SNDT Women's University, Mumbai

Master of Science (Chemistry)

M. Sc. (Chemistry)

As per NEP-2020

Syllabus Sem I & II

(2024-25)

Programme template

Programme	Master of Science M. Sc.
Paranthesis	Chemistry
Preamble	To achieve excellence in the academic disciplines, research, and extension activities through an emphasis on "Quality in every activity. This includes providing access to the field of higher education for women, enabling students for research in emerging areas of study, and training and developing scientists and technologists for industries and academics. Additionally, we aim to address the socio-economic demands by offering job-oriented courses, ensuring a comprehensive approach to education and preparing individuals for a dynamic and competitive future. Providing Higher Education for Women, Developing and Research Attitudes in Women Students, Achieving Academic Discipline in Women, Achieving Orientated Courses and Research with Regional Industrial Needs, developing a Basic Concept of Chemistry Applied in Industries
Programme Outcomes (POs)	After completing this programme, Learner will be able to, 1. Implement practical to enhance women's skills in using advanced instruments. Provide workshops, seminars, and training programs to supplement theoretical knowledge with practical expertise. Create an environment that encourages experimentation, critical thinking, and innovation in the field of chemistry. 2. Conduct regular consultations with local industries to understand their specific needs and challenges. Adapt academic programs to address the skill gaps identified by local industries. 3. Collaborate with industry experts to design and update curriculum to match the requirements of the job market. Provide career counselling and guidance to help women align their skills and aspirations with industry demands. Facilitate internships, co-op programs, and industry-sponsored projects to give women practical exposure to real-world challenges. 4. Integrate entrepreneurship and business skills into the curriculum to encourage women to explore opportunities for self-employment. Provide resources and support for women to start their own ventures or contribute to existing businesses. Develop a mindset of economic independence and financial literacy among women students. 5. Implement outreach programs to bring education and training to rural and backward communities. 6. Encourage faculty and students to engage in applied research that addresses the specific challenges faced by local industries. Enable knowledge transfer between academia and industry to drive innovation and problem solving. By incorporating these considerations into your educational framework.
Programme Specific Outcomes (PSOs)	After completing this programme, Learner will be able to

	1. Learn Various Skills, Including Handling Instruments and Advanced Analysis of Chemistry 2. Fulfil the Thrust of Industries in Our Area 3. Develop Women According to the Needs of Industries 4. Empower Women to Become Financially Independent 5. Empower Backward and Rural Women, Connecting Them to Modern Trends and Technical Knowledge 6. Develop Research in Industry to Meet Local Needs
Eligibility Criteria for Programme	B.Sc. graduate having Chemistry as main subject
Intake	30
Duration	4 semesters (2 years)

Course Structure with Title

Master of Science in Chemistry (M. Sc. Chemistry)

Year I

Subject Code	Courses	Type of Course	Credits	Marks	Int	Ext
	Semester I					
115311	Inorganic Chemistry	Major (Core) Theory	4	100	50	50
115312	Organic Chemistry	Major (Core) Theory	4	100	50	50
115313	Physical Chemistry	Major (Core) Theory	4	100	50	50
145311	Practical (Laboratory Course)	Major (Core) Practical	2	50	50	0
125311	Analytical Chemistry	Major (Elective) Theory	4	100	50	50
125312	Nuclear chemistry	Major (Elective) Theory				
125313	Polymer chemistry	Major (Elective) Theory				
135311	Research Methodology	Minor Stream (RM) Theory	4	100	50	50
			22	**550**	**300**	**250**
	Semester II					
215311	Inorganic Chemistry	Major (Core) Theory	4	100	50	50
215312	Organic Chemistry	Major (Core) Theory	4	100	50	50
215313	Physical Chemistry	Major (Core) Theory	4	100	50	50
245311	Practical (Laboratory Course)	Major (Core) Practical	2	50	0	50
225311	Analytical Chemistry	Major (Elective) Theory	4	100	50	50
225312	Nuclear Chemistry	Major (Elective) Theory				
225313	Polymer Chemistry	Major (Elective) Theory				
255311	Internship/Field Work	OJT	4	100	50	50
			22	**550**	**250**	**300**

Exit option (44 credits):

Year II

Subject code	Courses	Type of Course	Credits	Marks	Int	Ext
	Semester III					
315311	Organic Chemistry - I	Major (Core) Theory	4	100	50	50
315312	Organic Chemistry - II	Major (Core) Theory	4	100	50	50
315313	Organic Chemistry - III	Major (Core) Theory	4	100	50	50
345311	Practical (Laboratory Course)	Major (Core) Practical	2	50	0	50
325311	Medicinal Chemistry	Major (Elective) Theory	4	100	50	50
355311	Research project (Experimental)	RP	4	100	50	50
			22	**550**	**250**	**300**
	Semester IV					
415311	Organic Chemistry - I	Major (Core) Theory	4	100	50	50
415312	In-plant Training	Major (Core) Theory	4	100	50	50
445311	Practical (Laboratory Course)	Major (Core) Practical	4	100	50	50
425311	Organic Retro synthesis	Major (Elective) Theory	4	100	50	50
455311	Research Project (Dissertation, presentation and Seminar)	RP	6	150	100	50
			22	**550**	**300**	**250**

1.1 Major (Core)

Course Title	**Inorganic Chemistry (115311)**
Course Credits	4
Course Outcomes	After going through the course, learners will be able to, 1) **Apply** the principles of metallo porphyrin structures to understand their roles in biological processes like electron transfer, respiration, and photosynthesis. 2) Analyze different types of chemical bonding by deriving wave functions for hybridized orbital's and examining the involvement of d orbitals, resonance, and weak forces of attraction. 3) **Evaluate** molecular symmetry elements and point groups to classify molecules and predict their optical isomerism and chemical behavior. 4) **Design** experimental approaches to determine the stability constants of metal-ligand complexes, considering the influence of metal ion and ligand properties
Module 1 (Credit 1) – Inorganic chemistry in biological systems	
Content Outline	Essential and trace elements in biological systems and their functions, structure and function of metalloporphyrins, Hemoglobin, cytochromeand hemocyanine. Electron transfer, Respiration and photosynthesis reaction,MetaldeficientdiseasesofFe, Zn, Cu and Mn and their therapy
Module 2 (Credit 1) – Chemical Bonding	
Learning Outcomes	After going through the module, learners will be able to, 1) **Apply** the principles of orbital hybridization to predict the molecular geometry and bonding characteristics of various chemical species, focusing on sp, sp^2, and sp^3 hybridization. 2) **Analyze** the role of d orbitals in different types of hybridizations and the concept of resonance, including the derivation of resonance energy and its implications for molecular stability. 3) **Evaluate** the effectiveness of the Valence Bond Theory (VBT) and Molecular Orbital Theory (MOT) in explaining the bonding in diatomic and polyatomic species, such as SF_6, CO_2, B_2H_6, and I_3^-. 4) **Design** experiments to detect and study weak forces of attraction, including hydrogen bonding, Van der Waals forces, ion-dipole interactions, and London dispersion forces, and assess their significance in molecular interactions.
Content Outline	Recapitulation of hybridization Derivation of wave functions for sp, sp^2 ,sp^3 orbital hybridization types considering only sigma bonding ,Discussion of involvement of d orbitals in various types of hybridizations. Concept of resonance, resonance energy derivation expected, Formal charge with examples, Critical analysis of VBT, Molecular Orbital Theory for diatomic species of First transition Series, Molecular Orbital Theory for Polyatomic species considering σ bonding for SF6, CO2, B2H6, I3 -molecular species, Weak forces of attraction: Hydrogen bonding –concept, types, properties, methods of detection and importance. Van der Waal's forces,ion-dipole, dipole-dipole,London forces

Module 3 (Credit 1) - Molecular symmetry and symmetry groups	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the concepts of symmetry elements and operations to identify and classify symmetry planes, reflections, and inversion centers in various molecular structures. 2) **Analyze** the effects of proper and improper axes of rotation on the symmetry of molecules, and determine how these symmetry operations lead to the identification of equivalent symmetry elements and atoms. 3) **Evaluate** the relationship between symmetry elements and optical isomerism, and assess how different symmetry point groups influence the optical properties of molecules. 4) **Design** a systematic approach to classify molecular point groups by examining the classes of symmetry operations and applying this classification to predict the behavior of complex molecular systems.
Content Outline	Symmetry elements and operations. Symmetry planes, reflections, inversion centre, proper/improper axes of rotation, products of symmetry operations, equivalent symmetry elements and atoms, symmetry elements and optical isomerism, symmetry point groups,classes of symmetry operations, classification of molecular point groups.
Module 4 (Credit 1) – Metal ligand equilibria in solution	
Learning Outcomes	After going through the module, learners will be able to, 1) **Apply** the concepts of stability constants to define and differentiate between stepwise and overall formation constants in metal-ligand complexes. 2) **Analyze** the factors affecting the stability of metal complexes, with particular focus on the nature of the metal ion and ligand, to predict complex stability. 3) **Evaluate** the role of stability constants in determining the behavior of metal complexes in solution, and assess the significance of these constants in various chemical processes. 4) **Design** an experimental procedure using the pH-metric technique to determine the formation constant of binary metal-ligand complexes, ensuring accurate data collection and interpretation.
Content Outline	Definition of stability constant, step wise and overall formation constant, factors affecting the stability of metal complexes with reference to the nature of metal ion and ligand, Determination of formation constant for binary complexes using pH-Metric technique.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE): (Illustrative activities)

- **Module 1:** Involves studying the role of essential and trace elements in the human diet, particularly focusing on iron, zinc, copper, and manganese. The objective is to investigate how deficiencies in these metals affect health and to propose dietary or supplemental interventions. Students can collect data from local health centres, analyse dietary intake in their communities, and conduct literature reviews to understand the impact of these metals on physiological functions. The research can be done using nutritional databases, local laboratory resources for basic testing, and interviews with healthcare professionals.

- **Module 2:** Students will explore the types of chemical bonding through simple experiments that can be done using household items. The objective is to demonstrate hybridization and weak forces of attraction in everyday materials. Students can use models or diagrams to represent sp, sp^2, and sp^3 hybridization, and perform experiments to detect hydrogen bonding and Van der Waals forces using substances like water, alcohol, and oil. This project can be carried out at home or in a basic school lab, and students will document their observations and analyse the significance of these forces in molecular stability.

- **Module 3:** Students will investigate molecular symmetry and point groups by examining everyday objects and simple molecular models. The objective is to classify objects and molecules based on symmetry elements and operations, such as planes of symmetry and axes of rotation. Students can use objects like crystals, models of common molecules, or even geometric shapes to identify symmetry elements and classify them into point groups. The research can be conducted at home or in a classroom setting, using basic drawing tools and molecular models to visualize symmetry operations

- **Module 4:** Students will design a simple experiment using a ph meter to determine the formation constant of a binary metal-ligand complex, such as a copper-ammonia complex. The objective is to measure the ph changes during the complex formation and calculate the stability constants. Students can use readily available chemicals like copper sulfate and ammonia solution, and conduct the experiment in a school lab or community center with access to a ph meter. The research involves careful titration, data collection, and analysis to determine the formation constants and understand the factors influencing complex stability.

References:

1. Ameta, R. (2016). *Symmetry and group theory in chemistry*. Springer.
2. Veera Reddy, K. (2003). *Symmetry and spectroscopy of molecules*. New Age International.
3. Lee, J. D. (2008). *Concise inorganic chemistry* (5th ed.). Wiley.
4. Das, A. K. (2012). *A textbook of bioinorganic chemistry*. Wiley.
5. Malik, W. U., Tuli, G. D., & Madan, R. D. (2007). *Selected topics in inorganic chemistry*. S. Chand & Company Ltd.
6. Raj, G. (2000). *Advanced inorganic chemistry* (Vol. I). Pelenum. Raj, G. (2001). *Advanced inorganic chemistry* (Vol. II). Pelenum.
7. Cotton, F. A., & Wilkinson, G. (1988). *Advanced inorganic chemistry* (5th ed.). Wiley.
8. Jaffe, H., & Orchin, M. (2002). *Symmetry in chemistry*. Dover Publications.

1.2 Major (Core)

Course Title	**Organic Chemistry (115312)**
Course Credits	4
Course Outcomes	After going through the course, learners will be able to, 1) Apply the concepts of delocalized bonding, conjugation, and aromaticity to explain the stability and reactivity of various organic molecules, including benzenoid and non-benzenoid compounds. 2) Analyze the mechanisms of organic reactions by considering factors like thermodynamic and kinetic requirements, isotope effects, and Hammond's postulate to determine the pathways and outcomes of different reaction types. 3) Evaluate the stereochemistry of organic compounds, focusing on chirality, optical activity, and conformational analysis, to understand how molecular symmetry and spatial arrangement influence chemical properties and reactivity. 4) Design comparative studies on the acidity and basicity of organic compounds by considering factors like electronegativity, resonance, hybridization, and pKa values, and propose methods for acid-base catalysis in various chemical reactions.
Module 1 (Credit 1) – Nature of Bonding in Organic Molecules	
Learning Outcomes	After going through the module, learners will be able to, 1) Apply the principles of delocalized chemical bonding, including conjugation, resonance, and hyper conjugation, to predict the stability and reactivity of organic molecules. 2) Analyze the aromaticity of benzenoid and non-benzenoid compounds using the Huckel rule, and compare the energy levels of aromatic, anti aromatic, and non-aromatic compounds. 3) Evaluate the impact of weaker bonds, such as those found in addition compounds, crown ether complexes, and cryptands, on the overall stability and function of organic molecules. 4) Design models or diagrams to represent the structure and interactions of complex organic systems like inclusion compounds, cyclodextrins, catenanes, and rotaxanes, emphasizing their unique bonding and spatial arrangements.
Content Outline	Delocalized chemical bonding, conjugation, cross conjugation, resonance, hyper conjugation, -molecular orbitals, annulenes, tautomerism. Aromaticity in benzenoid and non-benzenoid compounds, alternant and non alternant compounds, Huckel rule, energy level ofaromaticity, Bonds weaker than covalent-addition compounds crown ether complexes and crypt ands, inclusion compounds, cyclodextrins, Catenanes and rotaxanes

Module 2 (Credit 1) – Reaction Mechanism	
Learning Outcomes	After going through the module, learners will be able to, 1) **Apply** knowledge of reaction mechanisms to predict the outcomes of various organic reactions, considering different types of mechanisms and reaction pathways. 2) **Analyze** the influence of thermodynamic and kinetic factors on reaction rates and product distribution, using concepts such as Kinetic vs. Thermodynamic control and Hammond's postulate. 3) **Evaluate** different methods for determining reaction mechanisms, including isotope effects, to assess the reliability and accuracy of mechanistic interpretations in organic chemistry. 4) **Design** experiments or computational models to study the structure and reactivity of organic molecules, focusing on the relationship between reaction conditions and the resulting products.
Content Outline	Structure and Reactivity Types of Mechanisms, Types of reactions, Thermodynamic and Kinetic requirements, Kinetic and Thermodynamic control, Hammond' spostulate, methods of determining mechanisms, isotope effects.
Module 3 (Credit 1) - Stereo-chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of symmetry and chirality to assign R/S and E/Z configurations to molecules, including those with multiple chiral centers, and predict their stereochemical properties. 2) **Analyze** enantiomeric and diastereomeric relationships in organic molecules, including those with prochiral groups, to determine the stereochemical outcomes of stereospecific and stereoselective reactions. 3) **Evaluate** the optical activity of molecules, particularly those without a chiral carbon, such as biphenyls, allenes, and spiranes, and assess the influence of helical chirality on molecular behavior. 4) **Design** a comprehensive conformational analysis of cycloalkanes, mono- and disubstituted cyclohexanes, and decalins to explore how different conformations affect the reactivity and stereochemistry of organic compounds containing nitrogen, sulfur, and phosphorus.
Content Outline	Elements of symmetry, chirality, Enantiomeric and diastereomeric relationships, R and S, E and Z nomenclature. Molecules with more thanone chiral center, Threo and Erythro isomers, Prochiral relationships, groups and faces, stereospecific and stereoselective reactions. Optical activity in the absence of Chiral Carbon (Biphenyls, allenes and Spiranes), Chirality due to hellical shape. Methods of resolution, optical purity, stereochemistry of the compounds containing Nitrogen, Sulphur and phosphorous. Conformational analysis of cycloalkanes, Mono and disubstituted cyclohexanes, decalins, effect of conformation on Reactivity

