Chemistry (Programme) CBCS Syllabus

1 Scheme for CBCS Curriculum for Pass (Programme) Course

1.1 Credit Distribution across Courses

Course Type		Total Papers	Credits Theory + Practical
Core Courses	4 papers each from 3 disciplines of choice	12	12*4=48 12*2=24
Elective Courses	2 papers each from 3 discipline of choice including interdisciplinary papers	6	12*2=24 6*2=12
Ability Enhancement Language Courses		2	2*2=4
Skill Enhancement Courses		4	4*2=8
Total		24	120

* All Pass courses will have 3 subjects/disciplines of interest. Student will select 4 core courses each from discipline of choice including

Chemistry as one of the disciplines. The details for core courses available in Chemistry have been detailed in Section 2 of this document

* Student may also chose Skill Enhancement courses in Chemistry. The details for skill enhancement courses available in Chemistry have been detailed in Section 3 of this document

* Student will select 2 core courses each from discipline of choice including Chemistry as one of the disciplines. The details for elective courses available in Chemistry have been detailed in Section 4 of this document

1.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course-I	English communication / Environmental Science	2
	Core course-I	Core Course 1A from Chemistry	4
	Core course-I Practical	Core Course 1A Practical from Chemistry	2
	Core course-II	Core Course 2A from other chosen discipline	4
	Core course-II Practical	Core Course 2A Practical from other chosen discipline	2
	Core course - III	Core Course 3A from other chosen discipline	4
	Core course - III Practical	Core Course 3A Practical from other chosen discipline	2
II	Ability Enhancement Compulsory Course-II	English communication / Environmental Science	2
	Core course-IV	Core Course 1B from Chemistry	4
	Core course-IV Practical	Core Course 1B Practical from Chemistry	2
	Core course-V	Core Course 2B from other chosen discipline	4
	Core course- V Practical	Core Course 2B Practical from other chosen discipline	2
	Core course - VI	Core Course 3B from other chosen discipline	4
	Core course - VI Practical	Core Course 3B Practical from other chosen discipline	2
III	Core course VII	Core Course 1C from Chemistry	4
	Core course-VII Practical	Core Course 1C Practical from Chemistry	2
	Core course - VIII	Core Course 2C from other chosen discipline	4
	Core course - VIII Practical	Core Course 2C Practical from other chosen discipline	2
	Core course-IX	Core Course 3C from other chosen discipline	4
	Core course-IX Practical	Core Course 3C Practical from other chosen discipline	2
	Skill Enhancement Course-1	TBD	2

IV	Core course-X	Core Course 1D from Chemistry	4
	Core course – X Practical	Core Course 1D Practical from Chemistry	2
	Core course-XI	Core Course 2D from other chosen discipline	4
	Core course-XI Practical	Core Course 2D Practical from other chosen discipline	2
	Core course-XII	Core Course 3D from other chosen discipline	4
	Core course-XII Practical	Core Course 3D Practical from other chosen discipline	2
	Skill Enhancement Course-2	TBD	2
V	Skill Enhancement Course – 3	TBD	2
	Discipline Specific Elective 1	DSE 1A from Chemistry	4
	Discipline Specific Elective 1 Practical	DSE 1A Practical from Chemistry	2
	Discipline Specific Elective 2	DSE 2A from other chosen discipline	4
	Discipline Specific Elective 2 Practical	DSE 2A Practical from other chosen discipline	2
	Discipline Specific Elective 3	DSE 3A from other chosen discipline	4
	Discipline Specific Elective 3 Practical	DSE 3A Practical from other chosen discipline	2

VI	Skill Enhancement Course – 4	TBD	2
	Discipline Specific Elective 4	DSE 1B from Chemistry	4
	Discipline Specific Elective 4 Practical	DSE 1B Practical from Chemistry	2
	Discipline Specific Elective 5	DSE 2B from other chosen discipline	4
	Discipline Specific Elective 5 Practical	DSE 2B Practical from other chosen discipline	2
	Discipline Specific Elective 6	DSE 3B from other chosen discipline	4
	Discipline Specific Elective 6 Practical	DSE 3B Practical from other chosen discipline	2

