M.Sc. Analytical Chemistry

Program Educational Objectives (PEOs):

PEO-1: To develop a strong foundation in fundamental and advanced concepts of chemistry, enabling students to apply scientific principles effectively in research, industry, and academia.

PEO-2: To equip students with practical laboratory skills and expertise in modern analytical, synthetic, and computational techniques for solving complex chemical problems.

PEO-3: To foster critical thinking, problem-solving abilities, and independent research skills to contribute to innovations in chemical sciences and interdisciplinary fields.

PEO-4: To prepare graduates for successful careers in chemical industries, research institutions, higher education, and entrepreneurship by promoting ethical practices and lifelong learning. 5.

Program Outcomes (POs): Students will be able to

PO-1: Demonstrate comprehensive knowledge of core chemistry subjects including physical, organic, inorganic, and analytical chemistry.

PO-2: Apply theoretical concepts and practical techniques to design and conduct experiments, analyse data, and interpret results effectively.

6 PO-3: Utilize modern instrumentation and computational tools for chemical analysis, synthesis, and characterization.

PO-4: Understand the societal, environmental, and safety aspects related to chemical research and industrial practices.

Programme Specific Outcomes (PSOs):

Students will be able to PSO-1: Apply the chemistry knowledge to provide solutions to the contemporary societal problems in fields of materials science, environmental science, and pharmaceutical chemistry.

PSO-2: Interpret the properties of various chemicals using the analytical techniques learned and relate the chemical characteristics to functioning and performance of various functional materials.

PSO-3: Assess and evaluate facts, claims and arguments using their scientific knowledge.

PSO-4: Define a problem, analyse, interpret and draw conclusion by planning, implementing and reporting the results of an experiment.

M.Sc. Part – I (Semester – I)

Paper I-CHT101: Inorganic Chemistry-I [Credit 4, 60 Hrs]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Learn the properties, bonding theories, and stereochemistry of transition metal complexes using Crystal Field Theory and Molecular Orbital Theory.

CO-2: Apply concepts of molecular symmetry and group theory to analyse and classify molecular structures and their spectroscopic properties.

CO-3: Study the synthesis, bonding, and catalytic applications of organometallic compounds and interpret their reaction mechanisms.

CO-4: Evaluate chemical and instrumental analytical methods, including chromatographic techniques, and apply statistical tools for data accuracy and error minimization.

Paper II-CHT102: Organic Chemistry-I [Credit 4, 60 Hrs]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Analyze the structure and reactivity of compounds and also understand different aliphatic nucleophilic substitution reaction

CO-2: Realize the terms aromaticity, anti-aromaticity, homoaromaticity in different organic molecules.

CO-3: Know about the types of reactions and mechanisms by realizing the various factors which are affecting on the reactions.

CO-4: Apply the concept of stereochemistry by writing the different projection formulae.

Paper-III, CHT103: Physical Chemistry-I [Credit 4, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Apply thermodynamic principles to analyze entropy, chemical potential, and phase equilibria in ideal and non-ideal solutions.

CO-2: Utilize statistical thermodynamics to relate molecular partition functions to macroscopic thermodynamic properties and equilibrium constants.

CO-3: Explain surface phenomena including adsorption, micellization, and their applications in advanced scientific fields like nanotechnology.

CO-4: Demonstrate the use of electroanalytical techniques such as voltammetry, polarography, and amperometry for qualitative and quantitative chemical analysis.

CHP104: Physical Chemistry Practical-I [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Analyze reaction kinetics and equilibrium by conducting experiments on chemical reaction rates and solubility product determinations.

CO-2: Apply physical chemistry techniques such as adsorption, viscosity, and refractometry to characterize molecular properties and solutions.

CO-3: Use electrochemical methods including potentiometry, conductometry, and pH-metry for qualitative and quantitative analysis of acids, salts, and mixtures.

CO-4: Perform spectrophotometric experiments to verify Beer-Lambert's law and determine concentrations and molar absorptivities of substances.

E-CHP105 (A): Inorganic and Organic Chemistry Practical-I [Credit 4, 120 Hours]

Practical paper divides into two sections:

Section I: Inorganic Chemistry Practicals (2 credits, and Section II: Organic Chemistry Practicals (2 credits)

SECTION I Inorganic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Perform quantitative ore and alloy analyses to determine the composition of metals and minerals using classical and instrumental methods.

CO-2: Synthesize and assess the purity of coordination compounds through standard preparation techniques.

CO-3: Apply ion exchange chromatography and colorimetric methods for separation and estimation of metal ions and inorganic species in complex mixtures.

CO-4: Utilize statistical tools and software like Excel for data analysis, including calculation of standard deviation and graphical representation of experimental results.

