SNDT Women's University, Mumbai

Master of Science in Analytical Chemistry

as per NEP – 2020

Syllabus

(2023-24)

JV Gade
23/02/2024
BOS - Chairperson

Programme Template:

Programme Degree e.g. M.A./M.Com./M.Sc./ M.M.S., etc.		Faculty of Science and Technology M.Sc. Analytical Chemistry
Parenthesis if any (Specialization) e.g. History, Human Development, English, etc.		Analytical Chemistry
Preamble (Brief Introduction to the programme)		To provide access to the field of higher education for women. * To provide Job oriented course to meet the socio-economic demands. * To arrange internship program to provide opportunities for experiential learning. * To enable students for research in emerging areas of study. * To achieve excellence in the academic disciplines, research and extension activities through emphasis on & out qualify in every activity". * To train and develop scientist and technologist for industries and academics.
Programme Specific Outcomes (POs)		After completing this programme, Learner will
	1.	To develop an understanding of the range and uses of analytical methods in chemistry.
	2.	To establish an appreciation of the role of chemistry in quantitative analysis
	3.	To develop an understanding of the broad role of the chemist in measurement and problem solving for analytical tasks.
	4.	To provide an understanding of chemical methods employed for elemental and compound analysis.
	5.	To provide experience in some scientific methods employed in analytical chemistry.
	6.	To develop some understanding of the professional and safety responsibilities residing in working on chemical analysis
	7.	
Eligibility Criteria for Programme		To develop some understanding of the professional and safety responsibilities residing in working on chemical analysis

Intake (For SNDT WU Departments and Conducted Colleges)		50

Structure with course title

Year I

SN	Courses	Type of Course	Credits	Marks	Int	Ext
Semester I						
115211	Analytical Chemistry Paper I	Major (Core)	4	100	50	50
115212	Food & Biochemical Analysis	Major (Core)	4	100	50	50
115223	Practical Analytical Chemistry	Major (Core)	4	100	50	50
115224	Practical Food and Biochemical Analysis	Major (Core)	2	50	50	0
125211	Drug Laws and Packaging	Major (Elective)	4	100	50	50
135211	Research Methodology	Minor Stream (Core)	4	100	50	50
			22	**550**	**300**	**250**
Semester II						
215211	Analytical Chemistry Paper II	Major (Core)	4	100	50	50
215212	Cosmetics Formulations & Quality Control	Major (Core)	4	100	50	50
215213	Environmental Science	Major (Core)	4	100	50	50
215224	Practical Analytical Chemistry Paper II	Major (Core)	2	50	0	50
225211	Pharmaceutical Analysis	Major (Elective)	4	100	50	50
245221	Practical Pharmaceutical Analysis	OJT	4	100	50	50
			22	**550**	**250**	**300**

Year II

SN	Courses	Type of Course	Credits	Marks	Int	Ext
Semester III						
315211	Analytical chemistry - III	Major (Core)	4	100	50	50
315212	Organic Analysis	Major (Core)	4	100	50	50
315213	Practical Analytical Chemistry	Major (Core)	4	100	50	50
315224	Practical Organic Analysis	Major (Core)	2	50	0	50
325211	Microbiological Methods of Analysis	Major (Elective)	4	100	50	50
355221	Research Project Part – I	RP	4	100	50	50
			22	**550**	**250**	**300**
Semester IV						
415211	Analytical Chemistry - IV	Major (Core)	4	100	50	50
415222	Practical Advanced Anal. Techniques	Major (Core)	4	100	50	50
415223	In-plant training	Major (Core)	4	100	50	50
425211	Advance Environmental Science	Major (Elective)	4	100	50	50
455231	Research Project Part - II	RP	6	150	100	50
			22	**550**	**300**	**250**

Semester III

3.1 Major (Core)

Course Title	**Analytical Chemistry III - 315211**
Course Credits	**4**
Course Outcomes	After going through the course, learners will be able to,
	1) **Analyze** the principles, instrumentation, and applications of Gas Chromatography, HPLC, Ion Chromatography, and other advanced chromatographic techniques. 2) **Evaluate** the effectiveness and suitability of various spectroscopic methods including AES, AMS, NMR, and miscellaneous techniques like chemiluminescence and photoacoustic spectroscopy. 3) **Discuss** the theoretical foundations and practical implications of laser-based techniques in atomic spectroscopy and their diverse applications in research and industry. 4) **Apply** knowledge gained to critically assess and solve complex analytical challenges in the field of advanced chromatography and spectroscopy.
Module 1(Credit 1) - Advanced Chromatography	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** the types of GC systems, their principles, instrumentation, and applications. 2) **Evaluate** the principles, instrumentation, and applications of HPLC in analytical chemistry.
Content Outline	• Gas chromatography – Types of GC, Principle, Instrumentation, Application • HPLC – Principle, Instrumentation, Application. • Ion chromatography – Ion exchange equilibria, Ion exchange packing, Application of Ion chromatography.
Module 2(Credit 1) - Laser-Based Techniques	
Learning Outcomes	After learning the module, learners will be able to, 1) **Explain** the concept of lasers, encompassing various types such as solid-state lasers (Ruby, Nd) and gaseous lasers (He-Ne, CO2). 2) **Compare** the operational principles and applications of 3L and 4L laser systems, dye lasers, and techniques like resonant ionization spectroscopy.

Content Outline	• Hydrophobic interaction chromatography – Principle, Steps in hydrophobic interaction chromatography, Factors affecting hydrophobic interaction, Application. • Concept of LASERS, types of lasers, solid state laser: Ruby laser, Nd:YAG laser, Comparison of 3L and 4L laser system, Dye laser, gaseous laser: He:Ne laser, CO2 laser, Resonant Ionization Spectroscopy, Laser-enhanced ionization spectroscopy.
Module 3(Credit 1) - Optical Atomic Spectroscopy	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** theoretical principles including atomic line width and factors influencing spectral width, emphasizing temperature effects. 2) **Evaluate** sources and techniques such as inductively coupled plasma (ICP) and electric arc discharges. 3) **Assess** AES instrumentation, including electrodes, and compare it with other methods. 4) **Apply** AES in various fields to demonstrate its versatility.
Content Outline	• Introduction to Optical Atomic Spectroscopic Analysis: Theory, atomic Line width, factors affecting spectral width, effect of temperature. • Atomic Emission Spectrometry (AES): Sources, inductively coupled Plasma and direct current plasma, Instrumentation of ICP- AES, AES with Electric arc discharges, electrodes in AES, DC Arc, AC Arc and Spark Sources, Stallwood jet apparatus, comparison of atomic absorption and Emission methods, Applications of AES. • Atomic Fluorescence Spectroscopy (AFS): Principle and working of AFS, applications of AFS. • Atomic Mass Spectroscopy: Atomic weight in mass spectroscopy, mass to Charge ratio, Types of atomic mass spectroscopy, transducer for mass Spectroscopy, quadrupole mass analyzer, time of flight mass analyzer, Double focusing mass analyzer, inductively coupled mass spectroscopy (ICPMS), Applications of ICPMS.
Module 4(Credit 1) - Nuclear Magnetic Resonance Spectroscopy	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** the theory of NMR, including quantum and classical descriptions. 2) relaxation processes and environmental effects on NMR spectra. 3) **Evaluate** Apply NMR spectroscopy techniques to interpret spectra and understand chemical exchange effects. 4) **Demonstrate** applications of proton NMR and C-13 NMR in various scientific fields.

Content Outline	• Nuclear Magnetic Resonance:Theory of NMR-Quantum description, Classical description ofNMR, Relaxation Processes in NMR. Environmental effects on NMRSpectra-Chemical shift, spin splitting, Rules governing theinterpretation of first order spectra, effect of chemical exchange, NMRSpectrometers, Applications of proton NMR, C-13 NMR. • Miscellaneous techniques Principle Instrumentation and Applications of ➢ Chemiluminesescence techniques ➢ Chirooptical methods ORD, CD ➢ Photoacouastic spectroscopy ➢ Spectroelectrochemistry

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

Module 1: Advanced Chromatography
Project Idea: Comparative Analysis of Chromatographic Techniques

- **Description:** Compare Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), and Ion Chromatography (IC) regarding principles, instrumentation, and applications.
- **Assessment:** Evaluate accuracy of data analysis and clarity of presentation. Ensure adherence to safety protocols.

Module 2: Laser-Based Techniques
Project Idea: Application of Laser Techniques in Analytical Chemistry

- **Description:** Investigate applications of specific laser types (e.g., solid-state, gaseous) in analytical techniques like Resonant Ionization Spectroscopy.
- **Assessment:** Assess depth of research, accuracy of experimental design, and clarity of presentation. Emphasize safety and ethical considerations.

Module 3: Optical Atomic Spectroscopy
Project Idea: Analyzing Environmental Effects on AES

- **Description:** Study how temperature affects Atomic Emission Spectrometry (AES) spectra, focusing on spectral line broadening and shifts.
- **Assessment:** Evaluate experimental setup, accuracy of data analysis, quality of scientific writing in the report, and adherence to safety protocols.

Module 4: Nuclear Magnetic Resonance Spectroscopy
Project Idea: Applications of NMR in Structural Elucidation

- **Description:** Use Proton NMR (1H-NMR) and Carbon-13 NMR (13C-NMR) to deduce molecular structures of organic compounds.
- **Assessment:** Assess experimental design, accuracy of spectral interpretation, clarity of case study presentation, and adherence to safety measures.

