Semester	**2**
Programme	**CHEMISTRY**
Course	**MINOR: GENERAL CHEMISTRY 2**
Paper Code	**B1CH230212T/ B1CH230212P**
Credits	**4 (THEORY – 3 PRACTICAL – 1)**
Hours/week	**5 (THEORY: 3 PRACTICAL: 2)**
Category: Core/MDC/SEC/VEC	**CORE**
Theory/Practical/Composite	**COMPOSITE**
Number of Modules	**4 (THEORY: 3; PRACTICAL: 1)**
Syllabus	**Theory:** **Group A** **Module 1: Chemical Thermodynamics 2 (12 Lectures)** 1. Statement of Second law of Thermodynamics and their equivalence. 2. Carnot's cycle and Carnot's theorem. 3. Entropy revisited, Absolute scale of temperature. 4. Clausius inequality, condition of reversibility and irreversibility of a process. 5. Auxiliary state functions: Helmholtz free energy and Gibbs free energy and their simple applications. 6. Laws of Thermochemistry and their applications, Born Haber Cycle, Standard Enthalpy changes in various transformations, Kirchoff relation. 7. Maxwell's relation, $Cp - Cv$ relation, Joule-Thompson coefficient for van der Waals gases 8. Thermodynamic Equation of state. 9. Gibbs- Helmholtz relation and its application 10. Chemical Equilibrium: State of equilibrium and thermodynamic condition of equilibrium 11. Condition of Minimum Gibbs' potential, 12. van't Hoff reaction isotherm (deduction using chemical potential). 13. Temperature dependence of Equilibrium constant. 14. Homogeneous equilibrium: Use of different standard states to define Kp, Kx, and Kc and their interrelations 15. Examples of homogenous equilibrium in gas phase. **Module 2 : Extra nuclear Structure of atom (12 Lectures)** 1. de Broglie equation, 2. Heisenberg's Uncertainty Principle and its significance, 3. Schrödinger's wave equation, 4. significance of ψ and ψ2. 5. Quantum numbers and their significance. 6. Radial and angular wave functions for hydrogen atom. 7. Radial and angular distribution curves. 8. Shapes of s, p, d and f orbitals. 9. Pauli's Exclusion Principle, 10. Hund's rules and multiplicity, 11. Exchange energy, 12. Aufbau principle and its limitations. **Group B** **Module 3 : Electrophilic addition and Aromatic Substitution Reactions (12 Lectures)**

	Electrophilic addition reactions (6 Lectures) Alkenes: Reactions and mechanism-- Addition of bromine, addition of HX [Markownikoff's (with mechanism) and anti-Markownikoff's addition], hydration: oxymercuration-demercuration and hydroboration-oxidation reaction, cis-addition (alkaline $KMnO_4$), ozonolysis, 1,3-dipolar cycloaddition, click reaction. **Aromatic Substitution Reactions (6 Lectures):** Electrophilic substitution (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), sulphonation and Friedel-Craft's reaction (alkylation and acylation) (up to 4 carbons on benzene); Reimer -Tiemann reaction, Houben–Hoesch condensation, Schotten– Baumann reaction, Fries rearrangement and Claisen rearrangement. Nucleophilic aromatic substitution, cine substitution. **Practicals:** Acid and Base Titrations: 1. Standardization of NaOH using oxalic acid. 2. Standardization of HCl/acetic acid using standardized NaOH. 3. Estimation of carbonate and hydroxide present together in mixture. 4. Estimation of carbonate and bicarbonate present together in a mixture. 5. Estimation of $NH+$ by formol titration. 6. Standardization of potassium permanganate by oxalic acid 7. Estimation of Fe(II)/ Fe(III) in a solution 8. Standardization of EDTA using zinc acetate solution. 9. Estimation of hardness of water
Course Overview	Theory: **General Chemistry 2 (B1CH230212T / B1CH230212P)** is a core composite undergraduate course designed to bridge fundamental physical laws with structural and mechanistic behaviors in chemistry. 1. **Advanced Thermodynamics & Chemical Equilibrium (Module I):** Explores the Second Law of Thermodynamics, Carnot efficiency, absolute entropy, Clausius inequality, and auxiliary functions (G and A). It covers non-ideal gas relations ($J\text{-}T$ coefficients), Kirchhoff's relations, the Born-Haber cycle, and the exact mathematical derivation of the van 't Hoff reaction isotherm to define gas-phase homogeneous equilibria (K_p, K_c, K_x). 2. **Extra-Nuclear Atomic Structure (Module II):** Investigates the quantum mechanical foundations of matter, analyzing wave-particle duality (de Broglie), the Heisenberg Uncertainty Principle, spatial boundary representations of $s, p,$ and d atomic orbitals, and the rules governing electronic configurations (Aufbau, Pauli, Hund). 3. **Organic Reaction Mechanisms (Module III):** Focuses on the energetics and pathway choices of foundational organic transformations, detailing addition and substitution mechanics for hydrocarbons and aromatic systems.