2. Core Subjects Syllabus

2.1 C1A-T1 – Fundamentals of Organic Chemistry & Aliphatic Hydrocarbons; Atomic Structure, Chemical Periodicity, Acids and Bases, Redox Reactions s

4 Credits

Organic Chemistry

1. Fundamentals of Organic Chemistry

Electronic displacements: inductive effect, resonance and hyperconjugation; cleavage of bonds: homolytic and heterolytic; structure of organic molecules on the basis of VBT; nucleophiles electrophiles; reactive intermediates: carbocations, carbanions and free radicals.

2. Stereochemistry

Different types of isomerism; geometrical and optical isomerism; concept of chirality and optical activity (up to two carbon atoms); asymmetric carbon atom; elements of symmetry (plane and centre); interconversion of Fischer and Newman representations; enantiomerism and diastereomerism, meso compounds; threo and erythro, D and L, cis and trans nomenclature; CIP Rules: R/S (upto 2 chiral carbon atoms) and E/Z nomenclature.

3. Nucleophilic Substitution and Elimination Reactions

Nucleophilic substitutions: SN1 and SN2 reactions; eliminations: E1 and E2 reactions (elementary mechanistic aspects); Saytzeff and Hofmann eliminations; elimination vs substitution.

4. Aliphatic Hydrocarbons

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

5. Alkanes: (up to 5 Carbons). Preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: mechanism for free radical substitution: halogenation.

6. Alkenes: (up to 5 Carbons). Preparation: elimination reactions: dehydration of alcohols and dehydrohalogenation of alkyl halides; cis alkenes (partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alkaline $KMnO_4$) and trans-addition (bromine) with mechanism, addition of HX [Markownikoff's (with mechanism) and anti-Markownikoff's addition], hydration, ozonolysis, oxymercuration-demercuration and hydroboration-oxidation reaction.

7. Alkynes: (up to 5 Carbons). Preparation: acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides.

8. Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$.

Inorganic Chemistry

1. Atomic Structure

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

2. Chemical Periodicity

Classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and f-block elements. Positions of hydrogen and noble gases. Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group-wise variation of above properties in respect of s- and p- block elements.

3. Acids and bases

Brönsted–Lowry concept, conjugate acids and bases, relative strengths of acids and bases, effects of substituent and solvent, differentiating and levelling solvents. Lewis acid-base concept, classification of Lewis acids and bases, Lux-Flood concept and solvent system concept. Hard and soft acids and bases (HSAB concept), applications of HSAB process.

4. Redox reactions

Balancing of equations by oxidation number and ion-electron method oxidimetry and reductimetry.

Reference Books

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

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

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

► Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education Ind

► Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.

► Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.

► Madan, R. L. Organic Chemistry, S. Chand & Sons.

► Wade, L. G., Singh, M. S., Organic Chemistry.

► Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

► Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

► Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.

► Sen Gupta, Subrata. Basic Stereochemistry of Organic molecules.

► Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.

► Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.

2.2 C1A- P1 – **Fundamentals of Organic Chemistry & Aliphatic Hydrocarbons; Atomic Structure, Chemical Periodicity, Acids and Bases, Redox Reactions** Lab **2 Credits**

Organic Chemistry

Qualitative Analysis of Single Solid Organic Compound(s)

1. Detection of special elements (N, Cl, and S) in organic compounds.
2. Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH)

3. Detection of functional groups: Aromatic-NO_2, Aromatic -NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), -OH (phenolic) in solid organic compounds.
Experiments 1 to 3 with unknown (at least 6) solid samples containing not more than two of the above type of functional groups should be done.

Inorganic Chemistry

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 $Na_2S_2O_3$.

Reference Books

► University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
► Das, S. C., Chakraborty, S. B., Practical Chemistry.
► Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
► Ghosal, Mahapatra & Nad, An Advanced course in practical Chemistry, New Central Book Agency
► Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
► Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.
► Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.

