomic Structure (14 Lectures): *Review of Bohr's theory and its limitations, dual behaviour of matterand radiation, de Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a new approach to Atomic structure.*

What is Quantum mechanics? Time independent Schrodinger equation and meaning of

various terms in it. Significance of ψ and ψ^2, Schrödinger equation for hydrogen atom. Radial and angular parts of the hydogenic wavefunctions (atomic orbitals) and their variations for 1*s*, 2*s*, 2*p*, 3*s*, 3*p* and 3*d* orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1*s* and 2*s* atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers *ml* and *ms*. Shapes of *s*, *p* and *d* atomic orbitals, nodal planes. Discovery of spin, spin quantum number (*s*) and magnetic spin quantum number (*ms*).

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.

B. Chemical Bonding and Molecular Structure (16 Lectures):

Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionicbonding, 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 based on VSEPR and hybridization 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 II: Organic Chemistry-1 **(30 Lectures)**

A. 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.

B. 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 Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threo and erythro; D and L; *cis-trans* nomenclature; CIP Rules: R/S (for upto 2 chiral carbon atoms) and E / Z Nomenclature (for upto two C=C systems).

C. 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'ssynthesis, from Grignard reagent. *Reactions:* Free radical Substitution: Halogenation.

Alkenes:(Upto 5 Carbons)*Preparation:*Elimination reactions: Dehydration of alkenes anddehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). *Reactions:* cis-addition (alk. $KMnO_4$) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation.

Alkynes: (Upto 5 Carbons)*Preparation:*Acetylene from CaC2and conversion into higheralkynes; 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:

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

2. Cotton, F.A., Wilkinson, G. &Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. *Concepts and Models in InorganicChemistry*, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. &Medhi, O.K. *Inorganic Chemistry:Principles of Structure and Reactivity*, Pearson Education India, 2006.
5. Graham Solomon, T.W., Fryhle, C.B. &Dnyder, S.A. *Organic Chemistry*, John Wiley & Sons (2014).
6. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
7. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
8. Eliel, E.L. *Stereochemistry of Carbon Compounds*, Tata McGraw Hill education, 2000.
9. Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
10. Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.
11. Bahl, A. &Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.

SYLLABUS CEMEGE1:ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS PRACTICAL (60 Lectures)

Section I: 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 II: Organic Chemistry

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing upto two extra elements)

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

(a) Identify and separate the components of a given mixture of two amino acids

(glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography

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

Reference Books:

1. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
2. Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
3. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbookof Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
4. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
5. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

SEMESTER II

COURSE STRUCTURE

Paper code	Brief Description	Credit	Marks	Lectures Hours		
CEMHCC3	ORGANIC CHEMISTRY-1	4	50	60		
	PRACTICAL	2	25	60		
CEMHCC4	PHYSICAL CHEMISTRY-1	4	50	60		
	PRACTICAL	2	25	60		
CEMEGE2	SECTION I: CHEMICAL ENERGETICS, EQUILIBRIA SECTION II: FUNCTIONAL ORGANIC CHEMISTRY-I	4	50	30 30		
	PRACTICAL	2	25	60		
Total		18	225	360		

PAPER CEMHCC3 THEORY:ORGANIC CHEMISTRY-1

COURSE OUTCOMES:

- **Knowledge of basic organic chemistry**
- **Learning of stereochemistry**
- **Knowledge of aliphatic and aromatic hydrocarbon**

- **Practical knowledge of instrument calibration**
- **Practical on acidimetric and alkalimetric titration**
- **Practical knowledge on oxidation and reduction process**

SYLLABUS OF **ORGANIC CHEMISTRY-1 (THEORY)**

A. **Basics of Organic Chemistry (20 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.

Aromaticity: Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples.

Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and their relative stability of Carbocations, Carbanions, Free radicals and Carbenes.

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

B. Stereochemistry (10 Lectures)

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. Elements of symmetry and concept of chirality /asymmetry.

Optical Isomerism: Optical Activity, Specific Rotation, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, mesostructures, Racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations.

C. Chemistry of Aliphatic Hydrocarbons (24 Lectures)

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

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. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

Cycloalkanes and Conformational Analysis: Types of cycloalkanes and their relative stability, Baeyer strain theory, Conformation analysis of alkanes: Relative stability: Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms; Relative stability of mono-, di-, tri- substituted cycloalkane with energy diagrams.

D. Aromatic Hydrocarbons (6 Lectures)

Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups.

Reference Books:

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

SYLLABUS CEMHCC 3 LAB: ORGANIC CHEMISTRY PRACTICAL-1(60 Lectures)

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 the above compounds and unknown organic compounds (Kjeldahl method and electrically heated melting point apparatus

4. Effect of impurities on the melting point–the 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. Detection of extra elements

7. Chromatography

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

(b) Separation of a mixture of two sugars by ascending paper chromatography

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

Reference Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
6. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry*, *5th Ed.,* Pearson (2012).
7. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

PAPER CEMHCC4: PHYSICAL CHEMISTRY-II

Course outcome:

- **The idea of Electrolytes and Solubility Product**
- **Concept of partial molar quantities, especially chemical potential and their role in understanding the thermodynamics of mixing**
- **Concept of activity in the ionic atmosphere and how ion-ion interactions are taken into account in electrolyte solutions**
- **Understanding of statistical and the use of the suitable coordinate system and other mathematical techniques to simplify the calculation**
- **Explaining the nature of migration of ions in electrolyte solutions in the presence of an electric field - its quantification and preliminary modelling**

SYLLABUS OF PHYSICAL CHEMISTRY-II (THEORY)

A. Ionic equilibria (18 Lectures):

Strong, moderate and weak electrolytes, degree of ionization, factors affecting the degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di-and triprotic acids (exact treatment).

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

Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid-base titration curves (calculation of pH at various stages). Theory of acid-base indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolyte systems; hydrolysis and hydrolysis constants.

B. Chemical Thermodynamics (14 Lectures):

Second Law: Concept of entropy; the 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.

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

C. Systems of Variable Composition (8 Lectures):

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

D. Statistical thermodynamics(12 Lectures):

Third law of thermodynamics*:* Statement of the third law, Nernst heat theorem, Lewis-Randall statement, Plank statement; the concept of residual entropy, calculation of absolute entropy of molecules., Macrostates and microstates, Ensemble, mathematical probability versus thermodynamic probability, thermodynamic probability and the concept of entropy, Partition function and representation of the thermodynamic functions; Boltzmann distribution, non-degenerate and degenerate cases.

E. Chemical Equilibrium (8 Lectures):

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

Reference Books

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

PAPER CEMHCC4 (PHYSICAL CHEMISTRY PRACTICAL)

SYLLABUS OF PHYSICAL CHEMISTRY-II (PRACTICAL) (60 Lectures)

A. pH metry

(a) Study the 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 the dissociation constant of a weak acid.

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

C. Thermochemistry

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

b) Determination of basicity/proticity of a polyprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculate the enthalpy of neutralization of the first step.

c) Determination of enthalpy of hydration of copper sulphate.

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

Reference Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry,* R. Chand & Co.: New Delhi (2011).
2. Athawale, V. D. & Mathur, P. *Experimental Physical Chemistry* New Age International: New Delhi (2001).
3. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

PAPER CEMEGE2: Section I: SYLLABUS OF PHYSICAL CHEMISTRY-1 (THEORY)(30 Lectures)

Course outcome:

- **Concept of Energetics of Chemical Reactions**
- **The fundamental concept of Chemical Kinetics and Chemical Equilibrium**
- **Fundamental of organic compounds with different functional groups**
- **Gather practical experience in Thermochemistry, pH, and Buffer solution**
- **Hands-on training in purification and Identification of Organic compounds.**

A. Chemical Energetics (10 Lectures):

Review of thermodynamics and the Laws of Thermodynamics.

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

B. Chemical Equilibrium (8 Lectures):

Free energy changes in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. The distinction between *G* and *G*o, Le Chatelier's principle. Relationships between *Kp, Kc* and *Kx* for reactions involving ideal gases.

C. Ionic Equilibria (12 Lectures):

Strong, moderate and weak electrolytes, degree of ionization, factors affecting the 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.

PAPER CEMEGE2 Section II: SYLLABUS OF ORGANIC CHEMISTRY-2(30 Lectures)

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

A. Aromatic hydrocarbons (8 Lectures)

Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.

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

B. Alkyl and Aryl Halides (8 Lectures)

Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (SN_1, SN_2 and SNi) 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 iodobenzene case): from phenol, Sandmeyer & Gattermann reactions.

Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of the 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.

C. Alcohols, Phenols and Ethers (Upto 5 Carbons) **(8 Lectures)**

Alcohols:Preparation: Preparation of 1o, 2o and 3o alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters. *Reactions:* With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. KMnO4, acidic dichromate, conc. HNO3). Oppeneauer oxidation *Diols:* (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols:(Phenol case) *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.

D. Aldehydes and ketones (aliphatic and aromatic): (Formaldehyde, acetaldehyde, acetone, and benzaldehyde)**(6 Lectures)**

Preparation: from acid chlorides and nitriles.

Reactions – Reaction with HCN, ROH, $NaHSO_3$, NH_2 -G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemmensen reduction and Wolff Kishner reduction. Meerwein-PondorffVerley reduction.

