Course Outcome (CO) of B.Sc. Major in Chemistry (CCF)

&

Course Outcome (CO) of B.Sc. Honours in Chemistry (CBCS)

(For Sem1, Sem2, Sem3, Sem5 and Sem6 students of Academic year, 2024-2025)

Semester	Paper	Course
I **(CCF)**	**CHEM-H-CC1-1-TH**	**Module : I** Chemical sciences at its grass root level involve elements to form the foundation level of chemistry. An element is characterized by its atoms which are exactly identical in their physical and chemical properties but totally different from the atoms of different elements. To be more specific the atomic behavior is exclusively dependent on the characteristic electron borne by the atom. Regarding the position of the electron, it is the extra nuclear part of an atom which houses the electrons, controls their interaction with the nucleus at the core of the atom as well as with the surrounding electrons. Therefore to explore the behavior of the electrons, studies on extra nuclear structure are highly essential. Chemistry without periodic table is meaningless. Periodic table is the main focal point from which chemical periodicity does arise. Periodicity plays the vital role to acquire the knowledge of chemistry on s & p -Block elements where noble gases are also included. **Module : II** Nomenclature of organic compounds. Idea of formal charge and Double bond Equivalent (DBE). Idea of spatial arrangement and structure of organic molecules considering Valence Bond Theory (VBT, hybridization) and Molecular Orbital Theory (MOT). Basics of electron displacement mechanism (inductive and resonance effect including hyperconjugation). Basics of Hückel π-MOT for acyclic and cyclic conjugated polyenes. Concept of aromaticity – antiaromatic, non-aromatic and homoaromatic molecules. Prediction of physical properties such as melting and boiling points based upon the understanding of non-covalent interactions. Preliminary idea of solvent-solute interactions as seen in organic chemistry. Concepts of stereochemistry: Bonding geometries of carbon compounds: concept of asymmetry; Fischer, sawhorse, flying wedge and Newman projection

		formulae and their inter translations. Concept of chirality and symmetry: symmetry elements and operations. Idea of stereoisomerism – enantiomerism and diastereomerism. Concept of asymmetry and dissymmetry. **Module : III** After successful completion of the course, student would learn the basic concept of Thermodynamics; zeroth law and first law of thermodynamics. They will know how to calculate heat, work and change of internal energy and enthalpy for different processes. They can explain basic principles of Thermochemistry. The students will also understand the concept of chemical kinetics, rate laws for zero, 1st and 2nd order reactions, temperature dependence of rate constant and Arrhenius equation.
	CHEM-H-SEC1-1-TH	**Module: I, II, III** Analytical chemistry is divided into two parts, qualitative analysis and quantitative analysis. Quantitative analysis shows what elements (or ions) a give substance contains. The aim of quantitative analysis is determination of the quantitative contents of individual elements or compounds present in a substance. Quantitative analysis is of enormous importance in science and industry. For example, the chemical formula of an unknown substance is found from the percentage contents of its constituents, found by analysis. Chemical analysis is a most important method of investigation and is widely used in all branches of science that are related to chemistry. For example, it is of great importance in mineralogy, geology, physiology, microbiology and medical, agricultural and environmental sciences. Chemical analysis is no less important in industry. The technologist must know at every stage of the production process both the qualitative and quantitative composition of the materials undergoing conversion. At the present time no material is taken into production or released without analytical data which characterize its quality and suitability for subsequent analysis. These results not only form the basis of all the processing calculations but they also determine the cost of the materials, which forms the basis of financial estimates. Analysis of intermediate products is of enormous importance. The technologist uses the results of such analysis for most efficient utilization of the raw material, for prevention of troubles in the course of the process and therefore for prevention of

		spoilage. The solutions to a host of problems are to be made by the undergraduate students with the most diverse background in analytical methods in chemistry. Workers in many fields are constantly confronted by analytical problems, and in many cases they work out their own solutions. What distinguishes the analytical chemist from other workers is an interest in the method and technique in their own right. To analytical chemists, developing methods is the challenging part of the research. They are likely to be skeptical of data presented without a full disclosure of experimental details and they retain a critical attitude toward results which some workers would like to accept so as to get on with other things. Analytical chemists deal with real, practical systems, and much of their effort is expended in an attempt to apply sound theory to actual chemical situations.
II (CCF)	**CHEM-H-CC2-2-Th**	**Module : I** Concept of pressure and temperature from kinetic theory of gas. 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; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Wall collision and rate of effusion 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. 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 behavior ; 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 the Virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential - elementary idea. **Module: II** Chemical Bonding - I: i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals. Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Elementary ideas on stoichiometric and non-stoichiometric defects in solids.