2.3 C1B- T2 – Bonding & Molecular Structure, Comparative Study of P-Block Elements; States of Matter & Chemical Kinetics

4 Credits

Inorganic Chemistry

1. Chemical Bonding and Molecular Structure
a. Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.
b. Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.
c. Concept of resonance and resonating structures in various inorganic and organic compounds.
d. 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.

2. Comparative study of p-block elements

a. Group trends in electronic configuration, modification of pure elements, common oxidation states, inert pair effect, and their important compounds in respect of the following groups of elements:

i. B-Al-Ga-In-Tl

ii. C-Si-Ge-Sn-Pb

iii. N-P-As-Sb-Bi

iv. O-S-Se-Te

v. F-Cl-Br-I

Physical Chemistry

1. Kinetic Theory of Gases and Real gases

a. Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Rate of effusion

b. Nature of distribution of velocities, Maxwell's distribution of speed and kinetic energy; Average velocity, root mean square velocity and most probable velocity; Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

c. Deviation of gases from ideal behavior; compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behaviour; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states

d. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only)

2. Liquids

a. Definition of Surface tension, its dimension and principle of its determination using stalagmometer; Viscosity of a liquid and principle of determination of coefficient of viscosity using Ostwald viscometer; Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only)

3. Solids

a. Forms of solids, crystal systems, unit cells, Bravais lattice types, Symmetry elements; Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices; Miller indices of different planes and interplanar distance, Bragg's law; Structures of NaCl, KCl and CsCl (qualitative treatment only); Defects in crystals; Glasses and liquid crystals.

4. Chemical Kinetics

a. Introduction of rate law, Order and molecularity; Extent of reaction; rate constants; Rates of First, second and nth order reactions and their Differential and integrated forms (with derivation); Pseudo first order reactions; Determination of order of a reaction by half-life and differential method; Opposing reactions, consecutive reactions and parallel reactions

b. Temperature dependence of rate constant; Arrhenius equation, energy of activation; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment)

Reference Books

► Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
► Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
► Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
► Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
► Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
► Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers
► Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.
► Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
► Mandal, A. K. Degree Physical and General Chemistry Sarat Book House
► Pahari, S., Physical Chemistry New Central Book Agency
► Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency
► Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
► Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
► Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
► Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008.

2.4 C1B- P2 – Bonding & Molecular Structure, Comparative Study of P-Block Elements; States of Matter & Chemical Kinetics

2 Credits

Inorganic Chemistry

Qualitative semi-micro analysis of mixtures containing three radicals. Emphasis should be given to the understanding of the chemistry of different reactions.

Acid Radicals: Cl^-, Br^-, I^-, NO_2^-, NO_3^-, S^{2-}, SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, H_3BO_3.

Basic Radicals: Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cr^{3+}, Mn^{2+}, Fe^{3+}, Ni^{2+}, Cu^{2+}, NH_4^+.

Physical Chemistry

1. 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

2. Viscosity measurement (use of organic solvents excluded)

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

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

3. Study the kinetics of the following reactions

a. Initial rate method: Iodide-persulphate reaction

b. Integrated rate method:

i. Acid hydrolysis of methyl acetate with hydrochloric acid

ii. Compare the strengths of HCl and H2SO4 by studying kinetics of hydrolysis of methyl acetate

Reference Books

► University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
► Palit, S.R., Practical Physical Chemistry Science Book Agency
► Mukherjee, N.G., Selected Experiments in Physical Chemistry J. N. Ghose & Sons
► Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall
► Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
► Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

2.5 C 1C-T3 – Organic Chemistry-II; Chemical Energetics, Chemical Equilibrium & Conductance **4 Credits**

Organic Chemistry

Functional group app roach for the following reactions (preparations & reactions) to be studied in context to their structures.

1. Aromatic Hydrocarbons

Benzene: Preparation: from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid. Reactions: electrophilic substitution (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), sulphonation and Friedel-Craft's reaction (alkylation and acylation) (up to 4 carbons on benzene); side chain oxidation of alkyl benzenes (up to 4 carbons on benzene).

2. Organometallic Compounds

Introduction; Grignard reagents: Preparations (from alkyl and aryl halide); concept of umpolung; Reformatsky reaction.

