Netaji Subhas Open University
Honours in Chemistry
Programme Code - HCH

Programme Objectives

The objective of the programme is to provide facility for lifelong education in Chemistry to intending learners. The Bachelor Degree in Chemistry is designed accordingly so that the learners at the end are able to secure practical training skills required for a profession with chemistry background or Industry. The syllabus for Chemistry at undergraduate level using the Choice Based Credit system has been framed in compliance with model syllabus given by UGC. The programme consists of fourteen (14) Core Courses (CC), four (04) Discipline Specific Elective [DSE] courses, two (02) Skill Enhancement Courses [SEC], two (02) Ability Enhancement Compulsory Courses [AECC] and four (04) Generic Elective Courses [GEC].

The main objective of framing this new syllabus is to give the learners a holistic understanding of the subject giving substantial weightage to both the core content and techniques used in Chemistry. The syllabus has given equal importance to the three main branches of Chemistry-Physical, Inorganic and Organic.

The ultimate goal of the programme is to equip learners with the necessary skills and competencies to progress in their academic career as well as it will help them to secure a jobs. Keeping in mind and in tune with the changing nature of the subject, adequate emphasis has been given on new techniques and understanding of the subject. The fresher and existing employees can take the advantage of ODL system to enhance their skills and competency in this particular field without disturbing their work schedule.

Expected Programme Outcome

After successful completion of this Bachelor's Degree Programme, students may increase their knowledge in the field of Chemistry as well as in the practical laboratory skills and it will help them to increase competencies to seek jobs as well as progress in their further academic career. The following are the expected programme outcomes-

- The learners will have a firm foundation in the fundamentals and application of current chemical and scientific theories including those in Inorganic, Organic and Physical Chemistry.
- Learners will be able to execute chemical experiments, compile raw data and provide conclusions.
- They will be able to design and carry out scientific experiments as well as accurately record and analyse the results of such experiments.
- Learners will appreciate the central role of chemistry in our society and use this as a basis for ethical behaviour in issues facing chemists including an understanding of safe handling of chemicals, environmental issues and key issues facing our society in energy, health and medicine.
- Achieve the skills required to succeed in graduate school, professional school and the chemical industry like cement industries, Agro product, Paint industries, Rubber industries, Petrochemical industries, Food processing industries, Fertilizer industries etc.
- Learners will be able to explain why chemistry is an integral activity for addressing social, economic, and environmental problems.

Programme Structure

	SEM	CODE	Course Name	Theory/ Prac.	Credit	Study Hours	TEE Full Marks	Assignment Full Marks	Total Marks	Pass Marks 30%
1st Year	I	CC-CH-01	Practical Paper–I	Practical	6	180	70	00	70	21
		CC-CH-02	Practical Paper- II	Practical	6	180	70	00	70	21
		AE-BG-11 /AE-EG-12	Bengali /English*	Theory	2	60	50	20	70	21
		#GEC-01	Refer Table Below	Theory	6	180	50	20	70	21
	II	CC-CH-03	Inorganic Chemistry –I	Theory	6	180	50	20	70	21
		CC-CH-04	Organic Chemistry-I	Theory	6	180	50	20	70	21
		AE-ES-21	Environmental Studies	Theory	2	60	50	20	70	21

		#GEC - 02	Refer Table Below	Theory	6	180	50	20	70	21
2nd Year	**III**	**CC-CH-05**	Practical Paper–III	Practical	6	180	70	00	70	21
		CC-CH-06	Practical Paper–IV	Practical	6	180	70	00	70	21
		CC-CH-07	Inorganic Chemistry -II	Theory	6	180	50	20	70	21
		SE-CH-11	Intellectual Property Rights (IPR)	Theory	2	60	50	10	60	18
		#GEC- 03	Refer Table Below	Theory	6	180	50	20	70	21
	IV	**CC-CH-08**	Organic Chemistry-II	Theory	6	180	50	20	70	21
		CC-CH-09	Physical Chemistry-I	Theory	6	180	50	20	70	21
		CC-CH-10	Physical Chemistry-II	Theory	6	180	50	20	70	21
		SE-CH-21	Pharmaceutical Chemistry	Theory	2	60	50	10	60	18
		#GEC- 04	Refer Table Below	Theory	6	180	50	20	70	18
3rd Year	**V**	**CC-CH-11**	Practical Paper–V	Practical	6	180	70	00	70	21
		CC-CH-12	Inorganic Chemistry-III	Theory	6	180	50	20	70	21
		DS-CH-11	Polymer Chemistry	Theory	6	180	50	20	70	21
		DS-CH-21	Practical Paper– VI	Practical	6	180	70	00	70	21
		CC-CH-13	Organic Chemistry-III	Theory	6	180	50	20	70	21
	VI	**CC-CH-14**	Physical Chemistry-III	Theory	6	180	50	20	70	21
		DS-CH-31	Analytical Chemistry and Green Chemistry	Theory	6	180	50	20	70	21

		DS-CH-41	Inorganic Materials of Industrial Importance And Green Chemistry	Theory	6	180	50	20	70	21
	TOTAL				140				1800	

*Learners will choose any one from AE-BG-11: Bengali or AE-EG-12: English as Ability Enhancement Compulsory Course 1

#Any one from each group (column) to be selected from the following

Option of GE courses for HCH

Subject	SEM-I: GE-01	SEM-II: GE-02	SEM-III: GE-03	SEM-IV: GE-04
Mathematics	**GE-MT-11**: Statistical Techniques	**GE-MT-21**: Dynamical Systems	**GE-MT-31**: Applications of Algebra	**GE-MT-41**: Modelling and Simulation
Physics	**GE-PH-11**: Mechanics	**GE-PH-21**: Thermal Physics	**GE-PH-31**: Waves and Optics	**GE-PH-41**: Elements of Modern Physics
Botany	**GE-BT-11**: Biodiversity	**GE-BT-21**: Plant Ecology and Taxonomy	**GE-BT-31**: Plant Anatomy and Embryology	**GE-BT-41**: Economic Botany and Plant Biotechnology

Examination System Per Semester

Term-End Examination Dec (Odd Sem July-Dec)

Semester I	Semester III	Semester V
CC1 CC2 AECC1 (Beng/ Eng) GEC1 Total credit: 20	CC5 CC6 CC7 SEC1 GEC3 Total credit: 26	CC11 CC12 DSEC1 DSEC2 Total credit: 24

Term-End Examination June (Even Sem Jan-June)

Semester II	Semester IV	Semester VI
CC3 CC4 AECC2 (ENVS) GEC2 Total credit: 20	CC8 CC9 CC10 SEC2 GEC4 Total credit: 26	CC13 CC14 DSEC3 DSEC4 Total credit: 24

Assignment will be conducted through digital platform on MCQ

Objective and Expected Outcome for Each Course

Course Code	Course Objectives	Expected Outcomes
Core Courses		
CC-CH-01 Practical Paper–I	The main objectives of this course are • To understand basic chemistry laboratory procedures • To gain expertise on quantitative inorganic analysis • To understand the application of different titrimetric methods at preliminary level • To learn measurement of boiling and melting points of organic molecules • To learn specific tests for identification of organic compounds • To gain preliminary knowledge of organic synthesis	The learner is expected to understand • Basic principles and titrimetric procedures used in quantitative analysis of inorganic metal ions • The process of preparation, separation and specific identification of organic compounds
CC-CH-02 Practical Paper-II	The objectives are • To understand the distinction between qualitative and quantitative chemical analysis • To learn about estimation of ions from a mixture of inorganic compounds • To know about preparation of inorganic metal complexes • To be able to perform qualitative analysis of single solid organic compound • To estimate the amount of certain organic compound in a solution	The learner is expected to understand • the Complexometric titration and inorganic preparation • the qualitative and quantitative analysis of organic compounds
CC-CH-03 Inorganic Chemistry –I	The objective of the course is to gain an understanding of • the fundamental properties of atoms, molecules, and the various states of matter with an emphasis on the particulate nature of matter • fundamental atomic structure and the periodicity of elements in the periodic table • simple quantum mechanical treatments of atoms and molecules • how to predict molecular geometries of selected molecular species • the fundamentals of acid/base reactions, redox reactions and precipitation reactions	The learner is expected • to understand structure of atom • learn about chemical periodicity • conceptualize redox reactions and acid base chemistry

	• the fundamentals of acid/base equilibria, including pH calculations, buffer behaviour, acid/base titrations, and their relationship to electrophiles and nucleophiles	
CC-CH-04 Organic Chemistry-I	The objective of the course is to gain an understanding of • the hybridization and geometry of atoms and the three-dimensional structure of organic molecules • the reactivity and stability of an organic molecule based on structure, including conformation and stereochemistry • an understanding of nucleophiles, electrophiles, electronegativity, and resonance • the prediction of mechanisms for organic reactions	The learner is expected to • Learn the bonding and physical properties of organic compound, • Learn the general Treatment of Reaction Mechanism • Learn the concept of stereochemistry
CC-CH-05 Practical Paper–III	The objective of the course is to gain an understanding of • common laboratory techniques including viscosity measurement, surface tension measurement, pH measurement, acid/base titrations, calorimetry etc. • the use of the techniques mentioned above to solve chemical problems • how to design and perform experiments to determine the rate, order, and activation energy of chemical reactions by varying concentrations and/or temperature	The learner is expected to • Learn the use of techniques used for physical chemistry experiments • Experiment on the properties and kinetics of physical parameters
CC-CH-06 Practical Paper–IV	The main objectives of the course are • to develop chemical analytical skills in inorganic qualitative analysis • understand the principles of chromatographic separation methods and perform experiments using them • learn the basic identification of organic compounds using IR, UV and NMR techniques	The learner is expected to • Experiment on quantitative and qualitative inorganic analysis • learn about chromatography • spectroscopic analysis of organic compounds
CC-CH-07 Inorganic Chemistry -II	The main objectives of the course are • To develop the ability to correlate the chemical and physical properties of elements and their compounds with their positions in the periodic table	The learner is expected to • Learn about chemical bonding • Basic principles of coordination chemistry