Module 4 (Credit 1) – Acids and Bases	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the concepts of electronegativity, inductive effects, resonance, and hybridization to explain the acidity and basicity of organic compounds, and predict their behavior based on pKa values. 2) **Analyze** the comparative acidity and basicity of various organic compounds by considering factors such as bond strength, electrostatic effects, aromaticity, and solvation in different solvents, including non-aqueous ones. 3) **Evaluate** the role of acid and base catalysis in chemical reactions, distinguishing between general and specific catalysis, and assess their impact on reaction mechanisms and rates using relevant examples. 4) **Design** experiments to study the effects of different factors on acidity and basicity, including the levelling effect in non-aqueous solvents, and propose methods for optimizing acid and base catalysis in practical applications.
Content Outline	Factors affecting acidity and basicity, Electronegativity and inductive effect, resonance, bond strength, electrostatic effects, hybridization, aromaticity and solvation. Comparative study of acidity and basicity of organic compounds on the basis of pKa values, Levelling effect and non-aqueous solvents. Acid and base catalysis, general and specific catalysis with examples.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

- **Module 1:** a research project could involve investigating the stability and reactivity of various organic compounds by preparing simple models of molecules with different types of delocalized bonding, such as conjugation and resonance, using molecular model kits or software available online. The objective is to predict how these bonding patterns influence molecular stability. Students can perform qualitative tests using household acids and bases or basic lab equipment available at school to observe reactivity patterns. This research can be conducted at home or in a school lab, with the results documented and compared to theoretical predictions.

- **Module 2:** Students could design a project to study the reaction mechanism of an everyday chemical reaction, such as the saponification of fats or the esterification of acetic acid with ethanol, using simple household items like vinegar and baking soda or a basic school lab setup. The objective is to analyze how reaction conditions such as temperature and concentration affect the reaction rate and product distribution. The methodology involves conducting the reaction under different conditions and recording observations, focusing on understanding kinetic vs. thermodynamic control.

- **Module 3:** a potential project could involve the analysis of stereochemistry in everyday objects or simple molecular models. The objective is to explore chirality by creating or observing objects with chiral centers, such as twisted ropes or spiral pasta, and relating these models to the stereochemistry of organic compounds. Students can use mirrors or drawings to visualize enantiomers and diastereomers. This can be done at home with available materials, and the focus should be on understanding spatial arrangements and their implications for molecular properties.

- **Module 4:** students could explore the acidity and basicity of various household substances, such as vinegar, baking soda, lemon juice, and soap, by performing pH tests using pH strips or a simple homemade indicator from red cabbage. The objective is to compare the relative strengths of these substances and understand how factors like concentration and solvation affect their acid-base behavior. This research can be conducted at home, and students can document their findings and relate them to theoretical concepts such as pKa values and the leveling effect.

References:

1. March, J. (2007). *Advanced organic chemistry* (4th ed.). Wiley.
2. Eliel, E. L. (1994). *Stereochemistry of carbon compounds*. Wiley.
3. Carey, F. A., & Sundburg, R. J. (2007). *Advanced organic chemistry: Part A* (5th ed.). Springer. Carey, F. A., & Sundburg, R. J. (2008). *Advanced organic chemistry: Part B* (5th ed.). Springer.
4. Sykes, P. (1986). *A guide book to mechanism in organic chemistry* (6th ed.). Longman.
5. Norman, R. O. C. (2000). *Principles of organic synthesis* (3rd ed.). CRC Press.
6. Nasipuri, D. (1994). *Stereochemistry of organic compounds*. Wiley.
7. Clayden, J., Greeves, N., & Warren, S. (2012). *Organic chemistry* (2nd ed.). Oxford University Press.
8. Gould, E. S. (1991). *Mechanism and structure in organic chemistry*. Holt, Rinehart & Winston.

1.3 Major (Core)

Course Title	**Physical Chemistry (115313)**
Course Credits	4
Course Outcomes	After going through the module, learners will be able to 1) Apply the concepts of chemical thermodynamics, including the Nernst heat theorem and the third law of thermodynamics, to determine absolute entropies of various states of matter and calculate partial molar properties such as free energy and fugacity. 2) Analyze the Schrödinger wave equation and its application to rotational and vibrational problems, including the hydrogen atom and molecular orbitals, to understand quantum numbers, wave functions, and energy quantization. 3) Evaluate different theories of reaction rates, including collision theory and the theory of absolute reaction rates, to assess their strengths and limitations in describing reaction kinetics and the effects of factors like isotope and salt on reaction rates. 4) Design experiments to investigate surface phenomena, such as surface tension and micellization, by applying concepts like the Laplace equation and Gibbs adsorption isotherm, and determine critical micellar concentration and surface area using relevant methods.
Module 1 (Credit 1) – Chemical Thermodynamics	
Learning Outcomes	After going through the module, learners will be able to, 1) Apply the Nernst heat theorem and the third law of thermodynamics to determine the absolute entropies of solids, liquids, and gases, and use these principles to calculate changes in entropy for various chemical processes. 2) Analyze partial molar properties, including partial molar free energy, chemical potential, partial molar volume, and partial molar heat content, to understand their significance in solution chemistry and how they influence the behavior of mixtures. 3) Evaluate the concept of fugacity and its role in describing real gas behavior, and assess methods for determining fugacity in different chemical systems. 4) Design experiments or calculations to determine partial molar properties and fugacity, incorporating techniques to measure these quantities and interpret their significance in thermodynamic analyses.
Content Outline	Nernst heat theorem, the third law of thermodynamics, Determination of absolute entropies of solids, liquids and gases. Partial molar properties : Partial molar free energy, chemical potential, partial molar volume and partial molar heat content and their significance, determination of these quantities, concept of fugacity and determination of fugacity

Module 2 (Credit 1) – Quantum Chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the Schrödinger wave equation in spherical coordinates to solve for the quantization of rotational energy in a rigid rotor model, using spherical harmonics to describe the wave functions and quantum numbers associated with rotational states. 2) **Analyze** the solutions of the Schrödinger equation for the hydrogen atom, including the separation of variables and the resulting quantum numbers, to understand the structure of atomic orbitals (1s, 2s, 2p, and 3d) and their probability density functions. 3) **Evaluate** the application of the Schrödinger equation to two-electron systems, identifying its limitations and the need for approximate methods, and assess various techniques used to obtain approximate solutions for complex systems. 4) **Design** a detailed derivation and application of Hückel Molecular Orbital Theory to ethylene, 1,3-butadiene, and benzene, including the calculation of molecular orbitals and energy levels, and interpret the results to explain the electronic structure and stability of these conjugated systems.
Content Outline	Rigid rotor, spherical coordinates Schrödinger wave equation inspherical coordinates, separation of the variables, the phi equation, wave function, quantum number, the theta equation, wave function, quantization of rotational energy, spherical harmonics. 2.2. Hydrogenatom, the two particle problem, separation of the energy as translational and potential, separation of variables, the R the θ * and the φ equations,solutionoftherequation,introductionofthefourquantumnumbersand their interdependence on the basis of the solutions of the three equations, total wave function, expression for the energy, probability density function, distances and energies in atomic units, radial and angular plots., points of maximum probability, expressions for the total wave function for 1s,2s, 2p and 3d orbitals of hydrogen. 2.3. Application of the Schrödinger equation to two electron system, limitations of the equation, need for the approximate solutions, methods of obtaining the approximate solution of the Schrödinger wave equation. 2.4. Hückel Molecular Orbitals theory for ethylene ,1,3-butadieneandbenzene. (Derivation expected)
Module 3 (Credit 1) – Classical Thermodynamics	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of collision theory and modified collision theory to explain reaction rates and understand their limitations in describing reaction mechanisms and rates for different chemical systems. 2) **Analyze** the theory of absolute reaction rates and the equilibrium hypothesis to derive rate equations and understand the statistical mechanical and thermodynamic formulations of reaction kinetics. 3) **Evaluate** the effects of isotopic substitution and salt effects (both primary and secondary) on reaction rates, and assess how these factors influence reaction dynamics and mechanisms. 4) **Design** experiments to study fast reactions using methods such as flow techniques, relaxation methods, flash photolysis, and NMR, and develop

	models to analyze reaction kinetics in solution, considering factors like ionic strength and solvent effects.
Content Outline	Collision theory, modified collision theory, weakness of the collision theory, Theory of absolute reaction rates, equilibrium hypothesis, Derivation of the rate equation, statistical mechanical derivation and thermodynamic formulation. Isotope effecton reaction rate. Primary Salt effect, secondary salt effect .Dynamics of uni-molecular reactions, Lindeman and Hinshelwood theory Kinetics of fast reactions, study of fast reactions by flow method, relaxation method, flash photolysis and NMR method. Reactions in solution: Reaction between ions, influence of Solvent-double sphere model, single sphere model, influence of ionic strength, numerical.
Module 4 (Credit 1) – Surface Chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of surface tension, capillary action, and the Laplace equation to calculate the pressure difference across curved surfaces and understand the behavior of droplets and bubbles in various systems. 2) **Analyze** the Gibbs adsorption isotherm and the BET equation to estimate surface areas and evaluate the formation and stability of surface films on liquids, including electro kinetic phenomena and catalytic activities at surfaces. 3) **Evaluate** the thermodynamics and mechanisms of micellization, including critical micellar concentration and the role of surface-active agents, to understand the formation and behavior of micelles in colloidal electrolytes. 4) **Design** experiments to determine the critical micellar concentration and study solubilization processes, including the classification and application of surface-active agents and reverse micelles, to explore their effects on colloidal systems.
Content Outline	Surface tension, capillary action, pressure difference across curved surface (Laplace equation) vapour pressure of droplets (Kelvin equation) Gibbs adsorption isotherm, estimation of surface area (BET equation), surface films on liquids (Electro kinetic phenomenon), catalytic activity at surfaces, numericals. Colloidal electrolytes, Types of micelles in colloidal electrolytes, Micellization, Thermodynamics of micellization, Mechanism of Micellization, critical micellar concentration, Determinations of critical micellar concentration, Surface active agents, Classifications of surface active agents,Reversemicelles,Solubilization

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

- **Module 1:** a research project could involve determining the absolute entropy of water in different states (ice, liquid water, steam) using household items like ice cubes, a thermometer, and a kitchen scale. The objective is to calculate entropy changes during the phase transitions. Students can measure temperature and mass changes during melting and boiling and use these to calculate entropy changes. This project can be conducted at home or in a school lab, with results compared to theoretical values.

- **Module 2:** students could explore the quantization of rotational energy by modeling a simple rigid rotor using a spinning top or a weighted string. The objective is to understand the relationship between rotational speed and energy levels. Students can vary the weight or length of the string to observe changes in rotational speed and stability. This hands-on experiment can be done at home, with the data analyzed to relate to quantum mechanical principles.

- **Module 3:** a possible project is to study the effect of temperature on reaction rates by observing the rate of a simple reaction, such as the decomposition of hydrogen peroxide using yeast as a catalyst. The objective is to apply the principles of collision theory and reaction rates. Students can conduct the reaction at different temperatures using household thermometers and measure the volume of gas produced. This can be done at home or in a school lab, with results used to derive rate constants.

- **Module 4:** students could investigate surface tension by observing the formation and stability of bubbles or droplets on different surfaces using soap solutions. The objective is to calculate the pressure difference across curved surfaces and understand factors affecting bubble stability. Students can use household items like straws, soap, and water, and compare how different concentrations or additives affect bubble formation. This simple experiment can be done at home, with observations recorded and analyzed using the Laplace equation.

References:

1. Laidler, K. J. (1987). *Chemical kinetics*. Harper & Row.
2. Rajaram, J., & Kuriacose, J. C. (1978). *Kinetic and mechanism of chemical transformations*. Macmillan India Ltd.
3. Atkins, P. (2006). *Physical chemistry* (7th ed.). Oxford University Press.
4. Glasstone, S. (1960). *Thermodynamics for chemists*. East-West Press.
5. Barrow, G. M. (1988). *Physical chemistry* (5th ed.). McGraw-Hill.
6. Raj, G. (2001). *Advanced physical chemistry*. Pelenum.
7. Moroi, V. (1994). *Micelles: Theoretical and applied aspects*. Plenum Press.
8. Glasstone, S. (1977). *Textbook of physical chemistry*. McMillan.
9. Glasstone, S. (1968). *An introduction to electrochemistry*. East-West Press.
10. Alberty, R. A., & Silbey, R. J. (2001). *Physical chemistry* (3rd ed.). Wiley.
11. Gupta, M. C. (1985). *Statistical thermodynamics*. Wiley Eastern.