3. Aryl Halides

Preparation: (chloro-, bromo- and iodobenzene): from phenol, Sandmeyer reactions. Reactions (Chlorobenzene): nucleophilic aromatic substitution (replacement by –OH group) and effect of nitro substituent (activated nucleophilic substitution).

4. Alcohols, Phenols and Ethers

a. Alcohols: (up to 5 Carbons). Preparation: 1°-, 2°- and 3°- alcohols: using Grignard reagent, reduction of aldehydes, ketones, carboxylic acid and esters; Reactions: With sodium, HX (Lucas test), oxidation (alkaline $KMnO_4$, acidic dichromate, concentrated HNO_3); Oppenauer oxidation;

b. Diols: Preparation (with OsO4); pinacol- pinacolone rearrangement (with mechanism) (with symmetrical diols only).

c. Phenols: Preparation: cumene hydroperoxide method, from diazonium salts; acidic nature of phenols; Reactions: electrophilic substitution: nitration and halogenations; Reimer -Tiemann reaction, Houben–Hoesch condensation, Schotten –Baumann reaction, Fries rearrangement and Claisen rearrangement.

d. Ethers: Preparation: Williamson's ether synthesis; Reaction: cleavage of ethers with HI.

5. Carbonyl Compounds

Aldehydes and Ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde): Preparation: from acid chlorides, from nitriles and from Grignard reagents; general

properties of aldehydes and ketones; Reactions: with HCN, ROH, $NaHSO_3$, NH_2-G derivatives and with Tollens' and Fehling's reagents; iodoform test; aldol
condensation (with mechanism); Cannizzaro reaction (with mechanism), Wittig reaction, benzoin condensation; Clemmensen reduction, Wolff- Kishner reduction and Meerwein-Pondorff- Verley (MPV) reduction.

Physical Chemistry

1. Chemical Energetics

a. Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics; Concept of heat, work, internal energy 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

b. Standard states; Heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; Laws of thermochemistry; bond energy, bond dissociation energy and resonance energy from thermochemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions; Adiabatic flame temperature; explosion temperature

c. Statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine, refrigerator and efficiency; Entropy change of systems and surroundings for various processes and transformations; Auxiliary state functions (G and A) and Criteria for spontaneity and equilibrium.

2. Chemical Equilibrium:

a. Thermodynamic conditions for equilibrium, degree of advancement; Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Definitions of KP, KC and KX and relation among them; van't Hoff's reaction isotherm, isobar and isochore from different standard states; Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant with addition to inert gas; Le Chatelier's principle.

3. Conductance

a. Conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Ostwald's dilution law; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations (acid-base)

b. Transport Number and principles of Hittorf's and Moving-boundary method

Reference Books

► Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).

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

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

► Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).

► Ekambaram, S. General Chemistry, Pearson.

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

► Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers

► Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.

► Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
► Mandal, A. K. Degree Physical and General Chemistry Sarat Book House
► Pahari, S., Physical Chemistry New Central Book Agency
► Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency
► Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
► Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
► Madan, R. L. Organic Chemistry, S. Chand & Sons.
► Wade, L. G., Singh, M. S., Organic Chemistry, Pearson.
► Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
► Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
► Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.

2.6 C 1C- P3– Organic Chemistry-II; Chemical Energetics, Chemical Equilibrium & Conductance Laby **2 Credits**

Organic Chemistry

Identification of a pure organic compound

1. Solid compounds: oxalic acid, tartaric acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.
2. Liquid Compounds: methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene

Physical Chemistry

(Minimum five experiments to complete)

Thermochemistry

1. Determination of heat capacity of 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 enthalpy of hydration of copper sulphate

Conductance

a. Determination of dissociation constant of a weak acid (cell constant, equivalent conductance are also determined)

b. Perform the following conductometric titrations: (Any one)

i. Strong acid vs. strong base

ii. Weak acid vs. strong base

Reference Books

► University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
► Palit, S.R., Practical Physical Chemistry Science Book Agency
► Mukherjee, N.G., Selected Experiments in Physical Chemistry J. N. Ghose & Sons

► Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall
► Bhattacharyya, R. C, A Manual of Practical Chemistry.
► Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.
► Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.