SECTION II Organic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Perform one-step organic syntheses involving diverse reaction types and confirm product identity and purity using Thin Layer Chromatography (TLC).

CO-2: Apply classical organic reaction mechanisms such as condensation, cyclization, and substitution for the synthesis of biologically and industrially important compounds.

CO-3: Quantitatively estimate organic compounds including dyes, amino acids, and pharmaceuticals using colorimetric and spectrophotometric techniques. 27

CO-4: Analyze and interpret experimental data to determine the concentration and purity of organic substances in pharmaceutical and food samples.

SECTION I Inorganic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Analyze ore samples to quantitatively determine the concentration of key metal and non-metal components using classical wet chemical methods.

CO-2: Perform alloy composition analysis to accurately estimate the percentages of constituent metals in common industrial alloys.

CO-3: Apply chromatographic and colorimetric techniques for the separation and estimation of metal ions and anions in complex mixtures.

CO-4: Utilize statistical tools and software like Excel to analyze experimental data, calculate error parameters, and graphically represent analytical results for precision and accuracy assessment.

SECTION II Organic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Perform single-step organic syntheses involving various reaction types and confirm product purity through recrystallization and Thin Layer Chromatography (TLC).

CO-2: Apply purification techniques including recrystallization and simple distillation to isolate and characterize organic compounds.

CO-3: Execute quantitative organic estimations such as unsaturation, formalin, dyes, and pharmaceutical contents using colorimetric and spectrophotometric methods.

CO-4: Understand and verify fundamental analytical principles like Beer-Lambert's Law through practical experiments involving organic dyes and biochemical samples.

RM-CH106 Research Methodology [Credit 4, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Demonstrate understanding of various research types, methodologies, and ethical considerations in scientific research.

CO-2: Perform effective literature search and critically evaluate scientific information using modern research databases and tools.

CO-3: Develop scientific reports, research proposals, and technical documents with appropriate structure, referencing tools, and scientific writing techniques.

CO-4: Apply quantitative techniques, computer applications, and presentation skills to analyze data and communicate scientific findings effectively.

M.Sc. Part – I (Semester – II)

Paper IV-CHT201: Inorganic Chemistry-II [Credit 4, 60 L Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Gain the periodic properties, bonding, structure, and reactivity of non-transition elements and their compounds.

CO-2: Analyze the properties, oxidation states, and spectral characteristics of lanthanides and actinides, and evaluate their industrial and chemical applications.

CO-3: Interpret crystal structures, electronic properties, and defects in solids, and describe the role of metal ions in biological systems.

CO-4: Demonstrate understanding of thermal analysis techniques (TGA, DTA, DSC) and apply them to interpret decomposition, phase transitions, and thermal behavior of materials.

Paper V-CHT202: Organic Chemistry-II [Credit 4, 60 L Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Explain the mechanisms and synthetic applications of key organic rearrangement reactions and photochemical processes.

CO-2: Analyze various organic oxidation and reduction reactions using classical and modern reagents and catalysts.

CO-3: Apply the concepts of hydroboration, enamine chemistry, and functional group protection-deprotection in organic synthesis.

CO-4: Interpret organic molecular structures using advanced analytical techniques such as NMR and Mass Spectrometry.

Paper VI-CHT203: Physical Chemistry-II [Credit 4, 60 L Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Apply the fundamental principles of quantum mechanics to solve problems involving wavefunctions, operators, and spectroscopic applications.

CO-2: Explain the concepts of electrochemistry including activity coefficients, electrode types, and electrokinetic phenomena with theoretical models.

CO-3: Analyse reaction kinetics using experimental methods, steady-state approximations, and catalytic mechanisms in homogeneous and heterogeneous systems.

CO-4: Describe the properties, classification, and applications of colloids, emulsions, and gels in analytical chemistry and research.

CHP205 Physical Chemistry Practical-II [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Learn advanced instruments and techniques, such as a conductometer, refractometer, pH meter, colourimeter, spectrometer, potentiometer, and polarimeter.

CO-2: Perform the calibration and handling of different instruments.

CO-3: Connect theoretical principles to observed phenomena and explain the underlying mechanisms. CO-4: Analyse experimental data, identify trends, and interpret results in the context of theoretical knowledge.

Inorganic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Analyze the composition of ores and alloys through classical and instrumental quantitative methods.

CO-2: Synthesize and assess the purity of coordination compounds using standard laboratory techniques.

CO-3: Demonstrate the principles of ion exchange by separating and quantifying metal ions using cationic and anionic resins.

CO-4: Apply nephelometry and turbidimetry for water quality assessment and quantify analytes such as sulphate and iron in real-world samples.

Organic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Perform the separation and identification of binary organic mixtures using microanalytical and TLC techniques.

