Semester	**4**
Programme	**CHEMISTRY**
Course	**MAJOR (PHYSICAL INORGANIC CHEMISTRY 3)**
Paper Code	**C2CH230421T**
Credits	**4 (THEORY: 4)**
Hours/week	**4 (THEORY: 4)**
Category: Core/MDC/SEC/VEC	**CORE**
Theory/Practical/Composite	**THEORY**
Number of Modules	**4**
Syllabus	**Gr. A: Physical Chemistry 3** **Module I: Chemical Equilibrium 12 L** 1. Chemical potential of a component in a mixture 2. Scales of chemical potential 3. Thermodynamics of mixing of ideal gases 4. Gibbs equations for system with variable composition 5. Conditions of spontaneity and equilibrium in terms of internal energy, Enthalpy, Gibbs and Helmholtz free energy 6. Molar Gibbs free energy and its change in a reacting system and its thermodynamic expression 7. Concept of standard state free energy change of a reaction in pressure and concentration scale 8. Equilibrium constant: partial pressure, concentration and mole fraction scale and their inter-relation 9. Activity and concentration: equilibrium constant in activity scale 10. Effect of temperature and pressure on equilibrium constants 11. Equilibrium in heterogeneous reaction 12. Perturbing the state of equilibrium: Le Chatelier principle 13. Solubility equilibria 14. Salt effect 15. Nernst distribution law and generalized Distribution equilibrium **Module II: Quantum Mechanics III 12 L** 1. Particle on a Ring 2. Concept of the effective potential 3. Particle on a sphere: coordinate system 4. Form of Schrodinger equation in polar coordinates 5. Form of Schrodinger equation for a two particle system in Cartesian co-ordinates and reduction to one particle system 6. The diatomic rigid rotor: solution of theta and phi part (derivation) 7. Generation and properties of the Spherical Harmonics. 8. Expression of L^2, L_Z in polar coordinate, physical significance 9. Shift Operators and their significance.

	10. Concept of effective potential 11. Central force problem and formulation of the Schrödinger equation for hydrogen atom **Gr. B: Inorganic Chemistry 3** **Module I: Redox Chemistry and Applications 12 L** Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions. **Module II: Acid-Base and solubility equilibria 12 L** Acid-base equilibria in aqueous solution (proton transfer equilibria in water); pH, hydrolysis of salt, buffer; acid-base neutralization curves; indicators, choice of indicators. Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides.
Course Overview	1. **Thermodynamic Foundation of Mixtures:** This module establishes the concept of chemical potential as the driving force for matter transfer, deriving its various scales and applying it to the thermodynamics of mixing ideal gases and the general Gibbs equations for systems with variable composition. 2. **Quantifying Reaction Spontaneity:** Students will learn to express the spontaneity and equilibrium conditions for chemical reactions using molar Gibbs free energy, deriving the fundamental thermodynamic expression that links the standard free energy change to the equilibrium constant across different scales (pressure, concentration, and mole fraction). 3. **Equilibrium in Real and Complex Systems:** The module extends equilibrium concepts to non-ideal systems through activity, explores the effect of external parameters (temperature and pressure) on equilibrium constants, and applies these principles to heterogeneous reactions, solubility equilibria, salt effects, and the Nernst distribution law. 4. **From 1-D to 3-D Rotational Motion:** This module transitions from simple linear models to three-dimensional systems by introducing the particle on a ring and particle on a sphere, culminating in the formulation and derivation of the Schrödinger equation for the diatomic rigid rotor in polar coordinates. 5. **Central Force Problems and Angular Momentum:** Students will learn to solve the angular parts of the Schrödinger equation, leading to the generation and properties of spherical harmonics, and will explore the physical significance of angular momentum operators (L^2, Lz) and shift operators in the context of rotational motion. 6. **Foundation for Atomic Structure:** The module introduces

	the concept of effective potential for central force problems, culminating in the formulation of the Schrödinger equation for the hydrogen atom, thereby bridging the gap between quantum mechanical principles and the electronic structure of atoms. 7. **Quantitative Redox Analysis:** This module covers the systematic ion-electron method for balancing redox equations and introduces the fundamental concepts of standard electrode potentials and the Nernst equation to predict the direction and extent of electron transfer reactions. 8. **Environmental and Chemical Influences on Redox:** Students will analyze how factors such as complex formation, precipitation, and pH changes affect redox potentials, leading to the concept of formal potential, and will learn to determine the feasibility and equivalence point of redox titrations. 9. **Visualizing Chemical Stability:** The module introduces Latimer and Frost diagrams as powerful tools to visually represent the redox properties of elements, predict the thermodynamic stability of oxidation states, and analyze the feasibility of disproportionation and comproportionation reactions. 10. **Aqueous Proton Transfer Equilibria:** This module delves into acid-base chemistry in water, covering proton transfer equilibria, the calculation of pH, salt hydrolysis, and the principles of buffer solutions, providing the theoretical basis for understanding pH control in chemical systems. 11. **Acid-Base Titration Analysis:** Students will learn to construct and interpret acid-base neutralization curves, understand the theory behind acid-base indicators, and develop the skills to choose appropriate indicators for quantitative analytical applications. 12. **Precipitation and Separation Strategies:** The module applies the solubility product principle and the common ion effect to predict precipitation and to design systematic separation schemes for common metallic ions (as hydroxides, sulfides, phosphates, carbonates, sulfates, and halides), demonstrating the practical utility of these equilibrium concepts.
Course Outcomes	Upon successful completion of this course, students will be able to: **CO1:** Define and explain the concept of chemical potential for components in mixtures, derive its various scales, and apply the thermodynamics of mixing to ideal gases. **CO2:** Derive the Gibbs equations for variable composition, formulate the conditions for spontaneity and equilibrium, and calculate the molar Gibbs free energy change for reacting systems. **CO3:** Interpret and interconvert equilibrium constants across pressure, concentration, mole fraction, and activity scales, predict the effect of temperature, pressure, and perturbations on equilibrium in homogeneous, heterogeneous, and solubility systems, and apply the Nernst distribution law to generalized distribution equilibria between immiscible phases. **CO4:** Formulate the Schrödinger equation for a two-particle system and reduce it to an effective one-particle problem, and solve the resulting equation for the particle on a ring and the diatomic rigid rotor to derive the angular wavefunctions (spherical harmonics).