	Practical: 1. **Analytical Practical Modules (Module IV):** Cultivates analytical lab mastery in quantitative redox titrimetry and standardizations.
Course Outcomes (COs)	Upon successful completion of this course, students will be able to: **CO1 [Entropy & Cyclic Systems]:** Delineate statements of the Second Law of Thermodynamics, calculate the thermal efficiency of ideal engines via the Carnot cycle, and quantify entropy transformations (dS) in reversible and irreversible physical paths. **CO2 [Free Energies & State Functions]:** Evaluate spontaneity and equilibrium conditions using Helmholtz (A) and Gibbs (G) free energies, and manipulate Maxwell relations, thermodynamic equations of state, and the Gibbs-Helmholtz equation to predict system properties. **CO3 [Thermochemistry & Born-Haber Cycles]:** Apply Kirchhoff's equation to predict the temperature variation of reaction enthalpies, and utilize Hess's Law and Born-Haber cycles to calculate lattice energies of ionic crystals. **CO4 [Thermodynamic Equilibria]:** Derive the van 't Hoff reaction isotherm from basic chemical potentials, formulate expressions for homogeneous equilibria (K_p, K_c, K_x), and compute shifts in equilibrium composition as a function of temperature and pressure. **CO5 [Quantum Foundations of Matter]:** Analyze wave-particle duality via de Broglie’s relation and apply the Heisenberg Uncertainty Principle to establish the limitations of classical mechanics for sub-atomic particles. **CO6 [Wave Mechanics & Probability Interpretation]:** Interpret the physical significance of the Schrödinger wave equation and the probability density (ψ^2) in describing the state of an electron within the hydrogen atom. **CO7 [Atomic Orbitals & Configurations]:** Deduce the physical significance of the four quantum numbers, construct radial and angular boundary diagrams for $s, p, d,$ and f orbitals, and apply the principles of Aufbau, Hund, and Pauli to assign ground-state electronic configurations. **CO8 [Electrophilic Addition to Alkenes]:** Formulate detailed mechanistic pathways for electrophilic addition reactions of alkenes, including halogenation, Markovnikov/anti-Markovnikov hydrohalogenation, oxymercuration-demercuration, hydroboration-oxidation, syn-hydroxylation, ozonolysis, 1,3-dipolar cycloaddition, and click reactions. **CO9 [Aromatic Substitution & Rearrangements]:** Apply mechanisms of electrophilic aromatic substitution (nitration, halogenation, sulphonation, Friedel-Craft’s alkylation/acylation), nucleophilic aromatic substitution (including cine substitution), and named rearrangements (Reimer-Tiemann, Houben–Hoesch, Schotten–

	Baumann, Fries, and Claisen) to predict reaction products and mechanistic pathways. **CO10 [Acid-Base Titrimetry]:** Standardize acid and base solutions and perform volumetric estimation of carbonate-hydroxide and carbonate-bicarbonate mixtures and the ammonium ion (by formol titration) using acid-base titration techniques. **CO11 [Redox Titrimetry]:** Standardize potassium permanganate solution using oxalic acid and estimate the Fe(II)/Fe(III) content of an unknown solution using permanganometric (redox) titration. **CO12 [Complexometric Titrimetry]:** Standardize EDTA solution using zinc acetate and determine the total hardness of water by complexometric titration.
Program Outcomes (POs)	**PO1: Fundamental Knowledge:** Demonstrate a comprehensive understanding of core concepts in chemistry, including organic, inorganic, physical, analytical, and biochemistry. **PO2: Laboratory Skills:** Acquire hands-on experience in laboratory techniques and instrumentation, applying safety protocols and proper methodologies to conduct experiments and analyse results. **PO3: Problem Solving:** Develop critical thinking and problem-solving skills by applying chemical principles to real-world scenarios, including the ability to design experiments and interpret data. **PO4: Research Competency:** Engage in independent and collaborative research projects, employing scientific methods to formulate hypotheses, conduct experiments, and communicate findings effectively. **PO5: Interdisciplinary Applications:** Understand the interdisciplinary nature of chemistry, exploring its applications in fields such as medicine, environmental science, materials science, and nanotechnology. **PO6: Communication Skills:** Effectively communicate scientific information, both verbally and in written form, to diverse audiences, demonstrating the ability to present complex ideas clearly and concisely. **PO7: Ethics and Sustainability:** Recognize the ethical implications and responsibilities of scientific research and practice in chemistry, emphasizing the importance of sustainability and environmental stewardship in chemical practices.