Reference Books:

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

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

CEMEGE2 LAB: CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY-IPRACTICAL (60 Lectures)

Section I: Physical Chemistry Practical

A. Thermochemistry

1. Determination of heat capacity of a calorimeter for different volumes.

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

3. Determination of enthalpy of ionization of acetic acid.

4. Determination of integral enthalpy of solution of salts (KNO_3, NH_4Cl).

5. Determination of enthalpy of hydration of copper sulphate.

6. Study of the solubility of benzoic acid in water and determination of *H*.

B. Ionic equilibria pH measurements

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

a) Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

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

Section II: Organic Chemistry Practical

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

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

3. Preparations: Mechanism of various reactions involved to be discussed. Recrystallisation, determination of melting point and calculation of quantitative yields to be done. (a) Bromination of Phenol/Aniline (b) Benzoylation of amines/phenols

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

Reference Books

1. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
3. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
4. Ghosh, S.; Das Sharma, M.;Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

SEMESTER III

COURSE STRUCTURE

Paper code	**Brief Description**	**Credit**	**Marks**	**Lectures Hours**		
CEMHCC5	INORGANIC CHEMISTRY-II	4	50	60		
	PRACTICAL	2	25	60		
CEMHCC6	ORGANIC CHEMISTRY-II	4	50	60		
	PRACTICAL	2	25	60		
CEMHCC7	PHYSICAL CHEMISTRY-III	4	50	60		
	PRACTICAL	2	25	60		
CEMHSE1	PHARMACEUTICAL CHEMISTRY	1	30	20		
	PRACTICAL	1	20	10		
CEMEGE3	SECTION I: SOLUTIONS, PHASE EQUILIBRIA, CONDUCTANCE, ELECTROCHEMISTRY SECTION II: FUNCTIONAL GROUP ORGANIC CHEMISTRY-II	4	50	30 30		
	PRACTICAL	2	25	60		
	Total	26	75	120		

COURSE OUTCOMES:

- **Concept of different chemical forces**
- **Methodical study of s and p block elements**
- **Knowledge of halogenated organic compounds, ether, alcohol, carbonyl, carboxylic acid, and amines and esters**

- **Practical knowledge of qualitative analysis of organic compounds**
- **Preparation Processes of organic compounds**
- **Iodometric titration and preparation of various inorganic salts**
- **Practical knowledge of kinetics, equilibrium, and the phase rule**
- **Analysis of drugs and preparation of drugs.**

CORE COURSECEMHCC5: INORGANIC CHEMISTRY-II

Syllabus of CEMHCC5 (Theory60 Lectures)

A. Chemistry of *s* and *p* Block Elements (30 Lectures):

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of the 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.

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

Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogens and basic properties of halogens.

B. Noble Gases (8 Lectures):

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds

(Valence bond treatment and MO treatment for XeF_2). Molecular shapes of noble gas compounds (VSEPR theory).

C. Chemical Bonding (26 Lectures):

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

(ii) *Covalent bond:* Lewis structure, Valence Bond theory (Heitler-London approach).Energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths. Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization. Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

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

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

Reference Books:

1. Lee, J.D. *Concise Inorganic Chemistry*, ELBS, 1991.
2. Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models ofInorganic 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* 4th Ed., Pearson, 2010.
7. Atkin, P. *Shriver & Atkins' Inorganic Chemistry* 5th Ed. Oxford University Press (2010).

CEMHCC5 (PRACTICAL INORGANIC CHEMISTRY-II) (*60 Lectures)*

(A) Iodo / Iodimetric Titrations

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

(ii) Estimation of mixtures of Fe(III)-Fe(II), Fe(III)-Cr(VI), Fe(III)-Cu(II).

(B) Inorganic preparations

(i) Cuprous Chloride, Cu_2C_{l2}

(ii) Preparation of Manganese(III) phosphate, $MnPO_4.H_2O$

(iii) Preparation of Aluminium potassium sulphate $KAl(SO_4)_2.12H_2O$ (Potash alum) or Chrome alum.

Reference Books:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6thEd.*, Pearson, 2009.

2. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

CEMHCC6: ORGANIC CHEMISTRY-II

SYLLABUS OF ORGANIC CHEMISTRY-II (THEORY)

A. Chemistry of Halogenated Hydrocarbons (16 Lectures):

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – SN1, SN1', SN2, SN2', SNi, SNi'and NGP mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

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

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

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

B. Alcohols, Phenols, Ethers and Epoxides(16 Lectures):

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-BlancReduction; 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 substitutionreactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism;

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

C. 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.

D. 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 sustitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann-bromamide degradation, Lossen rearrangement, Curtius rearrangement and smidth reaction.

E. Sulphur containing compounds (4 Lectures):

Preparation and reactions of thiols, thioethers and sulphonic acids.

Reference Books:

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

India Edition, 2013.

SYLLABUS OF ORGANIC CHEMISTRY-II (PRACTICAL)

1. Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group.
2. Organic preparations:
    i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method:
        a. Using conventional method.
        b. Using green approach
    ii. Benzolyation of one of the following amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the following phenols (β-naphthol, resorcinol, p-cresol) by Schotten-Baumann reaction.
    iii. Oxidation of ethanol/ isopropanol (Iodoform reaction).
    iv. Bromination of any one of the following:
        a. Acetanilide by conventional methods
        b. Acetanilide using green approach (Bromate-bromide method)
    v. Nitration of any one of the following:
        a. Acetanilide/nitrobenzene by conventional method
        b. Salicylic acid by green approach (using ceric ammonium nitrate).
    vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.
    vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.
    viii. Hydrolysis of amides and esters.
    ix. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.
    x. *S*-Benzylisothiouronium salt of one each of water soluble and water

insoluble acids(benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

xi. Aldol condensation using either conventional or green method.

xii. Benzil-Benzilic acid rearrangement.

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

Reference Books

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 OrganicChemistry, 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: QualitativeAnalysis,* University Press (2000).
5. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
6. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Publishers, Kolkata.

CEMHCC7: PHYSICAL CHEMISTRY-III

SYLLABUS OF CEMHCC7: PHYSICAL CHEMISTRY-III (THEORY)

A. Solutions and Colligative Properties (8 Lectures):

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

Thermodynamic derivation using the chemical potential to derive relations between the

four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

B. Phase Equilibria (25 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 tofractional distillation of binary miscible liquids (ideal and nonideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation.

Nernst distribution law: its derivation and applications.

C. Chemical Kinetics (18 Lectures)

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second-order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions.

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.

D. Catalysis (8 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.

E. Surface chemistry (6 Lectures):

Physical adsorption, chemisorption, adsorption isotherms. nature of the adsorbed state.

Reference Books:

1. Peter Atkins & Julio De Paula, *Physical Chemistry* 10th Ed., 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 Pvt. Ltd.: New Delhi (2004).
4. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.,* Prentice-Hall (2012).
5. Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S.
6. *Commonly Asked Questions in Thermodynamics.* CRC Press: NY (2011).
7. Zundhal, S.S. *Chemistry concepts and applications* Cengage India (2011).
8. Ball, D. W. *Physical Chemistry* Cengage India (2012).
9. Mortimer, R. G. *Physical Chemistry 3rd Ed.,* Elsevier: NOIDA,

UP (2009).

10. Levine, I. N. *Physical Chemistry 6th Ed.,* Tata McGraw-Hill (2011).
11. Metz, C. R. *Physical Chemistry 2nd Ed.,* Tata McGraw-Hill (2009).

SYLLABUS OF CEMHCC 7: PHYSICAL CHEMISTRY-III (PRACTICAL)

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

II. Phase equilibria: Construction of the phase diagram using cooling curves or ignition tube method:

   a. simple eutectic and

   b. congruently melting systems.

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

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

   (i) $I_2(aq) + I^- \rightarrow I_3^-(aq)^{2+}$

   (ii) $Cu^{2+}(aq) + nNH_3 \rightarrow Cu(NH_3)_n$

V. Study the kinetics of the following reactions.

1. Initial rate method: Iodide-persulphate reaction
2. Integrated rate method:
   a. Acid hydrolysis of methyl acetate with hydrochloric acid.
   b. Saponification of ethyl acetate.
3. Compare the strengths of HCl and H2SO4 by studying kinetics of hydrolysis of methyl acetate.

VI. Adsorption

Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

Reference Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry8th Ed.*; McGraw-Hill: New York (2003).
7. Halpern, A. M. &McBane, G. C. *Experimental Physical Chemistry 3rdEd.;* W.H. Freeman & Co.: New York (2003).
8. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
9. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

PAPER CEMHSE 1: PHARMACEUTICAL CHEMISTRY (Credits: 02)

SYLLABUS OF PHARMACEUTICAL CHEMISTRY (THEORY)

A. Drugs & Pharmaceuticals

Drug discovery, design and development; Basic Retrosynthetic approach. Synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (Aspirin, paracetamol, lbuprofen); antibiotics (Chloramphenicol); 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).

B. 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.

SYLLABUS OF PHARMACEUTICAL CHEMISTRY (PRACTICAL)

1. Preparation of Aspirin and its analysis.
2. Preparation of magnesium bisilicate (Antacid).

Reference Books:

1. Patrick, G. L. *Introduction to Medicinal Chemistry, Oxford University* Press, UK, 2013.
2. Singh, H. & Kapoor, V.K. *Medicinal and Pharmaceutical Chemistry,* Vallabh Prakashan, Pitampura, New Delhi, 2012.
3. Foye, W.O., Lemke, T.L. & William, D.A.: *Principles of Medicinal Chemistry*, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.
4. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

PAPER CEMEGE3: SOLUTIONS, PHASE EQUILIBRIUM,CONDUCTANCE,ELECTROCHEMISTRY & FUNCTIONAL GROUP ORGANIC CHEMISTRY-II

SYLLABUSSECTION *A:* SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE, ELECTROCHEMISTRY -II(30 Lectures)

A. Solutions (8 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.

B. Phase Equilibrium (8 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, FeCl3-H2O and Na-K only).

C. 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, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid-base).

D. 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: *G*, *H* and *S* 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).

SYLLABUS SECTION B: **FUNCTIONAL GROUP ORGANIC CHEMISTRY-II (THEORY)**

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

A. 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 theirinterconversion.

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

B. Amines and Diazonium Salts (6 Lectures):

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

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

Reactions: Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, withHNO_2,Schotten-Baumann Reaction. Electrophilic substitution (case aniline): nitration,bromination, sulphonation.