	• Discuss the d-orbital splitting pattern in different geometries like octahedral, tetrahedral etc. • Learn to Calculate magnetic moment & crystal field stabilization energy of metal complexes • Able to explain high spin and low spin complexes & formation of metal complexes in solution	
CC-CH-08 Organic Chemistry-II	The objective of the course is to gain an understanding of • the fundamentals of electronic structure and bonding in conjugated and aromatic systems • reactivity patterns of conjugated and aromatic molecules • the fundamental electronic structure and bonding in carbonyl compounds • the reactivity of carbonyl compounds with both hard and soft nucleophiles (carboxylic acids, aldehydes and ketones) • the kinetics and thermodynamics of carbonyl condensation reactions	The learner is expected to • Learn about substitution and elimination reactions • Learn about carbonyl and related compounds, organometallics and rearrangements reactions
CC-CH-09 Physical Chemistry-I	The objective of the course is to gain an understanding of • the application of mathematical tools to calculate thermodynamic and kinetic properties • the relationship between microscopic properties of molecules with macroscopic thermodynamic observables • the derivation of rate equations from mechanistic data • the use of simple models for predictive understanding of physical phenomena associated to chemical thermodynamics and kinetics • the limitations and uses of models for the solution of applied problems involving chemical thermodynamic and kinetic	The learner is expected to • Explore kinetic theory of gases, thermodynamics chemical kinetics and transport processes
CC-CH-10 Physical Chemistry-II	The main objectives of the course are • To familiarise with the basic ideas and concepts of quantum chemistry	The learner is expected to • Learn the applications of thermodynamics, foundation of quantum mechanics and

	• To explore the early experiments which led the foundations of quantum chemistry • Learn the application of thermodynamics in different systems especially in open systems • To learn about phase, phase diagrams etc. • To study the electrical properties of molecules	electrical properties of molecules
CC-CH-11 Practical Paper– V	The main objectives of the course are • To get familiar with instrumental techniques used in physical chemistry experiments • To explore the use of spectrophotometric analysis in determination of several chemical parameters • To learn about the processes involved in polymer synthesis • To get hands on knowledge of polymer characterisation and analysis	The learner is expected to • Learn the basic instrumental techniques of physical chemistry experiments • Get idea about synthesis, characterisation and analysis of polymers
CC-CH-12 Inorganic Chemistry-III	The main objectives of the course are • To Categorize the point group of molecules, Identify character tables • To understand the chemistry of d and f block elements • To know the fundamentals of organometallic and bio-inorganic chemistry	The learner is expected to • Explore the chemistry of d- and f-block elements • Understand Molecular symmetry and Point group • Learn about bioinorganic chemistry and organometallic
CC-CH-13 Organic Chemistry-III	The objective of the course is to • Give an idea about the logic of organic synthesis • Learn about carbocyclic and heterocyclic chemistry • Understand organic spectroscopy • Study the chemistry of carbohydrates and biomolecules	The learner is expected to • Learn about chemical synthesis, carbocycle and heterocycle and organic spectroscopy, pericyclic reactions and biomolecules
CC-CH-14 Physical Chemistry-III	The objective of the course is to • Gain deeper knowledge of quantum chemistry • Learn about the processes occurring at surfaces and interfaces • Know the principles of molecular spectroscopy	The learner is expected to • Explain quantum chemistry • Discover surface phenomenon,

	• Introduce photochemistry	• Learn about basics of molecular spectroscopy and photochemistry
Discipline Specific Elective Courses		
DS-CH-11 Polymer Chemistry	The objective of the course is to • Introduce polymer chemistry • Understand mechanisms associated with chain-growth and step-growth polymerization • To Study the, methods of measuring the molecular weight, polymerization kinetics and Copolymerization and polymer processing technologies • To study mechanical properties and applications of polymers	The learner is expected to • Develop specific skills, competencies, and thought processes sufficient to support further study or work in this field of Polymer Chemistry • Understand about the basics of polymer and the differences between crystalline melting temperature and glass transition temperature, as well as the effect of kinetics on both
DS-CH-21 Practical Paper– VI	The objective of the course is to • Introduce the basic principles of green chemistry • Use green chemistry in simple laboratory experiments • Understand and perform synthesis based on green chemistry principles • Perform experiments on analytical chemistry including separation, solvent extraction etc.	The learner is expected to • Learn how to use green chemistry in chemistry laboratory • Learn how to perform separation of chemical compounds • Able to estimate materials based on analytical chemistry principles
DS-CH-31 Analytical Chemistry and Green Chemistry	The objective of the course is to • Learn the qualitative and quantitative methods of chemical analysis • Understand the use of optical spectroscopy in analytical chemistry • Learn about thermal and electroanalytical methods • Understand the principles of green chemistry in details and designing chemical synthesis based on these principles	The learner is expected to • Gain knowledge about different methods used in analytical chemistry • Understand and design chemical processes based on green chemistry priciples
DS-CH-41 Inorganic Materials of Industrial Importance and Green Chemistry	The objective of the course is to • Explore chemicals processes used in industries • Understand the chemistry behind the silicate industry, fertilizers, alloys, batteries etc.	The learner is expected to • Gain knowledge about industrial chemical processes and how they are useful in everyday life

Skill Enhancement Courses		
SE-CH-11 Intellectual Property Rights (IPR)	The objective of the course is to • Introduce intellectual property rights and their importance • Learn about Indian and International Intellectual Property Rights • Learn about various facets of IPR • Understand the prospects and uses of IPR	The learner is expected to • Get a grasp on intellectual property rights • Use the rights in a proper manner
SE-CH-21 Pharmaceutical Chemistry	The objective of the course is to • Learn about pharmaceutical chemistry basics • Explore the basics drug discovery and design techniques • Learn about selected drug molecules and chemicals with medicinal uses	The learner is expected to • Know about drugs, their interaction and discovery • Know about chemicals with potential medicinal properties
Generic Elective Courses		
GE-CH-11 Basic Physical Chemistry	The objective of the course is to • Get a basic idea about chemical thermodynamics • Understand chemical and ionic equilibrium • Study basic physical chemistry of liquids and solids	The learner is expected to • Explain chemical energetics • Discuss basic formulations of chemical equilibrium • Explain the properties of liquids and solids
GE-CH-21 Basic Inorganic Chemistry	The objective of the course is to • Understand quantum mechanical model of atom, quantum numbers, electronic configuration etc. • Understand the underlying concepts of covalent and ionic bonds and attractive forces as well as theories (VBT, MOT) explaining those • Deduce the geometry of molecules using radius ratio rules & VSEPR theory • Learn about structure, bonding, preparation, properties and uses of compounds of s- and p- block Elements	The learner is expected to • Explain atomic structure • Explain periodic properties • Understand molecular structures • Learn about s and p block elements
GE-CH-31 Basic Organic Chemistry	The objective of the course is to • Get idea on aromaticity and its influence in stabilizing ring compounds and ions.	The learner is expected to • Familiarise with the reactions of organic compounds

	• Gain idea on syntheses, properties and reactions of various classes of aliphatic and aromatic hydrocarbons • Learn about chemical reactivity of different functional groups	• Understand aromaticity and its influence on chemical properties
GE-CH-41 Application Oriented Chemistry	The objective of the course is to • Understand the usefulness of chemistry in everyday life • Learn about several chemical processes involved in industries	The learner is expected to • Explain and understand the practical applications of chemistry

Detailed Syllabus

Semester-I

Core Course-1 (Practical) Credit-6, Full Marks-70

Course Code: CC-CH-01, Course Title: Practical Paper-I

Block –I (Inorganic Chemistry)

Unit-1: Estimation of ions

i. Method of preparation of standard solutions of titrants
ii. Estimation of carbonate and hydroxide present together in a mixture
iii. Estimation of carbonate and bicarbonate present together in a mixture
iv. Estimation of Fe(II) using $K_2Cr_2O_7$ solution
v. Estimation of Fe(III) using $K_2Cr_2O_7$ and $KMnO_4$ solution
vi. Estimation of Ca^{2+} using $KMnO_4$ solution
vii. Estimation of Cu^{2+} iodometrically
viii. Estimation of Cr^{3+} using $K_2Cr_2O_7$ solution

Block –II (Organic Chemistry)

Unit-2: Separation:

Based upon solubility, by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. $NaHCO_3$, etc., of components of a binary solid mixture; purification of any one of the separated components by crystallization and determination of its melting point. The composition of the mixture may be of the following types: Benzoic acid/*p*-Toluidine; *p*-Nitrobenzoic acid/*p*- Aminobenzoic acid; *p*-Nitrotolune/*p*-Anisidine; etc.

Unit-3: Determination of boiling point:

Determination of boiling point of common organic liquid compounds e.g., ethanol, cyclohexane, chloroform, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide, etc. [Boiling point of the chosen organic compounds should preferably be less than 160 ^{o}C]

Unit-4: Identification of a Pure Organic Compound by chemical test(s):

Solid compounds: oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, cane sugar, benzoic acid and salicylic acid.

Liquid Compounds: formic acid, acetic acid, methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene.