CO #	Core Curriculum Domain	Bloom's Taxonomy K-Level	Mapped POs	Pedagogical Justification for K-Level & PO Selection
CO 1	Entropy & Carnot Cycle Analysis	**K4** (Analyze)	PO1, PO3	Requires the calculation of mechanical boundaries, thermodynamic efficiencies, and entropy state parameters in variable mathematical pathways.
CO 2	State Equations & Maxwell Relations	**K3** (Apply), **K4** (Analyze)	PO1, PO3	Students map abstract exact differentials onto multi-variable physical states to derive mathematical identities for real and ideal systems.
CO 3	Enthalpy Transformations & Lattice Energies	**K3** (Apply)	PO1, PO3	Requires applying localized state cycles (Born-Haber) to resolve empirical step-wise enthalpy changes in solid-state chemistry.
CO 4	Isotherms & Gas-Phase Equilibria	**K4** (Analyze)	PO1, PO3	Students disassemble complex gaseous mixtures, mathematically interrelate different equilibrium constants, and predict real-world shifts.
CO 5	Wave-Particle Duality & Uncertainty	**K3** (Apply), **K4** (Analyze)	PO1, PO3	Requires applying de Broglie's relation and the Uncertainty Principle to demonstrate why classical mechanics fails for sub-atomic particles.
CO 6	Wavefunction & Probability Density	**K2** (Understand)	PO1, PO5	Formulates the conceptual transition from deterministic classical trajectories to a probabilistic description of electron behaviour via the wavefunction.

CO 7	Orbital Boundary Surfaces & Electronic States	**K3** (Apply), **K4** (Analyze)	PO1, PO3	Requires constructing spatial orbital boundary diagrams and applying electron-filling rules to derive ground-state configurations.
CO 8	Electrophilic Addition (Alkenes)	**K4** (Analyze)	PO1, PO3	Students analyze competing mechanistic pathways and regioselectivity rules to predict addition products on alkene substrates.
CO 9	Aromatic Substitution & Named Rearrangements	**K3** (Apply), **K4** (Analyze)	PO1, PO3	Requires applying directing-group effects and named-reaction mechanisms to predict substitution products and rearranged structures.
CO 10	Acid-Base Titrimetry & Mixture Analysis	**K3** (Apply), **K5** (Evaluate)	PO2, PO4	Requires precise volumetric technique and stoichiometric calculation to resolve the composition of multi-component alkaline mixtures.
CO 11	Redox (Permanganometric) Titrimetry	**K3** (Apply), **K5** (Evaluate)	PO2, PO4	Requires active titrimetric operations and redox stoichiometry to evaluate iron content from empirical endpoint data.
CO 12	Complexometric Titrimetry	**K3** (Apply), **K5** (Evaluate)	PO2, PO5	Requires complexometric titration technique and stoichiometric calculation to evaluate water hardness from EDTA endpoint data.

Reading/Reference Lists	Theory: 1. Castellan, G. W. Physical Chemistry, Narosa. 2. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva. 3. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970. 4. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010). 5. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals. 6. Pfennig, B. W. (2015), Principles of Inorganic Chemistry. John Wiley & Sons. 7. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003. 8. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Practical: 2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009. 3. Harris, D. C.; Lucy,C. A.(2016), Quantitative Chemical Analysis, 9th 4. Edition, Freeman and Company

Evaluation	Theory: 60 Internal: 15 (CIA: 10; Other form of Assessment: 2; Attendance: 3) Semester Exam:45 (Gr. A: 15; Gr. B:30)	Practical: 40 CA:38; Attendance: 2
Paper Structure for Theory Semester Exam	Gr. A: Attempt ONE out of TWO questions of 15 Marks each Gr. B: Attempt TWO out of THREE questions of 15 marks each.	