Diazonium salts:*Preparation:*from aromatic amines.

Reactions: conversion to benzene, phenol, dyes.

C. 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 –NH2group, complexationwith 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) & C-activating groups and Merrifield solid-phase synthesis.

D. *Carbohydrates* **(8 Lectures)**: Classification, and General Properties, Glucose and Fructose (open chainand 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:

1. Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
2. Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry*, Cengage Learning India Pvt. Ltd.: New Delhi (2009).
4. Mahan, B.H. *University Chemistry*, 3rd Ed. Narosa (1998).
5. Petrucci, R.H. *General Chemistry*, 5th Ed., Macmillan Publishing Co.: New York (1985).

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

CEMEGE3:: SECTION I:

SOLUTIONS,PHASEEQUILIBRIUM,CONDUCTANCE,ELECTROCHEMISTRY-II (60 Lectures)

A. Distribution

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

$I_2(aq) + I^-(aq) \quad I3^-(aq)$

$Cu^{2+}(aq) + x\text{NH2}(aq) \quad [Cu(NH3)x]^{2+}$

B. Phase equilibria

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

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

C. Conductance

I. Determination of cell constant
II. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
III. Perform the following conductometric titrations:
    i. Strong acid vs. strong base

ii. Weak acid vs. strong base

D. Potentiometry

Perform the following potentiometric titrations:

i. Strong acid vs. strong base

ii. Weak acid vs. strong base

iii. Potassium dichromate vs. Mohr's salt

Section B: Functional Organic Chemistry-II

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

II.

1. Separation of amino acids by paper chromatography
2. Determination of the concentration of glycine solution by formylation method.
3. Differentiation between a reducing and a nonreducing sugar.

Reference Books:

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

5. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
6. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

SEMESTER 4

COURSE STRUCTURE

Paper code	Brief Description	Credit	Marks	Lectures Hours		
CEMHCC8	INORGANIC CHEMISTRY-III	4	50	60		
	PRACTICAL	2	25	60		
	Total	6	75	120		
CEMHCC9	ORGANIC CHEMISTRY-III	4	50	60		
	PRACTICAL	2	25	60		
	Total	6	75	120		
CEMHCC10	PHYSICAL CHEMISTRY-IV	4	50	60		
	PRACTICAL	2	25	60		
	Total	6	75	120		
CEMHSE2	PESTICIDE CHEMISTRY	1	30	20		
	PRACTICAL	1	20	10		
	Total	2	50			
CEMEGE4	SECTION I: TRANSITION METAL AND COORDINATION CHEMISTRY SECTION II: STATE OF MATTER AND CHEMICAL KINETICS	4	50	30 30		
	PRACTICAL	2	25	60		
	Total	6	75	120		

COURSE OUTCOMES:

- **Knowledge of chemistry of transition metals and coordination compounds**
- **Study the properties like magnetism and color**
- **Concept of Bioinorganic Chemistry**
- **Chemistry of nitrogenated organic compounds and polynuclear hydrocarbons**

- **Knowledge of Heterocyclic Chemistry and Alkaloid and Terpenoids**
- **Concepts of conductance and electrochemistry**
- **Basic knowledge of Pesticides**

- **Practical knowledge of gravimetric analysis**
- **Procedures of inorganic preparation and metal separation techniques by the chromatographic method.**
- **Finding procedure of extra element functional group of organic compounds**
- **Conductometric and potentiometric analysis procedure of compounds.**
- **Analysis and preparation of Pesticides.**

CEMHCC 8: INORGANIC CHEMISTRY-III **(THEORY)**

SYLLABUS

A. 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(o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Oh and Td). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. The qualitative aspect of Ligand field and MO Theory.

IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Chelate effect, polynuclear complexes, Labile and inert complexes.

B. Transition Elements (10 Lectures):

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, 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)

C. Lanthanoids and Actinoids (6 Lectures):

Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction, separation of lanthanides (ion-exchange method only).

D. Magnetism and Colour (10 Lectures):

Paramagnetism, Diamagnetism, Ferromagnetism and antiferromagnetism. Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (an elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgal diagrams for 3d1-3d9 ions and their spectroscopic ground states; selection rules forelectronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

E. Bioinorganic Chemistry (10 Lectures):

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on the 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), reasons for toxicity, Use of chelating agents in medicine.Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

Reference Books:

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.

CEMHCC 8: INORGANIC CHEMISTRY-III (PRACTICAL)

SYLLABUS

A. Gravimetric Analysis:

i. Estimation of nickel (II) using Dimethylglyoxime (DMG).

ii. Estimation of copper as CuSCN

iii. Estimation of iron as Fe2O3 by precipitating iron as Fe(OH)3.

iv. Estimation of Al (III) by precipitating with oxine and weighing as Al(oxine)3 (aluminium oxinate).

B. 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)

C. Chromatography of metal ions

Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:

i. Ni (II) and Co (II)

ii. Fe (III) and Al (III)

Reference Book:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009.
2. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
3. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

CEMHCC9: ORGANIC CHEMISTRY-III (THEORY)

SYLLABUS

A. Nitrogen Containing Functional Groups (18 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 withHinsberg reagent and nitrous acid. Diazonium Salts: Preparation and their synthetic applications.

B. Polynuclear Hydrocarbons (8 Lectures)

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

C. Heterocyclic Compounds (22 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.

D. Alkaloids (6 Lectures)

Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation. Medicinal importance of Nicotine, Hygrine, Quinine,Morphine,Cocaine,andReserpin

E. Terpenes (6 Lectures)

Occurrence, classification, isoprene rule; synthesis of common terpinoidsCitral, Neral and α-terpineol.

Reference Books:

1. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Finar, I. L. *Organic Chemistry* (*Volume 2: Stereochemistry and the Chemistry of Natural Products*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Acheson, R.M. *Introduction to the Chemistry of Heterocyclic compounds,* John Welly & Sons (1976).
5. Graham Solomons, T.W. *Organic Chemistry,* John Wiley & Sons, Inc.
6. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
7. Kalsi, P. S. *Textbook of Organic Chemistry 1st Ed.*, New Age International (P) Ltd. Pub.

8. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
9. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, PrajatiParakashan (2010).

CEMHCC9: ORGANIC CHEMISTRY-III (PRACTICAL)

SYLLABUS

1. Detection of extra elements.

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

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

Reference Books

1. 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)
2. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, University Press (2000).
3. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
4. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

PAPER CEMHCC10: PHYSICAL CHEMISTRY-IV (THEORY)

SYLLABUS

A. Conductance (20 Lectures)

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. 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.

B. Electrochemistry (28 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/Sb2O3 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).

C. 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:

1. Atkins, P.W & Paula, J.D. *Physical Chemistry*, 10th Ed., Oxford University Press (2014).
2. Castellan, G. W. *Physical Chemistry 4th Ed.,* Narosa (2004).
3. Mortimer, R. G. *Physical Chemistry 3rd Ed.,* Elsevier: NOIDA, UP (2009
4. Barrow, G. M., *Physical Chemistry 5th Ed.,* Tata McGraw Hill: New Delhi (2006).
5. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
6. Rogers, D. W. *Concise Physical Chemistry* Wiley (2010).
7. Silbey, R. J.; Alberty, R. A. &Bawendi, M. G. *Physical Chemistry 4th Ed.,* John Wiley & Sons, Inc. (2005).

PAPER CEMHCC10: PHYSICAL CHEMISTRY-IV (PRACTICAL)

A. Conductometry

I. Determination of cell constant

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

III. Perform the following conductometric titrations:

(i) Strong acid vs. strong base

(ii) Weak acid vs. strong base

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

(iv) Strong acid vs. weak base

B. Potentiometry

I Perform the following potentiometric titrations:

(i) Strong acid vs. strong base

(ii) Weak acid vs. strong base

(iii) Dibasic acid vs. strong base

(iv) Potassium dichromate vs. Mohr's salt

Reference Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.;* McGraw-Hill: New York (2003).
3. Halpern, A. M. &McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York (2003).
4. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
5. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

CEMHSE2: PESTICIDE CHEMISTRY (THEORY)

SYLLABUS

General introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides, structure-activity relationship, synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene,); Organophosphates (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor).

CEMHSE2: PESTICIDE CHEMISTRY (PRACTICAL)

SYLLABUS

1 To calculate acidity/alkalinity in a given sample of pesticide formulations as per BIS specifications.

2 Preparation of simple organophosphates, phosphonates and thiophosphates

Reference Book:

1. Cremlyn, R. *Pesticides. Preparation and Modes of Action*, John Wiley & Sons, New York, 1978.
2. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

CEMEGE4: SECTION I: TRANSITION METAL & COORDINATION CHEMISTRY (THEORY)

SYLLABUS

A. Transition Elements (3*d* series) (12 Lectures)

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

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

B. Coordination Chemistry (8 Lectures)

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

C. Crystal Field Theory (10 Lectures)

Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Spectrochemical series. Comparison of CFSE for *Oh* and *Td* complexes, Tetragonal distortion of octahedral geometry. Jahn-Teller distortion, Square planar coordination.

SECTION II: STATES OF MATTER & CHEMICAL KINETICS (THEORY)

SYLLABUS

A. Kinetic Theory of Gases (8 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 co-efficient of viscosity (qualitative treatment only).

B. Liquids (6 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).

C. Solids (8 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.

D. Chemical Kinetics (8 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:

1. Atkins, P.W & Paula, J.D. *Physical Chemistry*, 10th Ed., Oxford University Press (2014).
2. Castellan, G. W. *Physical Chemistry 4th Ed.,* Narosa (2004).
3. Mortimer, R. G. *Physical Chemistry 3rd Ed.,* Elsevier: NOIDA, UP (2009

4. Barrow, G. M., *Physical Chemistry 5th Ed.*, Tata McGraw Hill: New Delhi (2006).
5. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
6. Rogers, D. W. *Concise Physical Chemistry* Wiley (2010).
7. Silbey, R. J.; Alberty, R. A. &Bawendi, M. G. *Physical Chemistry 4th Ed.*, John Wiley & Sons, Inc. (2005).