CO-2: Prepare and characterize derivatives of organic compounds to confirm structure and purity.

CO-3: Estimate pharmaceutical and bioactive compounds such as ibuprofen, aspirin, isoniazid, and caffeine from various samples.

CO-4: Determine the composition and properties of industrial and natural products, including oils, soaps, and tea extracts, through quantitative organic analysis.

Inorganic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Analyze the composition of ores and alloys through classical and instrumental analytical techniques.

CO-2: Synthesize coordination compounds and assess their purity using appropriate laboratory methods.

CO-3: Apply titrimetric, gravimetric, and colorimetric methods to determine the concentration of metal ions and non-metals in various samples.

CO-4: Utilize chromatographic and spectrophotometric techniques for separation and estimation of ions in complex mixtures.

Organic Chemistry Practical [Credit 2, 60 Hours]

COURSE OUTCOMES (COs): Students will be able to

CO-1: Perform one-stage organic syntheses involving condensation, substitution, and cyclization reactions, and confirm product formation using Thin Layer Chromatography (TLC).

CO-2: Quantitatively estimate organic compounds such as amino acids, dyes, and aldehydes using classical titrimetric and colorimetric methods.

CO-3: Analyze pharmaceutical and food samples to determine active ingredients and quality parameters like acid value and unsaturation index.

CO-4: Apply spectrophotometric techniques to verify Beer-Lambert's Law and quantify organic analytes in solution accurately.

OJT/FP-CH206: On Job Training/Field Project (4 credits, 120 hours)

The course will be run as per the guidelines of the Shivaji University and Government of Maharashtra. Under this course, students are required to enroll for On Job Training (OJT) or an internship or field projects in the relevant industries, or government departments, or research institutes, etc. This course is designed to offer students for gaining practical skills, hands-on experience that complements their academic learning and enhances their professional readiness. To support students in this transition, the department needs to organize lectures, workshops, and seminars for mentoring them with the necessary knowledge and skills. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their M.Sc. degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

- Internship in Industry/National research laboratory. OR

- Field projects that are aligned with the Chemistry Subject. OR

- Hands on Training on various analytical instruments: Gas Chromatography, HPLC, UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, X-Ray Diffractometer, Powder X-ray Diffractometer, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer, Thermal Analyzer (TGA-DSC), Scanning electron microscope etc. Note: i) Student has to spend minimum 120 hrs. for OJT/FP course

M.Sc. Part-II (SEM- III): Analytical Chemistry Detailed Syllabus:

MANDATORY PAPERS Paper-VII, PCHT301: Advanced Analytical Techniques (4 Cr, 60 hrs.)

Course Outcomes (COs):

CO1: Develop knowledge of fundamental, instrumentation and working of state of art instrumental analytical techniques, effective use and choice of technique, written and/or oral communication of the concepts of analytical chemistry which will be useful as analytical chemist and R&D.

CO2: Acquire knowledge of mass spectrometry, type of MS, ionization types and specific practical applications of MS.

CO3: Acquire knowledge of basics of nanochemistry, nanomaterials and nanotechnology and application orientated synthesis and characterization of nanomaterials.

CO4: This course gives wide understanding about the instrumental analytical techniques (SEM, TEM, EDS, STM, AFM, Raman, XFS, ESR, XPS, AES, SIMS etc.) employed for qualitative and quantitative analysis for contemporary research.

Paper-VIII, ACHT302: Advanced Methods in Chemical Analysis (4 Cr, 60 hrs.)

Course Outcomes (COs):

CO1: Fundamental knowledge of electrochemistry, electrodes, types of electrodes, its construction will lay foundation for the course.

CO2: Students will gain knowledge and skill in electroanalytical techniques like cyclic voltammetry and its types, polarography, coulometry and dynamic light scattering technique for qualitative and quantitative analysis.

CO3: Students will be familiar with the advanced electrodes used for chemical analysis, liquidliquid membrane electrodes, enzymes and gas electrodes.

CO4: Students will learn about electrophoretic techniques, advances in electrophoresis techniques and its analytical applications.

ELECTIVE PAPERS Paper-IX, E-ACHT303 (A): Organo Analytical Chemistry (4 Cr, 60 hrs.)

Course Outcomes (COs):

CO 1: Students will gain knowledge of the instruments used at the interface of Analytical-Organic chemistry useful for R&D and structural elucidation using UV-Visible, IR, 1H & 13C NMR, Mass spectrometry data and interpretation of the same.

CO 2: Students will acquire knowledge about the drug, their classification, sources of impurities (chemical, atmospheric and microbial contamination) in pharmaceutical raw materials and analysis of the same.