References:

1) Mendham, J., Denney, R. C., Barnes, J. D., Thomas, M. J. K., & Thomas, M. J. K. (2009). *Vogel's Quantitative Chemical Analysis* (6th ed.). ELBS.
2) Fifield, F. W., & Kealey, D. (2000). *Principle & Practice of Analytical Chemistry* (5th ed.). Blackwell Science.
3) Christian, G. D., Dasgupta, P., &Schug, K. (2013). *Analytical Chemistry* (7th ed.). John Wiley.
4) Skoog, D. A., Holler, F. J., & Crouch, S. R. (2006). *Principles of Instrumental Analysis* (6th ed.). Cengage Learning.
5) Ahuja, S., & Jespersen, N. (2006). *Modern Instrumental Analysis* (1st ed.). Elsevier Science.
6) Underwood, A. L. (1999). *Quantitative Analysis*. Prentice-Hall of India Pvt Ltd.

3.2 Major (Core)

Course Title	**Organic Analysis - 315212**
Course Credits	**4**
	After going through the course, learners will be able to
	1) **Analyze** and categorize impurities in samples using IR and UV-visible spectroscopy. 2) **Apply** NMR spectroscopy principles to interpret spectra and identify organic functional groups. 3) **Discuss** reaction outcomes and assess factors influencing organic reactions. 4) **Analyze** the unique properties of nanoparticles and develop skills for trace element analysis in nanotechnology.
Module 1(Credit 1) Spectroscopy and Molecular Analysis	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** organic molecules using infrared spectroscopy, focusing on modes of vibration and spectral analysis. 2) **Apply** principles of UV-visible spectroscopy to identify electronic excitations, chromophores, and conjugation effects in organic molecules, following the Woodward–Fieser rules for dienes.
Content Outline	• Infrared spectroscopic: - Introduction, Modes of Vibration, Complicating Factors, IR Spectral Analysis, Organic Molecules analysis (Hydrocarbons, Aromatic Rings, Alcohols and Phenols, Nitrogen containing compounds etc) • UV-visible Spectroscopy: - Introduction, Nature of Electronic Excitations, principles of Absorption Spectroscopy, Chromophore, Effect of Conjugation, The Woodward–Fieser Rules for Dienes Organic Molecules analysis (Aromatic Compounds, Unsaturated Aldehydes,Acids,and Esters etc)
Module 2(Credit 1) NMR Spectroscopy and Structural Analysis	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** molecular structures using ^{1}H-NMR spectroscopy, focusing on nuclear spin states, resonance absorption mechanisms, chemical shifts, shielding effects, and structural analysis. 2) **Discuss** organic molecule characteristics through ^{13}C-NMR spectroscopy, including carbon-13 chemical shifts, proton-coupled and decoupled spectra, and applications of Nuclear Overhauser Enhancement (NOE).

Content Outline	• ^{1}H-NMR:- Introductions, Nuclear Spin States, The Mechanism of Absorption (Resonance), Chemical Shift and Shielding, Magnetic Anisotropy, Pascal's Triangle , Structural Analysis and Fragmentation Patterns of Molecules. • ^{13}C- NMR:- Introduction, Carbon-13 Chemical Shifts, Proton-Coupled and decoupled spectra,NuclearOverhauser Enhancement (NOE), Organic Molecules analysis. • Advance NMR Technique :- Introduction to Two-Dimensional Spectroscopic Methods,COSY Technique, HETCOR Technique, NOESY Experiment, ^{19}F and ^{31}P Spectroscopy.
Module 3(Credit 1) - Organic Reactions and Synthesis	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** and compare the mechanisms and applications of major organic name reactions, including Cannizzaro Reaction, Baeyer-Villiger Oxidation, Suzuki Reaction, and others. 2) **Evaluate** the role and significance of key reagents such as LiAlH4, NaBH4, LDA, and others in organic synthesis, demonstrating understanding through practical applications. 3) **Apply** theoretical knowledge of spectroscopic techniques like ^{1}H-NMR, ^{13}C-NMR, and advanced NMR methods (COSY, HETCOR, NOESY) to interpret molecular structures and elucidate fragmentation patterns.
Content Outline	• Name reaction:- Cannizzaro Reaction, Baeyer-Villiger oxidation ,Chichibabin reaction, perkin reaction, sandmeyer reaction, Wacker process, suzuki reaction, Wurtz reaction ,Heck reaction • Reagent Reaction:- LiAlH4, NaBH4, LDA, H2O2, BH3,DDQ, sharpless
Module 4(Credit 1) - Nanotechnology and Trace Element Analysis	
Learning Outcomes	After learning the module, learners will be able to
	1) **Evaluate** the significance of carbon nanotubes and their various types (SWNT, MWNT) in nanotechnology, demonstrating an understanding of preparative methods and their diverse applications. 2) **Analyze** the principles and methodologies of organic trace analysis, including sampling techniques, concentration methods, and estimation techniques for elemental analysis (C, H, N, O, halogens).

Content Outline	• Nanotechnology: Introduction; Carbon nanotubes: Significance, Preparative methods, Types SWNT,MWNT and applications. Nanomaterials • Organic trace analysis: Introduction, Units, Sampling, Concentration techniques and estimation methods. Micro-elemental analysis of C,H,N,O and halogens

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

Module 1: Spectroscopy and Molecular Analysis
Project Idea: Characterization of Organic Compounds Using IR and UV-Visible Spectroscopy

- **Description:** Students will analyze different organic compounds (e.g., hydrocarbons, alcohols, aromatic rings) using IR and UV-Visible spectroscopy to identify functional groups and electronic transitions.
- **Assessment:** Evaluate accuracy of spectral interpretation, depth of analysis of structural features, and clarity of presentation. Ensure adherence to safety protocols.

Module 2: NMR Spectroscopy and Structural Analysis
Project Idea: Structural Elucidation of Organic Molecules Using NMR

- **Description:** Students will use ^{1}H-NMR and ^{13}C-NMR spectroscopy to determine molecular structures and elucidate chemical environments and bonding patterns in organic compounds.
- **Assessment:** Assess ability to interpret complex spectra, identify functional groups, and propose molecular structures. Emphasize safety and ethical considerations in handling NMR instruments.

Module 3: Organic Reactions and Synthesis
Project Idea: Investigation of Organic Name Reactions

- **Description:** Students will study major organic name reactions (e.g., Cannizzaro Reaction, Suzuki Reaction) through literature review and practical demonstrations, analyzing mechanisms and applications.
- **Assessment:** Evaluate depth of understanding of reaction mechanisms, practical skills in reaction setup, and ability to correlate theoretical knowledge with experimental outcomes. Ensure safety in handling reactive chemicals.

Module 4: Nanotechnology and Trace Element Analysis
Project Idea: Applications of Nanomaterials in Trace Element Analysis

- **Description:** Students will explore the use of nanomaterials, specifically carbon nanotubes (SWNT, MWNT), in enhancing trace element analysis techniques such as elemental analysis (C, H, N, O, halogens).
- **Assessment:** Assess critical analysis of nanomaterial applications, experimental design for trace element analysis, and presentation of findings. Ensure adherence to safety protocols when handling nanomaterials and analytical instruments.

References:

1) Pavia, D. L., Kriz, J. S., Vyvyan, J. R. (2012). *Spectroscopy* (4th ed.). Cengage Learning India Pvt Ltd.
2) Sheldon, R. A., Arends, I., Hanefeld, U. (2007). *Green Chemistry & Catalyst*. Wiley-VCH Verlag GmbH & Co.

3) Clark, J. H., Macquarrie, D. J. (Eds.). (2008). *Handbook of Green Chemistry and Technology*. John Wiley & Sons.
4) Vogel, A. I. (2011). *Elementary Practical Organic Chemistry: Small Scale Preparations Part I*. Dorling Kindersley India Pvt. Ltd.
5) Smith, M. B. (Ed.). (2013). *March's Advanced Organic Chemistry* (7th ed.). John Wiley & Sons.
6) Kalsi, P. S. (2004). *Spectroscopy of Organic Compounds* (6th ed.). New Age International.
7) Lancaster, M. (2002). *Green Chemistry: An Introductory Text*. Royal Society of Chemistry.
8) Silverstein, R. M., Bassler, G. C. (1991). *Spectrometric Identification of Organic Compounds*. John Wiley & Sons.
9) Siggia, S., Hanna, J. G. (1979). *Quantitative Organic Analysis Via Functional Groups*. Wiley Interscience.
10) Gunther, H. (2013). *NMR Spectroscopy*. Wiley-VCH

3.3 Major (Elective)

Course Title	**Practical Analytical Chemistry-lll**
Course Credits	**4**
Course Outcomes	After going through the course, learners will be able to**,** **Asses** Gain hands-on experience with various analytical instruments (potentiometer, spectrophotometer, polarograph, etc.). Learn to set up, calibrate, and operate different analytical instruments. Understand the principles behind each analytical technique. **Discuss** analytical results with the structural features and chemical properties of molecules, essential for roles in quality assurance and research and development
Module 1 (Credit 2) - Analysis of trace metal by Spectrophotometry	
Learning Outcomes	After going through the module, learners will be able to **Analyze** Learn to process raw experimental data and understand and apply statistical methods to evaluate data quality. **Asses** Identify sources of error in analytical measurements and learn to estimate and report uncertainty in measurements
Content Outline	• Estimation of acetic acid in vinegar potentiometrically • To determine copper and bismuth in a mixture spectrophotometrically • To determine the amount of fluoride in a given sample spectrophotometrically • To determine the amount of copper in the given solution by spectrometric titration against EDTA solution • To determine the amount of vanadium by standard addition method
Module 2 (Credit 2) - Analysis of heavy metal by Using Instrumentation Method	
Learning Outcomes	After going through the module, learners will be able to, **Apply** Deepen understanding of chemical equilibria, particularly in complex formation and acid-base reactions and Apply knowledge of redox reactions in analytical contexts **Discuss** Deepen understanding of spectroscopic and electrochemical principles and their applications in chemical analysis

Content Outline	• To determine the amount of manganese in a given solution by standard addition. • To estimate the amount of Fe(III) in a given solution colorimetrically using thiocyanate. • To determine the amount of iron by o-phenanthriline method • To determine the amount of quinine sulphate by standard addition. • Determination of half wave potential and the concentration of Cd(II) by Polarographic analysis.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

Lab Experiment 1:- Analysis of trace metal by Spectrophotometry

Objective: To identify and quantify the trace element using basic analytical techniques.