CEMEGE 4 LAB: SECTION I: TRANSITION METAL & COORDINATION CHEMISTRY (PRACTICAL)

SYLLABUS

A. QUALITATIVE ANALYSIS: Semi-micro qualitative analysis (using H2S or other methods) of mixtures - not more than four ionic species (two anions and two cations, excluding insoluble salts) out of the following:

Cations : NH^{4+}, Pb^{2+}, Bi^{3+}, Cu^{2+}, Cd^{2+}, Fe^{3+}, Al^{3+}, Co^{2+}, Ni^{2+}, Mn^{2+}, Zn^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, K^{+}.

Anions: CO_3^{2-}, S^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, NO_3^{-}, CH_3COO^{-}, Cl^{-}, Br^{-}, I^{-}, NO_3^{-}, SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, $C_2O_4^{2-}$, F^{-} *(Spot tests should be carried out wherever feasible)*

B. QUANTITATIVE ANALYSIS:

1. Estimate the amount of nickel present in a given solution as bis(dimethylglyoximato) nickel(II) or aluminium as oximate in a given solution gravimetrically.

2. Estimation of (i) Mg2+ or (ii) Zn2+ by complexometric titrations using EDTA.

3. Estimation of total hardness of a given sample of water by complexometric titration.

SECTION II: STATES OF MATTER & CHEMICAL KINETICS (PRACTICAL)

SYLLABUS

(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 a concentration of solute.

(III) Chemical Kinetics

Study the kinetics of the following reactions.

a) Initial rate method: Iodide-persulphate reaction

b) Integrated rate method:

c) Acid hydrolysis of methyl acetate with hydrochloric acid.

d) Saponification of ethyl acetate.

e) Compare the strengths of HCl and H2SO4 by studying kinetics of hydrolysis of methyl acetate

Reference Books:

1. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012. Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
2. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R. Chand & Co.: New Delhi (2011).
3. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
4. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

SEMESTER 5

COURSE STRUCTURE

Paper code	Brief Description	Credit	Marks	Lectures Hours		
CEMHCC11	ORGANIC CHEMISTRY-IV	4	50	60		
	PRACTICAL	2	25	60		
CEMHCC12	PHYSICAL CHEMISTRY-V	4	50	60		
	PRACTICAL	2	25	60		
CEMHDS2	ANALYTICAL METHODS IN CHEMISTRY	4	50	60		
	PRACTICAL	2	25	60		
CEMHDS3	GREEN CHEMISTRY	1	30	20		
	PRACTICAL	1	20	10		
Total		**20**	**275**	**390**		

COURSE OUTCOME

- Knowledge gathering about the nucleic acid, amino acids and peptide/protein, and enzymes and lipids
- Concept about the biosynthesis of important bio-important molecules.
- Structure and importance of pharmaceuticals
- Quantum mechanical treatment
- Learning about the molecular spectroscopy
- Knowledge of analytical methods (optical, thermal, and electroanalyticala)
- Knowledge of separation techniques
- Principle and practices of green chemistry

- Estimation of proteins, enzymes and experiments on oil/fat.
- DNA isolation and characterization processes.
- UV-Vis spectroscopic methods (colorometric estimations)
- Knowledge of chromatographic separation, solvent extraction.
- Food/drink pH estimation
- Experiments of soil testing

PAPER CEMHCC11: ORGANIC CHEMISTRY-IV

SYLLABUSORGANIC CHEMISTRY-IV (THEORY)

A. 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.

B. Amino Acids, Peptides and Proteins (16 Lectures) : Amino acids, Peptides and their classification.α-Amino Acids - Synthesis, ionic properties and reactions. Zwitterions, p*K*a 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.

C. Enzymes (8 lectures): Introduction, classification and characteristics of enzymes. Salient features of the active site of enzymes.Mechanism of enzyme action (taking trypsin as an 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, the phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition). **D.Lipids (8 Lectures):** Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Saponification value, acid value, iodinenumber. Reversion and rancidity.

E. Concept of Energy in Biosystems (7 Lectures): Cells obtain energy by the oxidation of foodstuff (organic molecules). Introduction to metabolism (catabolism, anabolism).ATP: The universal currency of cellular energy, ATP hydrolysis and free energy change. Agents for transfer of electrons in biological redox systems: NAD^+,

FAD.Conversion of food to energy: Outline of catabolic pathways of carbohydrate-glycolysis, fermentation, Krebs cycle.Overview of catabolic pathways of fat and protein.Interrelationship in the metabolic pathways of protein, fat and carbohydrate. The caloric value of food, the standard caloric content of food types.

F. 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:

1. Berg, J.M., Tymoczko, J.L. &Stryer, L. (2006) *Biochemistr*y. 6th Ed. W.H. Freeman and Co.
2. Nelson, D.L., Cox, M.M. &Lehninger, A.L. (2009) *Principles of Biochemistry. IVEdition.* W.H. Freeman and Co.
3. Murray, R.K., Granner, D.K., Mayes, P.A. & Rodwell, V.W. (2009) *Harper'sIllustrated Biochemistry.* XXVIII edition. Lange Medical Books/ McGraw-Hill.

ORGANIC CHEMISTRY-IV (PRACTICAL)

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 fat.

7. Determination of Iodine Number of an oil/ fat.
8. Isolation and characterization of DNA from onion/ cauliflower/peas.

Reference Books:

1. Manual of Biochemistry Workshop, 2012, Department of Chemistry, University of Delhi.
2. Arthur, I. V. *Quantitative Organic Analysis,* Pearson.
3. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

CEMHCC12: PHYSICAL CHEMISTRY V

SYLLABUSPHYSICAL CHEMISTRY V (THEORY)

A. Quantum Chemistry (24 Lectures)

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment), quantization of energy 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 H2. Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, the 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 AH2 type molecules.

B. 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.

C. 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, photostationary states, chemiluminescence.

Reference Books:

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

5. Lowe, J. P. & Peterson, K. *Quantum Chemistry*, Academic Press (2005).

SYLLABUS PHYSICAL CHEMISTRY V (PRACTICAL)

A. UV/Visible spectroscopy

I. 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).

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

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

B. Colourimetry

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

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

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

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

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

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

VII. Analysis of the given vibration-rotation spectrum of HCl(g)

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 PhysicalChemistry 8th Ed.;* McGraw-Hill: New York (2003).

Halpern, A. M. &McBane, G. C. *Experimental Physical Chemistry 3rdEd.;* W.H. Freeman & Co.: New York (2003).

CEMHDSE 1: ANALYTICAL METHODS IN CHEMISTRY

SYLLABUS

ANALYTICAL METHODS IN CHEMISTRY (THEORY)

A. Qualitative and quantitative aspects of analysis (5 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.

B. Optical methods of analysis (25 Lectures):

Origin of spectra, the interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, the 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 the 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.

C. 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.

D. Electroanalytical methods (10 Lectures):

Classification of electroanalytical methods, the basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

E. Separation techniques (15 Lectures):

Solvent extraction: Classification, principle and efficiency of the technique.

Mechanism of extraction: extraction by solvation and chelation.The 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. Chiralchromatographic techniques using chiral columns (GC and HPLC).

Role of computers in instrumental methods of analysis.

Reference Books:

Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.*, Pearson, 2009.

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

Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.

Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.

Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009.

Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Ed.

Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.

Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

SYLLABUS

CEMHDSE1: ANALYTICAL METHODS IN CHEMISTRY (PRACTICAL)

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 Rf values.

(b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify

them on the basis of their Rf values.

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

II. 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 zirconium with amberlit 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 flame 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.

III Spectrophotometry

1.Determination of pKa values of indicator using spectrophotometry.

2. Structural characterization of compounds by infrared spectroscopy.

3. Determination of dissolved oxygen in the 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:

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

CEMHDSE2: GREEN CHEMISTRY

SYLLABUS: GREEM CHEMISTRY (THEORY)

A. Introduction to Green Chemistry (4 Lectures)

What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry.

Limitations/ Obstacles in the pursuit of the goals of Green Chemistry

B. Principles of Green Chemistry and Designing a Chemical synthesis (30 Lectures)

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:

(a) 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, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.

(b) Prevention/ minimization of hazardous/ toxic products reducing toxicity.

risk = (function) hazard × exposure; waste or pollution prevention

hierarchy.

(c) Green solvents–supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents.

(d) Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy.

(e) Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups.

(f) Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis.

(g) Prevention of chemical accidents designing greener processes, inherent safer

design, principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation.

(h) Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

C. Examples of Green Synthesis/ Reactions and some real-world cases (16 Lectures))

(a) Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis)

(b) Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents Diels-Alder reaction and Decarboxylation reaction

(c) Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)

(d) Surfactants for carbon dioxide–replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments.

(e) Designing of Environmentally safe marine antifoulant.

(f) Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.

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

(h) Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils

(i) Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting

D. Future Trends in Green Chemistry (10 Lectures)

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; co crystal-controlled solid-state synthesis (C^2S^3); Green chemistry in sustainable development.

Reference Books:

1. Ahluwalia, V.K. & Kidwai, M.R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).
2. Anastas, P.T. & Warner, J.K.: *Green Chemistry - Theory and Practical*, Oxford University Press (1998).
3. Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
4. Cann, M.C. &Connely, M.E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000).
5. Ryan, M.A. &Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, Washington (2002).
6. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.

SYLLABUS: GREEM CHEMISTRY (PRACTICAL)

1. Safer starting materials

Preparation and characterization of nanoparticles of gold using tea leaves.