1.4 Major (Core)

Course Title	**Practical (Laboratory Course) (145311)**
Course Credits	**2**
Course Outcomes	After going through the module, learners will be able to 1) Apply various analytical techniques to prepare and estimate the percentage of metal ions in metal complexes and mixtures, demonstrating proficiency in quantitative analysis. 2) Analyze and evaluate the effectiveness of chemical methods in the separation, purification, and identification of solid-solid mixtures and organic compounds, including single-stage preparations. 3) Design and create laboratory experiments to determine molecular properties, such as radius and molecular refraction, and study the effects of surfactants on surface tension using both instrumental and non-instrumental techniques. 4) Evaluate the concentration of metal ions in solutions and the effectiveness of chemical processes by performing titrations, analyzing complex mixtures, and determining the breakthrough capacity of ion exchange resins.
Module 1 – Quantitative Analysis	
Learning Outcomes	After going through the module, learners will be able to 1) Apply analytical techniques to accurately prepare and estimate the percentage of metal ions present in various metal complexes such as Ti(C9H8NO), VO(acac)2, Cis-K[Cr(C2O4)2(H2O)2], and [Mn(acac)3]. 2) Analyze and evaluate the separation and estimation methods for metal ions in mixture solutions, including Copper-Nickel, Nickel-Zinc, and Iron-Magnesium, to determine their concentrations and assess the effectiveness of the separation techniques. 3) Design experiments to systematically separate and quantify metal ions from complex mixtures, ensuring precision in identifying and measuring metal ions in various sample solutions. 4) Create comprehensive reports documenting the preparation, estimation, and analysis of metal complexes and mixtures, including detailed results, methodologies used, and interpretations of the data obtained.
Content Outline	**Preparation and estimation of percentage metal ion present in a metal complexes:-** 1. Ti(C9H8NO) 2. 2H2O2.VO(acac)2 3.Cis-K[Cr(C2O4)2(H2O)2] 4.[Mn(acac)3] **Separationandestimationofamountofmetalionsfromthefollowingmixturesolutions** 1.Copper-Nickel 2. Nickel-Zinc 3. Iron-Magnesium
Module 2 – Qualitative Organic Analysis	

Learning Outcomes	After going through the module, learners will be able to 1) **Apply** chemical methods to effectively separate, purify, and identify binary solid-solid mixtures, ensuring accurate isolation of individual components and preparation of suitable derivatives for each compound. 2) **Analyze** and **evaluate** the outcomes of single-stage preparations, including the synthesis of p-nitro acetanilide from acetanilide and dibenzylidene acetone from benzaldehyde, by measuring yield, melting point, and TLC results. 3) **Design** experimental protocols for the preparation and purification of organic compounds, ensuring adherence to precise measurements and conditions for successful synthesis and characterization. 4) **Create** detailed reports documenting the separation, purification, and identification processes of solid-solid mixtures and single-stage preparations, including comprehensive data on yield, melting point, and thin-layer chromatography (TLC) results.
Content Outline	Separation, purification and identification of binary (Solid-Solid) mixtures. The separation should be carried out using Chemical method. The two components are solid-solid mixtures. Student should submit the purified samples of the separated compounds and prepare a suitable derivative of the two compounds separated out. **Single Stage Preparations: -** 1. p-nitroacetanilide fromacetanilide. 2. Dibenzylidene acetone from Benzaldehyde The preparations should be carried out using (0.02to 0.05mole)of the starting material. 3. The yield, melting point and TLC of the recrystalised product should be recorded.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

- **Module 1:** a project could involve preparing and analyzing a metal complex using common household chemicals and a basic titration setup. The objective is to estimate the percentage of metal ions in a metal complex such as copper sulfate or iron chloride, prepared using available salts. Students can perform titrations using kitchen scales, vinegar, and baking soda to determine the metal content. This experiment can be done at home with simple tools, with results documented and compared to expected values.

- **Module 2: Qualitative Organic Analysis**

  students could explore the separation and identification of components in a binary mixture using simple solvents and filtration methods. The objective is to separate, purify, and identify substances like salt-sugar or sand-iron filings mixtures using common kitchen items like filters, water, and magnets. Students will document the separation process, prepare derivatives (if possible), and determine purity through melting point or solubility tests. This project can be easily done at home.

References:

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2. Mendham, J., Denny, R. C., Barnes, J. D., & Thomas, M. (2000). *Vogel's textbook of quantitative chemical analysis* (6th ed.). Pearson Education.
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6. Sandell, E. B., & Onishi, H. (1978). *Spectrophotometric determination of traces of metals* (4th ed., Part II). Wiley-Interscience.

1.5 A. Major (Elective)

Course Title	**Analytical Chemistry (125311)**
Course Credits	**4**
Course Outcomes	After going through the course, learners will be able to, 1) **Apply** statistical methods to analyze analytical data, including the use of significant figures, precision and accuracy, and tests of significance (e.g., F test, T test) to validate and interpret results accurately. 2) **Analyze** chromatographic techniques and theories, such as plate theory and rate theory, to understand factors affecting zone broadening and to develop effective chromatographic methods for qualitative and quantitative analysis. 3) **Evaluate** laboratory safety protocols, including the use of Personal Protection Equipment (PPE), OSHA regulations, and hazard classifications, to ensure safe practices in handling chemicals and managing hazardous processes. 4) **Design** an environmental chemistry study to assess and analyze pollution levels, incorporating sampling methods and pollution control techniques to address issues such as air and water pollution, greenhouse effects, acid rain, and ozone depletion.
Module 1 (Credit 1) – Basic concepts of analytical chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** statistical methods, such as linear least squares, correlation coefficient, and tests of significance (F test, T test), to perform accurate and reliable analysis of quantitative data, including the plotting of calibration curves using spreadsheets. 2) **Analyze** different types of errors, methods of expressing accuracy and precision, and confidence limits to understand their impact on the validity and reliability of analytical results. 3) **Evaluate** the process of method validation and the significance of statistical tests (e.g., Q test) in ensuring the accuracy and reliability of analytical data, including the rejection of outlier results. 4) **Design** a comprehensive analytical procedure that incorporates statistical treatments, such as precision and accuracy measurements, and the use of numerical techniques for data analysis to ensure robust and validated results.
Content Outline	The role of analytical chemistry, qualitative and quantitative analysis, The analytical process, Validation of a method. Statistical treatment of analytical data: Introduction, types of errors, significant figures, precision and accuracy, methods of expressing accuracy, methods of expressing precision, the confidence limit, tests of significance- the F test, the student T test, rejection of results - the Q test. Statistics for small datasets, linear least squares, correlation coefficient, using spreadsheets for plotting calibration curves, slope, intercept and coefficient of determination, numericals.
Module 2 (Credit-1) – Chromatography Introduction	

Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the basic principles and theories of chromatographic techniques, including plate theory and rate theory, to select and utilize appropriate chromatographic systems for both qualitative and quantitative analysis. 2) **Analyze** factors affecting zone broadening in chromatographic processes and their impact on the resolution and accuracy of chromatographic separations. 3) **Evaluate** different methods of chromatogram development, such as frontal analysis, elution analysis, and displacement analysis, to determine their effectiveness in separating and analyzing chemical mixtures. 4) **Design** a chromatographic experiment that incorporates the appropriate technique and analysis method for a given sample, considering factors such as system selection, chromatogram development, and data interpretation to achieve accurate and efficient results.
Content Outline	Basic principles and theory of chromatographic techniques, plate theoryof chromatography, rate theory of chromatography, other factors inzone broadening, Development of the chromatogram - Frontal analysis, elutionanalysisdisplacementanalysis,selectionofchromatograph system,qualitativeandquantitativeanalysisbychromatography
Module 3 (Credit 1) - SafetyinLaboratories	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** basic safety concepts in laboratory settings, including the use of Personal Protection Equipment (PPE) and adherence to OSHA regulations, to ensure safe practices when handling chemicals and conducting experiments. 2) **Analyze** various Toxic Hazard (TH) classifications and their implications for laboratory safety, including the identification and management of hazardous chemical processes such as thermal build-up and process calorimetry. 3) **Evaluate** the effectiveness of different safety protocols and equipment in minimizing risks associated with hazardous chemical processes, and assess the compliance with safety standards and regulations. 4) **Design** a comprehensive safety plan for a laboratory environment that includes appropriate PPE, hazard classifications, and procedures for handling hazardous chemicals and managing thermal processes to ensure a safe working environment.
Content Outline	Basic concepts of Safety in Laboratories, Personal Protection Equipment(PPE), OSHA, Toxic Hazard (TH) classifications, Hazardous ChemicalProcesses(includingprocesscalorimetry/thermalbuildupconcepts).
Module 4 (Credit 1) - EnvironmentalChemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** sampling and analysis techniques to measure levels of air and water pollution, including the use of appropriate methods for detecting and quantifying pollutants. 2) **Analyze** the causes and effects of major environmental issues such as the greenhouse effect, acid rain, and ozone depletion, and assess their impact on ecosystems and human health.

	3) **Evaluate** pollution control methods and techniques for their effectiveness in reducing air and water pollution, and understand their implementation in mitigating the consequences of pollution. 4) **Design** a study to investigate the impact of pollution in specific regions, such as India, incorporating sampling, analysis, and control methods to address local pollution issues and propose solutions for improving environmental quality.
Content Outline	Air pollution, water pollution, Impact of pollution in India, Pollution,pollution in India,Greenhouse effect, Acid rain, Ozone depletion andtheir consequences on environment, Major air pollution disasters,Pollution control methods and techniques, Sampling and analysis of airandwaterpollution

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

- **Module 1:** a research project could involve analyzing household data, such as water quality from different sources (tap, filtered, bottled) using basic statistical methods. The objective is to apply statistical tools like mean, standard deviation, and linear regression to assess the accuracy and precision of the data, and to create calibration curves using spreadsheet software. Students can collect data samples at home or from a nearby laboratory, plot the data, and validate the results using tests of significance. The project emphasizes practical application of statistical analysis in real-world contexts.

- **Module 2:** students could explore the separation of food dyes using paper chromatography. The objective is to understand the principles of chromatography by analyzing the separation of different dyes present in candies or drinks. Resources required include filter paper, water, and simple solvents like vinegar or rubbing alcohol. Students will perform the experiment at home, observe the separation patterns, and interpret the results using chromatographic principles such as plate theory and rate theory. The project aims to provide hands-on experience with chromatographic techniques in a simple and accessible way.

- **Module 3:** a project could involve assessing the safety protocols for handling common household chemicals like bleach or vinegar. The objective is to design a safety plan that includes the use of PPE, identification of hazards, and adherence to safety regulations. Students can evaluate the risk of mixing chemicals, potential reactions, and necessary precautions. The research can be conducted at home or in a school laboratory setting, with a focus on applying laboratory safety concepts in everyday scenarios. The project emphasizes the importance of safety in any chemical handling process.

- **Module 4:** students could design a study to measure air quality by observing and recording the levels of particulate matter (dust) in different areas of their home or neighborhood. The objective is to assess the impact of pollution on air quality by using simple tools like sticky notes or tape to collect dust particles over time. Students can analyze the data to compare pollution levels in different environments (indoor vs. outdoor) and propose potential solutions or interventions. This project is intended to raise awareness of environmental pollution and encourage practical steps for improvement.

References:

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1. Christian, G. D. (2004). *Analytical chemistry* (6th ed.). Wiley.
2. Peters, D. G., Hayes, J. M., & Hiefti, G. M. (2002). *Chemical separations and measurements*. Academic Press.
3. Chatwal, G. R., & Anand, S. K. (2002). *Instrumental methods of chemical analysis*. Himalaya Publishing House.
4. De, A. K. (2018). *Environmental chemistry* (5th ed.). New Age International Publishers.
5. Mahajan, M. (2008). *Environmental pollution control in process industries*. Tata McGraw-Hill Publishing Company Limited.
6. Sharma, B. K., & Kaur, H. (2016). *Environmental pollution*. Krishna Prakashan Media Pvt. Ltd.

1.5 B. Major (Elective)

Course Title	**Nuclear Chemistry (125312)**
Course Credits	4
Course Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of nuclear particles and their properties to calculate mass defects, binding energies, and assess nuclear stability using various theories of nuclear composition. 2) **Analyze** different nuclear models, such as the shell model and liquid drop model, to understand periodicity in nuclear properties, energy levels, and the forces of nuclear potential. 3) **Evaluate** the energetics of nuclear reactions, including comparisons with chemical reactions, and assess the effectiveness of different types of nuclear reactions (e.g., photonuclear, spallation, and thermonuclear) using concepts such as cross sections and reaction rates. 4) **Design** a detailed investigation into specific nuclear reactions, incorporating the compound nucleus theory, optical model, and direct interaction model to explore and compare various reaction mechanisms and their practical applications.
Module 1 (Credit 1) - Nuclear particles and its properties	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of nuclear composition and the characteristics of fundamental particles to calculate mass defect and binding energy, and determine the stability of nuclei using relevant theories. 2) **Analyze** the role of different nuclear particles and theories of nuclear composition in explaining the properties of the nucleus, including factors affecting nuclear stability, size, and density. 3) **Evaluate** various factors influencing nuclear stability and compare them to understand how mass defect, binding energy, and nuclear density contribute to the stability of different nuclei. 4) **Design** a detailed study or model that explores the composition and properties of the nucleus, integrating theories of nuclear composition and empirical data on mass defect, binding energy, and nuclear stability to predict nuclear behavior.
Content Outline	The fundamental particles, roll call of elementary particles, composition of the nucleus, theories of nuclear composition, nuclear properties, mass defect and binding energy, nuclear stability explained by different factors. Nuclear size and density
Module 2 - Nuclear models	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of the shell model and the liquid drop model to explain periodicity in nuclear properties, including the significance of magic numbers and the behavior of nuclear configurations in potential wells. 2) **Analyze** the features and limitations of the shell model, liquid drop model,

	and Fermi gas model to understand the forces of nuclear potential and the energy levels within nuclear systems. 3) **Evaluate** the effectiveness of different nuclear models (shell model, liquid drop model, and Fermi gas model) in explaining observed nuclear properties and behaviors, including periodicity, binding energies, and stability. 4) **Design** a comparative study or simulation of nuclear models, incorporating the shell model, liquid drop model, and Fermi gas model, to investigate their application in predicting nuclear properties and configurations for various elements.
Content Outline	The shell model and its salient features, periodicity in nuclear properties - magic numbers, forces of nuclear potential, energy level in nuclear potential well, the sequence of filling the orbital including models, nuclear configuration. The liquid drop model, and its details and The Fermi gas model
Module 3 (Credit 1) - Nuclear structure	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the semi-empirical mass formula and principles of nuclear binding energy to calculate nuclear stability, mass size, and the impact of spin and parity on nuclear properties. 2) **Analyze** the differences between the liquid drop model and shell model by comparing their explanations of nuclear stability, binding energies, and the nature of nuclear forces, using empirical evidence to support findings. 3) **Evaluate** the energetics of nuclear reactions by comparing them to chemical reactions, and assess various types of nuclear reactions (photonuclear, spallation, thermonuclear) in terms of their energy release and practical applications. 4) **Design** a comprehensive analysis or simulation of nuclear reactions, incorporating calculations of mass-energy relationships and binding energies, to explore the efficiency and outcomes of different nuclear reactions and their comparison to chemical reactions.
Content Outline	Mass-energy relationship, nuclear binding energy, semi-empirical mass formula, nuclear stability rules, nuclear properties, mass size, spin and parity, nature of nuclear forces, liquid drop model, shell model, its evidence and advantages, comparison of the two models, calculations based on above.Energetics of nuclear reaction, cross reaction, comparison with chemical reactions, various types of nuclear reactions, photonuclear, spallation and thermonuclear reaction
Module 4 - Nuclear Reactions	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of Bethesda notation and nuclear reaction energetics to calculate the threshold energy and reaction rates of various nuclear reactions, including photonuclear, stripping, pickup, evaporation, spallation, and fragmentation reactions. 2) **Analyze** the characteristics and conservation laws of nuclear reactions by examining the cross section, reaction rate, and specific models (compound nucleus theory, optical model, direct interaction model) to understand their impact on different types of nuclear reactions.

	3) **Evaluate** the effectiveness of various nuclear reaction models (compound nucleus theory, optical model, direct interaction model) in predicting reaction outcomes and cross sections, and assess their applicability to specific nuclear reactions such as thermonuclear and photonuclear reactions. 4) **Design** a detailed study or simulation to investigate the dynamics of nuclear reactions, integrating calculations of cross sections, reaction rates, and different nuclear models, to explore their implications for reaction mechanisms and practical applications in nuclear chemistry.
Content Outline	Definition and Bethes notation, nuclear reaction energetic, nuclear reaction and threshold energy, characteristics of nuclear reactions, types of nuclear reactions, conservation in nuclear reactions, nuclear reactions cross section, cross section and reaction rate, the compound nucleus theory, general properties of compound nucleus, optical model, direct interaction model, specific nuclear reactions- photonuclear reactions, stripping and pickup reactions evaporation, spallation, fragmentation, direct nuclear reactions, thermonuclear reactions.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

- **Module 1:** a research project could involve calculating the mass defect and binding energy of various isotopes using data available from online nuclear databases. The objective is to determine the stability of different nuclei by applying the concepts of mass defect and binding energy, and comparing them to theoretical predictions from nuclear composition theories. Students can gather isotope data from online sources, perform calculations at home using a calculator or spreadsheet, and analyze the results to understand nuclear stability. This project emphasizes the practical application of theoretical nuclear chemistry concepts.