Unit-5: Organic Preparations:

Preparation, purification (only by recrystallization or sublimation), Melting point check and percentage yield calculation of organic compounds using the following reactions:

i. Nitration of aromatic compounds
ii. Condensation reactions
iii. Hydrolysis of amides/imides/esters
iv. Acetylation of phenols/aromatic amines
v. Benzoylation of phenols/aromatic amines
vi. Side chain oxidation of aromatic compounds
vii. Diazo coupling reactions of aromatic amines
viii. Bromination of anilides using green approach (Bromate-Bromide method)
ix. Redox reaction including solid-phase method
x. Green 'multi-component-coupling' reaction
xi. Selective reduction of m-dinitrobenzene to *m*-nitroaniline

Semester-I

Core Course-2 (Practical) Credit-6, Full Marks-70

Course Code: CC-CH-02, Course Title: Practical Paper-II

Block –I (Inorganic Chemistry)

Unit-1: Estimation of ions

i. Estimation of Fe(II) and Fe(III) in a given mixture using $K_2Cr_2O_7$ solution
ii. Estimation of Fe(III) and Cu(II) in a given mixture using $K_2Cr_2O_7$ solution
iii. Estimation of Cr(VI) and Mn(II) in a given mixture using $K_2Cr_2O_7$ solution
iv. Estimation of Fe(III) and Cr(VI) in a given mixture using $K_2Cr_2O_7$ solution
v. Estimation of Fe(II) and Mn(II) in a given mixture using $KMnO_4$ solution
vi. Estimation of Fe(III) and Ca(II) in a given mixture using $KMnO_4$ solution

Unit-2: Complexometric Titration

i. Estimation of Hardness of water
ii. Estimation of Ca(II) and Mg(II) in a mixture
iii. Estimation of Zn(II) and Mg(II) in a mixture

Unit-3: Inorganic Preparation

i. Mohr's salt
ii. Potassium tris(oxalato)chromate(III) trihydrate
iii. Tetraamminecarbonatocobalt(III) nitrate
iv. Potassiumbis(oxalato)cuprate(II) dihydrate
v. Tris(ethylenediamine)nickel(II) chloride

Block –II (Organic Chemistry)

Unit-4: Qualitative Analysis of Single Solid Organic Compounds

i. Detection of special elements (N, S, Cl, Br) by Lassaigne's test
ii. Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
iii. Detection of the following functional groups by systematic chemical tests:
iv. Aromatic primary amino (Ar-NH_2), aromatic nitro (Ar-NO_2), amido (-$CONH_2$, including imide), phenolic hydroxyl (Ph-OH), carboxylic acid (-COOH), carbonyl (-CHO and >C=O);
v. Melting point of the given compound
vi. Preparation, purification and melting point determination of a crystalline derivative of the given compound

vii. Identification of the compound through literature survey.
viii. Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups with relevant derivatisation in known and unknown (at least six) organic compounds

Unit-5: Quantitative Analysis of Organic Compounds

i. Estimation of glycine by Sörensen's formol method
ii. Estimation of glucose by titration using Fehling's solution
iii. Estimation of sucrose by titration using Fehling's solution
iv. Estimation of Vitamin-C (reduced)
v. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method
vi. Estimation of phenol by bromination (Bromate-Bromide) method
vii. Estimation of formaldehyde (Formalin)
viii. Estimation of acetic acid in commercial vinegar
ix. Estimation of urea (hypobromite method)
x. Estimation of saponification value of oil/fat/ester

Semester-II

Core Course-3 (Theory) Credit-6, Full Marks-70

Course Code: CC-CH-03, Course Title: Inorganic Chemistry-I

Unit-1: Extra nuclear Structure of atom

Bohr's model and atomic spectrum of hydrogen, Limitations of Bohr's model and Sommerfeld's modifications, wave mechanics: de Broglie's equation, Heisenberg's uncertainty principle and its significance, Schrödinger's wave equation (without application and solution detail), Significance of ψ and ψ^2, Quantum numbers and their significance. Radial and angular wave functions for hydrogen atom (qualitative idea), radial and angular probability distribution curves, shapes of s, p, d and f orbitals (qualitative idea). Pauli's exclusion principle, Aufbau principle and limitations, Hund's rules and multiplicity. Exchange energy, Electronic configurations of atoms.

Unit-2: Radioactivity and nuclear chemistry

Atomic nucleus; nuclear stability, n/p ratio and different modes of decay, mass defect, packing fraction and nuclear binding energy. Nuclear forces: Meson exchange theory, elementary idea of nuclear shell model and magic numbers. Fission, fusion and spallation reactions, artificial radioactivity, super heavy elements and their IUPAC nomenclature. Moderators, slow and fast neutrons, Applications of radio-isotopes in: determination of structures, establishment of reaction mechanisms and radio-carbon dating, hazards of radiation and safety measures.

Unit-3: Chemical periodicity

Modern IUPAC periodic table and classification of elements in the table; Effective nuclear charge and its calculation using Slater's rules; Atomic radii, Ionic radii and Pauling's method for determining univalent ionic radii, covalent radii, lanthanide contraction; Electronegativity (Pauling's, Mulliken's, Allred-Rochow's and Sanderson's scales) and its applications, Ionization energy, Electron affinity and factors influencing these properties, group ectronegativities. Group trends and periodic trends of these properties with reference to s, p and d-block elements. Secondary periodicity, Relativistic Effect, Inert pair effect.

Unit-4: Chemistry of s and p-block elements
Diagonal relationship (Li-Mg; B-Si) and anomalous behavior of first member of each group, Allotropy and catenation (examples of C, P and S compounds). Study of the following compounds with emphasis on preparation, properties, structure and bonding: Berylium hydrides and halides; diborane; borazine; boron nitride, boric acid, borax, fluorocarbons (with environmental effect); oxides and oxyacids of nitrogen, phosphorous, sulphur and chlorine; Peroxo acids of sulphur; tetrasulphur trtranitride; interhalogens, pseudohalogens, polyhalides, fluorides and oxides of xenon. Noble gas clathrates; basic properties of iodine. Synthesis, structural aspects and applications of silicones and phosphazines; Structural properties of various silicates.

Unit-5: Redox Reactions and precipitation reactions
Qualitative idea about complimentary, noncomplimentary, disproportionation and comproportionation reactions, standard redox potentials with sign conventions, Electrochemical series and its application to explore the feasibility of reactions and equilibrium constants, Nernst equation; effect of pH, complexation and precipitation on redox potentials, formal potential; Basis of redox titration and redox indicators, Redox potential diagrams (Latimer and Frost) of common elements and their applications. Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulphides, carbonates, sulphates and halides.

Unit-6: Acid-Base Concepts and Solvents
Arrhenius concept, Solvent system concept (in H_2O, liq. NH_3, liq. SO_2 and liq. HF), Bronsted-Lowry concept, Lux-Flood concept, Lewis concept, Drago-Wayland equation, Solvent levelling and differentiating effects, Relative strength of different acids and bases, Pauling's rules, Hammett acidity function and super acids, HSAB principle and its applications, Acid-base equilibria in aqueous solution, pH, Buffer, Acid-base neutralization curves and choice of indicators. Gas phase acidity.

Semester-II

Core Course-4 (Theory) Credit-6, Full Marks-70

Course Code: CC-CH-04, Course Title: Organic Chemistry-I

Unit-1: Bonding and Physical Properties

a. Valence Bond Theory: Concept of hybridisation, shapes of molecules, resonance (including hyperconjugation); calculation of formal charges and double bond equivalent (DBE); orbital pictures of bonding (SP^3, SP^2, SP: C-C, C-N & C-O systems and *s*-cis and *s*-trans geometry for suitable cases).
b. Electronic displacements: inductive effect, field effect, mesomeric effect, resonance energy; bond polarization and bond polarizability; electromeric effect; steric effect, steric inhibition of resonance.
c. MO theory: qualitative idea about molecular orbitals, bonding and antibonding interactions, idea about σ, σ*, π, π *, n – MOs; basic idea about Frontier MOs (FMO); concept of HOMO, LUMO and SOMO; interpretation of chemical reactivity in terms of FMO interactions; sketch and energy levels of π MOs of i) acyclic p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems) ii) cyclic p orbital system (neutral systems: [4],[6]-annulenes; charged systems: 3-,4-,5-membered ring systems); Hückel's rules for aromaticity up to [10]-annulene (including

mononuclear heterocyclic compounds up to 6-membered ring); concept of antiaromaticity and homoaromaticity; non-aromatic molecules; Frost diagram; elementary idea about α and β; measurement of delocalization energies in terms of β for buta-1,3-diene, cyclobutadiene, hexa-1,3,5-triene and benzene.

d. Physical properties: influence of hybridization on bond properties: bond dissociation energy (BDE) and bond energy; bond distances, bond angles; concept of bond angle strain (Baeyer's strain theory); melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular forces; polarity of molecules and dipole moments; relative stabilities of isomeric hydrocarbons in terms of heat of hydrogenation, heat of combustion and heat of formation.

Unit-2: General Treatment of Reaction Mechanism I

a. Mechanistic classification: ionic, radical and pericyclic (definition and example); reaction type: addition, elimination and substitution reactions (definition and example); nature of bond cleavage and bond formation: homolytic and heterolytic bond fission, homogenic and heterogenic bond formation; curly arrow rules in representation of mechanistic steps; reagent type: electrophiles and nucleophiles (elementary idea).
b. Reactive intermediates: carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes: generation and stability, structure using orbital picture and electrophilic/nucleophilic behavior of reactive intermediates (elementary idea).

Unit-3: Stereochemistry-I

a. Bonding geometries of carbon compounds and representation of molecules: Tetrahedral nature of carbon and concept of asymmetry; Fischer, sawhorse, flying-wedge and Newman projection formulae and their inter translations.
b. Concept of chirality and symmetry elements and point groups (Cv, Cnh, Cnv, Cn, Dh, Dnh, Dnd, Dn, Sn (Cs, Ci); molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of epimers; concept of stereogenicity, chirotopicity and pseudoasymmetry; chiral centres and number of stereoisomerism: systems involving 1/2/3-chiral centre(s) (AA, AB, ABA and ABC types).
c. Relative and absolute configuration: D/L and R/S descriptors; erythro/threo and meso nomenclature of compounds; syn/anti nomenclatures for aldols; E/Z descriptors for C=C, conjugated diene, triene, C=N and N=N systems; combination of R/S- and
d. E/Z- isomerisms: Optical activity of chiral compounds: optical rotation, specific rotation and molar rotation; racemic compounds, racemisation (through cationic, anionic, radical intermediates and through reversible formation of stable achiral intermediates); resolution of acids, bases and alcohols via diastereomeric salt formation; optical purity and enantiomeric excess; invertomerism of chiral trialkylamines.

