Semester	**6**
Programme	**CHEMISTRY**
Course	**MAJOR (PHYSICAL CHEMISTRY 5)**
Paper Code	**C3CH230632T / C3CH230632P**
Credits	**4 (THEORY: 3 PRACTICAL: 1)**
Hours/week	**6 (THEORY: 3 PRACTICAL: 3)**
Category: Core/MDC/SEC/VEC	**CORE**
Theory/Practical/Composite	**COMPOSITE**
Number of Modules	**03**
Syllabus	**Module I: Phase Equilibria (12 Lectures)** 1. Definition of phase and thermodynamic condition of equilibrium between phases 2. Components and degrees of freedom 3. Phase rule and its derivation 4. Phase equilibrium for one component system (for example H_2O, S, CO_2) 5. Degrees of freedom at different regions of the phase diagram: interpretation of area, line and point in the phase diagram 6. Position of triple point in phase diagram and prediction of melting or sublimation of a pure substance 7. First and second order phase transitions 8. Clapeyron equation 9. Clausius-Clapeyron equation 10. Trouton's rule 11. Liquid-vapor equilibrium for two component system: ideal solution 12. Non-ideality, azeotrope 13. Raoult's law and vapour pressure of a two component ideal solution 14. Non-volatile solute: Raoult's law of relative lowering of vapour pressure 15. Change in phase diagram due to addition of solute in a pure liquid: effect on freezing and boiling point of the solute 16. Chemical potential versus temperature line of one component system existing in three different phases

	18. phase transition temperature and its variation due to addition of non-volatile solute that does not solidify with the solvent 19. Variation of phase transition temperature with pressure 20. Non-ideality in two component system: implication in vapour pressure diagram 21. Henry's law 22. Duhem-Margules equation and its consequences 23. Constant boiling mixture 24. Two component partially miscible solution: Critical solution temperature 25. Lever rule and its application 26. Freezing point diagram: simple eutectic systems 27. Compound formation: implication in freezing point diagram 28. Ideal solution and ideally dilute solution **Module II: Spectroscopy 1 (12 Lectures)** 1. Spectroscopy- Nature of electromagnetic radiation, range of wavelength 2. Quantum mechanical picture of light-matter interaction: first order perturbation theory 3. Transition moment integral and allowed transitions 4. Einstein coefficient for spontaneous and stimulated transition 5. Stimulated emission and lasers and 3-level system 6. Width and intensity of transition, line broadening (Uncertainty broadening) 7. Rotational spectroscopy: rigid and non-rigid rotors (diatomic only) 8. Selection rule and spectrum 9. Isotope effect

	10. Hyperfine structure (effect of nuclear spin) **Module III: Hydrophilic Colloids and Colligative Properties (12 Lectures)** 1. Surfactants: variation in surface tension of water with surfactant addition. 2. Thermodynamics of interfacial adsorption: Gibbs adsorption isotherm. 3. Surface excess concentration: determination and significance. 4. Self-aggregation of surfactants in aqueous solution: micellization. 5. Spontaneity of micellization: iceberg model. 6. Types of surfactant: variation in cmc within homologous series. 7. Thermodynamics of micellization: mass action and pseudo-phase model. 8. Surfactant structure and shape of aggregate: packing fraction. 9. Viscosity of liquids. 10. Temperature dependence of viscosity of liquid. 11. Poiseuille equation and Measurement of viscosity. 12. Effect of addition of non-volatile solute on boiling point 13. Thermodynamic derivation of boiling point elevation 14. Addition of solute that does not solidify with solute: thermodynamics of freezing point depression 15. Freezing point elevation and boiling point depression 16. Osmotic pressure of a solution: thermodynamic derivation 17. Vapour pressure versus mole fraction (in liquid and vapour) diagram **Practical** 1. pH-metric estimation of amino acid (Glycine) 2. Determination of formal potential of Fe^{3+}/Fe^{2+} system using potentiometry 3. Determination of solubility product of $AgCl$ by potentiometry 4. Determination of concentration of strong and a weak acid in a mixture by conductometric method 5. Verification of Ostwald dilution law 6. Kinetics of perdisulphate-KI reaction using spectrocolourimeter
Course Overview	**Theory:** 1. Concept of ideal solutions and formulation of Raoult's and Henry's laws. From this, the effect of a solute on certain thermodynamic properties of the solution will be discussed. 2. Application to phase equilibria governed by the famous phase rule of Gibbs, which shows the extent to which various parameters can be varied with preservation of the equilibrium between phases. 3. Application to systems of gradually increasing