- **Module 2:** students could create a comparative analysis of the shell model and liquid drop model by simulating the behavior of nuclei with different numbers of protons and neutrons. The objective is to understand how these models explain nuclear properties such as binding energy and stability, and to explore the concept of magic numbers. Students can use simple programming tools or online nuclear simulation software to model different nuclei, analyze the results, and compare the effectiveness of each model in predicting nuclear properties. This project offers hands-on experience with nuclear models.

- **Module 3:** a project could involve calculating the binding energy of a given nucleus using the semi-empirical mass formula and comparing it to experimental values. The objective is to evaluate the accuracy of the liquid drop model and shell model in predicting nuclear stability. Students can perform calculations at home using a calculator or spreadsheet, and compare their results to experimental data available online. This project focuses on understanding the energetics of nuclear reactions and the application of theoretical models to real-world data.

- **Module 4:** students could design a simulation of a specific nuclear reaction, such as a photonuclear or spallation reaction, using available online tools or programming software. The objective is to calculate the threshold energy, reaction rates, and cross sections for the chosen reaction, and to explore the applicability of different nuclear reaction models, such as the compound nucleus theory or optical model. This project can be conducted using online resources and software, allowing students to analyze the dynamics of nuclear reactions and their practical implications in nuclear chemistry.

References:

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2. Harvey, B. G. (1969). *Introduction to nuclear physics and chemistry*. Prentice Hall of India.
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5. Brown, H. J. M. (1965). *Chemical applications of radioisotopes*. Academic Press.
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7. Glasstone, S. (1950). *Sources of atomic energy*. D. Van Nostrand Co. Inc.
8. Arora, M. G., & Singh, M. (2002). *Nuclear chemistry*. Anmol Publications.

1.5 C. Major (Elective)

Course Title	**Polymer Chemistry (125311)**
Course Credits	4
Course Outcomes	After going through the module, learners will be able to 1) Apply the concepts of monomers, oligomers, and polymers to calculate average molecular weight, molecular weight distribution, and poly dispersity index for various polymer samples, and understand their implications for polymer properties and performance. 2) Analyze the classification of polymers, including natural, synthetic, biopolymers, thermoplastics, thermosets, elastomers, and fibers, to determine their structure, characteristics, and applications in different industrial and commercial contexts. 3) Evaluate the different polymerization methods such as free radical polymerization, ionic polymerization, and Ziegler-Natta catalysts, as well as polymerization techniques like mass, bulk, and emulsion polymerization, to compare their efficiency, advantages, and limitations. 4) Design an experimental approach or industrial process for polymerization, incorporating techniques such as solution, suspension, and emulsion polymerization, to optimize the properties and performance of the final polymer product based on specific application requirements.
Module 1 (Credit 1) - Polymer Introduction	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the concepts of monomers, oligomers, and polymers to calculate average molecular weight, molecular weight distribution, and poly dispersity index, and interpret their significance in determining the properties of polymer materials. 2) **Analyze** the various types of polymerization processes, including addition and condensation polymerization, to understand their mechanisms, reactants, and products, and to classify polymers based on their polymerization methods. 3) **Evaluate** different classifications of polymers (such as natural, synthetic, thermoplastics, thermosets, and elastomers) and their structures to determine their specific applications, advantages, and limitations in industrial and commercial contexts. 4) **Design** a polymerization experiment or process considering the type of polymerization and polymer characteristics to achieve desired properties in the final polymer product, including controlling molecular weight and distribution.
Content Outline	Monomer, oligomer and polymer, Average Molecular Weight, Molecular weight, Distribution & Poly dispersity Index, classification of polymers, structure of polymer. Types of polymerization

Module 2 (Credit 1) - Classification of Polymers	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the knowledge of natural and synthetic polymers to identify and categorize various polymer types, including biopolymers, thermoplastics, thermosets, elastomers, and fibers, based on their properties and applications. 2) **Analyze** the characteristics and uses of different classes of polymers, such as thermoplastics, thermosets, elastomers, and fibers, to understand their suitability for specific applications and performance in various conditions. 3) **Evaluate** the impact of polymer classification on material properties and functionalities, including mechanical strength, flexibility, and chemical resistance, to determine the optimal polymer type for various industrial and consumer applications. 4) **Design** polymer materials with tailored properties by selecting appropriate polymer types (natural, synthetic, biopolymers, etc.) and classifications (thermoplastic, thermoset, elastomer, fiber) to meet specific performance criteria and application requirements.
Content Outline	Natural and synthetic polymers, Biopolymers, thermoplastic, thermosets, Elastomers, Fibers etc
Module 3 (Credit 1) - Chemistry of Polymerization	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** different polymerization methods, including free radical, ionic, and coordination polymerization, as well as the use of Ziegler-Natta catalysts, to synthesize polymers with desired properties and functionalities. 2) **Analyze** various polymerization techniques, such as step polymerization (polycondensation, polyaddition, ring opening), electrochemical polymerization, and group transfer polymerization, to determine their effects on polymer structure, molecular weight, and overall performance. 3) **Evaluate** the advantages and limitations of different polymerization methods and techniques, including bulk, solution, emulsion, and suspension polymerization, to optimize the production processes and material properties for specific applications. 4) **Design** advanced polymerization processes and select appropriate techniques based on the desired polymer characteristics, including molecular weight distribution, polymer structure, and polymerization conditions, to achieve targeted performance and applications.
Content Outline	Chain polymerization: free radical polymerization, ionic polymerization, co-ordination polymerization, Ziegler-Natta catalysts. Step Polymerization: polycondensation, polyaddition, ring opening, electro chemical polymerization, group, Transfer polymerization, Polymerization techniques

Module 4 (Credit 1) - Polymerization Techniques	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** different polymerization techniques, such as mass, bulk, solution, emulsion, and suspension polymerization, to synthesize polymers with specific characteristics and properties based on the requirements of various applications. 2) **Analyze** the mechanisms of each polymerization method, including their operational principles and the factors affecting polymerization, to determine their impact on polymer properties and processing conditions. 3) **Evaluate** the relative advantages and disadvantages of mass, bulk, solution, emulsion, and suspension polymerization techniques, including their effects on polymer yield, molecular weight, distribution, and overall quality. 4) **Design** optimized polymerization processes by selecting the most suitable technique for a given application, considering factors such as polymer characteristics, process efficiency, cost-effectiveness, and environmental impact.
Content Outline	Mass Polymerization, Bulk Polymerization, Solution Polymerization, Emulsion Polymerization, Suspension Polymerization, Mechanisms with explanation. Characteristics, Relative advantages and disadvantages

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

- **Module 1,** a research project could involve calculating the average molecular weight and polydispersity index of different polymer samples using online data sources or synthetic polymer samples available at home or in a nearby laboratory. The objective is to understand the relationship between molecular weight distribution and polymer properties. Students can gather data, perform calculations using a spreadsheet or calculator, and analyze the significance of molecular weight distribution on polymer performance. This project emphasizes practical application of fundamental concepts in polymer chemistry.

- **Module 2,** students could design a project to classify household polymers, such as plastics, rubber, and fibers, by identifying their properties and categorizing them as thermoplastics, thermosets, elastomers, or fibers. The objective is to understand the classification of polymers based on their structure and applications. This can be done by collecting various polymer samples (e.g., plastic bottles, rubber bands), performing simple tests to observe properties like flexibility and heat resistance, and categorizing them accordingly. This project allows students to connect theoretical knowledge with everyday materials.

- **Module 3,** a project could involve synthesizing a simple polymer, such as polyvinyl alcohol (PVA) slime, using available household chemicals (e.g., glue and borax) to understand the basics of polymerization. The objective is to explore the free radical polymerization process and its impact on polymer properties. Students can perform the synthesis at home, document the polymerization process, and analyze the resulting polymer's characteristics. This hands-on project introduces students to the practical aspects of polymer chemistry in a controlled, accessible manner.

- **Module 4,** students could conduct a comparative study of different polymerization techniques by synthesizing small batches of polymer using mass and solution polymerization methods, utilizing simple materials like glue, water, and a solvent. The objective is to evaluate the impact of different techniques on polymer properties such as viscosity and texture. Students can perform the synthesis in a home or community lab, document the process, and compare the resulting polymers. This project helps students understand the practical implications of choosing different polymerization techniques based on the desired outcome.

References-

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2. Ghosh, P. (Year). *Polymer science and technology*. [Publisher].
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1.6. Minor Stream (RM)

Course Title	**Research Methodology (135311)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) Apply various research methodologies to identify and formulate research problems, develop and test hypotheses, and conduct comprehensive literature reviews using resources such as journals, books, and digital libraries. 2) Analyze and utilize effective literature search techniques and referencing methods, ensuring adherence to ethical considerations and safety protocols in both laboratory and field research. 3) Evaluate and integrate qualitative and quantitative research approaches, assess the impact and relevance of research journals and digital platforms, and manage indexing and bibliography effectively to support research objectives. 4) Design and create research papers, presentations, and proposals, demonstrating effective scientific writing, adherence to publication standards, and understanding of the patenting process to contribute valuable scientific knowledge and innovations.
Module 1 (Credit 1) - Introduction to Research Methodology	
Learning Outcomes	After going through the module, learners will be able to 1) Apply the fundamental concepts of research, including definitions, types, methods, and methodologies, to formulate a coherent research proposal. 2) Analyze the problem identification and formulation process by evaluating various research areas, addressing measurement issues, and differentiating between null and alternative hypotheses, using both parametric and non-parametric methods. 3) Evaluate the effectiveness of different literature sources, including journals, books, E-books, websites, and databases like NCBI-PubMed, in supporting research hypotheses and theoretical frameworks. 4) Design a comprehensive research strategy incorporating hypothesis testing and literature review, demonstrating the ability to create a structured research plan that integrates theoretical and practical elements.
Content Outline	Basic concept of Research, Definition, Types and Methods of Research, Concept of methodology Problem Identification & Formulation – Exploring the research area, conducting investigations, addressing measurement issues, formulating hypotheses, and understanding the qualities of a good hypothesis. This includes the concepts of Null & Alternative Hypothesis, and Hypothesis Testing with a focus on logic and importance, encompassing both parametric and non-parametric methods. Review of Literature: Investigating into the library domain, the module covers essential concepts of a scientific library, incorporating various resources such as journals, books, E-books, websites, and digital libraries. It also highlights the use of databases, including a specific mention of NCBI-Pub Med.

Module 2 (Credit 1) - Searching & Referencing	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** effective literature search methods using search engines and academic databases to select and refine research topics, supported by case study-based approaches. 2) **Analyze** the process of maintaining accurate laboratory records and implementing safety protocols in laboratory settings, emphasizing ethical considerations and best practices in data management and fieldwork safety. 3) **Evaluate** the nuances of verbal and non-verbal communication in research contexts, assessing their impact on effective scientific collaboration and information dissemination. 4) **Design** a comprehensive research plan that incorporates field data collection techniques, safety measures, and key research areas in chemistry, demonstrating the ability to conduct thorough and ethical research.
Content Outline	Explore effective literature search methods, utilizing search engines, and delve into the selection of research topics with a case study-based method. The module includes practical guidance on maintaining laboratory records, emphasizing case studies. It covers safety protocols in laboratories, ethical considerations, and the nuances of effective verbal and non-verbal communication. Additionally, the curriculum addresses field data collection techniques and safety measures in fieldwork. The module also introduces key research areas in chemistry
Module 3 (Credit 1) - Approaching the Research	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** qualitative and quantitative research methodologies to design and conduct research, incorporating measurement, causality, generalization, and replication to address research questions effectively. 2) **Analyze** various types of journals and their metrics (such as H-index, impact factor, and ISSN), evaluating their relevance and credibility for research purposes, with a specific focus on UGC Care Journals. 3) **Evaluate** the effectiveness of digital research tools and platforms (e.g., Google Scholar, Research Gate, Scopus) in enhancing research productivity, and integrate these tools to streamline literature search and management. 4) **Design** an indexing and bibliography management system using open-source tools to organize and maintain research references efficiently, ensuring accurate and systematic documentation.
Content Outline	Qualitative and Quantitative Research: This section explores the concepts of measurement, causality, generalization, and replication in both qualitative and quantitative research. It also addresses the integration of these two approaches. Journals: The module covers various aspects of journals, including indexing, H-index, I-10, ISSN, ISBN, abstracting journals, research journals, review journals, e-journals, and the impact factor of journals. It includes a focus on UGC Care Journals. Information Resources and Platforms: The module discusses reprints, the open-access initiative, and platforms such as INFLIBNET, INSDOC, Shodh

	Ganga, among others. Digital Research Tools and Platforms: This section covers the utilization of digital platforms like Google Scholar, Research Gate, LinkedIn, Orcid ID, Scopus (Q1 to Q4), Web of Science, and Boolean word searches. Indexing and Bibliography Management: The curriculum includes guidance on the preparation of index cards, covering author and subject indexes. It also introduces open-source bibliography management systems.
Module 4 (Credit 1) - MethodsofScientificWriting & Research	
Learning Outcomes	After going through the module, learners will be able to 1) **Create** a well-structured research paper or thesis that effectively justifies scientific contributions, describes methods, and presents conclusions with clarity, adhering to scientific writing standards and ethical guidelines. 2) **Design** and deliver compelling presentations and research proposals that effectively communicate research findings and proposals, employing appropriate illustration and style to enhance audience engagement and understanding. 3) **Apply** principles of writing ethics and plagiarism avoidance to ensure originality and integrity in scholarly writing, while navigating the process of publishing scientific work. 4) **Evaluate** the patenting process within the fields of science and technology, including understanding intellectual property rights and developing strategies for protecting research innovations.
Content Outline	Justification for scientific contributions, description of methods, conclusions,the need for illustration,style,publicationsofscientificwork, writing ethics, avoiding plagiarism. Creating a research paper or thesis, crafting effective presentations, composing research proposals, and understanding the patenting process in the fields of science and technology are key components of this module. Students will develop skills in structuring and writing scholarly papers, honing the art of delivering compelling presentations, and formulating research proposals. Additionally, the module will delve into the intricacies of patenting within the realms of science and technology, providing a comprehensive understanding of intellectual property in research and innovation.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

- **Module 1,** students could design a research project that involves formulating a research proposal based on a selected topic of interest. The objective is to apply the fundamental concepts of research methodology, including problem identification, hypothesis formulation, and literature review. Using online databases like Google Scholar or PubMed, students can gather relevant literature, identify gaps, and develop a clear research question. The project can be completed using a computer and internet access, focusing on creating a structured research plan that integrates theoretical and practical elements.

- **Module 2,** students could conduct a project that involves performing a comprehensive literature search on a specific research topic using academic databases like Scopus or Google Scholar. The objective is to learn effective search techniques and referencing methods while ensuring the use of ethical guidelines in research. Students can document the process, select key references, and create a bibliography using open-source tools like Zotero. This project emphasizes practical skills in literature search, data management, and referencing, and can be completed at home or in a community library.