		Energetics of dissolution of the polar and non-polar solutes in different solvents. ii) Covalent Bonding: Polarizing power of cations and polarizabilty of the anions, ionic potential of positively charged species, Fajan's rules to assess polarisation qualitatively, Lewis structures following closed-shell representation, formal charge, Valence Bond Theory, The hydrogen molecule (Heitler – London approach), directional character of covalent bonds, hybridizations and molecular geometry, equivalent and non-equivalent hybrid orbitals, Bent's rules, dipole moments, VSEPR theory, shapes of molecules and ions containing lone pairs and multiple bonding manifesting σ and π bonds. Theoretical principles of inorganic qualitative analysis: Basic principles involved in analysis of cations and anions and solubility products, common ion effect concept. Principle involved in separation of cations into groups and choice of group reagents. Basis of classifying the interfering anions (fluoride, borate, oxalate and phosphate) and the need to remove them after Group II analysis during wet tests for he basic radicals. **Module: III** Concepts of stereochemistry-II: Chirotopicity and its relationship with stereogenicity; concept of pseudoasymmetry for ABA type systems. Relative and absolute configuration: *R*/*S* descriptors; erythro/threo and meso nomenclature of compounds; *E*/*Z* descriptors for C=C, combination of *R*/*S*- and *E*/*Z* isomerisms. Optical activity of chiral compounds: optical rotation, and specific rotation; racemic compounds, racemisation (through cationic, anionic intermediates); resolution of racemic organic acids and bases via diastereomeric salt formation; optical purity (o.p.) and enantiomeric excess (e.e.). Chemistry of reactive intermediates: Carbocations (carbenium and carbonium ions - non-classical carbocations), carbanions, carbon-based radicals: generation and stability, structure and elementary idea of philicity (electrophilic / nucleophilic behaviour) of these reactive intermediates. Reaction thermodynamics: Relationship between Gibbs free energy and equilibrium constant, enthalpy and entropy factor, calculation of enthalpy change via bond dissociation energy (BDE), intermolecular & intramolecular reactions. Reaction kinetics: Rate constant and its relation to free energy of activation; free energy profiles for one-step, and two-step reactions; catalyzed reactions, principle of microscopic reversibility; Hammond's postulate. Substitution Reaction-I: Free-radical substitution reaction: halogenation of alkanes, mechanism (with evidence) and

		stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate
III (CCF)	**CHEM-H-CC3-3-Th**	**Physical Chemistry - I** **Module : I** Need for a Second law of thermodynamics; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; 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; Physical concept of Entropy; Entropy is a measure of the microscopic disorder of the system. Entropy change of systems and surroundings for various processes and transformations; Entropy and unavailable work; Temperature – Entropy diagram. Useful work and The Gibbs and Helmholtz function. Changes at constant T, P. Application to electric work. Criteria for spontaneity and equilibrium. Gibbs- Helmholtz equation, The Gibbs Function and useful work in Biological systems. Gibbs free energy and spontaneous phase transition. Maxwell's relations; Joule-Thomson experiment and its consequences; inversion temperature; Joule-Thomson coefficient for a van der Waals gas; General heat capacity relations State functions for system of variable compositions. Criteria of equilibrium and spontaneity in systems of variable composition. Partial molar quantities, dependence of thermodynamic parameters on composition; Chemical potential as an escaping tendency. Gibbs-Duhem equation, Entropy and Gibbs function for mixing of ideal gases, the chemical potential of ideal mixtures. The Fugacity function of a pure real gas. Calculation of the fugacity of a van der Waals gas using compressibility factor. Activities and activity coefficients. Choice of standard states. Dependence of Activity on pressure and temperature. **Module : II** 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; Van't Hoff's reaction isobar and isochore from different standard states; Le Chatelier's principle and its derivation, variation of equilibrium constant under different conditions Nernst's distribution law; Application- (e.g. dimerization of benzene in benzoic acid). Solvent Extraction. **Module : III** 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; Debye-Huckel limiting law-brief qualitative description. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law. 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. 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. Salt hydrolysis- calculation of hydrolysis constant, degree of hydrolysis and pH for different salts (exact Treatment). Determination of hydrolysis constant conductometrically. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action. Theory of acid–base indicators; selection of indicators and their limitations.
	CHEM-H-CC4-3-Th	Acids and bases in Organic Chemistry: Concept of pK_a and pK_{aH}, effect of structure, substituent and solvent on acidity and basicity; proton sponge. Tautomerism in organic chemistry: Basic difference between tautomerism and resonance, prototropy (keto-enol, phenol-keto); 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, basic ideas about valence tautomerism and ring-chain tautomerism. Concepts of Stereochemistry –III: Conformation-I: Basic idea of conformation, concept of dihedral angle, torsion angle; energy barrier of rotation, conformational Nomenclature (Newman & Sawhorse): eclipsed, staggered, gauche, *syn* and *anti*; concept of torsional and steric strains, relative stability of conformers on the basis of steric effect: butane-gauche interaction, special reference to preferred geometry for β-elimination. Nucleophilic substitution reactions: Substitution at sp^3 centre (systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides, α-halocarbonyls]: 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 Neighbouring Group participation (NGP, with heteroatoms and phenyl groups). 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 reactions, comparison between nucleophilicity and basicity. Chemistry of Alkenes: Addition reactions - mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, syn and anti-hydroxylation, ozonolysis, cyclopropanation - addition of singlet and triplet carbenes; Simmons-Smith cyclopropanation reaction; electrophilic addition to 1,3-butadiene; concept of kinetic and thermodynamic control of products; radical addition of HBr; mechanism of allylic and benzylic bromination in competition with brominations across C=C; use of NBS; interconversion of *E* and *Z* alkenes. Chemistry of Alkynes: Addition reactions - mechanism, reactivity, regioselectivity (Markownikoff and anti-Markownikoff addition) and stereoselectivity; reactions: hydrogenation, Hg(II) ion catalysed hydration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity. Electrophilic aromatic substitution: Mechanisms and evidences in favour of it including PKIE; orientation and reactivity; reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction; one-carbon electrophiles (reactions: chloromethylation, Houben-Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmitt); *Ipso* substitution. Nucleophilic aromatic substitution: Addition-elimination mechanism and evidences in favour of it; S_N1 mechanism; *cine* substitution (benzynemechanism), structure of benzyne. Birch Reduction of benzenoid aromatics: Benzene, Alkylbenzene, Anisole, Benzoic acid (with mechanism).
V (CBCS)	**CEMA-CC-5-11-(TH+P)**	The first part explores the mathematical foundations of several facts of advanced quantum chemistry related to simple harmonic

		oscillator, angular momentum, hydrogen atom and hydrogen-like ions and LCAO approach. The course also focuses on statistical thermodynamics that provides a quantitative link between the properties of the microscopic particles and the behaviour of the bulk material. For a large number of particles, statistical thermodynamics is an extremely precise theory. It encompasses the equilibrium thermodynamics of the interacting and the non-interacting particles. The remaining part is the numerical analysis, which finds wide application in interdisciplinary science, and concerns the development and analysis of methods to compute numerical approximations to the solutions of mathematical problems.
	CEMA-CC-5-12-(TH+P)	Information about the importance of polynuclear hydrocarbons and heterocyclic compounds containing one heteroatom, their synthesis and reactions. Conformational analysis of cyclohexane ring systems, case studies regarding substitution, elimination, rearrangement and oxidation reactions of cyclohexyl substrates. Frontier Molecular Orbital (FMO) analysis and synthetic importance of the three fundamental pericyclic processes – cycloaddition, electrocyclic reaction and sigmatropic rearrangements. Glycochemistry – structure, stereochemical aspects and reactions of monosaccharides up to hexoses, introduction to disaccharides. Detail concept of proteins and peptides – amino acids and their chemistry, formation of peptide bonds, structural hierarchy of proteins and their functions. Idea about the genetic material – deoxyribonucleic acids and ribonucleic acids, their building blocks – nucleotides and nucleosides, their reactions. The practical part highlights chromatographic separations: Basic theory of chromatography and hands-on training to set the column, TLC plates and papers for chromatographic separations; as well the spectroscopic analysis of known organic compounds: Assignment, identification and related explanation of IR, NMR signals to known organic compounds. In addition, discussion of elucidation of structure for organic compounds by IR, NMR spectral data using prototypical samples, also form an interesting part of the practical course.
	DSE-A2: Applications of Computers in Chemistry	The topic computer programming basics, primarily deals with the first high-level FORTRAN programming language to facilitate the mathematical computations in science applications. Introduction to spreadsheet software is usually given to the students using Microsoft Excel, which is a spreadsheet program that is used to record and analyse numerical data. Statistical analysis deals with the science of collecting and analyzing data to identify trends and patterns and presenting them. Such applications of programming, handling various software, can