	CO5: Explain the physical significance of angular momentum operators (L^2, L_z), shift operators, and the concept of effective potential in the context of 3-D rotational motion. **CO6:** Formulate the Schrödinger equation for the hydrogen atom as a central force problem, reducing it from a two-particle to a one-particle system in polar coordinates. **CO7:** Balance complex redox reactions using the ion-electron method and apply the Nernst equation to calculate electrode potentials under non-standard conditions. **CO8:** Analyze the influence of complexation, precipitation, and pH on redox potentials, evaluate the feasibility of redox titrations, determine the potential at the equivalence point, and select appropriate redox indicators. **CO9:** Construct and interpret Latimer and Frost diagrams to predict the stability of oxidation states, and analyze the thermodynamic feasibility of disproportionation and comproportionation reactions. **CO10:** Analyze acid-base equilibria in aqueous solutions, including pH calculations, salt hydrolysis, buffer action, and the construction of acid-base neutralization curves. **CO11:** Select and justify the choice of appropriate indicators for acid-base titrations by interpreting their pH transition ranges and the theoretical titration curve. **CO12:** Apply the solubility product principle and the common ion effect to predict precipitation, and design systematic separation schemes for common metallic ions based on their solubility properties.
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 #	Course Outcome Summary	Bloom’s Taxonomy (K-Level)	Mapped POs
CO1	**Chemical Potential & Mixing**	**K3, K4**	**PO1, PO3**
CO2	**Gibbs Free Energy & Spontaneity**	**K4**	**PO1, PO3**
CO3	**Equilibrium Constants & Perturbations**	**K4**	**PO1, PO3**
CO4	**Rigid Rotor & Spherical Harmonics**	**K4**	**PO1, PO3**
CO5	**Angular Momentum & Operators**	**K2**	**PO1**
CO6	**H-atom Schrödinger Equation**	**K3, K4**	**PO1, PO3**
CO7	**Nernst Equation & Balancing**	**K3**	**PO1, PO3**
CO8	**Titrations & Redox Feasibility**	**K4, K5**	**PO1, PO3**
CO9	**Latimer/Frost Diagram Interpretation**	**K4**	**PO1, PO3, PO5**
CO10	**Acid-Base Equilibria & Buffers**	**K4**	**PO1, PO3**
CO11	**Titration Curve & Indicator Choice**	**K5**	**PO1, PO3, PO6**
CO12	**Solubility & Separation Schemes**	**K6**	**PO1, PO3, PO5**

Reading/Reference Lists	Group-A 1. Glasstone, S, Thermodynamics for Chemists, EWP. 2. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata McGraw-Hill. 3. Denbigh, K. The Principles of Chemical Equilibrium, Cambridge University Press. 4 Nag, A. K, Physical Chemistry Vol. 1, 2, Mcgraw Hill. 5. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Methods, Wiley. 6. Sears, F. W., Salinger, G. L., Thermodynamics, Kinetic Theory, and Statistical Thermodynamics (Addison-Wesley Principles of Physics Series), Pearson; 3rd edition. 7. Metiu, H., Physical Chemistry: Thermodynamics, Taylor and Francis. 8. Kaufman, M., Principles of Thermodynamics, Taylor and Francis 9. Honig, J. M., Thermodynamics, Academic Press. 10. Levine, I. N. Quantum Chemistry, PHI. 11. Atkins, P. W. and Friedman, Molecular Quantum Mechanics, Oxford. 12. Eisberg, R., Resnick, R, Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, 2ed, Wiley. 13. Griffiths, D. J., Introduction to Quantum Mechanics, Cambridge India. Group-B 1. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970. 2. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010). 3. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India. 4. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005. 5. Huheey, J. E.; Keiter, E.A. &Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006. 6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998). 7. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals. 8. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999). 9. Pfennig, B. W. (2015), Principles of Inorganic Chemistry. John Wiley & Sons. 10. Housecraft, C. E.; Sharpe, A. G., (2018), Inorganic Chemistry, 5th Edition, Pearson. Wulfsberg, G (2002), Inorganic Chemistry, Viva Books Private Limited.

Evaluation	Theory: 100 Internal: 30 (CIA:20, Other mode of Assesment:5, Attendance: 5) Semester Exam:70
Paper Structure for Theory Semester Exam	For each group, there will be a compulsory section of 5 marks. Also, THREE questions of 10 marks each should be attempted out of FOUR questions