- **Module 3,** a project could involve evaluating different scientific journals and their metrics, such as impact factor and H-index, to determine their relevance for a chosen research topic. The objective is to understand the importance of selecting credible sources for research. Students can analyze journals using resources like Google Scholar or Research Gate, and create a report comparing the quality of various journals. This project can be done using digital tools and emphasizes the importance of critical evaluation of scientific literature.

- **Module 4,** students could design a project that involves writing a research paper or thesis on a selected topic, focusing on the structure, clarity, and ethical standards of scientific writing. The objective is to develop skills in scientific communication, including avoiding plagiarism and adhering to publication standards. Students can draft the paper using word processing software, incorporating illustrations and references. This project can be completed at home or in a community setting, and it provides practical experience in writing and presenting scientific research.

References-

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3. Dawson, C. (2002). *Practical research methods*. UBS Publishers.
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Semester II

2.1 Major (Core)

Course Title	**Inorganic Chemistry (215311)**
Course Credits	4
Course Outcomes	After going through the module, learners will be able to 1) Apply: Apply the principles of spin-orbit coupling and microstates to determine the term symbols for various d-electron configurations in both octahedral and tetrahedral environments. 2) Analyze: Analyze the structural and bonding characteristics of organometallic compounds using the Valence Bond Theory (VBT) and Molecular Orbital Theory (MOT) for a range of transition metal complexes. 3) Evaluate: Evaluate the properties, synthesis methods, and applications of halogens and noble gases, including their oxyacids and oxoanions, with respect to their bonding and VSEPR theory. 4) Design: Design and create complex metal nitrosyl compounds, including nitrosyl halides and nitrosyls of various metals, while applying the EAN and eighteen-electron rules to understand their structure and applications.
Module 1 (Credit 1) - Spectroscopic term symbols	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply the concepts of inter-electronic repulsion and spin-orbit coupling to determine the term symbols for d1 to d5 electron configurations in both octahedral and tetrahedral complexes. 2) Analyze: Analyze the energy ordering of terms and microstates for various d-electron configurations using correlation diagrams and Orgel diagrams. 3) Evaluate: Evaluate the effects of weak and strong field approaches on the spectroscopic term symbols and Racah parameters for different d-electron configurations. 4) Design: Design and interpret Tanabe-Sugano diagrams for d2 and d3 configurations to predict and explain their spectral properties in octahedral and tetrahedral environments.
Content Outline	Inter-electronics repulsion, spin-orbit coupling, ground terms, determination of terms symbol of d1 to d5 Configuration/complexes, Energy ordering of terms, microstates. Racah parameter. Weak and stronger field approach. Correlation diagram of d^1, d^2, d^8 and d^9 configuration in octahedral and tetrahedral environments, non-crossing rule. Orgel diagram of d^1 to d^9 configuration in octahedral and tetrahedral environments, Tanabe Sugano diagram of d^2 and d^3 configurations.

Module 2 (Credit 1) – Organo metallic Chemistry of Transition metals	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply the eighteen and sixteen electron rules to count the electrons in organometallic compounds and predict their stability and reactivity with appropriate examples. 2) **Analyze:** Analyze the preparation methods and properties of various organometallic compounds, such as alkyl and aryl derivatives of Pd and Pt, carbenes, carbynes, and sandwich compounds of transition metals. 3) **Evaluate:** Evaluate the structure and bonding in selected organometallic compounds using Valence Bond Theory (VBT) and Molecular Orbital Theory (MOT) to explain their chemical behavior and properties. 4) **Design:** Design and synthesize organometallic complexes, such as Zeise's salt and bis(triphenylphosphine)diphenylacetylene platinum(0), by applying principles from VBT and MOT to understand their electronic structures and bonding characteristics.
Content Outline	1. Eighteen and sixteen electron rule and electron counting with examples. 2. Preparation and properties of the following compounds (a) Alkyl and aryl derivatives of Pd and Pt complexes (b) Carbenes and carbynes of Cr, Mo and W (c) Alkene derivatives of Pd and Pt (d) Alkyne derivatives of Pd and Pt (e) Allyl derivatives of nickel (f) Sandwich compounds of Fe, Cr and Half Sandwich compounds of Cr,Mo. 3. Structure and bonding on the basis of VBT and MOT in the following organometallic compounds: Zeise's salt, bis(triphenylphosphine)diphenylacetylene platinum(0) [Pt(PPh3)2(HC≡CPh)2], diallylnickel(II), ferrocene and bis(arene)chromium(0), tricarbonyl (η2 -butadiene) iron(0)
Module 3 (Credit 1) - Halogen group & Noble gases	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply the principles of chemical bonding and VSEPR theory to determine the structure and bonding of interhalogens, pseudohalogens, and oxyacids of halogens. 2) **Analyze:** Analyze the synthesis methods, properties, and applications of halogens and noble gases, including their oxyacids and oxoanions, to understand their chemical behavior and uses. 3) **Evaluate:** Evaluate the properties and bonding of noble gases, including their structure and applications, using VSEPR theory to predict their chemical reactivity and stability. 4) **Design:** Design experiments to synthesize and characterize interhalogens and pseudo halogens, applying knowledge of their bonding and properties to explore their potential applications in various chemical processes.
Content Outline	Halogen group: -Interhalogens, Pseudohalogen, synthesis, properties & applications, structure, oxyacids & oxoanions of Halogens Bonding. Noble gases: - Synthesis, properties, uses, structure & bonding with respect to VSEPR.
Module 4 (Credit 1) - Metal nitrosyl compounds	

Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply the principles of preparation and properties to synthesize and characterize nitrosyl halides, metal nitrosyl halides, and compounds containing NO- and NO+ groups. 2) **Analyze:** Analyze the structure and applications of sodium nitroprusside and nitrosyl compounds of cobalt, iron, and manganese, using the EAN and eighteen-electron rules to understand their chemical behavior and stability. 3) **Evaluate:** Evaluate the significance of nitric oxide (NO) for biological systems and its impact on the life of living animals, based on its chemical properties and biological functions. 4) **Design:** Design and conduct experiments to prepare and study various nitrosyl compounds, applying knowledge of their electronic structures and applications to explore their roles in different chemical and biological contexts.
Content Outline	Preparations and properties of Nitrosyl halides (NOX), Metal nitrosyl halides, compounds containing NO- group, Compounds containing NO+ groups, Preparation, structure and application of sodium Nitroprusside. EAN and Eighteen electron rules applied to nitrosyl compounds, Nitrosyl compounds of Cobalt, iron and Manganese. Significance of NO for the life of living animal.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1**: students could undertake a project that involves determining the term symbols for various d-electron configurations in octahedral and tetrahedral complexes. The objective is to apply concepts of spin-orbit coupling and microstates to predict and interpret the spectroscopic term symbols. Students can use online resources and computational tools to create Orgel and Tanabe-Sugano diagrams for different configurations. The project can be carried out using free software or online calculators for term symbols and correlation diagrams, which can be accessed from home or a nearby lab.

- **Module 2**: students might work on a project that involves preparing and analyzing organometallic compounds such as Zeise’s salt or bis(triphenylphosphine) diphenylacetylene platinum(0). The goal is to apply the eighteen-electron rule and use VBT and MOT to explain the bonding and properties of these compounds. Students can synthesize simple organometallic complexes using readily available reagents or perform computational simulations if lab resources are limited. The project can be conducted at home with minimal equipment or in a local community lab.

- **Module 3**: a research project could focus on the synthesis and characterization of interhalogens or pseudohalogens. The objective is to apply VSEPR theory to understand their structure and bonding. Students can use household chemicals or readily available lab reagents to create these compounds and analyze their properties using basic laboratory techniques or online resources. This project allows students to explore chemical synthesis and bonding in a practical setting, making use of local lab facilities or home chemistry kits.

- **Module 4:** students could design a project to prepare and study various nitrosyl compounds, such as nitrosyl halides or metal nitrosyls. The goal is to apply EAN and eighteen-electron rules to understand their structure and applications. Students can prepare these compounds using accessible chemicals or conduct theoretical studies using online resources. The project can be completed at home or in a community lab, focusing on synthesizing and characterizing nitrosyl compounds with available materials and equipment.

References-

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6. Raj, G. (2000). *Advanced inorganic chemistry* (Vol. I & II). Pelenum.
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2.2 Major (Core)

Course Title	**Organic Chemistry (215312)**
Course Credits	4
Course Outcomes	After going through the module, learners will be able to 1) Apply: Apply the arenium ion mechanism and various electrophilic substitution reactions to predict the orientation and reactivity of aromatic compounds in substitution reactions, including halogenation, nitration, sulphonation, and Friedel-Crafts reactions. 2) Analyze: Analyze the mechanisms of addition reactions to carbon-carbon multiple bonds, including electrophilic, nucleophilic, and free radical additions, to understand regioselectivity, chemoselectivity, and stereochemical outcomes. 3) Evaluate: Evaluate different oxidation and reduction techniques using various reagents and catalysts (e.g., CrO3, PCC, KMnO4, Pd/C, etc.) to determine their effectiveness and suitability for transforming organic molecules. 4) Design: Design and interpret experiments to assess aromaticity using structural, thermochemical, and magnetic criteria, applying Hückel's (4n+2) rule and HMO theory to analyze the aromaticity of various cyclic and conjugated systems, including benzenoid systems, heterocycles, and fullerenes.
Module 1 (Credit 1) - Aromatic Electrophilic and Nucleophilic Substitutions Electrophilic Substitutions	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply the arenium ion mechanism to predict the orientation and reactivity of aromatic compounds in electrophilic substitution reactions, including halogenation, nitration, sulphonation, and Friedel-Crafts reactions. 2) Analyze: Analyze the energy profile diagrams and ortho/para ratios to understand the influence of substituents on the reactivity and orientation of electrophilic aromatic substitution reactions. 3) Evaluate: Evaluate the effects of substrate structure, leaving groups, and attacking nucleophiles on the reactivity of nucleophilic aromatic substitutions (SNAr, SN1) and the benzyne mechanism. 4) Design: Design and predict outcomes for reactions involving IPSO substitution and diazonium coupling, applying knowledge of aromaticity and substitution mechanisms to explore their applications in synthetic chemistry.
Content Outline	The arenium ion mechanism, orientation and reactivity, energy profile diagram. The ortho/para ratio, IPSO substitution, orientation in other ring systems, Recapitulation of halogenation, nitration, sulphonation and Fridel Craft's reaction, diazonium coupling. Nucleophilic Substitution: The SNAr, SN1, benzyne mechanism, Effect of substrate structure, leaving group and attacking nucleophile on reactivity.

Module 2 (Credit 1) - Addition to Carbon-Carbon multiple bonds	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply the mechanisms of addition reactions involving electrophiles, nucleophiles, and free radicals to predict the stereochemical outcomes and regiochemistry of these reactions. 2) **Analyze:** Analyze the regioselectivity and chemoselectivity in addition reactions to carbon-carbon multiple bonds to understand how different functional groups and reaction conditions affect orientation and reactivity. 3) **Evaluate:** Evaluate the effectiveness and selectivity of specific addition reactions, such as Michael addition and Sharpless asymmetric epoxidation, in achieving desired stereochemical and regioselective products. 4) **Design:** Design experiments to perform and optimize addition reactions, including the application of Michael addition and Sharpless asymmetric epoxidation, to synthesize compounds with precise stereochemistry and regiochemistry.
Content Outline	Mechanism and stereochemical aspect of addition reaction involving electrophile, nucleophile and free radicals. Regioselectivity and chemoselectivity, orientation and reactivity, Michael addition, Sharpless asymmetric epoxidation
Module 3 (Credit 1) - Oxidation and Reduction	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply various oxidation and reduction reagents (e.g., CrO3, PCC, KMnO4, Pd/C) to transform organic molecules, selecting appropriate reagents for specific oxidation or reduction reactions. 2) **Analyze:** Analyze the mechanisms and outcomes of different oxidation and reduction methods, including the use of reagents like mCPBA, O3, and NaIO4, to determine their effectiveness and impact on the structure of organic compounds. 3) **Evaluate:** Evaluate the utility and limitations of reagents such as Swern, SeO2, and DIBAL in oxidation and reduction processes, assessing their suitability for various chemical transformations and their role in synthetic chemistry. 4) **Design:** Design and optimize synthetic pathways using reduction methods (e.g., H2/catalyst, NaCNBH3) and hydroboration reactions to achieve selective transformations and functional group modifications in complex organic molecules.
Content Outline	CrO3 (Jones reagent) PDC, PCC, KMnO4, MnO2, Swern, SeO2, Pb (OAc)4, Pd/C, OsO4, mCPBA, O3, NaIO4, HIO4 R3 SiH, Bu3SnH, Boranes&Hydroboration reactions, MVP, H2/ catalyst, Wilkinson’s catalyst, NaCNBH3, NH2NH2, DIBAL, etc
Module 4 (Credit 1) – Aromaticity	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply structural, thermochemical, and magnetic criteria, including NMR characteristics, to assess the aromaticity of various organic systems and understand the delocalization of π-electrons in aromatic compounds. 2) **Analyze:** Analyze the application of Hückel’s (4n+2) and 4n rules and use Frost-Musulin diagrams to determine the aromatic or antiaromatic nature of

	monocyclic conjugated systems. 3) **Evaluate:** Evaluate the aromaticity of complex systems, including benzenoid compounds, heterocycles, metallocenes, azulenes, annulenes, aromatic ions, and fullerenes, up to 18 carbon atoms, based on their adherence to aromaticity rules and structural characteristics. 4) **Design:** Design and interpret models of homoaromatic compounds and other aromatic systems, applying knowledge from HMO theory and aromaticity rules to predict their chemical behavior and stability.
Content Outline	2.2.1. Structural, thermochemical, and magnetic criteria for aromaticity, including NMR characteristics of aromatic systems. Delocalization and aromaticity. 2.2.2. Application of HMO theory to monocyclic conjugated systems. Frost-Musulin diagrams. Huckel's (4n+2) and 4n rules. 2.2.3. Aromatic and antiaromatic compounds up to 18 carbon atoms. Homoaromatic compounds. Aromaticity of all benzenoid systems, heterocycles, metallocenes, azulenes, annulenes, aromatic ions and Fullerene.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1:** students could undertake a project that involves investigating the orientation and reactivity of aromatic compounds in electrophilic substitution reactions. The objective is to apply the arenium ion mechanism to predict and analyze the outcomes of halogenation, nitration, sulphonation, and Friedel-Crafts reactions. Students can use simple organic compounds and common laboratory reagents to conduct these reactions, observing the effects of various substituents on the reactivity and orientation. They can perform these experiments in a community lab or at home with safe, available chemicals, and use online resources to analyze the results and understand the underlying mechanisms.

- **Module 2:** students might work on a project that involves performing addition reactions to carbon-carbon multiple bonds, such as Michael addition or Sharpless asymmetric epoxidation. The goal is to apply mechanisms involving electrophiles, nucleophiles, and free radicals to synthesize compounds with specific regioselectivity and stereochemistry. Students can use readily available chemicals and basic lab equipment to conduct these reactions, documenting their outcomes and analyzing the stereochemical and regioselective aspects. This project can be completed in a local lab or with home chemistry kits, depending on the availability of resources.

- **Module 3**: a research project could focus on the application of oxidation and reduction techniques to transform organic molecules. Students can select appropriate reagents like PCC, KMnO4, or Pd/C to carry out specific oxidation or reduction reactions and evaluate their effectiveness. The objective is to design and optimize synthetic pathways, using simple organic substrates and commonly available reagents. Students can conduct these reactions in a home lab or local community lab, assessing the suitability and impact of different reagents on their chemical transformations.