2. Using renewable resources

Preparation of biodiesel from vegetable/ waste cooking 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

Triethylamine ion + OH^- → propene + trimethylpropene + waterH_2SO_4/□

(II) 1-propanol ⟶ propene + water

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

3. Use of enzymes as catalysts

Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide.

4. Alternative Green solvents

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

Mechanochemical solvent-free synthesis of azomethines.

6. Alternative sources of energy

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

(ii) Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Reference Books:

1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice,* Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approach to the undergraduate chemistryexperiment*. American Chemical Society, Washington DC (2002).

3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).
4. Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. I.K. *Green Chemistry Experiment:A monograph International Publishing House Pvt Ltd. New Delhi*. Bangalore CISBN978-93-81141-55-7 (2013).
5. Cann, M.C. & Connelly, M. E. *Real-world cases in Green Chemistry*, American Chemical Society (2008).
6. Cann, M. C. & Thomas, P. *Real-world cases in Green Chemistry*, American Chemical Society (2008).
7. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.
8. Pavia, D.L., Lampman, G.M., Kriz, G.S. & Engel, R.G. *Introduction to OrganicLaboratory Techniques: A Microscale and Macro Scale Approach*, W.B.Saunders,1995.

SEMESTER 6

COURSE STRUCTURE

Paper code	Brief Description	Credit	Marks	Lectures Hours		
CEMHCC13	INORGANIC CHEMISTRY-V	4	50	60		
	PRACTICAL	2	25	60		
	Total	6	75	120		
CEMHCC14	ORGANIC CHEMISTRY-V	4	50	60		
	PRACTICAL	2	25	60		
	Total	6	75	120		
CEMHDS3	INDUSTRIAL CHEMICALS AND ENVIRONMENT	4	50	60		
	PRACTICAL	2	25	60		
	Total	6	75	120		
CEMHDS3	GREEN CHEMISTRY	1	30	20		
	PRACTICAL	1	20	10		
	Total	2	50			

COURSE OUTCOME

- Theoretical aspects of inorganic chemical analysis
- Knowledge of organometallics
- Reaction and mechanism of inorganic chemistry
- Organic spectroscopy
- Occurrence and classification of carbohydrates
- Knowledge of Dyes and Pigments
- Industrial chemical and Environment

- Preparation and uses of Biocatalyst
- Industrial metallurgy
- Extraction of caffeine
- Urea-formaldehyde resin
- Identification of organic molecules by IR and NMR.
- Analysis of BOD/OD/COD
- Estimation of SPM in air
- Preparation of antiseptic (Borax etc.)
- Industrial methods of chemical analysis.

PAPER CEMHCC13:INORGANIC CHEMISTRY-IV

SYLLABUS:INORGANIC CHEMISTRY-IV (THEORY)(60 Lectures)

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

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

B. Organometallic Compounds (22Lectures)

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 -acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain the extent of back bonding.

Zeise's salt: Preparation and structure, evidence 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), the concept of multicentre bonding in these compounds. Role of triethylaluminium in

polymerisation of ethene (Ziegler-Natta Catalyst). Species present in ether solution ofGrignard 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.

C. Reaction Kinetics and Mechanism (18Lectures)

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.

D. Catalysis by Organometallic Compounds (10 Lectures)

Study of the following industrial processes and their mechanism:

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:

1. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, 7th Edition, Prentice Hall, 1996.
2. Cotton, F.A.G.; Wilkinson &Gaus, P.L. *Basic Inorganic Chemistry 3rd Ed.;* Wiley India.
3. Huheey, J. E.; Keiter, E.A. &Keiter, R.L. *Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed.*, Harper Collins 1993, Pearson,2006.
4. Sharpe, A.G. *Inorganic Chemistry*, 4th Indian Reprint (Pearson Education) 2005
5. Douglas, B. E.; McDaniel, D.H. & Alexander, J.J. *Concepts and Models in Inorganic Chemistry3rd Ed.*, John Wiley and Sons, NY, 1994.

6. Greenwood, N.N. & Earnshaw, A. *Chemistry of the Elements*, *Elsevier 2nd Ed*, 1997 (Ziegler Natta Catalyst and Equilibria in Grignard Solution).
7. Lee, J.D. *Concise Inorganic Chemistry 5th Ed.,* John Wiley and sons 2008.
8. Powell, P. *Principles of Organometallic Chemistry*, Chapman and Hall, 1988.
9. Shriver, D.D. & P. Atkins, *Inorganic Chemistry 2nd Ed.,* Oxford University Press, 1994.
10. Basolo, F. & Pearson, R. *Mechanisms of Inorganic Reactions: Study of Metal Complexes in Solution 2nd Ed.,* John Wiley & Sons Inc; NY.
11. Purcell, K.F. &Kotz, J.C., *Inorganic Chemistry*, W.B. Saunders Company, 1977.
12. Miessler, G. L. &Tarr, D.A. *Inorganic Chemistry 4th Ed.,* Pearson, 2010.
13. Collman, J. P. *et al. Principles and Applications of Organotransition Metal Chemistry*. Mill Valley, CA: University Science Books, 1987.
14. Crabtree, R. H. *The Organometallic Chemistry of the Transition Metals*. *j* New York, NY: John Wiley, 2000.
15. Spessard, G. O. &Miessler, G.L. *Organometallic Chemistry*. Upper Saddle River, NJ: Prentice-Hall, 1996.

PAPER CEMHCC14: ORGANIC CHEMISTRY-V

SYLLABUS: ORGANIC CHEMISTRY-V (THEORY) (60 Lectures)

A. Organic Spectroscopy (24 Lectures)

General principles Introduction to 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, Interpretation of NMR spectra of simple compounds.

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

B. CarbohydratesOccurance, Classification, and their biological Importance (16 Lectures)

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.

C. Dyes (8Lectures)

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.

D. Polymers (12Lectures)

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:

1. Kalsi, P. S. *Textbook of Organic Chemistry 1st Ed.*, New Age International (P) Ltd. Pub. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).Billmeyer, F. W. *Textbook of Polymer Science*, John Wiley & Sons, Inc. Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. *Polymer Science*, New Age International (P) Ltd. Pub.
2. Finar, I. L. *Organic Chemistry* (*Volume 2: Stereochemistry and the Chemistry of Natural Products*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
4. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
5. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, PrajatiPrakashan (2010).

6. Kemp, W. *Organic Spectroscopy*, Palgrave.
7. Pavia, D. L. *et al. Introduction to Spectroscopy* 5th Ed. Cengage Learning India Edition 2015.

PAPER CEMHCC14

SYLLABUS: ORGANIC CHEMISTRY V-PRACTICAL (60 Lectures)

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, 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:

1. Vogel, A.I. *Quantitative Organic Analysis,* Part 3, Pearson (2012).
2. 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)
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).

CEMHDS3: INDUSTRIAL CHEMICALS AND ENVIRONMENT

SYLLABUS

INDUSTRIAL CHEMICALS AND ENVIRONMENT (THEORY)

A. 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.

B. Industrial Metallurgy (4 Lectures)

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

C. Environment and its segments

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, NOx, H_2S and other foul- smelling gases. Methods of estimation of CO, NOx, SOx 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.

D. Energy & 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.

E. Biocatalysis(6 Lectures)

Introduction to biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

Reference Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
4. S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.
5. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.
6. S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.
7. S.E. Manahan, *Environmental Chemistry*, CRC Press (2005).
8. G.T. Miller, *Environmental Science* 11th edition. Brooks/ Cole (2006).

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

PAPER CEMHDS3: INDUSTRIAL CHEMICALS & ENVIRONMENT PRACTICAL (60 Lectures)

SYLLABUS CEMHDS3 PRACTICAL

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:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. 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.

3. 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.

4. S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi. □

PAPER CEMHDS4: INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS (60 Lectures)

SYLLABUS INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS (THEORY)

A. Introduction to spectroscopic methods of analysis: (4 Lectures)

Recap of the spectroscopic methods covered in detail in the core chemistry syllabus: Treatment of analytical data, including error analysis. Classification of analytical methods and the types of instrumental methods. Consideration of electromagnetic radiation.

B. Molecular spectroscopy (16 Lectures):

Infrared spectroscopy:

Interactions with molecules: absorption and scattering. Means of excitation (light sources), separation of spectrum (wavelength dispersion, time resolution), detection of the signal (heat, differential detection), interpretation of spectrum (qualitative, mixtures, resolution), advantages of Fourier Transform (FTIR). Samples and results expected. Applications: Issues of quality assurance and quality control, Special problems for portable instrumentation and rapid detection.

UV-Visible/ Near IR – emission, absorption, fluorescence and photoaccoustic. Excitation sources (lasers, time resolution), wavelength dispersion (gratings, prisms, interference filters, laser, placement of sample relative to dispersion, resolution), Detection of signal (photocells, photomultipliers, diode arrays, sensitivity and S/N), Single and Double Beam instruments, Interpretation (quantification, mixtures, absorption vs. fluorescence and the use of time, photoaccoustic, fluorescent tags).

C. Separation techniques (16 Lectures)

Chromatography: Gas chromatography, liquid chromatography, supercritical fluids, Importance of column technology (packing, capillaries), Separation based on increasing number of factors (volatility, solubility, interactions with stationary phase, size, electrical

field), Detection: simple vs. specific (gas and liquid), Detection as a means of further analysis (use of tags and coupling to IR and MS), Electrophoresis (plates and capillary) and use with DNA analysis.

Immunoassays and DNA techniques

Mass spectroscopy: Making the gaseous molecule into an ion (electron impact, chemical ionization), Making liquids and solids into ions (electrospray, electrical discharge, laser desorption, fast atom bombardment), Separation of ions on basis of mass to charge ratio, Magnetic, Time of flight, Electric quadrupole. Resolution, time and multiple separations, Detection and interpretation (how this is linked to excitation).