Unit-4: Stereochemistry – II

a. Chirality arising out of stereoaxis: stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in` allenes, spiro compounds, alkylidene cycloalkanes and biphenyls; related configurational descriptors (Ra/Sa and P/M); atropisomerism; racemisation of chiral biphenyls.
b. Concept of prostereoisomerism: prostereogenic centre; concept of (pro)n-chirality: topicity of ligands and faces (elementary idea); pro-R/pro-S, pro-E/pro-Z and Re/Si descriptors; pro-r and pro-s descriptors of ligands on propseudo

asymmetric centre.

c. Conformation: conformational nomenclature: eclipsed, staggered, gauche, syn and anti; dihedral angle, torsion angle; Klyne-Prelog terminology; P/M descriptors; energy barrier of rotation, concept of torsional and steric strains; relative stability of conformers on the basis of steric effect, dipole-dipole interaction and H-bonding; butane gauche interaction; conformational analysis of ethane, propane, n-butane.
d. 2-methylbutane and 2,3-dimethylbutane; haloalkane, 1,2-dihaloalkanes and 1,2-diols (up to four carbons); 1,2-halohydrin; conformation of conjugated systems (s-cis and s-trans).

Unit-5: General Treatment of Reaction Mechanism – II

a. Reaction thermodynamics: free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change via BDE, intermolecular & intramolecular reactions.
b. Concept of organic acids and bases: effect of structure, substituent and solvent on acidity and basicity; proton sponge; gas-phase acidity and basicity; comparison between nucleophlicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.
c. Tautomerism: prototropy (keto-enol, nitro - aci-nitro, nitroso-oximino, diazo-amino and enamine-imine systems); valence tautomerism and ring-chain tautomerism; composition of the equilibrium in different systems (simple carbonyl; 1,2- and 1,3-dicarbonyl systems, phenols and related systems), factors affecting keto-enol tautomerism; application of thermodynamic principles in tautomeric equilibria.
d. Reaction kinetics: rate constant and free energy of activation; concept of order and molecularity; free energy profiles for one-step, two-step and three-step reactions; catalyzed reactions: electrophilic and nucleophilic catalysis; kinetic control and thermodynamic control of reactions; isotope effect: primary and secondary kinetic isotopic effect (k_H /k_D); principle of microscopic reversibility; Hammond's postulate.

Unit-6: Nitrogen Compounds

a. Amines: Aliphatic & Aromatic: preparation, separation (Hinsberg's method) and identification of primary, secondary and tertiary amines; reaction (with mechanism): Eschweiler–Clarke methylation, diazo coupling reaction, Mannich reaction; formation and reactions of phenylenediamines, diazomethane and diazoacetic ester.
b. Nitro compounds (aliphatic and aromatic): preparation and reaction (with mechanism): reduction under different conditions; Nef carbonyl synthesis, Henry reaction and conjugate addition of nitroalkane anion.
c. Alkylnitrile and isonitrile: preparation and reaction (with mechanism): Thorpe nitrile condensation, von Richter reaction.
d. Diazonium salts and their related compounds: reactions (with mechanism) involving replacement of diazo group; reactions: Gomberg, Meerwein, Japp-Klingermann.

Semester-III

Core Course-5 (Practical)   Credit-6, Full Marks-70

Course Code: CC-CH-05, Course Title: Practical Paper-III

Unit-1: Kinetic Study of physical parameters

a. Determination of heat of neutralization of a strong acid by a strong base.
b. Determination of heat of solute ion of oxalic acid from solubility measurement.
c. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate.
d. Study of kinetics of decomposition of H_2O_2.
e. Determination of partition coefficient for the distribution of I_2 between water and CCl_4.
f. Verification of Ostwald's dilution law and determination of K_a of weak acid.
g. Determination of solubility of sparingly soluble salt in water, in electrolyte with common ions and in neutral electrolyte (using common indicator).
h. Determination of K_{eq} for $KI + I_2 = KI_3$, using partition coefficient between water and CCl_4.
i. Determination of K_{eq} for acetic acid, using partition coefficient between water and 1-Butanol.
j. Determination of K_{sp} for AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution.

Unit-2: Study of physical parameter

a. Study of viscosity of unknown liquid (glycerol, sugar) with respect to water.
b. Determination of pH of unknown solution (buffer), by color matching method.
c. Conductometric titration of an acid (strong, weak/ monobasic, dibasic) against strong base.
d. Study of saponification reaction conductometrically.
e. Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$-solution.
f. Effect of ionic strength on the rate of Persulphate -Iodide reaction.
g. Study of phenol-water phase diagram.
h. pH-metric titration of acid (mono-and di-basic) against strong base.

Semester-III

Core Course-6 (Practical)   Credit-6, Full Marks-70

Course Code: CC-CH-06, Course Title: Practical Paper-IV

Block –I (Inorganic Chemistry)

Unit-1: Quantitative analysis

i. Estimation of available chlorine in bleaching powder using iodometry
ii. ii. Estimation of available oxygen in pyrolusite using permanganometry
iii. Estimation of Cu in brass using iodometry
iv. Estimation of Fe in cement using permanganometry
v. Estimation of chloride gravimetrically
vi. Estimation of Ni(II) using DMG gravimetrically

Unit-2: Experiment

i. Paper chromatographic separation of Ni(II) and Co(II)
ii. ii. Measurement of $10D_q$ by spectrophotometric method
iii. Preparation of $Mn(acac)_3$ and determination of its λ_{max} colorimetrically

Unit-3: Qualitative semimicro analysis

Qualitative semimicro analysis of mixtures containing four radicals (excluding oxide and carbonate). Emphasis should be given to the understanding of the chemistry of different reactions and to assign the most probable composition.

Basic Radicals: K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Al^3+, Cr^3+, Mn^{2+}, Fe^3+/ Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^3+, Sn^{2+} / Sn^{4+}, As^{3+}/As^{5+}, Sb^{3+}/ Sb^{5+}

Acid Radicals: Cl^-, Br^-, I^-, S^{2-}, SO_4^{2-}, $S_2O_3^{2-}$, SCN^-, NO_3^-, NO_2^-, BO_3^{3-}, PO_4^{3-}, AsO_4^{3-} and H_3BO_3

Insoluble Materials: Cr_2O_3, Fe_2O_3, Al_2O_3, SnO_2, $PbSO_4$, $BaSO_4$, $SrSO_4$

Block –II (Organic Chemistry)

Unit-4: Chromatographic Separations

i. TLC separation of a mixture containing 2/3 amino acids
ii. Column chromatographic separation of mixture of dyes
iii. Paper chromatographic separation of a mixture containing 2/3 sugars

Unit-5: Spectroscopic Analysis of Organic Compounds

i. Assignment of labelled peaks in the ^{1}H NMR spectra of the known organic compounds explaining the relative δ-values and splitting pattern.
ii. Assignment of labelled peaks in the IR spectrum of the same compound explaining the relative frequencies of the absorptions (C-H, O-H, N-H, C-O, C-N, C-X, C=C, C=O, N=O, C≡C, C≡N stretching frequencies; characteristic bending vibrations are included).
iii. The students must record full spectral analysis of at least 15 (fifteen) compounds from the following list:
    i) 4-Nitroaniline, ii) 2-Bromo-4'-methylacetophenone, iii) Vanillin, iv) 2-Methoxyacetophenone, v) 4-Aminobenzoic acid, vi) Pent-1-yn-3-ol, vii) 2-Hydroxyacetophenone, viii) 1,3-Dinitrobenzene, ix) Benzylacetate, x) 2-Hydroxy-3-nitrobenzaldehyde xi) 3-Ethoxy-4-hydroxybenzaldehyde, xii) 4-Nitrobenzaldehyde, xiii) Ethyl 4-aminobenzoate, xiv) 2-Methoxybenzaldehyde, xv) 2-Hydroxybenzaldehyde, xvi) Ethyl-3-aminobenzoate , xvii) 2,3-Dimethylbenzonitrile, xviii) 3-Aminobenzoic acid, xix) Methyl 3-hydroxybenzoate

Semester-III

Core Course-7 (Theory) Credit-6, Full Marks-70

Course Code: CC-CH-07, Course Title: Inorganic Chemistry-II

Unit-1: Chemical Bonding – I

Ionic Bond: Lattice energy, Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy, Born-Haber cycle and its applications, Polarising power and polarisability of ions, Fajan's rules and its applications, radius ratio rules – its applications and limitations, salvation energy and solubility energetics of dissolution process; Packing in crystals, voids in crystal lattice, packing efficiency, Structure of ionic solids: rock salt, zinc blende, wurtzite, fluorite, antifluorite, perovskite and layer lattice. Qualitative idea about stoichiometric and non-stoichiometric crystal defects.

Unit-2: Chemical Bonding – II

Covalent Bond: Lewis structures, formal charge; Qualitative idea of V.B.Theory, directional properties of covalent bond, Concept of Equivalent and nonequivalent Hybridization and shapes of simple molecules and ions (examples from main groups), Stereochemically non-rigid molecules – Berry's pseudorotation, Resonance and Dipole moments of inorganic molecules and ions, VSEPR theory and Bent's rule and their applications; M.O. Theory (elementary pictorial approach), concept of bond order, MO diagram of homo-nuclear diatomics (1st and 2nd period elements), hetero-nuclear diatomics (HF, CO, NO, NO^+ and CN^-) and triatomics (H_2O and BeH_2). Electron sea model and elementary idea about band theory, classification of inorganic solids and their conduction properties according to band theory; Hydrogen bonding: classifications, its effect on the properties of compounds and its importance in biological systems, vander Waal's forces.

Unit-3: Coordination Chemistry - I

Idea about double salts and complex salts, Werner's theory, EAN rule, classification of ligands and their binding modes, IUPAC nomenclature of coordination compounds (up to two metal centers), overall and stepwise stability constants, chelates, innermetallic complexes, Stereochemistry and isomerism (constitutional and stereo) of complexes with coordination no. 4 and 6.