- **Module 4:** students could design a project to assess the aromaticity of various organic systems using structural, thermochemical, and magnetic criteria. The goal is to apply Hückel's (4n+2) rule and HMO theory to analyze the aromaticity of compounds such as benzenoid systems, heterocycles, and fullerenes. Students can use online tools or software to model and interpret aromatic systems, exploring their delocalization and stability. This project can be done at home with computer-based resources or in a local lab with access to modeling software and literature.

References-

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7. Singh, J., & Yadav, L. D. S. (2009). *Organic synthesis*. Pragati Prakashan.

2.3 Major (Core)

Course Title	**Physical Chemistry (215313)**
Course Credits	4
Course Outcomes	After going through the module, learners will be able to 1) Apply: Apply the Schrödinger equation and quantum mechanical operators (e.g., Hamiltonian, angular momentum) to solve problems related to a particle in a one-dimensional and three-dimensional box, harmonic oscillator, and rigid rotator. 2) Analyze: Analyze the effects of solvent properties, ionic strength, and enzyme kinetics using Michaelis-Menten, Lineweaver-Burk, and Eadie-Analyses to understand the rates of elementary reactions and enzyme-catalyzed processes. 3) Evaluate: Evaluate term symbols, selection rules, and Huckel molecular orbital theory to predict and interpret the electronic structure and reactivity of conjugated systems such as ethylene, butadiene, and benzene. 4) Design: Design and interpret experiments using Raman, electronic, ESR, Mossbauer, and NMR spectroscopy to elucidate molecular structures, reaction mechanisms, and electronic properties of molecules.
Module 1 (Credit 1) - Quantum Chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply the Schrödinger equation to solve for eigen values and eigen functions of particles in a one-dimensional and three-dimensional box, as well as for harmonic oscillators and rigid rotators. 2) Analyze: Analyze the properties of quantum mechanical operators, including Hermitian, linear, ladder, Hamiltonian, and angular momentum operators, to understand their roles in quantum systems. 3) Evaluate: Evaluate the solutions of the Schrödinger equation for various quantum systems to determine their physical implications, such as energy levels and wave functions. 4) Design: Design and solve numerical problems involving the Schrödinger equation and quantum mechanical operators to model and predict the behavior of particles in different quantum mechanical systems.
Content Outline	The Schrodinger equation, particle in a one-dimensional box, Eigen values and Eigen functions, operators, properties of quantum mechanical operators, Hermitian, Linear, Ladder, Hamiltonian and angular momentum operators. Particle in three dimensional box, harmonic oscillator, rigid rotator and numericals.
Module 2 (Credit 1) - Chemical Kinetics and Molecular Reaction Dynamics	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply principles of solvent effects, including dielectric constant and ionic strength, to analyze and predict reaction rates and mechanisms in solution, incorporating linear free energy relationships and enzyme action.

	2) **Analyze:** Analyze the kinetics of enzyme-catalyzed reactions using Michaelis-Menten, Lineweaver-Burk, and Eadie analyses to understand enzyme efficiency, substrate affinity, and reaction rates. 3) **Evaluate:** Evaluate different types of enzyme inhibition (competitive, noncompetitive, and uncompetitive) and their effects on enzyme activity, considering factors such as pH, enzyme activation by metal ions, and regulatory mechanisms. 4) **Design:** Design and interpret experiments to study the kinetics of solid-state reactions, applying various rate laws (e.g., parabolic rate law, first-order rate law) and understanding the factors affecting reactions in solids through specific examples.
Content Outline	1. Elementary Reactions in Solution:- Solvent Effects on reaction rates, Reactions between ions- influence of solvent Dielectric constant, the influence of ionic strength, Linear free energy relationships Enzyme action 2. Kinetics of reactions catalyzed by enzymes -Michaelis-Menten analysis, Lineweaver-Burk and EadieAnalyses. 3. Inhibition of Enzyme action: Competitive, Noncompetitive and Uncompetitive Inhibition. Effect of pH, Enzyme activation by metal ions, Regulatoryenzymes. 4. Kinetics of reactions in the Solid State:- Factors affecting reactions in solids Rate laws for reactions in solid: The parabolic rate law, The first order rate Law, the contracting sphere rate law, Contracting arearate law, some examples of kinetic studies. 5.
Module 3 (Credit 1) - Quantum Chemistry	
Learning Outcomes	After going through the module, learners will be able to 1. **Apply:** Apply term symbols and selection rules, along with spin-orbital coupling concepts, to predict and explain the electronic transitions and spectral properties of various molecular systems. 2. **Analyze:** Analyze the effects of non degenerate perturbation theory and the variation theorem on the electronic structure and energy levels of quantum systems, including their practical applications. 3. **Evaluate:** Evaluate Huckel molecular orbital theory to determine the electronic structure, stability, and reactivity of conjugated systems such as ethylene, butadiene, cyclopropyl radical, cyclobutadiene, and benzene. 4. **Design:** Design and solve numerical problems involving Huckel molecular orbital theory to model and predict the electronic properties and behavior of conjugated organic molecules.
Content Outline	Term symbols and selection rules, spin-orbital coupling, the variation theorem, non degenerate perturbation theory and applications. Huckel molecular orbital theory of conjugated systems, application to ethylene, butadiene, cyclopropyl radical, cyclobutadiene and benzene, numericals.
Module 4 (Credit 1) - Molecular Spectroscopy	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply Raman spectroscopy techniques to analyze rotational and vibrational spectra, including the use of light polarization and the Raman effect, to elucidate molecular structures in combination with IR spectroscopy. 2) **Analyze:** Analyze electronic spectroscopy data using the Born-Oppenheimer

	approximation to interpret the electronic spectra, vibrational and rotational fine structures, dissociation energies, and electronic structures of diatomic molecules. 3) **Evaluate:** Evaluate the applications of ESR (Electron Spin Resonance) and Mossbauer spectroscopy for studying the electronic environments and structural properties of different materials. 4) **Design:** Design experiments using NMR (Nuclear Magnetic Resonance) principles to determine molecular structures, utilizing PMR (Proton Magnetic Resonance) for detailed chemical analysis and structure elucidation.
Content Outline	1. Raman Spectroscopy:- Introduction, Rotational Raman spectra, Vibrational Raman Spectra, the polarization of light and Raman effect, structure elucidation from combined Raman and IR spectroscopy, applications in structure elucidation. 2. Electronic spectroscopy of molecules:- Born – Oppenheimer approximation, electronic spectra of diatomic molecules, vibrational coarse structure, rotational fine structure dissociation energy and dissociation products, electronic structure of diatomic molecules, molecular photoelectron spectroscopy, application. 3. ESR and Mossbauer spectroscopy applications. 4. Principles of NMR: - Chemical applications of PMR in structure elucidation.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1 (Quantum Chemistry),** students can investigate the effect of potential well width on the energy levels of a particle in a one-dimensional box using an online simulation tool such as PhET's "Quantum Wave Interference." The objective is to understand how changing the dimensions of the box impacts the quantized energy levels and wave functions. Students will access the simulation from home or a local library, set different box lengths, and observe the corresponding changes in energy levels and wave functions. They will record their observations and analyze the results to see how the confinement affects the energy states. This project requires a computer with internet access and can be completed in a few hours.

- **Module 2 (Chemical Kinetics and Molecular Reaction Dynamics),** students can conduct a project to explore the effect of temperature on the rate of a reaction between baking soda and vinegar. The objective is to observe how different temperatures influence the reaction rate. Students will perform the reaction at various temperatures using hot water baths or ice packs to create temperature differences, measure the volume of carbon dioxide gas produced using a simple gas collection setup, and record the time required for the reaction to complete. This can be done at home with household items like baking soda, vinegar, a thermometer, and a timer. The project can be completed within a few hours, including setup and data collection.

- **Module 3 (Quantum Chemistry),** students can use a free molecular modeling software like ChemDraw to explore Huckel molecular orbital theory for a conjugated system such as butadiene. The objective is to apply Huckel theory to determine the π-electron distribution and stability of the molecule. Students will draw the structure of butadiene, perform Huckel calculations using the software, and analyze the results to understand the electronic structure and reactivity. This project requires a computer with the software and can be done at home or in a computer lab. The project should take a few hours to set up, perform calculations, and interpret results.

- **Module 4 (Molecular Spectroscopy),** students can use a smartphone app or an affordable infrared (IR) spectroscopy kit to analyze the vibrational spectra of common household substances, such as essential oils or vinegar. The objective is to identify functional groups and correlate the spectra with molecular structures. Students will scan the samples using the app or kit, compare the spectra with reference data to identify functional groups, and analyze how the spectra relate to the molecular structure. This project requires a smartphone with the app or access to an IR spectroscopy kit, and can be conducted at home or in a community lab. The project is designed to be completed in a few hours, including sample preparation and data analysis.

References-

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2.4 Major (Core)

Course Title	**Practical (Laboratory Course) (245311)**
Course Credits	**2**
Course Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply semi-micro qualitative inorganic analysis techniques to identify and separate acidic and basic radicals, including rare earth elements, and to estimate metal ions in mixtures such as copper-barium, iron-aluminum, and copper-iron. 2) **Analyze**: Analyze binary solid-liquid mixtures by separating, purifying, and identifying their components using chemical methods, and prepare suitable derivatives of the separated compounds. 3) **Evaluate**: Evaluate the strengths of halides and acids in mixtures using potentiometric and conductometric methods, determine the solubility and solubility product of sparingly soluble salts, and assess the pK values of acids and indicator constants using pHmetry and colorimetry. 4) **Design**: Design and perform experiments involving ion-exchange and thin-layer chromatography to estimate metal ions, determine pK values of metal ions, and analyze mixtures of metal ions through colorimetric analysis.
Module 1 - Semi micro qualitative inorganic analysis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply qualitative analysis techniques to identify three acidic and three basic radicals, including a rare earth element, from a given mixture. 2) **Analyze**: Analyze the composition of metal ion mixtures and determine the amounts of metal ions in solutions containing copper-barium, iron-aluminum, and copper-iron using separation and estimation methods. 3) **Evaluate**: Evaluate the accuracy and effectiveness of methods used for separating and estimating metal ions in complex mixtures, ensuring precise identification and quantification. 4) **Design**: Design and execute systematic procedures for the qualitative and quantitative analysis of metal ions in mixtures, integrating techniques for both separation and estimation.
Content Outline	Identification of three acidic and three basic radicals including one rare earth from the given mixture. **Separation and estimation of the amount of metal ions from the following mixture solutions: -** 1. Copper-Barium 2. Iron–Aluminum **3.** Copper-Iron

Module 2 - Qualitative Organic Analysis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply chemical methods to separate and purify binary solid-liquid mixtures, effectively isolating the two components from each mixture. 2) **Analyze**: Analyze the purity of the separated compounds by evaluating their physical and chemical properties, ensuring accurate identification of the components. 3) **Evaluate**: Evaluate the effectiveness of the separation and purification processes by comparing the properties and derivatives of the purified samples with known standards. 4) **Design**: Design and execute procedures for preparing suitable derivatives of the separated compounds, and submit detailed reports on the purification, identification, and derivative preparation processes.
Content Outline	Separation, purification, and identification of binary (Solid-Liquid) mixtures. The separation should be carried out using the Chemical method. The two components are solid-liquid mixtures. The student should submit the purified samples of the separated compounds and prepare a suitable derivative of the two compounds separated out.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1 (Semi-Micro Qualitative Inorganic Analysis),** students can perform a project to identify and separate acidic and basic radicals, including a rare earth element, from a mixed solution. The objective is to apply qualitative analysis techniques to determine the presence of specific radicals in a sample. Students will use semi-micro techniques involving reagent additions and color changes to detect and confirm the presence of these radicals. They will prepare solutions of known mixtures, apply systematic chemical tests, and document their findings. This project can be conducted in a home laboratory or a nearby community lab, using standard chemical reagents and equipment for qualitative analysis. The focus is on accurately identifying and quantifying the radicals in the mixture.

- **Module 2 (Qualitative Organic Analysis),** students will conduct a project to separate and purify a binary solid-liquid mixture, such as salt in water or sugar in alcohol. The objective is to isolate the two components using chemical methods and prepare suitable derivatives of the purified compounds. Students will use filtration, evaporation, and crystallization techniques to separate and purify the components. They will then prepare derivatives of the purified substances, such as salts or esters, and analyze their physical properties to confirm their identity. This project can be completed at home or in a community lab with access to basic lab equipment and chemicals. The project involves separation, purification, and derivative preparation, all within a few hours.

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2.5 A. Major (Elective)

Course Title	**Analytical Chemistry (225311)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply spectral methods of analysis to characterize electromagnetic radiation, understand interactions with matter, and interpret spectra using fundamental concepts such as absorption, emission, and resolution power. Utilize microwave spectroscopy techniques to analyze molecular rotation and spectral characteristics of diatomic and polyatomic molecules. 2) **Analyze**: Analyze and present data effectively using graphs, tables, and statistical methods. Employ descriptive statistics, choose appropriate statistical tests, and apply chemometric and computational chemistry techniques to interpret experimental results. 3) **Evaluate**: Evaluate laboratory techniques and data analysis methods, including basic principles of laboratory work, safety procedures, and the use of statistical software such as SPSS. Assess the effectiveness of different methods in experimental design and data interpretation. 4) **Design**: Design and conduct experiments in spectroscopy and data analysis, including vibrational and Raman spectroscopy. Develop experimental protocols for analyzing molecular vibrations, rotation, and spectra, and apply these techniques to real-world problems and applications.
Module 1 (Credit 1) - General introduction of spectral methods of analysis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of electromagnetic radiation characterization and interactions with matter to interpret spectra, including absorption, emission, transmission, reflection, dispersion, and polarization. 2) **Analyze**: Analyze spectral data by evaluating basic elements of practical spectroscopy, such as resolving power, signal-to-noise ratio, and natural line width. Use this analysis to understand the intensity of spectral lines and energy levels, and apply selection rules in spectral interpretations. 3) **Evaluate**: Evaluate the impact of different molecular rotation models (rigid and non-rigid rotators) and isotopic substitutions on microwave spectroscopy. Assess the effectiveness of techniques and instrumentation in studying rotational spectra of diatomic and polyatomic molecules. 4) **Design**: Design experiments to measure and analyze rotational spectra using microwave spectroscopy. Develop protocols to address numerical problems related to the spectra of rigid and non-rigid rotators, ensuring accurate data collection and interpretation.
Content Outline	Characterization of electromagnetic radiations, Regions of the spectrum, Interaction of radiations with matter - absorption, emission, transmission, reflection, dispersion, polarization and representation of spectra, basic elements of practical spectroscopy, resolving power, signal to noise ratio. Uncertainty relation and natural line width, natural line broadening, the intensity of spectral lines, energy levels, selection rules, components of the spectrometer and their functions. Microwave spectroscopy: Rotation of molecules, rotational spectra, diatomic molecules - rigid diatomic molecules, intensities of spectral lines, the effect of the isotopic substitution, non-rigid rotator, the spectrum of a non-rigid rotator,

	polyatomic molecules, technique and instrumentation in outline, applications, numerical problems.
Module 2 (Credit 1) - Laboratory work	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply fundamental laboratory techniques to conduct experiments safely and effectively. Utilize principles of solution chemistry, pH, and buffer solutions to perform basic laboratory procedures and work with liquids. 2) **Analyze:** Analyze and record experimental measurements accurately, applying the scientific method and SI units. Conduct literature reviews and project work to gather and interpret primary and secondary data, using appropriate investigative approaches. 3) **Evaluate:** Evaluate and present experimental data using graphs, tables, and descriptive statistics. Choose and apply statistical tests for data analysis, and use chemometrics and computational chemistry techniques to solve numerical problems and draw chemical structures. 4) **Design:** Design and implement experiments with a focus on data collection and analysis. Develop and execute projects that integrate laboratory techniques with statistical analysis, and utilize statistical packages such as SPSS to analyze and interpret data effectively.
Content Outline	1. Fundamental Laboratory Techniques:- Basic principles, Health and safety, Working with liquids, Basic laboratory procedures I & II, Principles of solution chemistry, pH and buffersolutions. 2. The investigative approach:- Making and recording measurements, SI units (International System of Units) and their use, Scientific method and design of experiments, Project work. Collection of data (primary, secondary), literature survey & review. 3. Analysis and presentation of data: Using graphs, Presenting data in tables, Hints for solving numerical problems, Descriptive statistics, Choosing and using statistical tests, drawing chemical structures, Chemometrics, Computationalchemistry. 4. Statistical Packages for Social Science (SPSS)Workshop.
Module 3 (Credit 1) - Data Analysis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply various methods for data analysis and presentation, including the use of graphs, tables, and descriptive statistics. Utilize these methods to interpret and solve numerical problems, and to accurately draw chemical structures. 2) **Analyze:** Analyze experimental data using appropriate statistical tests and techniques. Implement chemometric methods and computational chemistry tools to evaluate complex datasets and derive meaningful insights. 3) **Evaluate:** Evaluate the effectiveness of different statistical tests and analysis techniques in the context of experimental data. Assess the impact of data presentation methods on the clarity and accuracy of results. 4) **Design:** Design and conduct data analysis projects using statistical software such as SPSS. Develop and implement strategies for analyzing and presenting data, ensuring that the approach is suitable for the type of data and the objectives of the research.