Experiment Description:

Objective: Identify and quantify trace element(such as Cu, V, Mg,Feetc) in given sample.

Materials Needed: samples, basic laboratory glassware, UV-visible spectrophotometer, standard solutions.

Procedure:

Sample Preparation: Dilute samples appropriately.

UV-Vis Spectrophotometry: Use UV-Vis spectrophotometer to measure absorbance spectra of the samples.

Standard Curve Preparation: Prepare standard solutions of known additives for calibration.

Data Analysis: Compare absorbance peaks with standards to identify and quantify additives.

Connection to Career: Relevant for careers in various chemical industry.

Lab Experiment 4: Analysis of heavy metal by Using Instrumentation Method

Objective: To assess the antioxidant activity of herbal extracts using basic analytical techniques.

Experiment Description:

Objective: Determination of half wave potential and the concentration of Cd(II) by Polarographic analysis.

Materials Needed: Sample solution, basic laboratory glassware, UV-Vis spectrophotometer.

Procedure:

Preparation of Solution: Prepare cd(ll) solution in appropriate solvent.

Sample Preparation: Dilute samole extracts to various concentrations.

Data Analysis: Calculate percentage of cd(ll) using graph

Connection to Career: Relevant for careers in pharmaceuticals industries.

References:

1. Harris, D. C., & Lucy, C. A. (2020). Quantitative chemical analysis (10th ed.). W. H. Freeman.

2. Skoog, D. A., West, D. M., Holler, F. J., & Crouch, S. R. (2013). Fundamentals of analytical chemistry (9th ed.). Cengage Learning.

3. Harvey, D. (2016). Analytical chemistry 2.0. OpenStax CNX.

4. Rubinson, K. A., & Rubinson, J. F. (2000). Contemporary instrumental analysis. Prentice Hall.

5. Christian, G. D., Dasgupta, P. K., & Schug, K. A. (2013). Analytical chemistry (7th ed.). Wiley.

6. Kellner, R., Mermet, J. M., Otto, M., & Widmer, H. M. (Eds.). (2004). Analytical chemistry: A modern approach to analytical science (2nd ed.). Wiley-VCH.

7. Laitinen, H. A., & Harris, W. E. (1975). Chemical analysis: An advanced text and reference (2nd ed.). McGraw-Hill.

8. Wang, J. (2006). Analytical electrochemistry (3rd ed.). Wiley-VCH.

9. Pavia, D. L., Lampman, G. M., Kriz, G. S., & Vyvyan, J. R. (2014). Introduction to spectroscopy (5th ed.). Cengage Learning.

10. Meier, P. C., &Zünd, R. E. (2000). Statistical methods in analytical chemistry (2nd ed.). Wiley.

3.4 Major (Core)

Course Title	**Practical Organic Analysis (315224)**
Course Credits	**2**
Course Outcomes	After going through the course, learners will be able to**,** 1) **Asses** and Develop skills in the identification of organic compounds based on their spectra, preparing for careers in analytical chemistry and pharmaceuticals. **2) Discuss** organic compounds based on functional group analysis, relevant to roles in quality control and chemical analysis laboratories.
Module 1 (Credit 1) - Identification of Organic Compounds:	
Learning Outcomes	After going through the module, learners will be able to 1) **Analyze** non-aqueous titrations using solvents other than water, essential for roles in organic compound analysis and pharmaceutical research. **2) Asses** advanced titration techniques such as potentiometric titrations for accurate endpoint detection, crucial for careers in analytical chemistry and chemical engineering.
Content Outline	• Estimation of formaldehyde • Estimation of glycine (Amino acid) • Estimation of phenol by bromination method • Chromatographic separation of a mixture of dyes methyl orange and methylene blue by TLC (using benzene) and determination of Rf values. • Chromatographic separation of a mixture of 2,4-dinitrophenylhydrazones of acetaldehyde and benzaldehyde by TLC and determination of Rf values.
Module 2 (Credit 1) - Thin-Layer Chromatography (TLC):	
Learning Outcomes	After going through the module, learners will be able to, 1. **Apply** organic titrations to analyze the concentration of various functional groups in organic compounds (carboxylic acids, amines, esters, alcohols), preparing for careers in pharmaceuticals and chemical analysis. 2. **Discuss** analytical results with the structural features and chemical properties of organic molecules, essential for roles in quality assurance and research and development.
Content Outline	• Estimation of amine by bromination method • Determination of unsaturation by bromination method • Determination of iodine value of an oil or fat • Determination of equivalent weight of an ester • Estimation of acid • Estimation of acetone • Chromatographic separation of a mixture of dyes methyl red and methylene blue by TLC and determination of Rf values. • Chromatographic separation of a mixture of 2,4-

	dinitrophenylhydrazones of acetaldehyde and benzaldehyde by TLC and determination of Rf values.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

Module 1: -Identification of Organic Compounds:

* **Objectives**: To differentiate between organic compounds based on their physical and chemical properties.

* **Experimental Design:** Conduct tests for solubility, pH, and functional groups.

*** Sample Preparation**: Obtain pure samples of unknown compounds.

* **Solution Procedures:** Perform tests using appropriate reagents and observe results.

* **Observation**: Record observations related to solubility, pH, and positive/negative tests.

* **Analysis**: Identify the functional groups present in the unknown compounds based on the observations.

* **Communication**: Prepare a report summarizing the experimental procedure, observations, and conclusions.

Module 2: - Thin-Layer Chromatography (TLC):

* **Objectives**: To separate and identify components of a mixture using TLC.

* **Experimental Design**: Prepare a TLC plate, apply the mixture, develop the plate, and visualize the spots.

*** Sample Preparation**: Obtain a mixture of compounds and prepare appropriate solutions.

* **Solution Procedures**: Spot the solutions onto the TLC plate, develop the plate with a suitable solvent, and visualize the spots using a suitable method.

* **Observation**: Record the retention factors (Rf values) of the spots.

* **Analysis**: Compare the Rf values with those of known standards to identify the components of the mixture.

* **Communication**: Prepare a report detailing the TLC procedure, Rf values, and identification of components.

Assessment Criteria:

Experimental Design: Clarity and coherence of experimental procedures.

Data Analysis: Accuracy in measurement and interpretation of results.

Scientific Rigor: Adherence to experimental protocols and safety procedures.

Report Writing: Quality of lab reports, including structure, analysis, and conclusions.

References-

1) Pavia, D. L., Kriz, J. S., Vyvyan, J. R. (2012). *Spectroscopy* (4th ed.). Cengage Learning India Pvt Ltd.

2) Sheldon, R. A., Arends, I., Hanefeld, U. (2007). *Green Chemistry & Catalyst*. Wiley-VCH Verlag GmbH & Co.
3) Clark, J. H., Macquarrie, D. J. (Eds.). (2008). *Handbook of Green Chemistry and Technology*. John Wiley & Sons.
4) Vogel, A. I. (2011). *Elementary Practical Organic Chemistry: Small Scale Preparations Part I*. Dorling Kindersley India Pvt. Ltd.
5) Smith, M. B. (Ed.). (2013). *March's Advanced Organic Chemistry* (7th ed.). John Wiley & Sons.
6) Kalsi, P. S. (2004). *Spectroscopy of Organic Compounds* (6th ed.). New Age International.
7) Lancaster, M. (2002). *Green Chemistry: An Introductory Text*. Royal Society of Chemistry.
8) Silverstein, R. M., Bassler, G. C. (1991). *Spectrometric Identification of Organic Compounds*. John Wiley & Sons.
9) Siggia, S., Hanna, J. G. (1979). *Quantitative Organic Analysis Via Functional Groups*. Wiley Interscience.
10) Gunther, H. (2013). *NMR Spectroscopy*. Wiley-VCH

3.5 Major (Elective)

Course Title	**Microbiological Methods of Analysis - 315213**
Course Credits	4
Course Outcomes	After going through the course, learners will be able to
	1) **Evaluate** the functioning of the immune system, contributing to careers in immunology and healthcare. 2) Implement methods for controlling microbial growth, essential for roles in public health and microbiology research. 3) **Discuss** and formulate and optimize various culture media for different microorganisms, supporting careers in clinical microbiology and biotechnology. 4) **Apply** various staining techniques for microorganisms, aiding careers in diagnostic microbiology and laboratory technology.
Module 1(Credit 1) - General Bacteriology and Staining Techniques	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** the basic characteristics and structure of bacteria, enhancing their capability in bacteriological research. 2) **Discuss** and Classify and differentiate types of bacteria, improving their proficiency in diagnostic microbiology.
Content Outline	● GENERAL BACTERIOLOGY 1.1 Classification of Bacteria & Methods of study of Morphology. 1.2 Physiology of Bacteria and basic features of bacteria 1.3 Growth requirements of Bacteria, Growth Curve/measurement of growth ● Staining method:- 1.1 Gram's stain, negative staining, acid –fast staining, 1.2 Spore staining, capsule staining, 1.3 Flagella staining, cell wall staining, observation of motility.
Module 2(Credit 1) - Virology and Virus Cultivation Techniques	
Learning Outcomes	After learning the module, learners will be able to
	1) **Apply** different types of viruses and understand their taxonomy, enhancing their ability to work in virology and infectious disease control. 2) **Discuss** and employ virus cultivation techniques, vital for careers in vaccine development and antiviral research.