Unit-4: Coordination Chemistry – II

Structure and bonding of coordination compounds on the basis of V.B. Theory and its limitations. Elementary idea about CFT, splitting of d^n configuration in ML_4 to ML_6 and ML_8 systems, factors affecting , measurement of o, spectrochemical series of ligands, CFSE in weak and strong fields, OSSE, High spin and low spin complexes, spin isomerism, tetragonal distortion, Jahn Teller theorem and applications, achievements and limitations of CFT, nephalauxetic effect, stabilization of unusually high and low oxidation states of 3d series elements, MOT (elementary idea), σ and π bonding in octahedral complexes (a pictorial approach). Colour and electronic spectra of complexes: selection rules for electronic transitions, d-d transition, charge transfer transition (qualitative idea), L-S coupling and R-S ground state term for atomic no. up to 30, qualitative ORGEL diagram for 3d1 – 3d9 ions with appropriate symbols for the energy levels.

Unit-5: Reaction Kinetics and Mechanism

Introduction to inorganic reaction mechanisms, substitution reactions in square planar complexes; *trans*-effect - theories and applications; lability and inertness in octahedral complexes towards substitution reactions. Elementary concept of *cis*-effect.

<u>Semester-IV</u>

<u>Core Course-8 (Theory) Credit-6, Full Marks-70</u>

<u>Course Code: CC-CH-08, Course Title: Organic Chemistry-II</u>

Unit-1: Substitution and Elimination Reactions

Free-radical substitution reaction: halogentaion of alkanes, mechanism (with evidence) and stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate. Nucleophilic substitution reactions: substitution at SP^3 centre: mechanisms (with evidence), relative rates & stereochemical features: S_N1, S_N2, S_N2', S_N1' (allylic rearrangement) and S_Ni; effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite); substitutions involving NGP; role of crown ethers and phase transfer catalysts; [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides].

Elimination reactions: E1, E2, $E1_{cB}$ and Ei (pyrolytic syn eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity; comparison between substitution and elimination; importance of Bredt's rule relating to the formation of C=C.

Unit-2: Aromatic Substitution

Electrophilic aromatic substitution: mechanisms and evidences in favour of it; orientation and reactivity; reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction; one-carbon electrophiles (reactions: chloromethylation, Gatterman-Koch, Gatterman, Houben-Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt); Ipso substitution.

Nucleophilic aromatic substitution: addition-elimination mechanism and evidences in favor of it; S_N1 mechanism; cine substitution (benzyne mechanism), structure of benzyne.

Unit-3: Carbonyl and Related Compounds

Addition to C=O: structure, reactivity and preparation of carbonyl compounds; mechanism (with evidence), reactivity, equilibrium and kinetic control; Burgi-Dunitz trajectory in nucleophilic additions; formation of hydrates, cyano hydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen- based nucleophiles; reactions: benzoin condensation, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement, oxidations and reductions: Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, Oppenauer, Bouveault-Blanc, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

Exploitation of acidity of α-H of C=O: formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence): halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H. V. Z.) reaction, nitrosation, SeO_2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Tollens', Knoevenagel, Claisen-Schmidt, Claisen ester including Dieckmann, Stobbe; Mannich reaction, Perkin reaction, Favorskii rearrangement; alkylation of active methylene compounds; preparation and synthetic applications of diethyl malonate and ethyl acetoacetate; specific enol equivalents (lithium enolates, enamines, aza-enolates and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction.

Elementary ideas of Green Chemistry: Twelve (12) principles of green chemistry; planning of green synthesis; common organic reactions and their counterparts: reactions: Aldol, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, benzoin condensation and Dieckmann condensation.

Nucleophilic addition to α,β-unsaturated carbonyl system: general principle and mechanism (with evidence); direct and conjugate addition, addition of enolates (Michael reaction), Stetter reaction, Robinson annulation.

Substitution at Sp^2 carbon (C=O system): mechanism (with evidence): $B_{AC}2$, $A_{AC}2$, $A_{AC}1$, $A_{AL}1$ (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

Unit-4: Organometallics

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organolithium to carbonyl compounds; substitution on -COX; directed ortho metalation of arenes using organolithiums, conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; Blaise reaction; concept of umpolung and base-nucleophile dichotomy in case of organometallic reagents.

Unit-5: Chemistry of alkanes and alkenes

Addition to C=C: mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenations, iodolactonisation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, syn and anti-hydroxylation, ozonolysis, addition of singlet and triplet carbenes; electrophilic addition to diene (conjugated dienes and allene); radical addition: HBr addition; mechanism of allylic and benzylic bromination in competition with brominations across C=C; use of NBS; Birch reduction of benzenoid aromatics; interconversion of E - and Z - alkenes; contra-thermodynamic isomerization of internal alkenes.

Addition to C≡C (in comparison to C=C): mechanism, reactivity, regioselectivity (Markownikoff and anti-Markownikoff addition) and stereoselectivity; reactions: hydrogenation, halogenations, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity; interconversion of terminal and non- terminal alkynes.

Unit-6: Rearrangements

Mechanism with evidence and stereochemical features for the following:

Rearrangement to electron-deficient carbon: Wagner-Meerwein rearrangement, Pinacol rearrangement, dienone-phenol; Wolff rearrangement in Arndt-Eistert synthesis, benzil- benzilic acid rearrangement, Demjanov rearrangement, Tiffeneau–Demjanov rearrangement.

Rearrangement to electron-deficient nitrogen: rearrangements: Hofmann, Curtius, Lossen, Schmidt and Beckmann.

Rearrangement to electron-deficient oxygen: Baeyer-Villiger oxidation, cumene hydroperoxide-phenol rearrangement and Dakin reaction.

Aromatic rearrangements: Migration from oxygen to ring carbon: Fries rearrangement and Claisen rearrangement.

Migration from nitrogen to ring carbon: Hofmann-Martius rearrangement, Fischer-Hepp rearrangement, N-azo to C-azo rearrangement, Bamberger rearrangement, Orton rearrangement and benzidine rearrangement.

Rearrangement reactions by green approach: Fries rearrangement, Claisen rearrangement, Beckmann rearrangement, Baeyer-Villiger oxidation.

Semester-IV
Core Course-9 (Theory) Credit-6, Full Marks-70
Course Code: CC-CH-09, Course Title: Physical Chemistry-I

Unit-1: Kinetic Theory and Gaseous state
Kinetic Theory of gases: 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). Maxwell's distribution of speed and energy: Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Calculation of number of molecules having energy $\geq \varepsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases. Real gas and virial equation: 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, other equations of state (Berthelot, Dietrici); Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; virial equation of state; van der Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard - Jones potential – elementary idea).

Unit-2: Chemical Thermodynamics - I
Zeroth and 1st law of Thermodynamics: 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 (ideal and van der Waals) under isothermal and adiabatic conditions; Joule's experiment and its consequence. Thermochemistry: 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.

Unit-3: Chemical Thermodynamics – II
Second Law: Need for a Second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine and refrigerator; Kelvin –Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; Values of dq/T and Clausius inequality; Entropy change of systems and surroundings for various processes and transformations; Entropy and unavailable work; Auxiliary state functions (G and A) and their variation with T, P and V. Criteria for spontaneity and equilibrium. Thermodynamic relations: Maxwell's relations; Gibbs-Helmholtz equation, Joule-Thomson experiment and its consequences; inversion temperature; Joule- Thomson coefficient for a van der Waals gas; General heat capacity relations.

Unit-4: Chemical kinetics
Rate law, order and molecularity: Introduction of rate law, Extent of reaction; rate constants, order; Forms of rates of First, second and nth order reactions; Pseudo first order reactions (example using acid catalyzed hydrolysis of methyl acetate); Determination of order of a reaction by half -life and differential method; Opposing reactions, consecutive reactions and parallel reactions (with explanation of kinetic and thermodynamic control of products; all steps

first order). Role of Temperature and theories of reaction rate: Temperature dependence of rate constant; Arrhenius equation, energy of activation; Rate-determining step and steady-state approximation –explanation with suitable examples; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment). Homogeneous catalysis: Homogeneous catalysis with reference to acid-base catalysis; Primary kinetic salt effect; Enzyme catalysis; Michaelis-Menten equation, Lineweaver-Burk plot, turn-over number.

Unit-5: Transport processes

Viscosity: General features of fluid flow (streamline flow and turbulent flow); Newton's equation, viscosity coefficient; Poiseuille's equation; Principle of determination of viscosity coefficient of liquids by falling sphere method; Temperature variation of viscosity of liquids and comparison with that of gases. Conductance and transport number: Ion conductance; Conductance and measurement of 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; Debye –Huckel theory of Ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Ostwald's dilution law; Ionic mobility; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations. Transport number, Principles of Hittorf's and Moving-boundary method.

Semester-IV

Core Course-10 (Theory) Credit-6, Full Marks-70

Course Code: CC-CH-10, Course Title: Physical Chemistry-II

Unit-1: Applications of Thermodynamics –I

Partial properties and chemical potential: Chemical potential and activity, partial molar quantities, relation between chemical potential and Gibb's free energy and other thermodynamic state functions; variation of chemical potential (μ) with temperature and pressure; Gibbs-Duhem equation; fugacity and fugacity coefficient; Variation of thermodynamic functions for systems with variable composition; Equations of states for these systems, Change in G, S H and V during mixing for binary solutions. Chemical Equilibrium: Thermodynamic conditions for equilibrium, degree of advancement; Van't Hoff's reaction isotherm (deduction from chemical potential); Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Definitions of KP, KC and KX; Van't Hoff's reaction 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. Nernst's distribution law; Application-(finding out K_{eq} using Nernst distribution law for $KI+I_2 = KI_3$ and dimerization of benzene. Chemical potential and other properties of ideal substances-pure and mixtures: Pure ideal gas: Its chemical potential and other thermodynamic functions and their changes during a change of thermodynamic parameters of mixing; Chemical potential of an ideal gas in an ideal gas mixture; Concept of standard states and choice of standard states of ideal gases. Condensed Phase: Chemical potential of pure solid and pure liquids, Ideal solution–Definition, Raoult's law; Mixing properties of ideal solutions, chemical potential of a component in an ideal solution; Choice of standard states of solids and liquids.