Content Outline	1) Analysis and presentation of data: Using graphs, Presenting data in tables, Hints for solving numerical problems, Descriptive statistics, Choosing and using statistical tests, drawing chemical structures, Chemometrics, Computationalchemistry. **2)** Statistical Packages for Social Science (SPSS)Workshop
Module 4 (Credit 1) - Spectroscopy	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply the principles of vibrational spectroscopy to analyze the spectra of diatomic and polyatomic molecules. Utilize concepts such as harmonic and anharmonic oscillators, vibration-rotation spectra, and group frequencies in the interpretation of infrared spectra. 2) **Analyze:** Analyze vibrational and rotational spectra, including overtones and combination frequencies. Evaluate the influence of factors like nuclear spin, rotation, and the Born-Oppenheimer approximation on the spectra of polyatomic molecules. 3) **Evaluate:** Evaluate the effectiveness of Raman spectroscopy techniques, including classical and quantum theories, to interpret pure rotational, vibrational, and vibrational-rotational spectra. Assess the impact of the rule of mutual exclusion and rotational fine structure on Raman spectra. 4) **Design:** Design and implement experimental procedures for analyzing molecular spectra using infrared and Raman spectroscopy. Develop protocols for applying the techniques and instrumentation to study group frequencies, overtone vibrations, and rotational spectra.
Content Outline	Vibrational spectroscopy Review of the linear harmonic oscillator, the vibrating diatomic molecule, the simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator, the vibration- rotation spectrum of carbon monoxide, breakdown of the Born- Oppenheimer approximation, the vibration of polyatomic molecules, overtones and combination frequencies, the influence of rotation on the spectra of polyatomic molecules, the influence of nuclear spin, symmetric top molecules, analysis by Infra-red technique - Group frequencies, the outline of technique and instrumentation. Raman spectroscopy: Classical and quantum of the theory of Raman effect, pure rotational, vibrational and vibrational-rotational Raman spectra, rule of mutual exclusion, overtone and combination vibrations, Rotational fine structure, the outline of technique and instrumentation, applications.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1 (General Introduction of Spectral Methods of Analysis),** students can conduct a project to characterize and interpret the rotational spectra of a diatomic molecule, such as carbon monoxide (CO). The objective is to apply principles of electromagnetic radiation and microwave spectroscopy to understand rotational spectra. Students will use online simulation tools or access spectral data from databases to analyze rotational spectra, focusing on identifying spectral lines and understanding the effects of isotopic substitution. They will evaluate resolving power, signal-to-noise ratio, and natural line width using available data. This project can be completed at home using online resources or in a lab with access to spectroscopy databases. The project involves data analysis and interpretation of rotational spectra.

- **Module 2 (Laboratory Work),** students can perform a project to measure and analyze pH and buffer solutions. The objective is to apply fundamental laboratory techniques to assess the effectiveness of various buffer solutions in maintaining a stable pH. Students will prepare buffer solutions with different pH values and measure their stability using a pH meter. They will analyze the data by recording pH changes over time and comparing their findings with theoretical expectations. This project can be done at home with basic laboratory equipment or in a local lab with pH meters and buffer solutions. It involves preparing solutions, measuring pH, and analyzing data to evaluate buffer effectiveness.

- **Module 3 (Data Analysis),** students can design a project to analyze a dataset using statistical software such as SPSS. The objective is to apply statistical methods to interpret experimental data and draw meaningful conclusions. Students will use SPSS to perform descriptive statistics, create graphs and tables, and apply appropriate statistical tests to a dataset, such as experimental results from a chemical reaction. They will evaluate the effectiveness of different analysis techniques and present their findings. This project can be completed using SPSS software on a computer, and it involves data entry, statistical analysis, and presentation of results.

- **Module 4 (Spectroscopy),** students can undertake a project to analyze vibrational spectra of a diatomic molecule, such as carbon dioxide (CO_2), using infrared (IR) spectroscopy. The objective is to apply principles of vibrational spectroscopy to interpret the IR spectra and identify characteristic peaks associated with vibrational modes. Students will analyze spectral data to determine group frequencies, overtones, and combination frequencies, and evaluate the influence of anharmonicity on the spectra. This project can be conducted using IR spectroscopic data available online or in a lab with IR spectroscopy equipment. It involves interpreting IR spectra and understanding the molecular vibrations of CO_2.

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2.5 B. Major (Elective)

Course Title	**Nuclear Chemistry (225312)**
Course Credits	**4**
Course Outcomes	After going through the module,learners will be able to 1) **Apply**: Apply the principles of radioactive decay and decay kinetics to solve problems related to the activity of daughter nuclides and the behavior of radioactive substances. Utilize concepts such as Geiger-Nuttall's law and ɑ-decay in practical scenarios. 2) **Analyze**: Analyze the interaction of different types of radiation (γ, ɑ, β) with matter, and evaluate the effects of radiation on water, including radiolysis and free radical formation. Interpret units for measuring radiation absorption and apply radiation dosimetry in practical contexts. 3) **Evaluate**: Evaluate the impact of radiation chemistry on various applications, including the preparation of isotopes and the use of radioisotopes in chemical, physio-chemical, agricultural, and industrial research. Assess the significance of radiation interactions, such as Linear Energy Transfer (LET) and Bremsstrahlung, in these applications. 4) **Design**: Design experiments and processes for nuclear fission and fusion, including the study of fission fragments, fission energy, and the production of isotopes by nuclear reactions. Develop methods for the manufacturing and use of heavy water in reactors, and apply theoretical knowledge to practical situations involving nuclear reactions.
Module 1 (Credit 1) - Radioactivity	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of radioactive decay, including ɑ-decay, internal conversion, and the Auger effect, to analyze and interpret the behavior of radioactive substances. Use these principles to calculate and predict the activity of daughter nuclides and their implications in practical scenarios. 2) **Analyze**: Analyze the general characteristics of radioactive decay and decay kinetics. Investigate the general expression for the activity of a daughter nuclide, and evaluate how factors such as decay rate and the Geiger-Nuttall law affect the decay process. 3) **Evaluate**: Evaluate the impact of various types of radioactive decay on the stability and energy distribution of radioactive materials. Assess the significance of ɑ-decay as a classical physics problem and the role of internal conversion and the Auger effect in radiation processes. 4) **Design**: Design experiments to measure and analyze the decay kinetics of radioactive substances, incorporating the Geiger-Nuttall law and other relevant models. Develop methods to investigate and quantify the effects of ɑ-decay and internal conversion in different experimental setups.
Content Outline	Types of radioactive decay, general characteristics of radioactive decay, decay kinetics, general expression for the activity of a daughter nuclide, Geiger-Nuttalis law, ɑ-decay: A problem in classical physics, Internal conversion and the Auger effect
Module 2 (Credit 1) - Elements of Radiation	

Learning Outcomes	After going through the module, learners will be able to, 1) **Apply:** Apply principles of radiation interaction with matter to assess the effects of γ radiation on different materials. Use this understanding to measure radiation absorption and perform radiation dosimetry in practical scenarios. 2) **Analyze:** Analyze the processes involved in the interaction of radiation with matter, including the specific effects of γ radiation. Evaluate the role of radiation dosimetry in quantifying exposure and its implications for safety and health. 3) **Evaluate:** Evaluate the radiolysis of water and the formation of free radicals during this process. Assess the impact of radiolysis on aqueous solutions and its significance in understanding radiation effects on chemical systems. 4) **Design:** Design experiments to measure and analyze the interaction of γ radiation with various materials. Develop methods for radiation dosimetry and investigate the effects of radiation-induced free radicals on water and other aqueous solutions.
Content Outline	Chemistry: Interaction of radiation with matter, interaction of γ radiation with matter, units for measuring radiation absorption, Radiation dosimetry, Radiolysis of water, free radicals in water radiolysis, Radiolysis of some aqueous solutions
Module 3 (Credit 1) - Radiation chemistry and its applications	
Learning Outcomes	After going through the module, learners will be able to, 1) **Apply:** Apply the concepts of linear energy transfer (LET) and Bremsstrahlung to analyze the primary effects of different types of radiation (charged particles, electrons, neutrons, heavy charged particles, and rays) on matter. Use these principles to design experiments for measuring radiation interactions and energy transfer. 2) **Analyze:** Analyze the interaction of various types of radiation with matter, including the effects of charged particles, electrons, neutrons, and heavy charged particles. Assess the role of Cerenkov radiation and determine the implications of these interactions for radiation safety and material science. 3) **Evaluate:** Evaluate the effectiveness of different methods for measuring radiation absorption, including the use of units for quantifying absorption in water and other materials. Critically assess the application of these methods in practical scenarios, such as in radiochemical research and industrial applications. 4) **Design:** Design and conduct experiments to investigate typical reactions involved in the preparation of isotopes, such as the Scillard-Chalmers reactions. Develop and apply radiochemical principles to utilize radioisotopes in various applications, including chemical investigations, analytical procedures, agriculture, and industrial processes.
Content Outline	Introduction of radiation with matter, primary effects due to charged particle/radiation, Linear energy transfer(LET), Bethes equation for LET, Bremsstrahulung, the cerenkov radians, interactions of electron with matter, interaction of neutrons with matter, interaction of heavy charged particles with matter, interaction of rays with matter, units for measuring radiation absorption, absorption in water B. Typical reactions involved in the preparations of isotopes: the scillard-chalmers reactions, radiochemical principles in the use of tracers, typical application of radioisotopes as tracers-chemical investigation, physio-chemical research, analytical applications, agricultural applications, industrial applications, use of nuclear radiations, radioisotope as a source of electricity

Module 4 (Credit 1) - Nuclear fission and fusion	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply:** Apply the theoretical concepts of nuclear fission to understand the process, including the discovery of nuclear fission, the production of fission fragments, and the distribution of their mass and charge. Utilize this knowledge to evaluate the fission process in nuclear reactors and accelerators. 2) **Analyze:** Analyze the mechanisms of nuclear fission, including the fission energy, cross-section, and threshold, as well as the production and role of fission neutrons. Assess the implications of neutron evaporation and spallation in the context of fission reactions and reactor operations. 3) **Evaluate:** Evaluate the manufacturing and use of heavy water in reactors, including its role in sustaining nuclear reactions and its advantages in the context of nuclear fission. Assess the effectiveness and efficiency of heavy water reactors compared to other types of reactors. 4) **Design:** Design experiments or reactor setups that incorporate the principles of nuclear fusion and isotope production. Develop methods to optimize nuclear reactions for isotope production and explore innovative approaches to enhance fusion processes and applications in nuclear technology.
Content Outline	The discovery of nuclear fission, the process of nuclear fission, fission fragments and their mass distribution, charge distribution, Ionic charge of fission fragments, fission energy, fission cross-section and threshold, fission neutrons, theory of nuclear fission, Neutron evaporation and spallation, heavy water-manufacturing and use in reactors. accelerators, nuclear fusion. Production of isotopes by nuclear reactions

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1 (Radioactivity),** students can undertake a project to measure and analyze the decay kinetics of a specific radioactive isotope using online simulation tools or data from a local lab. The objective is to apply principles of radioactive decay, such as α-decay and internal conversion, to analyze the behavior of the isotope over time. Students will use software or data to calculate the activity of the isotope, apply the Geiger-Nuttall law, and interpret the results to understand decay kinetics. This project involves analyzing data, performing calculations, and evaluating the effects of different decay processes, and can be completed with available online resources or laboratory data.

- **Module 2 (Elements of Radiation),** students can design a project to investigate the interaction of γ radiation with various materials. The objective is to measure radiation absorption and perform radiation dosimetry using materials like water, plastic, or metal sheets. Students will use available radiation detection tools, such as scintillation counters or dosimeters, to assess how different materials absorb γ radiation and investigate the effects of radiolysis and free radical formation in water. This project can be done in a local lab with radiation detection equipment or using online data from radiation research studies.

- **Module 3 (Radiation Chemistry and Its Applications),** students can conduct a project on the application of Linear Energy Transfer (LET) in radiation interactions. The objective is to analyze how different types of radiation, such as charged particles and neutrons, affect matter based on LET. Students will use simulation software or available experimental data to calculate LET values and assess their implications for radiation safety and material science. This project involves analyzing data, interpreting results, and understanding the role of LET in various radiation applications. It can be done using online resources or in a lab with access to radiation simulation tools.

- **Module 4 (Nuclear Fission and Fusion),** students can design a project to investigate the principles of nuclear fission using online simulation tools or data from local reactors. The objective is to understand the process of nuclear fission, including the production of fission fragments and their mass and charge distribution. Students will simulate fission reactions, analyze fission energy and neutron production, and evaluate the use of heavy water in reactors. This project involves using simulation software or reactor data to study fission processes and can be completed with available online tools or in a local laboratory with reactor simulation resources.