Content Outline	• VIROLOGY 1.1 Introduction to virology, general properties of viruses and Classification of viruses 1.2 Replication of viruses, Antiviral agents 1.3 Principles of viral diseases Common viral vaccines COVID 19, Polio, rubella, HIV/ AIDS. • TECHNIQUES OF VIRUS CULTIVATION 1.1 Animal Inoculation 1.2 Inoculation into embryonated egg 1.3 Cell Culture, Cultivation of plant viruses and bacteriophages advantage and Disadvantage
Module 3(Credit 1) - Culturing Microorganisms and Microbial Control Methods	
Learning Outcomes	After learning the module, learners will be able to
	1) **Evaluate** the principles of microbial growth and the factors influencing it, supporting careers in microbiological research and food safety. 2) **Apply** sterilization techniques to control microbial contamination in laboratory settings and industrial processes, essential for careers in pharmaceuticals and clinical laboratories.
Content Outline	• CULTURING OF MICROORGANISM 1.1 Introduction, Composition and types of culture media, 1.2 Preparation of culture media, 1.3 Quality control of various culture media. • METHODS FOR CONTROL OF MICROBES 1.1 Characteristics of an ideal chemical and physical agents 1.2 Classification, mode of action, efficiency :- Disinfectants,antiseptic, antimicrobial agents, sanitization 1.3 Sterilization :- Principal, method used in general and as applied to pharmaceutical products.
Module 4(Credit 1) - Immunology and Disease Control	
	After learning the module, learners will be able to

Learning Outcomes	1) **Analyze** the basic principles of immunology, including the structure and function of the immune system, improving their readiness for careers in immunology and public health. 2) **Assess** the impact of environmental factors, social determinants, and global health policies on the spread and control of infectious diseases, vital for roles in epidemiology and health policy.
Content Outline	• IMMUNOLOGY 1.1 Introduction to Immunology. 1.2 Natural & Non-specific Immune Mechanisms Antigen, Hapten, Adjuvants ,Antibody, Complement System ,Structure & Function of Immune System • CONTROL AND PREVENTION OF DISEASE 1.1 Food borne diseases:- Bacteria responsible for food borne diseases, Signs and Symptoms of bacterial infection, Antibacterial drugs. 1.2 Water-borne diseases: - Microorganism responsible for water borne diseases, Signs & Symptoms 1.3 Airborne diseases: - Air borne diseases and microorganism, Signs & symptoms

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

Module 1: General Bacteriology and Staining Techniques
Project Idea: Home-Based Bacterial Culture and Staining

- **Description:** Students will collect bacterial samples from various household surfaces (kitchen counters, bathroom sinks, door handles) and culture them using simple nutrient media prepared from kitchen ingredients (gelatin, sugar, and water). They will perform basic staining techniques (using homemade dyes such as turmeric for gram staining) to observe and classify the bacteria.
- **Assessment:**
  - **Research Findings Report:** Document the culture process, staining techniques, observations, and classification of bacteria (30%).
  - **Presentation:** Create a video or slideshow presentation detailing the findings and methodologies used (20%).
  - **Practical Skills:** Evaluate students' ability to creatively adapt and apply staining techniques using household items (30%).
  - **Safety Protocols:** Ensure students follow safety guidelines, including proper handling and disposal of samples (20%).

Module 2: Virology and Virus Cultivation Techniques
Project Idea: Data Analysis of Viral Outbreaks

- **Description:** Students will gather publicly available data on recent viral outbreaks (e.g., COVID-19, flu seasons) from reliable sources such as WHO or CDC. They will analyze the data to understand the spread, control measures, and impact of these outbreaks.
- **Assessment:**

- **Research Findings Report:** Analyze and interpret data on viral outbreaks, highlighting trends, control measures, and outcomes (30%).
- **Group Discussion:** Participate in virtual group discussions to share insights and strategies for controlling viral spread (20%).
- **Data Analysis Skills:** Assess students' ability to collect, analyze, and interpret data accurately (30%).
- **Critical Thinking:** Evaluate students' critical thinking and problem-solving abilities in proposing strategies based on data analysis (20%).

Module 3: Culturing Microorganisms and Microbial Control Methods
Project Idea: Testing Antimicrobial Properties of Household Products

- **Description:** Students will test the antimicrobial properties of various household products (vinegar, baking soda, salt, soap) on common bacteria cultured from household surfaces. They will create simple agar plates using gelatin and test the effectiveness of these substances.
- **Assessment:**
  - **Research Findings Report:** Document the methodology, observations, and effectiveness of different household products as antimicrobial agents (30%).
  - **Demonstration:** Create a short video demonstrating the experiment and discussing the results (20%).
  - **Practical Skills:** Evaluate the students' ability to conduct experiments using low-cost, easily available materials (30%).
  - **Safety Protocols:** Ensure students follow safety guidelines, including proper handling and disposal of microbial cultures (20%).

Module 4: Immunology and Disease Control
Project Idea: Survey-Based Analysis of Public Health Measures

- **Description:** Students will design and conduct a survey to collect data on public awareness and adherence to immunization and hygiene practices within their community. They will analyze the data to identify gaps in knowledge and propose measures to improve public health practices.
- **Assessment:**
  - **Research Findings Report:** Analyze survey data, identify trends, and propose recommendations for improving public health practices (30%).
  - **Case Study Presentation:** Create a presentation summarizing the survey findings and proposed measures (20%).
  - **Data Collection Skills:** Assess students' ability to design and conduct effective surveys, and analyze the collected data (30%).
  - **Critical Thinking:** Evaluate students' critical thinking and problem-solving abilities in proposing public health interventions based on survey data (20%).

These projects encourage students to utilize readily available resources, think creatively, and apply analytical skills to solve real-world problems, thereby developing practical knowledge and a problem-solving mindset.

Reference books: -

1) Chander, J. (2018). *Textbook of Medical Mycology* (4th ed.). Jaypee Brothers Medical Publishers.
2) Bennett, J. E., Dolin, R., &Blaser, M. J. (Eds.). (2015). *Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases* (8th ed.).
3) Chatterjee, K. D. (2019). *Parasitology Protozoology And Helminthology* (13th ed.). Jaypee Brothers Medical Publishers.
4) Paniker, C. K. J. (2007). *Textbook of Medical Parasitology* (6th ed.). Jaypee Brothers Medical Publishers Private Limited.

3.6 Research Project

Course Title	**Research Project Part – I (355221)**
Course Credits	**4**
Course Outcomes	After this course, the students will be able to, 1) Apply advanced analytical techniques to investigate complex research questions 2) Design and execute experiments to collect and analyze data in analytical chemistry.
Module 1 (Credit 1) - Research Proposal Development	
Learning Outcome	1) Identify research gaps specific to analytical chemistry and formulate clear research objectives and hypotheses. 2) Design robust experimental methodologies to effectively address the identified research questions.
Content Outline	**Guidelines for Students:** • **Tasks:** Engage in an extensive literature review focusing on analytical chemistry to identify gaps and emerging research areas. • **Approach:** Develop clear research objectives and hypotheses based on identified gaps. Discuss potential experimental designs with faculty for feasibility and relevance.
Module 2 (Credit 1) - Experimental Setup and Data Collection	
Learning Outcome	1) Implement experimental protocols meticulously to ensure accuracy and reliability in data collection. 2) Maintain detailed records of experimental procedures to facilitate reproducibility and comprehensive analysis.
Content Outline	**Guidelines for Students:** • **Tasks:** Implement designed experimental protocols with meticulous attention to detail and accuracy. • **Approach:** Record experimental procedures comprehensively, including variables, controls, and data collection methods. Use standardized techniques and equipment under supervision.
Module 3 (Credit 1) - Data Analysis and Interpretation	
Learning Outcomes	1) Perform preliminary data analysis using appropriate statistical tools to validate experimental methods and ensure robustness. 2) Interpret initial findings and integrate results with existing knowledge to refine research hypotheses in analytical chemistry.

Content Outline	**Guidelines for Students:** • **Tasks:** Conduct preliminary data analysis using statistical software to validate experimental results. • **Approach:** Interpret findings in the context of existing literature. Discuss with peers and faculty to refine interpretations and implications for further experimentation.
Module 4 (Credit 1) - Interim Report and Presentation Preparation	
Learning Outcome	1) Compile an interim report summarizing research progress, including challenges encountered and preliminary conclusions. 2) Prepare and deliver a structured presentation outlining research objectives, methodologies, and initial findings to solicit constructive feedback.
Content Outline	**Guidelines for Students:** • **Tasks:** Compile a comprehensive interim report documenting research progress, challenges, and preliminary conclusions. • **Approach:** Develop a structured presentation highlighting research objectives, methodologies, and initial findings. Practice presentation skills and incorporate feedback for clarity and coherence

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

Module 1 (Credit 1) - Research Proposal Development
Assessment Components:

1. **Literature Review (30%):**
    - **Task:** Submit a comprehensive literature review identifying gaps and emerging areas in analytical chemistry.
    - **Evaluation Criteria:** Depth of research, clarity in identifying research gaps, relevance to current trends, and integration of sources.
2. **Research Objectives and Hypotheses (20%):**
    - **Task:** Develop and submit clear research objectives and hypotheses based on the literature review.
    - **Evaluation Criteria:** Clarity, feasibility, alignment with identified research gaps, and potential impact.
3. **Experimental Design Discussion (20%):**
    - **Task:** Present potential experimental designs to faculty for feedback and feasibility assessment.
    - **Evaluation Criteria:** Robustness of experimental design, feasibility, alignment with research objectives, and thoroughness of preparation.
4. **Participation and Engagement (10%):**

- **Task:** Actively participate in discussions with faculty and peers.
- **Evaluation Criteria:** Contribution to discussions, receptiveness to feedback, and collaborative engagement.