D. Elemental analysis (8 Lectures):

Mass spectrometry (electrical discharges).

Atomic spectroscopy: Atomic absorption, Atomic emission, and Atomic fluorescence.

Excitation and getting sample into gas phase (flames, electrical discharges, plasmas), Wavelength separation and resolution (dependence on technique), Detection of radiation (simultaneous/scanning, signal noise), Interpretation (errors due to molecular and ionic species, matrix effects, other interferences).

E. **NMR spectroscopy (4 Lectures)**: **P**rinciple, Instrumentation, Factors affecting chemical shift, Spin-coupling, Applications

F. **Electroanalytical Methods (4 Lectures): P**otentiometry & Voltammetry

G. Radiochemical Methods (4 Lectures):

H. **X-ray analysis and electron spectroscopy (surface analysis (4 Lectures)**

Reference Books:

1. D.A. Skoog, F.J. Holler & S. Crouch (ISBN 0-495-01201-7) *Principles of Instrumental Analysis*, Cengage Learning India Edition, 2007

2. Willard, Merritt, Dean, Settle, *Instrumental Methods of Analysis*, 7th ed, IBH Book House, New Delhi.
3. Atkins, P.W & Paula, J.D. *Physical Chemistry*, 10th Ed., Oxford University Press (2014).
4. Kakkar, R. *Atomic and Molecular Spectroscopy: Concepts and Applications.* Cambridge University Press, 2015.
5. Castellan, G. W. *Physical Chemistry 4th Ed.,* Narosa (2004).
6. Banwell, C. N. &McCash, E. M. *Fundamentals of Molecular Spectroscopy* 4th Ed. Tata McGraw-Hill: New Delhi (2006).
7. Smith, B.C. *Infrared Spectral Interpretations: A Systematic Approach.* CRC Press, 1998.
8. Moore, W.J., *Physical Chemistry* Orient Blackswan, 1999.

PAPER CEMHDSE4 LAB: INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS PRACTICAL

SYLLABUS: CEMHDSE4 PRACTICAL

ANY TEN EXPERIMENTS TO BE PERFORMED
1. Safety Practices in the Chemistry Laboratory
2. Determination of the isoelectric pH of a protein.
3. Titration curve of an amino acid.
4. Determination of the void volume of a gel filtration column.
5. Determination of a Mixture of Cobalt and Nickel (UV/Vis spec.)
6. Study of Electronic Transitions in Organic Molecules (i.e., acetone in water)
7. IR Absorption Spectra (Study of Aldehydes and Ketones)
8. Determination of Calcium, Iron, and Copper in Food by Atomic Absorption
9. Quantitative Analysis of Mixtures by Gas Chromatography (i.e., chloroform and carbon tetrachloride)
10. Separation of Carbohydrates by HPLC
11. Determination of Caffeine in Beverages by HPLC
12. Potentiometric Titration of a Chloride-Iodide Mixture
13. Cyclic Voltammetry of the Ferrocyanide/ Ferricyanide Couple
14. Nuclear Magnetic Resonance
15. Use of fluorescence to do “presumptive tests” to identify blood or other body fluids.
16. Use of “presumptive tests” for anthrax or cocaine
17. Collection, preservation, and control of blood evidence being used for DNA testing

18. Use of capillary electrophoresis with laser fluorescence detection for nuclear DNA (Y chromosome only or multiple chromosome)
19. Use of sequencing for the analysis of mitochondrial DNA

20. Laboratory analysis to confirm anthrax or cocaine
21. Detection in the field and confirmation in the laboratory of flammable accelerants or explosives
22. Detection of illegal drugs or steroids in athletes
23. Detection of pollutants or illegal dumping
24. Fibre analysis

Reference Books:

1. Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Ed.
2. Willard, H.H., Merritt, L.L., Dean, J. &Settoe, F.A. *Instrumental Methods of Analysis*, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.
3. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).
4. Ghosal, A.; Mahapatra, B.&Nad, A. K. An Advanced Course in Practical Chemistry, Central Book Agency, Kolkata.

COURSE CURRICULUM UNDER CHOICE BASED CREDIT SYSTEM (CBCS)

B.Sc. in GENERAL CHEMISTRY

DEPARTMENT OF CHEMISTRY

PANSKURA BANAMALI COLLEGE

(AN AUTONOMOUS COLLEGE UNDER VIDYASAGAR UNIVERSITY)

PANSKURA R.S., MIDNAPORE (EAST) – 721152

WEST BENGAL

Education in India is largely based on a basic foundation for understanding and realization in everyone's life. Through this, a society can achieve a pioneering model of education in the universe. Rationalization and interpretation of the natural phenomena through the model subject are accounted for by chemical science. The theories have contributed most to the understanding of the subject chemistry and qualitative models of bonding/reactivity clarify and systematize the subject. The ultimate authority consists of observations and measurements, such as identities of the product(s) of a reaction, structure, thermodynamic properties, spectroscopic signature, and measurement of reaction rates.

The curriculum framework for the B. Sc. general chemistry course specifically covers the understanding of knowledge, enhancement of skill, and practices. The value addition in the course structure is primarily considered. The curriculum is more leaned towards self-discovery of concepts. The motivation to lead the global scenario has been met by the course structures. The beneficiaries enhance the universal outlook through the subject. The augmentation of practical theoretical concepts is visualized with substantial coverage of laboratory works and field works. The gathering of knowledge followed by practicing the earned knowledge is the key component of the chemistry course. To meet the curiosity of the students, the practiceisadopted in the final year of the course. The curriculum helps the graduate students to build chemistry-related careers, and higher education in Chemistry and allied subjects. The DSE and SEC courses in the higher class were adopted to include the aptitude for chemistry knowledge in everyday life. The furnished students can move to other disciplines with vast knowledge in chemistry. The student-centric pedagogy is maintained in the B. Sc course in Chemistry. After completing the general course in Chemistry, a student becomes a very potential a critical thinker, psychologist, environmentalist, and moral-ethical scientist.

Aims of the General Degree Courses provide the followings:

(i) A broad spectrum of balanced knowledge in chemistry following the key components of chemical concepts, principles, and theories that relate the natural phenomena.
(ii) The ability and skill in solving both theoretical and practical chemistry problems of the students.
(iii) The elevation of the self-confidence to undertake further studies in chemistry in related areas or multidisciplinary areas that will be helpful for self-employment/entrepreneurship.
(iv) The cognitive development of students in a holistic manner.

(v) A complete dialogue about chemistry, chemical equations and its significance is fostered in this framework, rather than mere theoretical aspects.

(vi) The successful candidates for the national level competitive examinations.

COURSE STRUCTURE B.SC(GEN)

Course component	**No. of Papers**	**Credit / paper**	**Total credit**
Core Course (**CC**) (Discipline specific core - 4 each from three disciplines)	4 + 4 + 4	6	72
Elective Course (**Discipline Specific**) (Two papers from each discipline of choice including paper of interdisciplinary nature)	2 + 2 +2	6	36
Ability Enhancement Compulsory Course (**AECC**) (English – 01, ENVS – 01)	1+1	2 (English) + 4 (ENVS)	6
Skill Enhancement Course (**SEC**)	4	2	8
	24		122

SEMESTER WISE DISTRIBUTION OF COURSES AND CREDITS FOR B.Sc. GENERAL

Course (Credits)	**SEMESTER**						**Total No. of Course**	**Total Credits**
	I	**II**	**III**	**IV**	**V**	**VI**		
DSC(6)	**3**	**3**	**3**	**3**			**12**	**72**
DSE(6)					**3**	**3**	**6**	**36**
AECC (2/4)	**1**	**1**					**2**	**6**
SEC(2)			**1**	**1**	**1**	**1**	**4**	**8**
Total No. of course per Semester	**4**	**4**	**4**	**4**	**4**	**4**	**24**	
Total No. of credits per Semester	**20/22***	**22*/20**	**20**	**20**	**20**	**20**		**122**

***Means if the choice of AECC be ENVS (4 credit)**

SCHEME FOR CHOICE BASED CREDIT SYSTEM IN B.Sc. (GEN) WITH CHEMISTRY

Semester	**Core Course(12)**	**Ability Enhancement Compulsory Course (AECC) (2)**	**Skill Enhancement Course (SEC) (4)**	**Elective: Discipline-Specific (DSE) (6)**
I	**DSC – I**	English / Environmental Science		
II	**DSC – II**	Environmental Science / English		
III	**DSC – III**		**SEC - 1**	
IV	**DSC – IV**		**SEC - 2**	
V			**SEC - 3**	**DSE – I**
VI			**SEC - 4**	**DSE – II**

SEMESTER-I (DSC-I)

Paper code	Brief Description	Credit	Marks	Lectures Hours
DSC-I (Chemistry)	ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS	4	50	60
	PRACTICAL	2	25	60
	Total	**06**	**75**	**120**

PAPER DSC-I CHEMISTRY: ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS

Course outcome:

- **Concept of Atomic model and chemical forces**
- **Ionization potential, electron affinity, and various scales of electro negativity**
- **Hybridization and shape of molecules/ions**
- **Molecular orbital and bonding**
- **Inorganic quantitative analysis**
- **Fundamental of organic chemistry (theoretical and practical aspect)**
- **Concept of stereochemistry**
- **Qualitative analysis of organic compounds**

Section A: **Inorganic Chemistry-1 (30 Lectures)**

(a) Atomic Structure: *Review of Bohr's theory and its limitations, dual behavior of matterand radiation, de Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need for a new approach to Atomic structure.*

What is Quantum mechanics? Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ^2, Schrödinger equation for the hydrogen atom. Radial and angular parts of the hydrogenic wavefunctions (atomic orbitals) and their variations for 1*s*, 2*s*, 2*p*, 3*s*, 3*p*, and 3*d* orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1*s* and 2*s* atomic orbitals. Significance of quantum numbers, orbital angular momentum, and quantum numbers *ml* and *ms*. Shapes of *s*, *p*, and *d* atomic orbitals, nodal planes. Discovery of spin, spin quantum number (*s*) and magnetic spin quantum number (*ms*).