2.7 C 1D-T4 – Functional Group Organic Chemistry; Inorganic Chemistry: Coordination Chemistry and Transition Metal Chemistry, Analytical and Industrial Chemistry. 4 Credits

Organic Chemistry

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

1. Carboxylic Acids and Their Derivatives

a. Carboxylic acids (aliphatic and aromatic): strength of organic acids: comparative study with emphasis on factors affecting pK values; Preparation: acidic and alkaline hydrolysis of esters (BAc2 and AAC2 mechanisms only) and from Grignard reagents; Reactions: Hell - Vohlard - Zelinsky reaction and Claisen condensation; Perkin reaction.

b. Carboxylic acid derivatives (aliphatic): (up to 5 carbons). Preparation: acid chlorides, anhydrides, asters and amides from acids; Reactions: Comparative study of nucleophilicity of acyl derivatives; interconversion among acid derivatives.

2. Amines and Diazonium Salts

a. Amines (aliphatic and aromatic): strength of organic bases; Preparation: from alkyl halides, Gabriel's phthalimide synthesis, Hofmann degradation, by reduction of nitro compounds; Reactions: with HNO2 (distinction of 1°-, 2°- and 3°- amines), Schotten – Baumann reaction , Diazo coupling reaction (with mechanism).

b. Diazonium salts: Preparation: from aromatic amines; Reactions: conversion to benzene, phenol, benzoic acid and nitrobenzene.

c. Nitro compounds (aromatic): reduction under different conditions (acidic, neutral and alkaline).

3. Amino Acids and Carbohydrates

a. Amino Acids: Preparations (glycine and alanine only): Strecker synthesis, Gabriel's phthalimide synthesis; general properties; zwitterion, isoelectric point; ninhydrin reaction.

b. Carbohydrates: classification and general properties; glucose and fructose: constitution; osazone formation; oxidation-reduction reactions; epimers of
glucose (definition and example only); cyclic structures of glucose (determination of ring-size excluded); ascending (Kiliani –Fischer method) and descending (Ruff's and Wohl's methods) in monosaccharides (aldoses only); mutarotation.

Inorganic Chemistry

1. Transition Elements (3d series)

a. 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.

b. Lanthanoids and actinoids: Electronic configurations, oxidation states, colour, magnetic properties, lanthanide contraction, separation of lanthanides (ion exchange method only).
2. Coordination Chemistry
a. Werner's coordination theory, 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.
b. Drawbacks of VBT. IUPAC system of nomenclature.
3. Crystal Field Theory
a. 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.
b. Jahn-Teller distortion, Square planar coordination.

Analytical and Industrial Chemistry

1. Error Analysis and Computer Applications
a. Error analysis: accuracy and precision of quantitative analysis, determinate, indeterminate, systematic and random errors; methods of least squares and standard deviations.
2. Industrial Chemistry
a. Fuels: classification of fuel; heating values; origin of coal, carbonization of coal, coal gas, producer gas, water gas, coal based chemicals; origin and composition of petroleum, petroleum refining, cracking, knocking, octane number, antiknock compounds, kerosene, liquefied petroleum gas (LPG), liquefied natural gas (LNG); petrochemicals (C1 to C3 compounds and their uses).
b. Fertilizers: manufacture of ammonia and ammonium salts, urea, superphosphate, biofertilizers.
c. Cement: portland cement: composition and setting of cement, white cement.

Reference Books

► Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
► Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
► Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
► Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008.
► Gangopadhyay, P. K. Application Oriented Chemistry, Book Syndicate.
► Mondal, A. K & Mondal, S. Degree Applied Chemistry, Sreedhar Publications.
► Banerjee, S. P. A Text Book of Analytical Chemistry, The New Book Stall
► Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
► Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
► Madan, R. L. Organic Chemistry, S. Chand & Sons.
► Ekambaram, S. General Chemistry, Pearson.
► Wade, L. G., Singh, M. S., Organic Chemistry.
► Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).

► Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt.Ltd. (Pearson Education).
► Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.
► Gangopadhyay, P. K. Application Oriented Chemistry, Book Syndicate.

2.8 C1D-P4 – Functional Group Organic Chemistry;Inorganic Chemistry: Coordination Chemistry and Transition Metal Chemistry$_{ra}$

2 Credits

Organic Chemistry

1. The following reactions are to be performed, noting the yield of the crude product:
a. Nitration of aromatic compounds
b. Condensation reactions
c. Hydrolysis of amides/imides
d. Acetylation of aromatic amines
e. Benzoylation of aromatic amines
2. Purification of the crude product is to be made by crystallisation from water/alcohol.

Inorganic Chemistry

1. Gravimetric and Complexometric estimation of metals ions:
a. Estimate the amount of nickel present in a given solution as bis(dimethylglyoximato) nickel(II) or aluminium as oxine in a given solution gravimetrically.
b. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
2. Preparation of any two of the following complexes and measurement of their conductivity:
a. tetraamminecarbonatocobalt (III) nitrate
b. tetraamminecopper (II) sulphate
c. potassium trioxalatoferrate (III) trihydrate
3. Compare the conductance of the complexes with that of M/1000 solution of NaCl, $MgCl_2$ and $LiCl_3$.

Reference Books

► Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
► Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
► University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003.
► Das, S. C., Chakraborty, S. B., Practical Chemistry.
► Ghosal, Mahapatra & Nad, An Advanced Course in Practical Chemistry, New Central Book Agency.

3. Skill Enhancement Subjects SyllabusIT Skills for Chemists 2 Credits

3.1 SEC T1 – Basic Analytical Chemistry Basic Analytical Chemistry 2 Credits

Introduction

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

Analysis of soil

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

1. Determination of pH of soil samples.
2. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

Analysis of water

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

1. Determination of pH, acidity and alkalinity of a water sample.
2. Determination of dissolved oxygen (DO) of a water sample.

Analysis of food products

Nutritional value of foods, idea about food processing and food preservations and adulteration.

1. Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.
2. Analysis of preservatives and colouring matter.

Chromatography

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

1. Paper chromatographic separation of mixture of metal ion (Fe3+ and Al3+).
2. To compare paint samples by TLC method.

Ion-exchange

1. Column, ion-exchange chromatography etc.
2. Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

Analysis of cosmetics

Major and minor constituents and their function

1. Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.
2. Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration

Suggested Applications (Any one)

1. To study the use of phenolphthalein in trap cases.
2. To analyse arson accelerants.
3. To carry out analysis of gasoline.

Suggested Instrumental demonstrations

1. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.
2. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.
3. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drinks

Reference Books

► Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. Instrumental Methods of Analysis, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.

► Skoog, D.A., Holler, F.J. & Crouch, S. Principles of Instrumental Analysis, Cengage Learning India Edition, 2007.

► Skoog, D.A.; West, D.M. & Holler, F.J. Analytical Chemistry: An Introduction 6th

► Ed., Saunders College Publishing, Fort Worth, Philadelphia (1994).

► Harris, D. C. Quantitative Chemical Analysis, 9th ed. Macmillan Education, 2016.

► Dean, J. A. Analytical Chemistry Handbook, McGraw Hill, 2004.

► Day, R. A. & Underwood, A. L. Quantitative Analysis, Prentice Hall of India, 1992.

► Freifelder, D.M. Physical Biochemistry 2nd Ed., W.H. Freeman & Co., N.Y. USA (1982).

► Cooper, T.G. The Tools of Biochemistry, John Wiley & Sons, N.Y. USA. 16 (1977).

► Vogel, A. I. Vogel's Qualitative Inorganic Analysis 7th Ed., Prentice Hall, 1996.

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

► Robinson, J.W. Undergraduate Instrumental Analysis 5th Ed., Marcel Dekker, Inc., New York (1995).

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

3.2 SEC T2 – Pharmaceuticals Chemistry P**harmaceuticals Chemistry 2 Credits**

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).