Module 2 (Credit 1) - Experimental Setup and Data Collection
Assessment Components:

1. **Experimental Protocol Implementation (30%):**
   - **Task:** Submit a detailed report on the implementation of experimental protocols.
   - **Evaluation Criteria:** Accuracy, attention to detail, adherence to protocols, and thorough documentation.
2. **Record Keeping (20%):**
   - **Task:** Maintain and submit detailed records of experimental procedures.
   - **Evaluation Criteria:** Completeness, clarity, reproducibility, and thoroughness.
3. **Standardized Techniques Usage (20%):**
   - **Task:** Demonstrate proper usage of standardized techniques and equipment under supervision.
   - **Evaluation Criteria:** Proper usage, adherence to standards, accuracy, and compliance with supervision.
4. **Participation and Engagement (10%):**
   - **Task:** Actively participate in experimental activities and discussions.
   - **Evaluation Criteria:** Contribution to team efforts, engagement in the process, and responsiveness to supervision.

Module 3 (Credit 1) - Data Analysis and Interpretation
Assessment Components:

1. **Preliminary Data Analysis (30%):**
   - **Task:** Submit a preliminary data analysis report using appropriate statistical tools.
   - **Evaluation Criteria:** Correctness, application of statistical methods, validation of results, and thoroughness.
2. **Interpretation of Findings (20%):**
   - **Task:** Submit a report interpreting initial findings in the context of existing literature.
   - **Evaluation Criteria:** Depth of analysis, integration with existing knowledge, clarity of interpretation, and alignment with research hypotheses.
3. **Peer and Faculty Discussion (20%):**
   - **Task:** Participate in discussions with peers and faculty to refine interpretations.
   - **Evaluation Criteria:** Constructive engagement, openness to feedback, and ability to refine hypotheses.
4. **Participation and Engagement (10%):**
   - **Task:** Actively participate in data analysis activities and discussions.
   - **Evaluation Criteria:** Contribution to team efforts, engagement in the process, and responsiveness to feedback.

Module 4 (Credit 1) - Interim Report and Presentation Preparation
Assessment Components:

1. **Interim Report (30%):**
   - **Task:** Submit a comprehensive interim report documenting research progress, challenges, and preliminary conclusions.
   - **Evaluation Criteria:** Completeness, clarity, thoroughness, and organization.

2. **Structured Presentation (20%):**
    - **Task:** Prepare and deliver a structured presentation outlining research objectives, methodologies, and initial findings.
    - **Evaluation Criteria:** Structure, clarity, coherence, and effectiveness of communication.
3. **Feedback Incorporation (20%):**
    - **Task:** Incorporate feedback from the presentation into the research process.
    - **Evaluation Criteria:** Responsiveness to feedback, clarity of revisions, and improvement in presentation skills.
4. **Participation and Engagement (10%):**
    - **Task:** Actively participate in presentation preparation and delivery.
    - **Evaluation Criteria:** Contribution to team efforts, engagement in the process, and responsiveness to feedback

References-

1) Harris, D. C. (1982). Quantitative chemical analysis. W Freeman.
2) Skoog, D. A. (n.d). Fundamentals of analytical chemistry. Saunders College Publishing.
3) Christian, G. D. (n.d). Analytical chemistry. John Wiley & Sons.
4) Hage, D. (n.d). Analytical chemistry and quantitative analysis. Cengage Learning.
5) Fifield, F. W., & Kealey, D. (n.d). Principles and practice of analytical chemistry. Blackwell Science.
6) Harvey, D. (2016). Analytical chemistry 2.1. Lulu Press

Semester IV

4.1 Major (Core)

Course Title	**Analytical chemistry IV (415211)**
Course Credits	**4**
Course Outcomes	After going through the course, learners will be able to
	1) **Assess** evaluate the concepts and principles of green chemistry and emerging green technologies, preparing them for careers in environmental sustainability and green manufacturing. 2) **Analyze** and apply the principles of Mössbauer spectroscopy, including its effects, instrumentation, and applications, essential for roles in materials science and advanced physics research. 3) **Discuss** advanced thermal methods and radioactive methods of analysis, equipping them for careers in nuclear chemistry and materials characterization. 4) **Synthesize** and apply the fundamentals of X-ray and neutron diffraction techniques, critical for careers in crystallography and nanotechnology research.
Module 1(Credit 1) - X-ray techniques and principles of Nanotechnology	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** the fundamentals of X-ray diffraction and its underlying theory. 2) **Evaluate** neutron diffraction techniques, including their theory, instrumentation, and applications. 3) **Apply** nanotechnology principles and analytical techniques to study the properties and applications of nanomaterials.
Content Outline	● Fundamentals of x-ray diffraction Theory of x-ray diffraction, diffraction of x-rays by crystals, determination of crystal structure (powder as well as single crystals), Instrumentation, determination of lattice parameters, x-ray intensity calculations and application of x-rays ● Introduction to neutron diffraction, theory, Instrumentation and application. ● Introduction to Nanotechnology Analytical techniques in nanotechnology, consequences of nanoscale (nanoparticles, morphology, electronic structure, optical properties), one dimensional nano material (nanofilms , nanolayers) two dimensional nano material (nanotubes, nanowires) three dimensional nano material (nano particles, quantum dots)
Module 2(Credit 1) - Thermal and Radioactive Methods of Analysis	
Learning Outcomes	After learning the module, learners will be able to

	1) **Apply** thermogravimetry and differential thermal analysis techniques, understanding their instrumentation and applications. 2) **Evaluate** thermometric titration methods for various analyses. 3) **Analyze** radioactive decay products and processes, utilizing neutron activation methods and understanding their applications.
Content Outline	● Thermal method of analysis [15] Thermogravimetriy [TG], differential thermal analysis [DTA], differential Scanning Calorimetric [DCS], Thermo mechanical analysis [TMA] Instrumentation and application, Thermometric titrations. ● Radioactive methods of analysis Radioactive decay products and processes, Radioactive decay rates, Instrumentation. ● Neutron activation method : Destructive, Non destructive Application of Neutron Activation.
Module 3(Credit 1) - Advanced Spectroscopic Techniques	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** the Mössbauer effect and its applications, including the principles, instrumentation, and effects. 2) **Evaluate** and apply the principles, instrumentation, and applications of Raman, Auger electron, and scanning electron spectroscopy.
Content Outline	● Introduction to Mossabaur effect, recoilless emission & absorption of x-rays, Instrumentation, isomer shift, Quadrapole splitting and hyperfine interactions, application Of Mossbaur effect to the investigations of compounds of iron and tin . ● Principle, Instrumentation, Application. ● Raman Spectroscopy ● Auger electron spectroscopy ● Scanning electron microscopy
Module 4(Credit 1) - Green Chemistry and Technologies	
Learning Outcomes	After learning the module, learners will be able to
	1) **Evaluate** the principles and concepts of green chemistry. 2) **Assess** and apply emerging green technologies. 3) **Discuss** green instrumental analysis techniques in various applications.
Content Outline	● Principle and concept of green Chemistry: sustainable development and green chemistry, atom economy, example of atom economic and uneconomic reaction reducing toxicity. ● Emerging green technologies – photochemical reaction (advantages and challenges), examples. ● Chemistry using microwaves sonochemistry and electro chemical synthesis green sample treatment, Green instrumental analysis.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE):

Project Title: Determination of Crystal Structures Using X-ray Diffraction

Description: Students will investigate the crystal structure of table salt (NaCl) using X-ray diffraction.

Readily Available Resources:

- **Materials:** Table salt.
- **Instruments:** Access to an X-ray diffractometer (most colleges have one in the chemistry lab).
- **Software:** Open-source software for X-ray data analysis, such as GSAS-II or PowderCell.

Procedure:

1. **Sample Preparation:** Grind the table salt to a fine powder to ensure a uniform sample.
2. **Data Collection:** Use the X-ray diffractometer to collect diffraction data from the sample.
3. **Analysis:** Analyze the diffraction pattern using software to determine the crystal structure and lattice parameters.
4. **Reporting:** Prepare a report discussing the methodology, data analysis, and the crystal structure findings.

Connection to Professional Career: This project provides hands-on experience with X-ray diffraction, a key technique in crystallography, materials science, and nanotechnology research.

Assessment Strategy:

- **Practical Execution:** Evaluate the proper use of the X-ray diffractometer and sample preparation techniques.
- **Data Analysis:** Assessment of the accuracy and thoroughness of data analysis and interpretation.
- **Report:** Quality of the written report, including clarity, completeness, and scientific rigor.

Module 2 - Thermal and Radioactive Methods of Analysis
Project Title: Thermal Analysis of Household Plastics

Description: Students will perform thermogravimetric analysis (TGA) and differential thermal analysis (DTA) on household plastic materials.