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.

(b) Chemical Bonding and Molecular Structure(30 Lectures)

(i) Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionicbonding, 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.

(ii) Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basisof VSEPR and hybridization 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.

(iii) 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 combinationof 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-1 **(30 Periods)**

(a) 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, andreactivity 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.

(b) 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 Optical isomerism; Enantiomerism, Diastereomerism, and Meso compounds). Threo/erythro; D/L; *cis/trans* nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z Nomenclature (for upto two C=C systems).

(c) Aliphatic Hydrocarbons (12 Lectures)

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

(i) Alkanes:(Upto 5 Carbons).*Preparation:*Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. *Reactions:* Free radical Substitution: Halogenation.

(ii) Alkenes:(Upto 5 Carbons)*Preparation:*Elimination reactions: Dehydration of alkenes anddehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). *Reactions:* cis-addition (alk. $KMnO_4$) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation.

(iii) Alkynes: (Upto 5 Carbons)*Preparation:*Acetylene from $CaC_2$and conversion into higheralkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides.

(d)Reactions:formation of metal acetylides, the addition of bromine and alkaline KMnO4,ozonolysis,and oxidation with hot alk. $KMnO_4$

Reference Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. &Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. *Concepts and Models in InorganicChemistry*, John Wiley & Sons.

4. Huheey, J.E., Keiter, E.A., Keiter, R.L. &Medhi, O.K. *Inorganic Chemistry:Principles of Structure and Reactivity*, Pearson Education India, 2006.
5. Graham Solomon, T.W., Fryhle, C.B. &Dnyder, S.A. *Organic Chemistry*, John Wiley & Sons (2014).
6. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
7. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
8. Eliel, E.L. *Stereochemistry of Carbon Compounds*, Tata McGraw Hill education, 2000.
9. Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
10. Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.
11. Bahl, A. &Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.

CHEMISTRY DSC 1 LAB: ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS

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 upto two extra elements)

2. Separation of mixtures by Chromatography: Measure the Rf 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:

1. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
2. Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
3. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbookof Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
4. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
5. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

SEMESTER- II

Paper code	Brief Description	Credit	Marks	Lectures Hours
DSC-II (Chemistry)	CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY	4	50	60
	PRACTICAL	2	25	60
	Total	**06**	**75**	**120**

Course outcome:

- **Concept of Energetics of Chemical Reactions**
- **The fundamental concept of Chemical Kinetics and Chemical Equilibrium**
- **Fundamental of organic compounds with different functional groups**
- **Gather practical experience in Thermochemistry, pH, and Buffer solution**
- **Hands-on training in purification and Identification of Organic compounds.**

CHEMISTRY-DSC II: CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY

Section A: Physical Chemistry-1 **(30 Lectures)**

(a) Chemical Energetics

Review of thermodynamics and the Laws of Thermodynamics.Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchhoff's equation. Statement of Third Law of thermodynamics and calculation of absolute entropies of substances. **(10 Lectures)**

(b) Chemical Equilibrium:

Free energy changes in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. The distinction between *G* and *G*o, Le Chatelier's principle. Relationships between *Kp, Kc* and *Kx* for reactions involving ideal gases. **(8 Lectures)**

(c)Ionic Equilibria:

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect. Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. **(12 Lectures)**

Section B: Organic Chemistry-2 **(30 Lectures)**

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

(a) Aromatic hydrocarbons (8 Lectures)

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

(b) Alkyl and Aryl Halides (8 Lectures)

(i) Alkyl Halides(Upto 5 Carbons) Types of Nucleophilic Substitution (SN1, SN2 and SNi) reactions. *Preparation:* from alkenes *and* alcohols.*Reactions:* hydrolysis, nitrite & nitro formation, nitrile &isonitrile formation. Williamson's ether synthesis: Elimination vs substitution.

(ii) Aryl HalidesPreparation: (Chloro, Bromo and iodobenzene case): from phenol, Sandmeyer & Gattermann reactions.

Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of the nitro substituent. Benzyne Mechanism: $KNH_2/NH3$ (or $NaNH_2/NH_3$). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

(c)Alcohols, Phenols, and Ethers (Upto 5 Carbons) **(6 Lectures)**

(i) Alcohols:Preparation: Preparation of 1o, 2^o and 3^o alcohols: using a Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.

Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. $KMnO_4$, acidic dichromate, conc. HNO_3). Oppenheimer oxidation *Diols:* (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

(ii) Phenols:(Phenol case) *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.

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

(d) Aldehydes and ketones (aliphatic and aromatic) (6 Lectures): (Formaldehyde, acetaldehyde, acetone and benzaldehyde)

Preparation: from acid chlorides and nitriles.

Reactions – Reaction with HCN, ROH, $NaHSO_3$, NH_2 -G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemmensen reduction and Wolff Kishner reduction. Meerwein-PondorffVerley reduction.

Reference Books:

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

CHEMISTRY DSC II LAB: CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY (60 Classes)

Section A: Physical Chemistry

Thermochemistry

1. Determination of heat capacity of a calorimeter for different volumes.

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

3. Determination of enthalpy of ionization of acetic acid.

4. Determination of integral enthalpy of solution of salts (KNO_3, NH_4Cl).

5. Determination of enthalpy of hydration of copper sulfate.

6. Study of the solubility of benzoic acid in water and determination of *H*.

Ionic equilibria

pH measurements:

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

a) Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

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

Section B: Organic Chemistry

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

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

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

(a) Bromination of Phenol/Aniline

(b) Benzoylation of amines/phenols

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

Reference Books

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

4. Ghosh, S.; Das Sharma, M.; Majumder, D. & Manna, S. Chemistry in Laboratory, Santra Publication, Kolkata (2021).

SEMESTER III

Paper code	Brief Description	Credit	Marks	Lectures Hours
DSC-III (Chemistry)	SOLUTIONS, PHASE EQUILIBRIA, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL GROUP ORGANIC CHEMISTRY-II	4	50	60
	PRACTICAL	2	25	60
SEC-I (Chemistry)	**PHARMACEUTICAL CHEMISTRY**	1	30	60
	PRACTICAL	1	20	60
Total		**08**	**125**	**240**

COURSE OUTCOME

- **Knowledge of solution chemistry, phase equilibrium, conductance, and electrochemistry**
- **Preparations and reactions of carboxylic acid & anhydride, esters, and amines.**
- **Gain the practical knowledge of partition coefficient, potentiometry, and equilibrium constant**
- **Hands-on training chromatography separation of amino acids**
- **Determination of protein concentration**
- **Differentiation of reducing and nonreducing sugar**
- **Qualitative organic analysis of organic functional groups**

PAPER: DSC-IIICHEMISTRY: SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE,ELECTROCHEMISTRY & FUNCTIONAL GROUP ORGANIC CHEMISTRY-II (Theory: 60 Lectures)

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

(a) Solutions (8 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.

(b) Phase Equilibrium (8 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 sulfur) and two-component systems involving eutectics, congruent and incongruent melting points (lead-silver, $FeCl_3$-H_2O and Na-K only).

(c)**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 the degree of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid-base).

(d) 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: *G*, *H*, and *S* 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.

(a) 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 theirinterconversion.

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

(b) Amines and Diazonium Salts (6 Lectures)

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

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

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.

(c)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, complexationwith 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) & C-activating groups and Merrifield solid-phase synthesis.

(d) Carbohydrates (8 Lectures): Classification, and General Properties, Glucose and Fructose (open-chainand cyclic structure), Determination of configuration of monosaccharides, the absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disaccharides (sucrose,

cellobiose, maltose, lactose) and polysaccharides (starch and cellulose) excluding their structure elucidation.

Reference Books:

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

DSC IIICHEMISTRY LAB: SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL ORGANIC CHEMISTRY-II (60 Lectures)

Section A: Physical Chemistry

(a) Distribution

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

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

$Cu^{2+}(aq) + xNH_2(aq) \quad [Cu(NH_3)x]^{2+}$

(b) Phase equilibria

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

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

(c)Conductance

I. Determination of cell constant

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

III. Perform the following conductometric titrations:

i. Strong acid vs. strong base

ii. Weak acid vs. strong base

(d) Potentiometry

Perform the following potentiometric titrations:

i. Strong acid vs. strong base

ii. Weak acid vs. strong base

iii. Potassium dichromate vs. Mohr's salt

Section B: Organic Chemistry

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

II.

1. Separation of amino acids by paper chromatography
2. Determination of the concentration of glycine solution by formylation method.
4. Differentiation between a reducing and a nonreducing sugar.

Reference Books:

1. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbookof Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

3. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
4. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry*, Universities Press.

SEMESTER-IV

Paper code	Brief Description	Credit	Marks	Lectures Hours
DSC-IV (Chemistry)	TRANSITION METAL AND COORDINATION CHEMISTRY, STATE OF MATTER & CHEMICAL KINETICS	4	50	60
	PRACTICAL	2	25	60
SEC2	PESTICIDE CHEMISTRY	4	50	60
	PRACTICAL	2	25	60
	Total	**14**	**150**	**240**

Course outcome:

- **Primary Concept of Transition elements, Lanthanides, and actinides**
- **The persuasion of the structures and bonding of the coordination compounds**
- **Fundamentals of theories of gas, liquid, and solid.**
- **Experience in practicals onsemi-micro qualitative analysis of inorganic radicals.**
- **Gain practical knowledge of gravimetric analysis. Hands-on practices of viscosity, surface tension, and kinetics of reactions**

PAPER DSC-IV CHEMISTRY:TRANSITION METAL & COORDINATION CHEMISTRY, STATES OFMATTER & CHEMICAL KINETICS (60 Lectures)

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

A. Transition Elements (3*d* series) (12 Lectures)

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

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

B. Coordination Chemistry (8 Lectures)

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

C. Crystal Field Theory (10 Lectures)

Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Spectrochemical series. Comparison of CFSE for *Oh* and *Td* complexes, Tetragonal distortion of octahedral geometry. Jahn-Teller distortion, Square planar coordination.