		eventually expose a student to compute the analytical solutions of a given problem.
	DSE-B1: Inorganic Materials of Industrial Importance	This discipline specific elective course primarily focuses on the structure, property, use and more importantly the synthesis of inorganic and organic materials having plethora of industrial applications. The subject matter broadly deals with silicates, fertilizers, surface coatings, batteries, alloys, catalysis, and chemical explosives. The course is designed in a way to ensure that the students come to know how the theoretical principles that they learn in different branches of chemistry are implemented in the industry. The practical part enables a student to determine the free acidity and calcium content of a fertiliser, metal composition of alloy, composition of an ore, and composition of cement.
VI (CBCS)	**CEMA-CC-6-13-(TH+P)**	The course is composed of two versatile subjects: Bioinorganic chemistry and Organometallics. At the higher studies level there is no demarcation between chemical sciences and biological sciences. Both the sciences are in the same level. Therefore any chemistry honors student desiring to switch over to the Biological field in his future career, knowledge on bioinorganic field may serve as the fuel for him to cope up with biology related subject matter. Organometallics chemistry deserves immense importance in the context of industrial catalysis. Therefore, a knowledge over the aspects of metal-carbon bonding supported by ancillary ligands is worthwhile. A proper understanding of the stereo-electronic factors of organometallic complexes can eventually increase the cognitive power of a student to a different level. So long as organometallic chemistry is concerned, it is vital for the students choosing job in industrial field. The practical part focuses on the qualitative analysis of a mixture of inorganic salts. The module is highly effective in a sense that a student comes to know how to identify a specific radical in solution in presence of the others.
	CEMA-CC-6-14-(TH+P)	After successful completion of the course, student would i) Understand various aspects of molecular spectroscopy. ii) Explain the basic principles of microwave, infrared, Raman Spectroscopy. iii) Understand principles and applications of electronic spectroscopy, fluorescence and phosphorescence, Jablonski diagram. iv) Understand laws of photochemistry, photochemical and biochemical processes, chemiluminescence, quantum yield. v) Understand the theory of reaction rate. vi) Discuss the theoretical basis of surface phenomenon, surface tension and surface energy; basic concept of adsorption and adsorption isotherms, heterogenous catalysis.

		vii) Describe different types of colloids, their properties and stability. viii) Explain the theoretical aspects of dipole moment and polarizability.
	DSE-A4: Analytical Methods in Chemistry	Analytical methods in chemistry is concerned with the theory and practice of methods used to determine the composition of matter. In developing methods of analysis, the analytical chemist feels to draw upon the principles from any field of science- chemistry, physics, biology, engineering and technology, computer science, etc. For example, instruments developed by the physicists such as potentiometer, IR spectrophotometer etc. have found wide applications in solving analytical problems. There are today many new techniques available for application to analytical problems, and for this reason the undergraduate students need to have a sound knowledge of a number of analytical techniques. The explosion of technological developments in recent years has created analytical problems which demand increasingly sophisticated knowledge and instrumentation for their solution. Typical examples of such problems are determining traces of impurities at the parts-per-billion (ppb) level in ultrapure semiconductor materials, deducing the sequence of about 20 different amino acids in a giant protein molecule, detecting traces of unusual molecules in the polluted atmosphere of a smog-bound city and determining pesticide residues at the ppb level in food products.
	DSE-B4: Dissertation	It focuses the background of research motivation for the students. It is quite obvious that a certain percent of students always enter the research field after completion of post-graduate degree. This topic germinates the seed of research motivation in a student's tender mind.