Readily Available Resources:

- **Materials:** Household plastic items (e.g., plastic bottles, packaging).
- **Instruments:** TGA and DTA instruments (typically available in college labs).
- **Software:** Analysis software provided with the TGA/DTA instruments.

Procedure:

1. **Sample Preparation:** Cut small, uniform pieces from the plastic items.
2. **TGA Analysis:** Conduct TGA to measure weight changes as the plastic is heated.
3. **DTA Analysis:** Conduct DTA to measure heat flow associated with the plastic's thermal transitions.
4. **Data Interpretation:** Analyze the data to determine the thermal properties of the plastics.
5. **Reporting:** Write a report detailing the procedures, results, and interpretations.

Connection to Professional Career: Understanding thermal properties is crucial for careers in materials science, polymer chemistry, and industrial applications where material stability and performance are critical.

Assessment Strategy:

- **Experimental Technique:** Evaluation of the accuracy and care taken in performing the thermal analyses.
- **Data Analysis:** Assessment of the student's ability to interpret TGA/DTA data.
- **Report:** Quality and clarity of the written report, including discussion of thermal properties and potential applications.

Module 3 - Advanced Spectroscopic Techniques
Project Title: Investigating the Mössbauer Effect in Iron Compounds

Description: Students will explore the Mössbauer effect by analyzing iron compounds using a Mössbauer spectrometer.

Readily Available Resources:

- **Materials:** Iron compounds (e.g., iron oxide).
- **Instruments:**Mössbauer spectrometer (if available in the college lab).
- **Software:**Mössbauer data analysis tools.

Procedure:

1. **Sample Preparation:** Prepare samples of iron oxide for analysis.
2. **Data Collection:** Use the Mössbauer spectrometer to collect spectra from the samples.
3. **Data Analysis:** Analyze the spectra to identify isomer shifts, quadrupole splitting, and hyperfine interactions.
4. **Reporting:** Prepare a report discussing the Mössbauer effect, experimental procedure, data analysis, and findings.

Connection to Professional Career: Experience with Mössbauer spectroscopy is valuable for careers in materials science, solid-state physics, and advanced research in inorganic chemistry.

Assessment Strategy:

- **Experimental Procedure:** Evaluation of the setup and operation of the Mössbauer spectrometer.
- **Data Analysis:** Assessment of the interpretation and presentation of the spectroscopic data.
- **Report:** Quality of the written report, including explanation of the Mössbauer effect and its applications.

Module 4 - Green Chemistry and Technologies
Project Title: Microwave-Assisted Synthesis of Organic Compounds

Description: Students will perform green synthesis of an organic compound using microwave-assisted techniques.

Readily Available Resources:

- **Materials:** Common organic precursors (e.g., ethanol, acetic acid), microwave-safe reaction vessels.
- **Instruments:** Household microwave oven.
- **Software:** Not required.

Procedure:

1. **Reaction Setup:** Set up the reaction mixture in a microwave-safe vessel.
2. **Microwave Reaction:** Use a household microwave oven to heat the reaction mixture for a specified time.
3. **Product Isolation:** Isolate and purify the reaction product using simple techniques like filtration or distillation.
4. **Analysis:** Characterize the product using techniques available in the lab (e.g., melting point determination, TLC).
5. **Reporting:** Write a report on the synthesis process, including reaction conditions, yield, and environmental benefits.

Connection to Professional Career: Green synthesis techniques are essential for careers in environmental sustainability, pharmaceutical chemistry, and chemical manufacturing.

Assessment Strategy:

- **Experimental Design:** Evaluation of the design and execution of the green synthesis experiment.
- **Product Analysis:** Assessment of the purity and yield of the synthesized product.
- **Report:** Quality of the written report, including discussion of green chemistry principles and the advantages of microwave-assisted synthesis.

References:

1) Skoog, D. A., West, D. M., Holler, F. J., & Crouch, S. R. (2011). *Fundamentals of Analytical Chemistry*. Cengage Learning, Wiley-VCH Weinheim.

2) Mendham, J., Denney, R. C., Barnes, J. D., & Thomas, M. J. K. (2009). *Vogel's Quantitative Chemical Analysis* (6th ed.). Pearson Education, ELBS.

3) Fifield, F. W., & Kealey, D. (2000). *Principle & Practice of Analytical Chemistry* (5th ed.). Blackwell Science.

4) Christian, G. D., Dasgupta, P., &Schug, K. (2013). *Analytical Chemistry* (7th ed.). John Wiley.

5) Skoog, D. A., Holler, F. J., & Crouch, S. R. (2006). *Principles of Instrumental Analysis* (6th ed.). Cengage Learning.

6) Ahuja, S., & Jespersen, N. (2006). *Modern Instrumental Analysis*. Elsevier Science.

7) Harris, D. C. (2005). *Exploring Chemical Analysis* (3rd ed.). W.H. Freeman.

8) Patnaik, P. (Ed.). (2004). *Dean's Analytical Chemistry Handbook* (2nd ed.). McGraw Hill.

9) Danzer, K. (2007). *Analytical Chemistry*. Springer-BBH.

10) Underwood, A. L. (1999). *Quantitative Analysis*. Prentice-Hall of India Pvt Ltd.

11) Koel, M., &Kaljurand, M. (2012). *Green Analytical Chemistry*. RSC Publishing.

12) Guardia, M., &Carrigues, S. (2012). *A Handbook of Green Analytical Chemistry*. Wiley Interscience.

4.2 Major (Core)

Course Title	**PRACTICAL ADVANCED ANALYTICAL TECHNIQUES (415222)**
Course Credits	**4**
Course Outcomes	After going through the course, learners will be able to**,** 1) **Develop** advanced analytical skills in conductometry, pH-metry, and thermometry for accurate analysis of acids and bases, enhancing problem-solving capabilities in complex chemical environments. 2) **Evaluate** and interpret water quality parameters using sophisticated analytical techniques, preparing for leadership roles in environmental monitoring and water resource management. 3) **Analyze** and innovate methods for evaluating cosmetic raw materials, contributing to advancements in the cosmetics and personal care industry. 4) **Apply** interdisciplinary knowledge and advanced analytical techniques to address and solve complex real-world problems in various fields of applied chemistry.
Module 1 (Credit 1) Analysis of Water Quality Parameters	
Learning Outcoms	1) **Analyze** the concept of pH and its quantitative relationship to hydrogen ion concentration in various chemical environments. 2) **Evaluate** the functioning principles of a pH meter, including the detailed roles of the glass and reference electrodes. 3) **Apply** the Nernst equation to relate measured potential to solution pH and interpret the implications for different chemical systems.
Content Outline	● Estimation of acetic acid pH-metrically ● Estimation of HCl ● Estimation of HCl and phosphoric acid in a mixture
Module 2 (Credit)- Analysis of Soil Nutrients and pH	
Learning Outcoms	1) **Assess** and refine practical skills in performing complexometric titration using EDTA, and evaluate its efficacy for determining total hardness in diverse water samples. 2) **Analyze** the underlying principles of complexometric titration and its application, and critically assess its limitations and advantages in water analysis
Content Outline	● Estimation of vitamin C in a tablet ● Determination of dissolved oxygen (DO) in water samples using Winkler's method ● Determination of total hardness in given water samples
Module 3 (Credit 1) - Analysis of Food Additives in Soft Drinks	

Learning Outcomes	1) **Analyze** how detergents and surfactants affect the physical and chemical properties of soil, and propose solutions to mitigate negative impacts. 2) **Discuss** the potential of detergents to mobilize pollutants or nutrients in soil, and critically evaluate their environmental consequences based on chemical properties.
Content Outline	● Determination of mixed oxides in soil samples ● Determination of percentage moisture in detergent powder
Module 4 (Credit 1) - Analysis of Antioxidant Activity in Herbal Extracts	
Learning Outcoms	1) **Analyze** and interpret the solubility behavior of powders in seawater compared to freshwater, and hypothesize the underlying chemical interactions. 2) **Evaluate** the salinity of seawater samples using advanced analytical techniques, and investigate its effect on solubility and related chemical properties.
Content Outline	● Determination of zinc content in Nycil powder ● Determination of seawater salinity using Volhard's method

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

Lab Experiment 1: Analysis of Water Quality Parameters
Objective: To assess the ability to evaluate and interpret water quality parameters using basic analytical techniques.

Experiment Description:

- **Objective:** Determine the pH, turbidity, and dissolved oxygen (DO) in a given water sample.
- **Materials Needed:** pH meter, turbidity meter (or homemade turbidity tube), DO meter (or Winkler's method equipment), standard solutions (for calibration), water sample.
- **Procedure:**
    1. **pH Measurement:** Calibrate the pH meter and measure the pH of the water sample.
    2. **Turbidity Measurement:** Use a turbidity tube and standard solution to visually compare and measure turbidity.
    3. **DO Measurement:** Perform DO measurement using a DO meter or Winkler's method to determine dissolved oxygen concentration.
- **Data Analysis:** Compare results with standard limits for drinking water and interpret the water quality.
- **Connection to Career:** Relevant for careers in environmental monitoring, water resource management, and public health.

Lab Experiment 2: Analysis of Soil Nutrients and pH
Objective: To analyze soil samples for nutrients and pH using simple analytical techniques.