Unit-2: Application of Thermodynamics – II

Colligative properties: Vapour pressure of solution; Ideal solutions, ideally diluted solutions and colligative properties; Raoult's law; Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) Osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution; Abnormal colligative properties. Phase rule: Definitions of phase, component and degrees of freedom; Phase rule and its derivations; Definition of phase diagram; Phase diagram for water, CO_2, Sulphur. First order phase transition and Clapeyron equation; Clausius-Clapeyron equation – derivation and use; Liquid vapour equilibrium for two component systems; Phenol-water system. Three component systems, water-chloroform-acetic acid system, triangular plots. Binary solutions: Ideal solution at fixed temperature and pressure; Principle of fractional distillation; Duhem-Margules equation; Henry's law; Konowaloff's rule; Positive and negative deviations from ideal behavior; Azeotropic solution; Liquid-liquid phase diagram using phenol-water system; Solid-liquid phase diagram; Eutectic mixture.

Unit-3: Foundation of Quantum Mechanics

Beginning of Quantum Mechanics: Wave-particle duality, light as particles: photoelectric and compton effects; electrons as waves and the de Broglie hypothesis; Uncertainty relations (without proof). Wave function: Schrodinger time-independent equation; nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function. Concept of Operators: Elementary concepts of operators, eigen functions and eigenvalues; Linear operators; Commutation of operators, commutator and uncertainty relation; Expectation value; Hermitian operator; Postulates of Quantum Mechanics. Particle in a box: Setting up of Schrodinger equation for one-dimensional box and its solution; Comparison with free particle eigen functions and eigenvalues. Properties of particle in a box wave functions (normalization, orthogonality, probability distribution); Expectation values of x, x2, px and px2 and their significance in relation to the uncertainty principle; Extension of the problem to two and three dimensions and the concept of degenerate energy levels.

Unit-4: Electrical Properties of molecules

Ionic equilibria: Chemical potential of an ion in solution; Activity and activity coefficients of ions in solution; Debye-Huckel limiting law-brief qualitative description of the postulates involved, qualitative idea of the model, the equation (without derivation) for ion-ion atmosphere interaction potential. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law; Derivation of mean ionic activity coefficient from the expression of ion-atmosphere interaction potential; Applications of the equation and its limitations. Electromotive Force: 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 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). Dipole moment and polarizability: Polarizability of atoms and molecules, dielectric constant and polarization, molar polarization for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation (both without derivation) and their application; Determination of dipole moments.

Semester-V
Core Course-11 (Practical) Credit-6, Full Marks-70
Course Code: CC-CH-11, Course Title: Practical Paper-V

Block-I (Physical Chemistry)
Unit-1: Determination of physical parameter

i. Determination of surface tension of a liquid using Stalagmometer.
ii. Determination of CMC from surface tension measurements.
iii. Verification of Beer and Lambert's Law for $KMnO_4$and $K_2Cr_2O_7$ solution.
iv. Study of kinetics of $K_2S_2O_8$ + KI reaction, spectrophotometrically.
v. Determination of pH of unknown buffer, spectrophotometrically.
vi. Spectrophotometric determination of CMC.

Block-I (Polymer Chemistry)
Unit-2: Polymer Synthesis

i. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).
ii. Purification of monomer
iii. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bis-isobutylonitrile (AIBN)
iv. Preparation of nylon 66/6
v. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
vi. Redox polymerization of acrylamide
vii. Precipitation polymerization of acrylonitrile
viii. Preparation of urea-formaldehyde resin
ix. Preparations of novalac resin/ resold resin.
x. Microscale Emulsion Polymerization of Poly(methylacrylate).

Unit-3: Polymer characterization

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

Unit-4: Polymer analysis

i. Estimation of the amount of HCHO in the given solution by sodium sulphite method
ii. Instrumental Techniques
iii. IR studies of polymers
iv. DSC analysis of polymers
v. Preparation of polyacrylamide and its electrophoresis

Semester-V
Core Course-12 (Theory)   Credit-6, Full Marks-70
Course Code: CC-CH-12, Course Title: Inorganic Chemistry-III

Unit-1: Chemistry of d- and f-block elements

d-block elements: Characteristic properties, Comparison among the elements of 3d series with reference to electronic configuration, oxidation states and E^0 values; General comparison between 3d, 4d and 5d series elements in term of electronic configuration, oxidation states, atomization energy, magnetic properties and coordination chemistry.

f-block elements: Comparison between d and f-block elements; Electronic configuration, oxidation states, variation of magnetic properties (Ln^{3+}), atomic and ionic (3+) radii of lanthanides; consequences of lanthanide contraction, separation of lanthanides by ion exchange and solvent extraction methods; comparison between lanthanides and actinides.

Unit-2: Molecular symmetry and Point group

Symmetry as a universal theme, concept of symmetry elements and operations (with examples); symmetry properties of atomic orbitals (s, p and d); concept of point groups, identification of molecular point groups in some simple molecules and ions; applications of symmetry for polarity and chirality.

Unit-3: Magnetochemistry

Classification of magnetic substances, Origin of para magnetic moments, temperature dependence of para magnetism – Curie and Curie-Weiss law, TIP, magnetic susceptibility and its measurement (Gouy method), diamagnetic correction, effective magnetic moment, spin only moment for 3d metals, Orbital contribution to magnetic moment, spin-orbit coupling, quenching of orbital contribution, Sub-normal magnetic moments and antiferromagnetic interactions (elementary idea with examples).

Unit-4: Bio-inorganic Chemistry

Essential elements of life, Role of metal ions in living systems- a brief review, Elementary idea about proteins, enzymes and ionophores; Structure of ATP, Na^+ ion pump and transport of Na^+ and K^+ across cell membrane; active site structures and bio-functions of hemoglobin, myoglobin, carboxy peptidase A, carbonic anhydrase B, cytochrome c, ferredoxins and chlorophyll; biological nitrogen fixation; toxic metals (Pb, Cd and Hg) and their effects, Wilson disease, chelation therapy; platinum and gold complexes as drugs (examples only).

Unit-5: Organometallic Chemistry and Catalysis

Definition, Classification of organometallic compounds, hapticity of ligands, nomenclature, 16- electron & 18-electron rule and its applications; preparation and structure of mono- and bi-nuclear carbonyls of 3d series, synergic effect of CO and use of IR data to explain extent of back bonding; General methods of preparation of metal-carbon σ-bonded complexes, Zeise's salt, Metal-carbon multiple bonding; Preparation, structures, properties and reactions of ferrocene; elementary idea about oxidative addition, reductive elimination, insertion reactions; Study of the following catalytic processes: alkene hydrogenation (Wilkinson's catalyst), hydroformylation, Wacker process, Synthetic gasoline (Fischer Tropsch reaction) and Olefin polymerization reaction (Ziegler-Natta catalyst)

<u>Semester-VI</u>
<u>Core Course-13 (Theory)   Credit-6, Full Marks-70</u>
<u>Course Code: CC-CH-13, Course Title: Organic Chemistry-III</u>

Unit-1: The Logic of Organic Synthesis
Retrosynthetic analysis: disconnections; synthons, donor and acceptor synthons; natural reactivity and umpolung; latent polarity in bifunctional compounds: consonant and dissonant polarity; illogical electrophiles and nucleophiles; synthetic equivalents; functional group interconversion and addition (FGI and FGA); C-C disconnections and synthesis: one-group and two-group (1,2- to 1,5-dioxygenated compounds), reconnection (1,6-dicarbonyl); protection-deprotection strategy (alcohol, amine, carbonyl, acid).

1. Strategy of ring synthesis: thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique.
2. Asymmetric synthesis: stereoselective and stereospecific reactions; diastereoselectivity and enantioselectivity (only definition); enantioselectivity: kinetically controlled MPV reduction; diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogenic centre: Felkin-Anh and Zimmermann-Traxler models.

Unit-2: Carbocycles and Heterocycles:

1. Polynuclear hydrocarbons and their derivatives: synthetic methods include Haworth, Bardhan-Sengupta, Bogert-Cook and other useful syntheses (with mechanistic details); fixation of double bonds and Fries rule; reactions (with mechanism) of naphthalene, anthracene, phenanthrene and their derivatives.
2. Heterocyclic compounds: 5- and 6-membered rings with one heteroatom; reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine; synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis, Paal-Knorr synthesis, Hantzsch; furan: Paal-Knorr synthesis, Feist- Benary synthesis and its variation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis; benzo-fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and important reactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Doebner- Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis.

Unit-3: Cyclic Stereochemistry
Alicyclic compounds: concept of I-strain; conformational analysis: cyclohexane, mono and disubstituted cyclohexane; symmetry properties and optical activity; topomerisation; ring-size and ease of cyclisation; conformation & reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic *syn* elimination and fragmentation reactions

Unit-4: Organic Spectroscopy

1. UV Spectroscopy: introduction; types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic and Hypsochromic shifts; intensity of absorptions

(Hyper-/Hypochromic effects); application of Woodward's Rules for calculation of λ_{max} for the following systems: conjugated diene, α,β-unsaturated aldehydes and ketones (alicyclic, homoannular and heteroannular); extended conjugated systems (dienes, aldehydes and ketones); relative positions of λ_{max} considering conjugative effect, steric effect, solvent effect, effect of pH; effective chromophore concentration: keto-enol systems; benzenoid transitions.

2. IR Spectroscopy: introduction; modes of molecular vibrations (fundamental and non- fundamental); IR active molecules; application of Hooke's law, force constant; fingerprint region and its significance; effect of deuteration; overtone bands; vibrational coupling in IR; characteristic and diagnostic stretching frequencies of C-H, N-H, O-H, C-O, C-N, C-X, C=C (including skeletal vibrations of aromatic compounds), C=O, C=N, N=O, C≡C, C≡N; characteristic/diagnostic bending vibrations are included; factors affecting stretching frequencies: effect of conjugation, electronic effects, mass effect, bond multiplicity, ring- size, solvent effect, H-bonding on IR absorptions; application in functional group analysis.