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.

Hands On Practical

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

Reference Books

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

3.3 SEC T3 – IT Skills for Chemists IT Skills for Chemists 2 Credits

Mathematics

1. Fundamentals, mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs.
2. Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities.
3. Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).
4. Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms).Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).
5. Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).
6. Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

Computer programming

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.
BASIC programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

Hands On Practical

1. Introductory writing activities: Introduction to word processor and structure drawing (ChemSketch) software. Incorporating chemical structures, chemical equations, and expressions from chemistry (e.g. Maxwell-Boltzmann distribution law, Bragg's law, van der Waals equation, etc.) into word processing documents.
2. Handling numeric data: Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and

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

3. Numeric modelling: Simulation of pH metric titration curves. Excel functions LINEST and Least Squares. Numerical curve fitting, linear regression (rate constants from concentration- time data, molar extinction coefficients from absorbance data), numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pKa of weak acid), integration (e.g. entropy/enthalpy change from heat capacity data).

4. Statistical analysis: Gaussian distribution and Errors in measurements and their effect on data sets. Descriptive statistics using Excel. Statistical significance testing: The t test. The F test.

5. Presentation: Presentation graphics

Reference Books

► McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).

► Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).

► Steiner, E. The Chemical Maths Book Oxford University Press (1996).

► Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007).

► Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.

► Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.

► Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).

► Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

3.4 SEC T4 – Analytical Clinical Biochemistry **Analytical Clinical 2 Credits**

Review of Concepts from Core Course

1. Carbohydrates: Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle. Isolation and characterization of polysachharides.

2. Proteins: Classification, biological importance; Primary and secondary and tertiary structures of proteins: α-helix and β- pleated sheets, Isolation, characterization, denaturation of proteins.

3. Enzymes: Nomenclature, Characteristics (mention of Ribozymes), and Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Introduction to Biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

4. Lipids: Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications. Lipoproteins. Properties, functions and biochemical functions of steroid hormones. Biochemistry of peptide hormones.

5. Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy.

6. Enzymes: Nomenclature, classification, effect of pH, temperature on enzyme activity, enzyme inhibition.

Biochemistry of disease: A diagnostic approach by blood/ urine analysis.

1. Blood: Composition and functions of blood, blood coagulation. Blood collection and preservation of samples. Anaemia, Regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.
2. Urine: Collection and preservation of samples. Formation of urine. Composition and estimation of constituents of normal and pathological urine.

Hands On Practical

Identification and estimation of the following:
1. Carbohydrates – qualitative and quantitative.
2. Lipids – qualitative.
3. Determination of the iodine number of oil.
4. Determination of the saponification number of oil.
5. Determination of cholesterol using Liebermann- Burchard reaction.
6. Proteins – qualitative.
7. Isolation of protein.
8. Determination of protein by the Biuret reaction.
9. Determination of nucleic acids

Reference Books

► Cooper, T.G. Tool of Biochemistry. Wiley-Blackwell (1977).
► Wilson, K. & Walker, J. Practical Biochemistry. Cambridge University Press (2009).
► Varley, H., Gowenlock, A.H & Bell, M.: Practical Clinical Biochemistry, Heinemann, London (1980).
► Devlin, T.M., Textbook of Biochemistry with Clinical Correlations, John Wiley & Sons, 2010.
► Berg, J.M., Tymoczko, J.L. & Stryer, L. Biochemistry, W.H. Freeman, 2002.
► Talwar, G.P. & Srivastava, M. Textbook of Biochemistry and Human Biology, 3rd Ed. PHI Learning.
► Nelson, D.L. & Cox, M.M. Lehninger Principles of Biochemistry, W.H. Freeman, 2013.
► O. Mikes, R.A. Chalmers: Laboratory Handbook of Chromatographic Methods, D. Van Nostrand & Co., 1961.