Experiment Description:

- **Objective:** Determine the pH and nutrient content (nitrogen, phosphorus, potassium) of soil samples.
- **Materials Needed:** Soil samples, pH meter, basic laboratory glassware, reagents for nutrient analysis (N, P, K), standard solutions.
- **Procedure:**
    1. **pH Measurement:** Calibrate the pH meter and measure the pH of soil samples.
    2. **Nutrient Analysis:** Perform nutrient analysis using colorimetric methods (e.g., Nessler's reagent for ammonia-N, colorimetric methods for phosphorus and potassium).
- **Data Analysis:** Calculate nutrient concentrations and interpret soil fertility based on pH and nutrient content.
- **Connection to Career:** Essential for careers in agronomy, soil science, and environmental consulting.

Lab Experiment 3: Analysis of Food Additives in Soft Drinks
Objective: To identify and quantify food additives in soft drinks using basic analytical techniques.

Experiment Description:

- **Objective:** Identify and quantify food additives (such as preservatives, colorants) in soft drinks.
- **Materials Needed:** Soft drink samples, basic laboratory glassware, UV-visible spectrophotometer, standard solutions.
- **Procedure:**
    1. **Sample Preparation:** Dilute soft drink samples appropriately.
    2. **UV-Vis Spectrophotometry:** Use UV-Vis spectrophotometer to measure absorbance spectra of the samples.
    3. **Standard Curve Preparation:** Prepare standard solutions of known additives for calibration.
    4. **Data Analysis:** Compare absorbance peaks with standards to identify and quantify additives.
- **Connection to Career:** Relevant for careers in food chemistry, quality control in food industry, and regulatory compliance.

Lab Experiment 4: Analysis of Antioxidant Activity in Herbal Extracts
Objective: To assess the antioxidant activity of herbal extracts using basic analytical techniques.

Experiment Description:

- **Objective:** Determine the antioxidant capacity of herbal extracts using DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay.
- **Materials Needed:** Herbal extracts (e.g., green tea extract), DPPH solution, basic laboratory glassware, UV-Vis spectrophotometer.
- **Procedure:**
    1. **Preparation of DPPH Solution:** Prepare DPPH solution in appropriate solvent.
    2. **Sample Preparation:** Dilute herbal extracts to various concentrations.
    3. **Antioxidant Assay:** Mix herbal extracts with DPPH solution, measure absorbance at λmax using UV-Vis spectrophotometer.
    4. **Data Analysis:** Calculate percentage inhibition and IC50 values to assess antioxidant activity.
- **Connection to Career:** Relevant for careers in pharmaceuticals, herbal product development, and nutraceuticals.

Assessment Criteria:

- **Experimental Design:** Clarity and coherence of experimental procedures.
- **Data Analysis:** Accuracy in measurement and interpretation of results.
- **Scientific Rigor:** Adherence to experimental protocols and safety procedures.

- **Report Writing:** Quality of lab reports, including structure, analysis, and conclusions.

References-

1) Hill, J. W., &Petrucci, R. H. (1996). Chemistry in the laboratory. Wiley.
2) Knapp, D. R. (1995). Microscale and macroscale organic experiments. Wiley.
3) Lehman, K. A. (2001). General chemistry laboratory manual. Prentice Hall.
4) Vogel, A. I. (1978). Vogel's textbook of practical organic chemistry. Longman. (Revised editions published in 1986, 1996, and 2002)
5) Harris, D., Housecroft, M. D., &Raston, C. M. (1999). Experimental inorganic chemistry. Royal Society of Chemistry.
6) Jacquett, M. B., &Rockell, R. S. (1985). Techniques in organic chemistry. Wiley.

4.3 Major (Core)

Course Title	**In-Plant Training (402302)**
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. • 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.
Module 2 (Credit 1) - Problem-Solving and Process Optimization	
Learning Outcomes	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.
Content Outline	• **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.

Module 3 Credit 1) - Safety and Regulatory Compliance	
Learning Outcomes	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.
Content Outline	• **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. • 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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4.4 Major (Elective)

Course Title	**Advanced Environmental Chemistry (425211)**
Course Credits	**4**
Course Outcomes	After going through the course, learners will be able to
	1) **Analyze** and assess the environmental and societal impacts of various energy technologies, including nuclear energy, bioenergy, and renewable energy sources. 2) **Demonstrate** comprehensive knowledge of environmental science principles, focusing on the interactions between living organisms and their ecosystems. 3) **Evaluate** the role and effectiveness of environmental NGOs in managing and conserving natural resources and biodiversity. 4) **Apply** ethical principles and social responsibilities in addressing environmental challenges and promoting sustainable development practices.
Module 1(Credit 1) - Fundamentals of Environmental Science	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** the basic principles and scope of environmental science, emphasizing interactions between living organisms and their environment. 2) **Evaluate** the structure and composition of the Earth's atmosphere, hydrosphere, lithosphere, and biosphere, and their roles in supporting life and regulating environmental processes. 3) **Assess** and discuss the biotic and abiotic components of ecosystems.
Content Outline	• Definition, Principles and Scope of Environmental Science. • Structure and composition of atmosphere, hydrosphere, lithosphere and biosphere. • Interaction between Earth, Man and Environment. Biogeographic provinces of the world and agro-climatic zones of India. Concept of sustainable development.
Module 2(Credit 1) - Nuclear Energy and Environmental Impacts	
Learning Outcomes	After learning the module, learners will be able to
	1) **Evaluate** the environmental and social impacts associated with nuclear energy, including risks of radioactive contamination. 2) **Analyze** nuclear waste management strategies, potential accidents, and implications for public health and safety.

Content Outline	● Nuclear energy - fission and fusion, Nuclear fuels, Nuclear reactor – principles and types. ● Bioenergy: methods to produce energy from biomass. Environmental implications of energy use; energy use pattern in India and the world, emissions of CO2 in developed and developing countries ● Impacts of large scale exploitation of solar, wind, hydro and ocean energy.
Module 3(Credit 1) - Environmental Management	
Learning Outcomes	After learning the module, learners will be able to
	1) **Evaluate** environmental management principles, including sustainability, conservation, and natural resource stewardship. 2) **Analyze** Gain knowledge of environmental laws, regulations, and policies at local, national, and international levels. 3) **Apply** principles of environmental risk assessment and management.
Content Outline	● Microbial Reactors, genetically modified microbes & their uses in Environmental management recycling ● Biogas technology, plant design, construction, operation ● water weeds, landfills, biogas form organic wastes.
Module 4(Credit 1) - Role of Environmental NGOs and Ethical Responsibilities	
Learning Outcomes	After learning the module, learners will be able to
	1) **Analyze** the ethical and social responsibilities of environmental NGOs, emphasizing transparency, inclusivity, and equity in operations and partnerships. 2) **Assess** effectively about the roles and contributions of environmental NGOs to various stakeholders, including policymakers, donors, volunteers, and the general public.
Content Outline	● Basic concepts of environmental planning,Vehicular pollution and urban air quality ● Role of NGO's public participation in environmental movements, Concepts of Environmental education and awareness Internationals environmental initiatives. ● Water crisis-conservation of water . Narmada dam, Tehri dam, Almetti dam.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE:)

Module 1 - Fundamentals of Environmental Science
Project Title: Comprehensive Ecosystem Analysis

Description: Students will conduct an extensive analysis of a local ecosystem to explore its biodiversity, interactions between biotic and abiotic factors, and its resilience to environmental changes.

Elaboration: For this project, students can utilize readily available resources such as:

- **Field Tools:** Basic field equipment like magnifying glasses, pH meters, and thermometers.
- **Local Libraries and Databases:** Access to local biodiversity records, climate data, and ecological studies.
- **Collaboration with Local Experts:** Engagement with local environmental organizations or experts for guidance and data sharing.

Connection to Professional Career: By conducting this analysis, students connect classroom knowledge with real-world applications:

- They learn to apply environmental science principles to assess ecosystem health.
- Engagement with local experts builds networking skills essential for careers in environmental consulting or conservation.

Module 2 - Nuclear Energy and Environmental Impacts
Project Title: Comparative Analysis of Energy Technologies

Description: Students will conduct a comparative analysis of nuclear energy and renewable energy sources, focusing on environmental impacts, energy efficiency, and societal acceptance.

Elaboration: Resources available for this project include:

- **Laboratory Facilities:** Use of analytical instruments like spectrometers or calorimeters available in the college lab for data analysis.
- **Publicly Available Data:** Access to energy production data, environmental impact assessments, and public opinion surveys from government websites or international organizations.
- **Collaboration with Industry Partners:** Engagement with local energy companies or NGOs focused on renewable energy for case studies and expert insights.

Connection to Professional Career: This project enables students to:

- Analyze complex energy data and apply environmental science principles.
- Engage with industry partners to understand real-world energy challenges, preparing them for careers in energy policy or environmental engineering.

Module 3 - Environmental Management Principles
Project Title: Sustainability Assessment and Action Plan

Description: Students will assess the sustainability practices of a local industry or community, identify environmental challenges, and propose an action plan for sustainable resource management.

Elaboration: Key resources for this project include:

- **Site Visits:** Conducting on-site assessments of industrial facilities or community sites to observe practices and collect data.

- **Regulatory Guidelines:** Access to local and international environmental regulations and guidelines for benchmarking and compliance assessment.
- **Collaboration with Stakeholders:** Engagement with industry professionals, community leaders, and regulatory bodies for consultation and data validation.

Connection to Professional Career: Through this project, students:

- Gain practical experience in environmental auditing and management.
- Develop skills in stakeholder engagement and regulatory compliance essential for careers in environmental consultancy or sustainability management.

Module 4 - Role of Environmental NGOs and Ethical Responsibilities
Project Title: Environmental Policy Advocacy Campaign

Description: Students will develop an advocacy campaign addressing a pressing environmental issue, targeting policymakers, stakeholders, and the general public to promote sustainable practices and policy change.