3. NMR Spectroscopy: introduction; nuclear spin; NMR active molecules; basic principles of Proton Magnetic Resonance; equivalent and non-equivalent protons; chemical shift and factors influencing it; ring current effect; significance of the terms: up-/downfield,

4. Shielded and deshielded protons; spin coupling and coupling constant (1^{st} order spectra); relative intensities of first-order multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR ; elementary idea about non-first-order splitting; anisotropic effects in alkene, alkyne, aldehydes and aromatics; NMR peak area, integration; relative peak positions with coupling patterns of common organic compounds (both aliphatic and benzenoid-aromatic); rapid proton exchange; interpretation of NMR spectra of simple compounds.

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

Unit-5: Pericyclic Reactions

Mechanism, stereochemistry, regioselectivity in case of

i. Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.
ii. Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.
iii. Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]- H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

Unit-6: Carbohydrates

1. Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $–CH_2OH$ of aldoses, reduction to alditols, Lobry de Bruyn-van Ekenstein rearrangement; stepping–up (Kiliani-Fischer method) and stepping–down (Ruff's & Wohl's methods) of aldoses; end-group-interchange of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.

2. Disaccharides: Glycosidic linkages, concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose, inversion of cane sugar.
3. Polysaccharides: starch (structure and its use as an indicator in titrimetric analysis).

Unit-7: Biomolecules

1. Amino acids: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction; resolution of racemic amino acids.
2. Peptides: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger & 'dansyl' methods); partial hydrolysis; specific cleavage of peptides: use of CNBr.
3. Nucleic acids: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; mechanism for acid catalyzed hydrolysis of nucleosides (both pyrimidine and purine types); comparison of alkaline hydrolysis of DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA.

Semester-VI

Core Course-14 (Theory) Credit-6, Full Marks-70

Course Code: CC-CH-14, Course Title: Physical Chemistry-III

Unit-1: Quantum Chemistry

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. 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). LCAO and HF-SCF: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+; Bonding and antibonding orbitals; Qualitative extension to H_2; Comparison of LCAO-MO and VB treatments of H_2 and their limitations; Hartree-Fock method development, SCF and configuration interaction (**only basics**).

Unit-2: Surface phenomenon

Surface tension and energy: Surface tension, surface energy, excess pressure, capillary rise and surface tension; Work of cohesion and adhesion, spreading of liquid over other surface; Vapour pressure over curved surface; Temperature dependence of surface tension. Adsorption: Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm (no derivation required); Gibbs adsorption isotherm and surface excess; Heterogenous catalysis (single reactant); Zero order and fractional order reactions. Colloids: Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method; Stability of colloids and zeta potential; Micelle formation.

Unit-3: Molecular Spectroscopy

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; Diatomic vibrating rotator, P, Q, R branches.\ Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Vibrational Raman spectra, Stokes and anti-Stokes lines. Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and low resolution spectra. Electron Spin Resonance (ESR) spectroscopy: Its principle, ESR of simple radicals.

Unit-4: Photochemistry

Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert- Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields. Photochemical Processes: Potential energy curves (diatomic molecules), Frank- Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonskii diagram. Rate of Photochemical processes: Photochemical equilibrium and the differential rate of photochemical reactions, Photostationary state; HI decomposition, H_2-Br_2 reaction, dimerisation of anthracene; photosensitised reactions, quenching; Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence.

Discipline Specific Elective Courses

Semester-V

Discipline Specific Elective-1 (Theory) Credit-6, Full Marks-70

Course Code: DS-CH-11, Course Title: Polymer Chemistry

Unit-1: Introduction and history of polymeric materials
Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.

Unit-2: 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.

Unit-3: Kinetics of Polymerization
Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations.

Unit-4: Crystallization and crystallinity
Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.

Unit-5: Nature and structure of polymers
Structure Property relationships.

Unit-6: 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.

Unit-7: Glass transition temperature (T_g) and determination of T_g
Free volume theory, WLF equation, Factors affecting glass transition temperature (T_g).

Unit-8: Polymer Solution
Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Lower and Upper critical solution temperatures.

Unit-9: 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)].

Unit-10: Composite materials
Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix

composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

Unit-11: Specialty polymers:

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

Semester-V

Discipline Specific Elective-2 (Practical) Credit-6, Full Marks-70

Course Code: DS-CH-21, Course Title: Practical Paper VI

Unit-1: Safer starting materials

Preparation and characterization of nanoparticles of gold using tea leaves.

Unit-2: 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. $\text{1-propanol} \xrightarrow{H_2SO_4/\Delta} \text{propene} + \text{water}$

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

Unit-3: Use of enzymes as catalysts

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

Unit-4: Alternative Green solvents

Extraction of D-limonene from orange peel using liquid CO_2 prepared form dry ice. Mechanochemical solvent free synthesis of azomethines

Unit-5: 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.

Block-II (Analytical & Industrial chemistry)

Unit-6: Separation Techniques - Chromatography

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

Unit-7: 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. Analysis of soil:
   a. Determination of pH of soil.
   b. Total soluble salt
   c. Estimation of calcium, magnesium, phosphate, nitrate

iii. Ion exchange:
   a. Determination of exchange capacity of cation exchange resins and anion exchange resins.

Unit-8: Experiment

i. Determination of chemical oxygen demand (COD)
ii. Determination of Biological oxygen demand (BOD)

Unit-9: List of Practical

i. Determination of free acidity in ammonium sulphate fertilizer.
ii. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
iii. Estimation of phosphoric acid in superphosphate fertilizer.
iv. Determination of composition of dolomite (by complexometric titration).
v. Analysis of (Cu, Ni); (Cu, Zn) in alloy or synthetic samples.
vi. Analysis of Cement.

Semester-VI

Discipline Specific Elective-3 (Theory)   Credit-6, Full Marks-70

Course Code: DS-CH-31, Course Title: Analytical Chemistry and Green Chemistry

Block-I (Analytical Chemistry)

Unit-1: Qualitative and quantitative aspects of analysis

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

Unit-2: Optical methods of analysis

i. Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law. ii. UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;
ii. Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.
iii. 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.
iv. Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and 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.

Unit-3: Thermal methods of analysis

Theory of thermogravimetry (TG), instrumentation. Composition determination of Ca and Mg from their mixture.

Unit-4: Electroanalytical methods
Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pK_a values.

Unit-5: Separation techniques
i. Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation.
ii. Technique of extraction: batch, continuous and counter current extractions.
iii. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.
iv. Chromatography: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange.
v. Development of chromatograms: frontal, elution and displacement methods.
vi. Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Block-II (Green Chemistry)

Unit-6: 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

Unit-7: 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:
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. Prevention/ minimization of hazardous/ toxic products reducing toxicity. risk = (function) hazard × exposure; waste or pollution prevention hierarchy.
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. Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy. Selection of starting materials; avoidance of unnecessary derivatization-careful use of blocking/protecting groups. Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, symmetric catalysis and photocatalysis.

Semester-VI
Discipline Specific Elective 4 (Theory) Credit-6, Full Marks-70
Course Code: DS-CH-41, Course Title: Inorganic Materials of Industrial Importance and Green Chemistry

Block-I (Industrial Chemistry)

Unit-1: Silicate Industries
i. Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of

glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

ii. Ceramics: Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fiber.

iii. Cements: Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cements.

Unit-2: Fertilizers

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

Unit-3: Surface Coatings

Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Pigments, toners and laker pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Water and Oil paints, additives, Metallic coatings (electrolytic and electroless),

Unit-4: Batteries

Primary and secondary batteries, battery components and their role, Characteristics of Battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

Unit-5: Alloys

Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation). Composition and properties of different types of steels.

Unit-6: Catalysis

General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrial applications, Deactivation or regeneration of catalysts. Phase transfer catalysts, application of zeolites as catalysts.

Unit-7: Chemical explosives

Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX). Introduction to rocket propellants.

Block-II (Green Chemistry)

Unit-8: Examples of Green Synthesis/ Reactions and some real world cases:

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

Unit-9: Microwave assisted reactions:

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.

Unit-10: Ultrasound assisted reactions:

Sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine), Carbon Dioxide as a replacement for smog producing and ozone depleting solvents, CO_2 surfactant for precision cleaning and dry cleaning of garments. Designing of Environmentally safe marine antifoulant.

Unit-11: Rightfit pigment:

Synthetic azopigments to replace toxic organic and inorganic pigments. An efficient, green synthesis of a compostable and widely applicable plastic (polylactic acid) made from corn.

Unit-12: Healthier Fats and oil by Green Chemistry:

Enzymatic Interesterification for production of no Trans-Fats and Oils

Unit-13: Development of Fully Recyclable Carpet:

Cradle to Cradle Carpeting.

Unit-14: Future Trends in Green Chemistry:

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; Cocrystal Controlled Solid-State Synthesis (C^3S^3); Green chemistry in sustainable development.

Skill Enhancement Courses

Semester-III

Skill Enhancement Course 1 (Theory) Credit-2, Full Marks-60
Course Code: SE-CH-11, Course Title: Intellectual Property Rights (IPR)

Theories of IPR: Introduction to Intellectual Property Right (IPR), historical theory, labour theory, psychological theory, functional theory, metaphysical theory, property as creation of state, monopoly profit incentive, exchange for secrets thesis

Historical background of IPR: Historical Perspective, World Trade Organization (WTO), General Agreement on Tariffs & Trade (GATT), Madrid Protocol, Berne Convention

Various facets of IPR:

Copyrights: Introduction, How to obtain, Differences from Patents.

Patents: Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Healthcare – balancing promoting innovation with public health, Software patents and their importance for India.

Trade Marks: Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, Trade names, etc. Differences from Designs.

Geographical Indications: Definition, rules for registration, prevention of illegal exploitation, importance to India.

Industrial Designs: Definition, How to obtain, features, International design registration.