4. Discipline Specific Electives Syllabus

4.1 DSE T1 – Green Chemistry **Green Chemistry** **4 Credits**

Introduction to Green Chemistry

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

Principles of Green Chemistry and Designing a Chemical synthesis

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

1. 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.
2. Prevention/ minimization of hazardous/ toxic products reducing toxicity.
risk = (function) hazard × exposure; waste or pollution prevention hierarchy.
3. 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.
4. Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy.
5. Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups.
6. 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.
7. 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.
8. Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

Examples of Green Synthesis/ Reactions and some real world cases

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 CO2 for precision cleaning and dry cleaning of garments.
5. Designing of 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 (poly lactic acid) made from corn.
8. Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils
9. Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting

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.

Reference Book

► Anastas, P.T. & Warner, J.K.: Green Chemistry - Theory and Practical, Oxford University Press (1998).
► Matlack, A.S. Introduction to Green Chemistry, Marcel Dekker (2001).
► Cann, M.C. & Connely, M.E. Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).
► Ryan, M.A. & Tinnesand, M. Introduction to Green Chemistry, American Chemical Society, Washington (2002).
► Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010.

4.2 DSE P1 – Green Chemistry Lab **Green Chemistry** **2 Credits**

Safer starting materials

1. Preparation and characterization of nanoparticles of gold using tea leaves.

Using renewable resources

1. Preparation of biodiesel from vegetable/ waste cooking oil.

Avoiding waste

Principle of atom economy.

1. Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.
2. Preparation of propene by two methods can be studied

a. Triethylamine ion + OH- → propene + trimethylpropene + water

b. 1-propanol→propene + water in presence of heat and H_2SO_4

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

Use of enzymes as catalysts

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

Alternative Green solvents

Extraction of D-limonene from orange peel using liquid CO2 prepared form dry ice. Mechanochemical solvent free synthesis of azomethines

Alternative sources of energy

1. Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).
2. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Reference Books

► Anastas, P.T & Warner, J.C. Green Chemistry: Theory and Practice, Oxford University Press (1998).
► Kirchoff, M. & Ryan, M.A. Greener approaches to undergraduate chemistry experiment. American Chemical Society, Washington DC (2002).
► Ryan, M.A. Introduction to Green Chemistry, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).

► Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. I.K. Green Chemistry Experiment: A monograph International Publishing House Pvt Ltd. New Delhi. Bangalore CISBN 978-93-81141-55-7 (2013).
► Cann, M.C. & Connelly, M. E. Real world cases in Green Chemistry, American Chemical Society (2008).
► Cann, M. C. & Thomas, P. Real world cases in Green Chemistry, American Chemical Society (2008).
► Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010.
► 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.

4.3 DSE T2 – Polymer Chemistry **Polymer Chemistr** **4 Credits**

Introduction and history of polymeric materials

Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers. Functionality and its importance

Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bi-functional systems, Poly-functional systems. Kinetics of Polymerization

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

Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point. Nature and structure of polymers

Structure Property relationships. Determination of molecular weight of polymers

(Mn, Mw, etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

Glass transition temperature (Tg) and determination of Tg

Free volume theory, WLF equation, Factors affecting glass transition temperature (Tg).

Polymer Solution

Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

Properties of Polymer

(Physical, thermal, Flow & Mechanical Properties)

Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers,

Polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes,

Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphide polypyrrole, polythiophene)].

Reference Book

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

4.4 DSE P2 – Polymer Chemistry Lab **Polymer Chemistry** **2 Credits**

Polymer Synthesis

1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).
2. Purification of monomer
3. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bis-isobutylonitrile (AIBN)
4. Preparation of nylon 66/6
5. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
6. Redox polymerization of acrylamide
7. Precipitation polymerization of acrylonitrile
8. Preparation of urea-formaldehyde resin
9. Preparations of novalac resin/ resold resin.
10. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry:
a. Polyacrylamide-aq.$NaNO_2$ solution
b. (Poly vinyl proplylidine (PVP) in water
2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).
4. Testing of mechanical properties of polymers.
5. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer analysis

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method
2. Instrumental Techniques
3. IR studies of polymers
4. DSC analysis of polymers
5. Preparation of polyacrylamide and its electrophoresis

Reference Books

► M.P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed., Oxford University Press, 1999.

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