	complexity with the help of phase diagrams. 4. After eigenstates and eigenvalues have been obtained from quantum mechanical recipes, transitions between the energy levels resulting from interaction with electromagnetic radiation, become very important. Students will be exposed to selection rules governing transitions, unravelling of molecular parameters, explanation of intensity patterns and ratios, presence of isotopes etc. The focus will be on rotational excitation of the molecules. 5. Colloids, forming a micro heterogeneous phase deserve a separate treatment in terms of stability and coagulation, scattering power, double layered potential and various electrokinetic phenomena. Soft colloidal systems will also be dealt with in sufficient detail. **Practical:** 1. Various experiments involving measurement of strengths of solutions, solubility product and reaction rate constants are determined using potentiometric, pH-metric, potentiometric and conductometric methods.
Course Outcomes	Upon successful completion of this course, students will be able to: **CO1 [Phase Rule & 1-Component Systems]:** Derive the thermodynamic phase rule and interpret the area, line, and triple point constraints in phase diagrams for pure substances (H_2O, S, CO_2) using the Clapeyron and Clausius-Clapeyron equations, classify first- and second-order phase transitions, and apply Trouton’s rule. **CO2 [2-Component Mixtures & Non-Ideality]:** Analyze two-component liquid-vapor and solid-liquid equilibria, applying Raoult’s law, Henry’s law, the Duhem-Margules equation, and the Lever rule to predict azeotropic behavior, the critical solution temperature of partially miscible liquids, and simple eutectic compound formation. **CO3 [Quantum Light-Matter Interaction]:** Explain the principles of light-matter interaction using first-order perturbation theory, evaluating transition moment integrals, Einstein coefficients, and the mechanisms of stimulated emission in lasers. **CO4 [Rotational Spectroscopy]:** Apply quantum mechanics to rigid and non-rigid diatomic rotors, determining selection rules, predicting energy spectra, and evaluating the effects of line broadening, isotopic substitution, and hyperfine structure arising from nuclear spin. **CO5 [Surfaces & Micellization]:** Analyze the thermodynamics of interfacial adsorption using the Gibbs adsorption isotherm and evaluate the self-aggregation of surfactants (micellization) using the iceberg, mass-action, and pseudo-phase models, relating surfactant structure to the packing fraction and shape of the resulting aggregate. **CO6 [Viscosity & Fluid Dynamics]:** Determine the temperature dependence of liquid viscosity and apply the Poiseuille equation to

	evaluate fluid properties. **CO7 [Thermodynamics of Colligative Properties]:** Derive rigorous thermodynamic expressions for boiling point elevation, freezing point depression, and osmotic pressure by analyzing changes in the chemical potential of non-volatile solute mixtures. **CO8 [Advanced Instrumental Analysis]:** Execute potentiometric, pH-metric, conductometric, and colorimetric protocols to quantify equilibrium constants (K_{sp} of $AgCl$), formal potentials (Fe^{3+}/Fe^{2+}), and reaction kinetics in multi-component systems, and verify the Ostwald dilution law for a weak electrolyte.
Program Outcomes	**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
CO1	Phase Rule & 1-Component Systems	**K4** (Analyze)	PO1, PO3
CO2	2-Component Solutions & Eutectics	**K4** (Analyze), **K5** (Evaluate)	PO1, PO3
CO3	Light-Matter Interaction & Lasers	**K2** (Understand), **K4** (Analyze)	PO1, PO3
CO4	Diatomic Rotational Spectroscopy	**K3** (Apply), **K4** (Analyze)	PO1, PO3
CO5	Adsorption Isotherms & Micelles	**K4** (Analyze)	PO1, PO3, PO5
CO6	Liquid Viscosity Dynamics	**K3** (Apply)	PO1, PO3
CO7	Thermodynamic Colligative Derivations	**K4** (Analyze), **K5** (Evaluate)	PO1, PO3
CO8	Electrometric & Kinetic Practicals	**K3** (Apply), **K4** (Analyze)	PO2, PO4, PO6

Reading/Reference Lists	**Theory:** 1. Castellan, G. W. Physical Chemistry, Narosa. 2. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 3. Moore, W. J. Physical Chemistry, Orient Longman. 4. Glasstone, S, Thermodynamics for Chemists, EWP. 5. Denbigh, K. The Principles of Chemical Equilibrium Cambridge University Press. 6. Silbey, R. J. Alberty, R. A. Bawendi, M. G., Physical Chemistry, Wiley. 7. Banwell, C. N. Fundamentals of Molecular Spectroscopy, Tata McGraw-Hill. 8. Barrow, G. M. Molecular Spectroscopy, McGraw- Hill. 9. Hollas, J.M. Modern Spectroscopy, Wiley India. 10. McHale, J. L. Molecular Spectroscopy, Pearson Education. 11. Wayne, C. E. & Wayne, R. P. Photochemistry, OUP. 12. Brown, J. M. Molecular Spectroscopy, OUP. 13. Heimz, P. C., Rajagopalan, R., Principle of Colloid and Surface Chemistry, Marcel Dekker. 14. Shaw, D. J., Introduction to Colloid and Surface Chemistry, Butterworth Heinemann. 15. Ohshima, H., Theory of Colloid and Interfacial Electric Phenomena, Elsevier. **Practicals:** 1. Mukherjee, G. N., University Hand Book of Undergraduate Chemistry Experiments	
Evaluation	Theory: 60 Internal: 15 (CIA: 10; Other form of Assessment: 2; Attendance: 3) Semester Exam: 45	Practical: 40 CA: 38; Attendance:2
Paper Structure for Theory Semester Exam	Answer THREE out of FOUR questions, of 15 marks each.	