Undisclosed information: trade secrets, test data

Design of integrated circuits: Circuit Boards, Integrated Chips, Importance for electronic industry, Protection of new plant varieties

The TRIPS Agreement: Paris Convention, WIPO and TRIPS, IPR**,** Trade Related Intellectual Property Rights (TRIPS) agreement, Trips Agreement: Articles, Restrictive trade practices, Different International agreements

Restrictive Trade Practices: Restrictive clauses in agreement, Restrictions on innovation and research, Non-competition clause

The Indian Scenario: Intellectual Property in the Indian Context, timelines in India regarding intellectual property rights, Various laws in India Licensing and technology transfer.

Some areas of concern: Management of intellectual property, Care and management of confidential information, Valuation of intellectual property, Business deals involving intellectual property, Merger and acquisition involving IP related business, IPR and Biodiversity,

Semester-IV

Skill Enhancement Course 2 (Theory) Credit-2, Full Marks-60
Course Code: SE-CH-21, Course Title: Pharmaceutical Chemistry

Drugs & Pharmaceuticals:

Drug discovery, design and development; Basic Retrosynthetic approach. Preparation of Aspirin and magnesium bisilicate (Antacid). 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 B_2, Vitamin B_{12} and Vitamin C.

Generic Elective Courses
(For Learners of Honours programmes other than Chemistry)

Semester-I

Generic Elective Course-1 (Theory) Credit-6, Full Marks-70

Course Code: GE-CH-11, Course Title: Basic Physical Chemistry

Unit-1: Chemical Energetic:

Brief 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.

Unit-2: Chemical Equilibrium:

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

Unit-3: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.

Unit-4: Kinetic Theory of Gases:

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation. Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance.

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

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.

Unit-5: Liquids:

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

Unit-6: Solids:

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

Unit-7: Solutions:
Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions. Vapour pressure-composition and temperature- composition curves of ideal and non-ideal solutions. Partial miscibility of liquids: Critical solution temperature; Principle of steam distillation. Nernst distribution law and its applications, solvent extraction.

Unit-8: Chemical Kinetics
The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants). Half–life of a reaction. General methods for determination of order of a reaction. Concept of activation energy and its calculation from Arrhenius equation.
Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular reactions. Comparison of the two theories (qualitative treatment only).

Semester-II

Generic Elective Course-2 (Theory) Credit-6, Full Marks-70

Course Code: GE-CH-21, Course Title: Basic Inorganic Chemistry

Unit-1: Atomic Structure:
Review of: Bohr's theory and its limitations, dual behavior of matter and radiation, de-Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Significance of quantum numbers, orbital angular momentum and quantum numbers m_l and m_s. Shapes of s, p and d atomic orbitals, nodal planes. Discovery of spin, spin quantum number (s) and magnetic spin quantum number(m_s).
Rules for filling electrons in various orbitals, Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

Unit-2: Chemical Bonding and Molecular Structure:
Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.
Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, 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 and heteronuclear diatomic molecules such as CO, NO and NO^+. Comparison of VB and MO approaches.

Unit-3: *s*-and *p*-Block Elements:
Periodicity in *s*- and *p*-block elements with respect to electronic configuration, atomic and ionic size, ionization enthalpy, electronegativity (Pauling, Mulliken, and Alfred-Rochow scales). Allotropy in C, S, and P.
Oxidation states with reference to elements in unusual and rare oxidation states like carbides and nitrides), inert pair effect, diagonal relationship and anomalous behaviour of first member of each group.

Unit-4: Compounds of *s*- and *p*-Block Elements:
Hydrides and their classification (ionic, covalent and interstitial), structure and properties with respect to stability of hydrides of p- block elements.
Structure, bonding and their important properties like oxidation/reduction, acidic/basic nature of the following compounds and their applications in industrial, organic and environmental chemistry.
Hydrides of nitrogen (NH_3, N_2H_4, N_3H, NH_2OH) Oxoacids of P, S and Cl.
Halides and oxohalides: PCl_3, PCl_5, $SOCl_2$ and SO_2Cl_2

Unit-5: Transition Elements (3d series)
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 for Mn, Fe and Cu.

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

Semester-III
Generic Elective Course-3 (Theory) Credit-6, Full Marks-70
Course Code: GE-CH-31, Course Title: Basic Organic Chemistry

Unit-1: Fundamentals of Organic Chemistry:
Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis.
Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals.
Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Hückel's rule.

Unit-2: Stereochemistry:
Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threo and erythro; D and L; *cis - trans* nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E/Z Nomenclature (for upto two C=C systems).
[N.B: For Alkanes, Alkenes & Alkynes functional group approach for the following reactions

(preparations & reactions) to be studied in context to their structure]

Unit-3: Alkanes: (Upto 5 Carbons). *Preparation:* Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. *Reactions:* Free radical Substitution: Halogenation.
Unit-4: Alkenes: (Upto 5 Carbons) *Preparation:* Elimination reactions: Dehydration of alkohols and dehydrohalogenation 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.
Unit-5: Alkynes: (Upto 5 Carbons) *Preparation:* Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides. *Reactions:* formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alk. $KMnO_4$.

Organic Chemistry-I

Unit-6: Aromatic hydrocarbons:
Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.
Reactions: (Case benzene): Electrophilic substitution: nitration, halogenation and sulfonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene).
Unit-7: Alkyl and Aryl Halides:
Alkyl Halides (Upto 5 Carbons) *Preparation:* from alkenes *and* alcohols.
Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis
Aryl Halides *Preparation:* (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions. *Reactions (Chlorobenzene):* Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/NH_3 (or $NaNH_2/NH_3$). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

Unit-8: Alcohols: *Preparation:* Preparation of 1^o, 2^o and 3^o 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. $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation *Diols:* oxidation of diols. Pinacol-Pinacolone rearrangement.
Unit-9: 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.
Unit-10: Ethers (aliphatic and aromatic): *Preparation & Reactions:* Cleavage of ethers with HI.
Unit-11: Carbonyl compounds (Aldehydes and ketones): (Formaldehye, acetaldehyde, acetone and benzaldehyde) *Preparation:* from acid chlorides and from nitriles. *Reactions* – Reaction with HCN, ROH, $NaHSO_3$, NH_2-G derivatives. Iodoform test. Aldol Condensation,

Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Pondorff Verley reduction.

Organic Chemistry-II

Unit-12: Carboxylic acid derivatives (aliphatic and aromatic):

Preparation: Acidic and Alkaline hydrolysis of esters,Acid chlorides, Anhydrides, Esters. Amide derivative from acids and their interconversion. *Reactions:* Comparative study of nucleophilicity of acyl derivatives. Hell – Vohlard - ZelinskyReaction, Reformatsky Reaction, Perkin condensation.

Unit-13: Amines and Diazonium Salts:

Amines (Aliphatic and Aromatic): (Upto 5 carbons) *Preparation*: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction. *Reactions:* Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO_2, Schotten – Baumann Reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation.

Diazonium salts: *Preparation:* from aromatic amines. *Reactions:* conversion to benzene, phenol, dyes.

Unit-14: Carbohydrates: Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose, Mutarotation, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, maltose, lactose) and polysacharride (starch) excluding their structure elucidation.

Semester-IV

Generic Elective Course-4 (Theory) Credit-6, Full Marks-70

Course Code: GE-CH-41, Course Title: Application Oriented Chemistry

Unit-1. Chemical Analysis: Principle and Application

Principles of acid-base, oxidation-reduction (Permanganometry, Dichromatometry) and complexometric titrations, Hardness of water, Principles of chromatographic separation, GLC, TLC, GC and HPLC, Elementary idea of Solvent extraction.

Unit-2. Polymer Chemistry:

Preliminary ideas of polymers, different schemes of classification of polymers, polythene, PVC, polyurethane, biopolymers, composition and uses of polymers.

Unit-3. Fuels: (i) Gaseous Fuel: Manufacture & uses of producer gas, water gas, light petroleum gas and bio-gas.

(ii) Liquid fuels: Crude oil-gasoline, diesel oil, octane number, cetane number, antiknock compounds

Unit-4. Paints, Varnishes and Synthetic Dyes: Primary constitution of paints, binders and solvents for paints, oil based paints, latex paints, Composition of varnishes, formulation of paints and varnishes, synthesis of methyl orange, Congo red, malachite green, crystal violet and applications

Unit-5. **Drug and Pharmaceuticals**

Introduction about drug and pharmaceuticals, preparation and extraction, purification and uses of aspirin, paracetamol, enovid, sulphadiazine, chloroquine, metronidazole, vitamins-B_{12} & B_6, penicillin

Unit-6. Domestic and useful materials

Fats and oils, edible and inedible oil, glycerides, enzyme based detergents, detergents powders, liquid soaps, Cosmetics and perfumes, application and side effects of hair dyes, hair sprays, creams, lipstic, face powder, talcom powder, tooth paste, nailm polish, shampoos, jasmone, amylacetate

Unit-7. Pesticides, Insecticides and Food additives

Classification of Pesticides, Common pesticides: Production, application and toxicity of gammaxene, aldrin, parathion, malhathion, DDT, paraquat, organaophosphorous, carbamates, Food Additives: Food flavour, food colour, food preservatives, artificial sweeteners, MSG its applications and side effects, edible emulsifiers and edible foaming agents.

Unit-8. Cement and electroplating

Composition of cement, manufacture and uses, setting of cement, determination of quality of cement, Theories of electroplating, galvanization application and uses

Unit-9. The atmosphere

Structure of atmosphere, Ozone layer and its role, major air pollutants, CO, SO_2, NO_x, SPM, ozone layer depletion, greenhouse effect, acid rain, smoke, sulphurous smoke, air pollution effect and methods of prevention

Unit-10. The hydrosphere

Water pollutants: action of soaps, detergents, phosphates, arsenic, industrial effluents, agriculture runoff, radioactive pollution and effects on animal and plants.

Water pollution control measures, waste water treatments, chemical treatments and microbial treatment, water quality parameters, DO, BOD, COD, and TDS. Desalination of sea water and reverse osmosis

Special Note: For this paper, GE-CH-4, students may take options (if any notified in the University Website: Please follow website) from the available MOOCs courses approved by the University.