References-

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2.5 C. Major (Elective)

Course Title	**Polymer Chemistry (225313)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of free radical, anionic, cationic, and copolymerization to design and synthesize various types of polymers. Utilize knowledge of polymerization mechanisms to select appropriate methods for creating specific polymeric materials. 2) **Analyze**: Analyze the structure-property relationships in polymers, including how polymer structure affects their amorphous, semicrystalline, and crystalline states. Evaluate the impact of these structural characteristics on the chemical, mechanical, electrical, and optical properties of polymers. 3) **Evaluate**: Evaluate the methods used to determine the molecular weight of macromolecules, including viscosity, osmometry, and light scattering. Assess the accuracy and suitability of these techniques for various types of polymers and macromolecules. 4) **Design**: Design and optimize processes for the production and modification of natural rubber, including latex tapping, processing, and conversion into dry rubber. Develop strategies to improve the properties and applications of natural rubber based on its technical specifications and classification.
Module 1 (Credit 1) - Kinetics of Polymerization	
Learning Outcomes	After going through the module, learners will be able to, 1) **Apply**: Apply the principles of free radical, anionic, cationic, and copolymerization to synthesize various polymers, choosing the appropriate polymerization method based on the desired properties and application of the polymer. 2) **Analyze**: Analyze the mechanisms and kinetics of free radical and ionic polymerizations, including their influence on the molecular weight and distribution of the resulting polymers. Evaluate the differences between free radical copolymerization and ionic copolymerization. 3) **Evaluate**: Evaluate the effectiveness of copoly condensation techniques in producing copolymers with specific properties. Assess the impact of different copolymerization methods on the polymer's structure and performance. 4) **Design**: Design and optimize polymerization processes for creating specific polymeric materials, considering factors such as polymerization conditions, type of initiators, and reaction environment. Develop strategies for achieving targeted polymer characteristics through controlled polymerization techniques.
Content Outline	Free radical chain polymerization, Anionic polymerization, Cationic polymerization, Copolymerization, Free radical copolymerization, Ionic copolymerization, Copoly condensation
Module 2 - Structure Property Relationship in Polymers	

Learning Outcomes	After going through the module, learners will be able to, 1) **Apply**: Apply knowledge of polymer structures to predict and manipulate the amorphous, semi crystalline, and crystalline states of polymers, and determine how these structures affect the polymer's properties. 2) **Analyze**: Analyze the influence of glass transition temperature, melting temperature, and crystallization temperature on the physical properties of polymers. Evaluate how these thermal properties impact the material's performance in various applications. 3) **Evaluate**: Evaluate how the structural characteristics of polymers, such as molecular weight and degree of crystallinity, affect their chemical, mechanical, electrical, and optical properties. Assess the implications of these effects for practical uses of polymer materials. 4) **Design**: Design polymer materials with tailored properties by adjusting the polymer's structure, including its degree of crystallinity and glass transition temperature. Develop strategies to optimize the polymer's performance for specific applications based on its structural attributes.
Content Outline	Structure of polymers, amorphous, semi crystalline and crystalline states in polymers, glass transition, melting and crystallization temperature. Effect of structure on the chemical, mechanical, electrical and optical properties of polymers.
Module 3 (Credit 1) - Macromolecules	
Learning Outcomes	After going through the module, learners will be able to, 1) **Apply:** Apply principles of polymerization reactions (chain and step) to synthesize synthetic high polymers, and classify these polymers based on their formation and structure. 2) **Analyze:** Analyze the average molecular weight and number average weight of polymers using various methods, such as viscosity measurements, osmometry, and light scattering, to determine the polymer's size and distribution. 3) **Evaluate:** Evaluate different techniques for determining the molar masses of polymers, including ultracentrifugation and diffusion, to assess their accuracy and suitability for different types of macromolecules. 4) **Design:** Design and implement a polymer characterization protocol that utilizes methods such as Donnan membrane equilibrium and other analytical techniques to effectively determine the molar mass and structural properties of charged macromolecules.
Content Outline	Introduction, Formation of synthetic high polymers classification, Polymerization reactions: Chain and Step. Average molecular weight, Number average weight, Methods of determination of molar masses of polymers; Viscosity, Osmometry, Molar mass of charged macromolecules, Donnan membrane equilibrium, Ultracentrifugation, light scattering, Diffusion.
Module 4 - Natural Rubber	
Learning Outcomes	After going through the module, learners will be able to, 1) **Apply:** Apply the techniques of latex tapping and processing to convert natural rubber latex into dry rubber, understanding the stages involved in each step of the conversion process. 2) **Analyze:** Analyze the properties of natural rubber and dry rubber, including their mechanical and chemical characteristics, to evaluate their performance in various applications. 3) **Evaluate:** Evaluate the classification of dry rubber based on technical specifications and standards, to determine the suitability of different types

	of rubber for specific industrial and commercial uses. 4) **Design:** Design modifications to natural rubber to enhance its properties for specialized applications, using knowledge of processing techniques and rubber chemistry to tailor the material's performance.
Content Outline	Origin–Natural Rubber Latex, tapping, processing, properties and applications – Conversion of Latex into dry rubber – Properties of dry rubber – Classification based on technical specifications – Modifications of Natural Rubber

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1 (Kinetics of Polymerization),** students could undertake a project that involves synthesizing a specific polymer using either free radical or ionic polymerization methods. The project would require them to select appropriate polymerization techniques based on the desired properties of the polymer, such as molecular weight and distribution. Students would then analyze the kinetics of their polymerization process, evaluate the effects of different conditions (e.g., temperature, initiators), and compare the outcomes with theoretical predictions. This project can be conducted in a chemistry lab with standard polymerization equipment or using simulation tools if lab access is limited.

- **Module 2 (Structure-Property Relationship in Polymers),** students can design a project that involves studying the impact of polymer structure on its physical properties. They could synthesize or obtain polymers with different degrees of crystallinity and glass transition temperatures and then characterize their mechanical, electrical, and optical properties. Students would analyze how these structural features affect the performance of the polymers in specific applications, such as flexibility, strength, or conductivity. This project might include both experimental work and theoretical analysis.

- **Module 3 (Macromolecules),** students could perform a project focusing on the characterization of synthetic high polymers. They would use various methods like viscosity measurements, osmometry, and light scattering to determine the average molecular weight and size distribution of different polymers. The project could involve comparing these techniques and assessing their accuracy and suitability for different types of macromolecules. This could be done using lab equipment for molecular weight determination or by analyzing data from online resources if lab access is limited.

- **Module 4 (Natural Rubber),** students could undertake a project involving the processing of natural rubber latex into dry rubber. The project would involve hands-on activities such as latex tapping, processing, and converting latex into dry rubber. Students would analyze the properties of the resulting rubber and evaluate its performance in various applications. They could also explore modifications to enhance the properties of natural rubber for specific uses. This project would be practical and could be conducted with local resources or in a lab with the necessary equipment for rubber processing.

References-

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2.6 OJT

Course Title	**Internship/Field Work (255311)**
Course Credits	4
Course Outcomes	An orientation program for the In-Plant Training for aspiring students should be planned before students proceed for training. This program is essential in preparing students for real-world industrial environments, ensuring they gain valuable practical experience and develop problem-solving skills. As a faculty advisor, your role is critical in facilitating this training. You will: ● Identify suitable plants for student training. ● Liaise with plant authorities to establish and sign MOUs. ● Ensure students understand and commit to safety protocols through a signed undertaking. ● Coordinate with industry mentors assigned to the students. ● Conduct surprise visits to review student performance. ● Assist students with any issues they encounter during training. ● Help students make the most of their training experience, fostering a problem-solving aptitude. For students, this orientation will outline the skills and competencies you need to develop during your training. You will learn about the technical, safety, and professional expectations from your in-plant training, and how to identify and propose improvements within the plant. After going through the course, learners will be able to: 1) **Analyze** proficiency in laboratory techniques, instrumentation, and data analysis relevant to the analytical chemistry industry. 2) **Apply** knowledge to solve problems, optimize processes, and develop innovative solutions in an industrial setting. 3) **Discuss** communicate with colleagues, supervisors, and clients, both verbally and in writing, while collaborating with cross-functional teams to achieve common goals. **4) Assess** industry-specific safety protocols and regulations to ensure a safe working environment
Module 1 (Credit) - Introduction to Analytical Chemistry in the Plant	
Learning Outcomes	1) **Assess** proficiency in using advanced analytical instruments such as mass spectrometers and chromatographs, applying theoretical knowledge to practical scenarios. **2) Apply** and execute experiments independently, analyze experimental data using statistical methods, and interpret results effectively.
Content Outline	● **Technical Skills:** Demonstrate proficiency in laboratory techniques, instrumentation, and data analysis relevant to the industry. ● **Safety and Regulations:** Ensure students understand industry-specific safety protocols and regulations, such as OSHA guidelines, and have signed an undertaking acknowledging their responsibility. ● **Communication:** Stress the importance of effective communication with colleagues, supervisors, and mentors, both verbally and in writing. **Tasks for Students:** ● Participate in a detailed tour of the plant's analytical laboratories and facilities.

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- Observe and document safety procedures and protocols.
- Engage with plant staff to understand daily operations and communication practices.

Identifying Areas for Improvement:

- Encourage students to note any inefficiencies or safety concerns during their tour and suggest practical improvements, such as better equipment organization or enhanced safety signage.

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<tr><td colspan="2">Module 2 (Credit 1) - Problem-Solving and Process Optimization</td></tr>
<tr><td>Learning Outcomes</td><td>

1) **Apply** chemical knowledge to identify problems in industrial processes, propose innovative solutions, and optimize processes to enhance efficiency and quality.
2) **Analyze** complex chemical problems, troubleshoot experimental setups, and adapt methodologies for optimal outcomes in real-world applications.

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<tr><td>Content Outline</td><td>

- **Technical Skills:** Provide an overview of key analytical instruments (HPLC, GC, UV-Vis, IR spectroscopy) and their applications.
- **Problem-Solving:** Teach students how to apply their chemical knowledge to develop and optimize analytical methods.
- **Adaptability:** Encourage students to be flexible and willing to learn new skills, procedures, and technologies.

Tasks for Students:

- Participate in hands-on training sessions with key analytical instruments.
- Conduct experiments and analyze data, documenting their processes and results.
- Review current analytical methods used in the plant, identifying potential improvements.

Identifying Areas for Improvement:

- Guide students to propose new or modified analytical methods to enhance accuracy and efficiency, such as optimizing reagent usage or improving calibration techniques.

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<tr><td colspan="2">Module 3 Credit 1) - Safety and Regulatory Compliance</td></tr>
<tr><td>Learning Outcomes</td><td>

1) **Analyze** of industry-specific safety protocols and regulations, ensuring compliance with standards such as OSHA guidelines and environmental regulations.
2) **Assess** safety measures effectively in laboratory and industrial settings, contributing to a safe working environment while mitigating risks associated with chemical handling and experimentation.

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<tr><td>Content Outline</td><td>

- **Quality Control:** Explain the role of quality control in ensuring product safety and compliance with regulatory standards.
- **Teamwork:** Highlight the importance of collaborating with cross-functional teams, including scientists, engineers, and technicians.
- **Professionalism:** Emphasize rthe need for punctuality, responsibility, and a strong work ethic in a professional setting.

Tasks for Students:

- Perform quality tests on production samples and review quality assurance documentation.

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	• Participate in a simulated quality audit to identify gaps or inconsistencies. • Collaborate with team members to discuss quality control challenges and solutions. **Identifying Areas for Improvement:** • Encourage students to suggest improvements in documentation practices or testing procedures, such as implementing digital records or refining test protocols.
Module 4 (Credit 1) - Research and Development in Analytical Chemistry	
Learning Outcomes	1) **Analyze** communicate scientific findings and experimental results clearly and concisely, both orally and in written reports, tailored to technical and non-technical audiences. 2) **Assess** effectively with interdisciplinary teams, including scientists, engineers, and technicians, to achieve project goals, solve complex problems, and deliver high-quality analytical solutions.
Content Outline	• **Industry-Specific Knowledge:** Introduce students to ongoing research projects and the significance of R&D in the plant. • **Report Writing and Presentation Skills:** Teach students how to prepare clear, concise reports and present scientific data to both technical and non-technical audiences. • **Time Management:** Emphasize the importance of prioritizing tasks and managing time efficiently. **Tasks for Students:** • Design and conduct their own experiments, applying advanced analytical techniques. • Collaborate with R&D teams and participate in problem-solving sessions. • Present their research findings to the plant's R&D team and prepare detailed reports. **Identifying Areas for Improvement:** Guide students to review ongoing R&D projects, identify challenges, and propose innovative solutions or collaborations, such as new research methodologies or cross-functional team projects.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

Module 1 - Introduction to Analytical Chemistry in the Plant

Assessment Strategy:

1. **Plant Laboratory Tour Assessment:**
   - Students will submit a reflective report detailing their observations during the plant's analytical laboratory tour, focusing on equipment, safety protocols, and communication practices.
   - Assessment Criteria: Accuracy of observations, understanding of safety procedures, and clarity in communication.
2. **Safety and Regulations Understanding:**
   - Students will take a safety quiz to assess their understanding of industry-specific safety protocols and regulations discussed during the orientation.

- Assessment Criteria: Knowledge retention of safety guidelines and compliance with regulatory standards.

3. **Communication Skills Assessment:**
    - Students will prepare a mock email or report addressing a hypothetical safety concern or procedural suggestion observed during the tour.
    - Assessment Criteria: Clarity, professionalism, and effectiveness in communicating ideas.

Module 2 - Problem-Solving and Process Optimization

Assessment Strategy:

1. **Hands-on Instrumentation Skills:**
    - Students will conduct practical sessions using HPLC, GC, UV-Vis, and IR spectroscopy.
    - Assessment Criteria: Ability to operate instruments accurately, collect data, and troubleshoot basic issues.
2. **Experimental Design and Analysis:**
    - Students will submit a detailed experimental report on a selected analytical method, including data analysis and interpretation.
    - Assessment Criteria: Experimental design, data accuracy, statistical analysis, and interpretation of results.
3. **Process Optimization Proposal:**
    - Students will propose a process improvement related to analytical methods used in the plant, supported by data and feasibility analysis.
    - Assessment Criteria: Innovation, practicality, and potential impact of the proposed improvement.

Module 3 - Safety and Regulatory Compliance

Assessment Strategy:

1. **Quality Control Simulation:**
    - Students will participate in a simulated quality control exercise, analyzing samples and reviewing quality assurance documentation.
    - Assessment Criteria: Accuracy of analysis, adherence to quality control procedures, and identification of potential improvements.
2. **Safety Implementation Project:**
    - Students will develop a safety enhancement plan for a specific laboratory process, emphasizing risk mitigation and compliance with regulations.
    - Assessment Criteria: Clarity of safety measures proposed, feasibility of implementation, and alignment with industry standards.
3. **Team Collaboration Assessment:**
    - Students will work in teams to solve a safety or regulatory compliance challenge, presenting their solutions and rationale.
    - Assessment Criteria: Collaboration skills, problem-solving approach, and effectiveness in presenting solutions.

Module 4 - Research and Development in Analytical Chemistry

Assessment Strategy:

1. **Experimental Research Report:**
    - Students will prepare a comprehensive research report on their independent experiment, including methodology, results, and discussion.
    - Assessment Criteria: Scientific rigor, data interpretation, critical analysis, and clarity of presentation.

2. **Team Collaboration and Presentation:**
    - Students will collaborate with R&D teams to solve a complex analytical problem and present their findings to the R&D department.
    - Assessment Criteria: Teamwork, contribution to problem-solving, presentation skills, and ability to engage with interdisciplinary teams.
3. **Innovation Proposal:**
    - Students will propose an innovative research project or improvement initiative based on current R&D activities in the plant.
    - Assessment Criteria: Originality, feasibility, potential impact, and alignment with plant objectives.

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