Elaboration: Resources students can utilize include:

- **Social Media and Digital Platforms:** Creating advocacy materials such as infographics, videos, and blog posts to reach a broader audience.
- **Policy Briefs:** Researching and drafting policy recommendations based on scientific evidence and ethical considerations.
- **Collaboration with NGOs:**Partnering with environmental NGOs for guidance, networking opportunities, and access to advocacy resources.

Connection to Professional Career: This project allows students to:

- Apply communication and advocacy skills to influence policy and promote environmental sustainability.
- Collaborate with NGOs and policymakers, preparing them for careers in environmental policy, advocacy, or public relations.

References

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4.5 Research Project

Course Title	**Research Project Part – II (402301)**
Course Credits	**6**
Course Outcomes	After this course, the students will be able to, 1) **Analyze** advanced proficiency in experimental design, data analysis, and scholarly communication in analytical chemistry. **2) Evaluate** a comprehensive research report and a concise research article suitable for publication.
Module 1 (Credit 1) - Experimental Work	
Learning Outcome	1) **Analyze** and expand experimental protocols based on insights gained from Semester III findings, incorporating necessary methodological refinements. 2) **Assess** rigorous data collection practices and document experimental details comprehensively to support robust analysis.
Content Outline	**Guidelines for Students:** • **Tasks:** Extend experimental protocols based on Semester III outcomes, addressing identified limitations or refining methodologies. • **Approach:** Document all experimental procedures meticulously, ensuring reproducibility and reliability. Seek guidance from faculty on protocol adjustments and experimental setups.
Module 2 (Credit 1) - Advanced Data Analysis	
Learning Outcome	1) **Analyze** advanced statistical techniques to analyze complex datasets thoroughly, extracting meaningful insights relevant to research objectives. 2) **Discuss** data trends, patterns, and correlations, ensuring alignment with research hypotheses in analytical chemistry.
Content Outline	**Guidelines for Students:** • **Tasks:** Apply advanced statistical methods to analyze collected data comprehensively. • **Approach:** Interpret data trends and correlations to derive meaningful conclusions. Discuss findings with faculty and peers to validate interpretations and refine analytical approaches.
Module 3 (Credit 1) - Final Results Compilation	
Learning Outcomes	1) **Analyze** experimental results into a coherent narrative that aligns with research hypotheses and objectives in analytical chemistry. 2) **Discuss** findings with existing literature to contextualize contributions and demonstrate the significance of the research outcomes
Content Outline	**Guidelines for Students:** • **Tasks:** Compile experimental results into a cohesive narrative

	that supports research hypotheses. • **Approach:** Conduct a thorough review of literature to contextualize findings. Discuss implications of results with faculty to ensure completeness and relevance to the field.
Module 4 (Credit 1) - Research Article Preparation	
Learning Outcome	1) **Analyze** a concise research article following journal-specific guidelines, ensuring clarity, adherence to formatting requirements, and incorporation of appropriate references. 2) **Apply** research findings effectively, preparing the manuscript for submission to a peer-reviewed scientific journal in analytical chemistry.
Content Outline	**Guidelines for Students:** • **Tasks:** Draft a concise research article suitable for submission to a peer-reviewed journal. • **Approach:** Follow journal-specific formatting guidelines and incorporate feedback received from faculty. Emphasize clarity, coherence, and adherence to scholarly writing conventions.
Module 5 (Credit 1) - Research Report Finalization	
Learning Outcomes	1) **Analyze** the comprehensive research report documenting all stages of the study, from initial proposal through to final experimental outcomes. 2) **Assess** and refine content based on feedback received to ensure completeness, coherence, and scholarly rigor in analytical chemistry.
Content Outline	**Guidelines for Students:** • **Tasks:** Finalize the research report, incorporating all stages of the study and addressing feedback received. • **Approach:** Revise content for clarity, coherence, and academic rigor. Seek guidance from faculty on structuring and presenting findings effectively in the final report.
Module 6 (Credit 1) - Final Presentation and Defense	
Learning Outcome	1) **Analyze** a professional presentation summarizing key research findings, methodologies employed, and implications for the field of analytical chemistry. 2) **Apply** mastery of analytical concepts and research methodologies during the defense session before an academic panel, showcasing the depth of understanding and contributions to analytical chemistry research.

Content Outline	Guidelines for Students:
	• **Tasks:** Prepare a professional presentation summarizing research findings and methodologies. • **Approach:** Practice presentation skills and anticipate questions from the academic panel. Demonstrate comprehensive understanding of research outcomes and their implications for analytical chemistry.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

Module 1 (Credit 1) - Experimental Work
Assessment Components:

1. **Protocol Extension (30%):**
    - Submission of extended experimental protocols based on Semester III outcomes, with refinements.
    - Evaluation Criteria: Effectiveness of protocol adjustments, addressing limitations, and feasibility.
2. **Data Documentation (20%):**
    - Comprehensive documentation of experimental procedures and data collection methods.
    - Evaluation Criteria: Clarity, completeness, and adherence to documentation standards.
3. **Protocol Adjustment Discussion (20%):**
    - Engagement with faculty to discuss protocol adjustments and experimental setups.
    - Evaluation Criteria: Ability to justify adjustments, responsiveness to feedback, and collaboration.
4. **Participation and Engagement (10%):**
    - Active participation in experimental activities and discussions.
    - Evaluation Criteria: Contribution to team efforts, engagement in the process, and responsiveness to supervision.

Module 2 (Credit 1) - Advanced Data Analysis
Assessment Components:

1. **Advanced Statistical Analysis (30%):**
    - Submission of a detailed data analysis report using advanced statistical techniques.
    - Evaluation Criteria: Correct application of methods, depth of analysis, and relevance to research objectives.
2. **Data Interpretation (20%):**
    - Interpretation of data trends, patterns, and correlations in relation to research hypotheses.
    - Evaluation Criteria: Clarity of interpretation, alignment with hypotheses, and integration with existing knowledge.
3. **Discussion and Validation (20%):**

- Discussion of findings with faculty and peers to validate interpretations.
- Evaluation Criteria: Constructive engagement, openness to feedback, and ability to refine analytical approaches.

4. **Participation and Engagement (10%):**
    - Active participation in data analysis discussions and activities.
    - Evaluation Criteria: Contribution to team efforts, engagement in the process, and responsiveness to feedback.

Module 3 (Credit 1) - Final Results Compilation

Assessment Components:

1. **Synthesis of Experimental Results (30%):**
    - Compilation of experimental results into a coherent narrative supporting research hypotheses.
    - Evaluation Criteria: Clarity, completeness, and alignment with research objectives.
2. **Literature Review Integration (20%):**
    - Comparison of findings with existing literature to contextualize contributions.
    - Evaluation Criteria: Depth of review, relevance of comparisons, and contribution to the field.
3. **Feedback Incorporation (20%):**
    - Incorporation of feedback from faculty to refine and finalize the narrative.
    - Evaluation Criteria: Responsiveness to feedback, clarity of revisions, and improvement in content coherence.
4. **Participation and Engagement (10%):**
    - Active participation in discussions on result synthesis and literature review.
    - Evaluation Criteria: Contribution to team efforts, engagement in the process, and responsiveness to feedback.

Module 4 (Credit 1) - Research Article Preparation

Assessment Components:

1. **Research Article Draft (30%):**
    - Submission of a draft research article adhering to journal-specific guidelines.
    - Evaluation Criteria: Clarity, adherence to formatting requirements, and appropriateness of references.
2. **Presentation of Findings (20%):**
    - Presentation of research findings effectively in manuscript form.
    - Evaluation Criteria: Structure, coherence, and scholarly rigor in writing.
3. **Feedback Incorporation (20%):**
    - Incorporation of feedback received from faculty on the draft manuscript.
    - Evaluation Criteria: Responsiveness to feedback, clarity of revisions, and improvement in manuscript quality.
4. **Participation and Engagement (10%):**
    - Active participation in manuscript preparation and feedback discussions.
    - Evaluation Criteria: Contribution to team efforts, engagement in the process, and responsiveness to feedback.

Module 5 (Credit 1) - Research Report Finalization

Assessment Components:

1. **Final Research Report (30%):**

- Submission of a finalized research report documenting all stages of the study.
- Evaluation Criteria: Completeness, coherence, and academic rigor in presenting findings.

2. **Revision Based on Feedback (20%):**
    - Revision and refinement of the research report based on feedback received.
    - Evaluation Criteria: Clarity of revisions, improvement in content coherence, and incorporation of final insights.
3. **Participation and Engagement (10%):**
    - Active participation in final report preparation and revision discussions.
    - Evaluation Criteria: Contribution to team efforts, engagement in the process, and responsiveness to feedback.

Module 6 (Credit 1) - Final Presentation and Defense

Assessment Components:

1. **Presentation Preparation (30%):**
    - Preparation of a professional presentation summarizing key research findings and methodologies.
    - Evaluation Criteria: Clarity, structure, and effectiveness in communicating research outcomes.
2. **Defense Session (20%):**
    - Performance during the defense session before an academic panel.
    - Evaluation Criteria: Mastery of analytical concepts, ability to defend research methodologies, and depth of understanding.
3. **Q & A Session (20%):**
    - Responses to questions from the academic panel during the defense.
    - Evaluation Criteria: Clarity of responses, depth of knowledge, and ability to engage with panel inquiries.
4. **Participation and Engagement (10%):**
    - Active participation in presentation practice and defense preparation.
    - Evaluation Criteria: Contribution to team efforts, engagement in the process, and responsiveness to feedback.

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