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

A. Kinetic Theory of Gases (8 Lectures)

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

Deviation of real gases from ideal behavior, 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. The viscosity of gases and the effect of temperature and pressure on the coefficient of viscosity (qualitative treatment only).

B. Liquids (6 lectures)

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

C. Solids (8 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.

D. Chemical Kinetics (8 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). The half-life of a reaction. General methods for the determination of the 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).

DSC 4 CHEMISTRY LAB: TRANSITION METAL & COORDINATION CHEMISTRY, STATES OF MATTER& CHEMICAL KINETICS (60 Classes)

Section A: Inorganic Chemistry

Semi-micro qualitative analysis (using H2S or other methods) of mixtures - not more than four ionic species (two anions and two cations, excluding insoluble salts) out of the following:

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

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

(Spot tests should be carried out wherever feasible)

1. Estimate the amount of nickel present in a given solution as bis(dimethylglyoximato) nickel(II) or aluminum as oximate in a given solution gravimetrically.
2. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
3. Estimation of total hardness of a given sample of water by complexometric titration.

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 a concentration of solute.

(III) Chemical Kinetics

Study the kinetics of the following reactions.

3. Initial rate method: Iodide-persulphate reaction

4. Integrated rate method:

c. Acid hydrolysis of methyl acetate with hydrochloric acid.

d. Saponification of ethyl acetate.

e. Compare the strengths of HCl and H_2SO_4 by studying the kinetics of hydrolysis of methyl acetate

Reference Books:

1. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
2. Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
3. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).

PAPER DSC4 SEC-II: PESTICIDE CHEMISTRY (30 Lectures)

Theory:

General introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides, structure-activity relationship, synthesis, and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene,); Organophosphates (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor).

Practical:

1 To calculate acidity/alkalinity in a given sample of pesticide formulations as per BIS specifications.

2 Preparation of simple organophosphates, phosphonates and thiophosphates

Reference Book:

1. Cremlyn, R. *Pesticides. Preparation and Modes of Action*, John Wiley & Sons, New York, 1978.

SEMESTER V

Course Name	Course code	Title of the Course	Credit	Marks
Skill Enhancement Course	DSCSEC 3	SEC 3T: CHEMISTRY OF COSMETICS & PERFUMES SEC 3P: Lab	2	50
Discipline Specific Electives -1	DSCDSE-1	DSE-1T: ANALYTICAL METHODS IN CHEMISTRY DSE-1P: Lab	6	75
		Total	8	125

COURSE OUTCOME:

- **Skill enhancement course increases the professional skill and techniques for handling the intimate chemicals like cosmetics, talc and perfumes that are used in everyday life.**
- **Discipline-specific course outcomesstrengthen the learning and operating skills of various instruments and methodology in the field of interdisciplinary subjects.**

PAPER DSC SEC-III :CHEMISTRY OF COSMETICS & PERFUMES(30 Lectures)

Theory:

A general study includesthe 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 flavors.

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:

1. E. Stocchi: *Industrial Chemistry*, Vol -I, Ellis Horwood Ltd. UK.
2. P.C. Jain, M. Jain: *Engineering Chemistry*, Dhanpat Rai & Sons, Delhi.
3. Sharma, B.K. & Gaur, H. *Industrial Chemistry*, Goel Publishing House, Meerut (1996).

DSCDSE 1:ANALYTICAL METHODS IN CHEMISTRY(Theory-04, Practicals-02)

(Theory: 60 Lectures)

PAPER-DSCDSE 1: ANALYTICAL METHODS IN CHEMISTRY (THEORY)

A. Qualitative and quantitative aspects of analysis (5 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.

B. Optical methods of analysis (25 Lectures):

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

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

(ii) Basic principles of quantitative analysis: estimation of metal ions from aqueous solution,geometrical isomers, keto-enol tautomers. Determination of the 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.

(iii) 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 levels of metal ions from water samples.

C. Thermal methods of analysis (5 Lectures):

Theory of thermogravimetry (TG), the basic principle of instrumentation.

Techniques for quantitative estimation of Ca and Mg from their mixture.

D. Electroanalytical methods (10 Lectures):

Classification of electroanalytical methods, the basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

E. Separation techniques (15 Lectures):

Solvent extraction: Classification, principle, and efficiency of the technique.

Mechanism of extraction: extraction by solvation and chelation.

The 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. Chiralchromatographic techniques using chiral columns (GC and HPLC).

Role of computers in instrumental methods of analysis.

Reference Books:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6thEd.,* Pearson, 2009.

2. Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.
5. Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009.
6. Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Ed.
7. Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.
8. Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

PAPER-DSCDSE 1 LAB: ANALYTICAL METHODS IN CHEMISTRY (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 Rf values.

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

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

II. 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 zirconium 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 flame photometric techniques.

5. Analysis of soil:

(i) Determination of pH of soil.

(ii) Total soluble salt

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

(iv) 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.

III Spectrophotometry

1. Determination of pKa values of indicator using spectrophotometry.

2. Structural characterization of compounds by infrared spectroscopy.

3. Determination of dissolved oxygen in the 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:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6thEd.*, Pearson, 2009.
2. Willard, H.H. *et al*.: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, D.C. *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.
5. Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. *Principles of Instrumental Analysis*,

Cengage Learning India Edition.

7. Mikes, O. &Chalmes, R.A. *Laboratory Handbook of Chromatographic & AlliedMethods*, Elles Harwood Ltd. London.
8. Ditts, R.V. *Analytical Chemistry: Methods of separation.* Van Nostrand, New York, 1974.

SEMESTER VI

Course Name	Course code	Title of the Course	Credit	Marks
Skill Enhancement Course	DSCSEC 4	SEC 3T: FUEL CHEMISTRY SEC 3P: Lab	2	50
Discipline Specific Electives -1	DSCDSE-1	DSE-1T: GREEN CHEMISTRY DSE-1P: Lab	6	75
		Total	8	125

COURSE OUTCOME

- **Skill enhancement course increases the professional skill and techniques in renewable energy and energy harvesting technology for the learners.**
- **Discipline-specific course outcome relies on the practices of environmentally and eco-friendly processes for the sustainable development of the world avoiding the long practices of hazardous methods in chemistry.**
- **Knowledge of green chemistry and adoption of green technology in Chemistry**

PAPER: DSC SEC-IV FUEL CHEMISTRY (Credits: 02) (30 Lectures)

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

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

(ii) 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, biogas, 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.

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

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

Reference Books:

1. Stocchi, E. *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK (1990).
2. Jain, P.C. & Jain, M. *Engineering Chemistry* Dhanpat Rai & Sons, Delhi.
3. Sharma, B.K. & Gaur, H. *Industrial Chemistry*, Goel Publishing House, Meerut (1996).

PAPER-DSC DSE 2:CHEMISTRY-DSE: GREEN CHEMISTRY

(Credits: Theory-04, Practicals-02) Theory: 60 Lectures

A. Introduction to Green Chemistry (4 Lectures)

What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry

B. Principles of Green Chemistry and Designing a Chemical synthesis (30 Lectures)

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:

i) 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, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.

ii) Prevention/ minimization of hazardous/ toxic products reducing toxicity. risk = (function) hazard × exposure; waste or pollution prevention hierarchy.

iii) Green solvents– supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents

iv) Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy

v) Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups.

vi) Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis, and photocatalysis.

Prevention of chemical accidents designing greener processes, inherently safer design, the principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation. Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

C. Examples of Green Synthesis/ Reactions and some real-world cases (16 Lectures)

1. Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis)

2. Microwave-assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave-assisted reactions in organic solvents Diels-Alder reaction and Decarboxylation reaction

3. Ultrasound-assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)

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

5. Designing Environmentally safe marine antifoulant.

6. Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.

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

8. Healthier fats and oil by Green Chemistry: Enzymatic interesterification for production of no Trans-Fats and Oils

9. Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting

D. Future Trends in Green Chemistry

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; co crystal-controlled solid-state synthesis (C2S3); Green chemistry in sustainable development.

(10 Lectures)

Reference Books:

1. Ahluwalia, V.K. & Kidwai, M.R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).
2. Anastas, P.T. & Warner, J.K.: *Green Chemistry - Theory and Practical*, Oxford University Press (1998).
3. Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
4. Cann, M.C. &Connely, M.E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000).
5. Ryan, M.A. &Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, Washington (2002).
6. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.

CHEMISTRY PRACTICAL-DSE LAB: GREEN CHEMISTRY (60 Lectures)

1. Safer starting materials

Preparation and characterization of nanoparticles of gold using tea leaves.

2. Using renewable resources

Preparation of biodiesel from vegetable/ waste cooking 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

H_2SO_4/(II) 1-propanol propene + water

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 uses Thiamine Hydrochloride as a catalyst instead of cyanide.

5. Alternative Green solvents

Extraction of D-limonene from orange peel using liquid CO2 prepared from dry ice.

Mechanochemical solvent-free synthesis of azomethines

6. Alternative sources of energy

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

Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Reference Books:

1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice,* Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approach to the undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).
3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).
4. 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).
5. Cann, M.C. & Connelly, M. E. *Real-world cases in Green Chemistry*, American Chemical Society (2008).
6. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.
7. Pavia, D.L., Lampman, G.M., Kriz, G.S. & Engel, R.G. *Introduction to Organic Laboratory Techniques: A Microscale and Macro Scale Approach,* W.B.Saunders, 1995.