CO 3: Students will gain knowledge about the conventional and advanced analytical approaches for analysis of drug, vitamin, body fluids and clinical samples.

CO 4: Students will have an idea of commonly used pesticides and their analysis and also about forensic science and forensic sample analysis.

Paper-IX, E-ACHT303 (B): Environmental Chemical Analysis and Control (4 Cr, 60 hrs.)

Course Outcomes (COs):

CO1: Students will acquire knowledge about sampling, criteria of good sampling, handling, preservation and storage of the samples, pretreatment and post treatment of samples.

CO2: Students will acquire knowledge of conditions and strategies required during sampling and electrochemical and spectral methods for analysis of environmental samples.

CO3: Students will learn about the air and water pollution, sources of pollution, typical parameters and properties (physical, chemical and biological) to be measured in air and water pollution with relevance to specific case studies.

CO4: Students will be acquainted with organic pollutants and their analysis with special reference to pesticide analysis.

Paper-IX, E-ACHT303(C): Recent Advances in Analytical Chemistry (4 Cr, 60 hrs.)

Course Outcomes (COs):

CO1: Students will be acquainted with ultra-purity and ultra-trace analysis required in electronic and semiconductor processing.

CO2: Students will learn Radio-Analytical techniques for analysis.

CO3: Student will be well versed with C13, P15 and O17 NMR Spectroscopy applications.

CO4: Student will learn about ESR spectrometry and its applications quantitative analysis.

Paper-IX, E-ACHT304 (D): Automation and Sensor (4 Cr, 60 hrs.)

Course Outcomes (COs):

CO-1. Study the various terms used and methods in sensors and automation.

CO-2. Describe application of automation in analytical laboratory and sensors.

CO-3. Explain importance sensors and automation in analytical chemistry.

CO-4. Explain principles of different types of sensors in analytical chemistry.

Analytical Chemistry Practical Course Practical-V: ACHP304 (4 Cr, 120 hrs.)

Course Outcomes (COs):

CO1: In-depth training on laboratory solution preparations on all concentration scales

CO2: Training on laboratory safety and lab ethics in scientific work

CO3: Training on planning, design and execution of experiments

CO4: Training on uncertainty estimations for experimentally measured and derived properties of solutions.

Practical-VI: ACHP305 (2 Cr, 60 hrs.)

Course Outcomes (COs):

CO1: Training on scientific literature search, defining the objective of the work, research skills, data representation in tabular and graphical form etc.

CO2: Training on experimental verification of fundamental theories, comparison of data with literature and scientific discussion on any deviation of data from expected theoretical values or reported literature.

CO3: Developing analytical skills

CO4: Training on qualitative and quantitative analysis of analyte.

M.Sc. Part-II (SEM- IV) Analytical Chemistry

MANDATORY PAPERS

Paper-X, ACHT401: Modern Separation Method in Analysis (4 Cr, 60 hrs.)

Course Outcome (COs):

CO1: Students will learn about modern separation and chromatographic used for analysis of different type of samples.

CO2: The student will understand instrumentation and mechanism of various separation techniques. CO3: Student will acquire knowledge regarding various choices of instrument and detectors to be used for analysis depending on the sample and matrix.

CO4: Student will learn fundamentals of extractive chromatography, types of extraction techniques, advances in extraction methods and their hyphenations with chromatography leading to addressing challenging problems in analytical chemistry.

Paper-XI, ACHT402: Advanced Methods in Chemical Analysis (4 Cr, 60 hrs.)

Course Outcome (COs):

CO1: Students will be skilled in the techniques like fluorescence, phosphorescence, types of quenching, FRET and applications of the same in Analytical Chemistry and for addressing research problems.

CO2: Students will gain knowledge of the kinetic methods of analysis supporting the analysis and data procured in research.

CO3: The students will acquire the knowledge of advanced method of chemical analysis XPS, XRF, fluorescence and phosphorescence spectroscopy which will be beneficial in research.

CO4: Students will acquire knowledge of identifying types of plastic and will also be able to and determination of metallic impurities in plastics.

ELECTIVE PAPERS Paper-XII, E-ACHT403 (A): Organic Industrial Analysis (4 Cr, 60 hrs.)

Course Outcome (COs):

CO1: Acquire knowledge of handling and investigating the characteristics of the oils, fats, detergents and soap samples and analysis of the same providing opportunity in cosmetic, pharmaceuticals, dyes and polymers industries.

CO2: Student will gain knowledge and importance of food quality, probe for food adulteration and adulterants, food preservative, food flavors and analysis of their components.

CO3: Students will also gain knowledge about the animal food stuff and the additives added in the animal food stuff as antibiotics, dietary supplements and growth promoting drugs, preservatives etc. and analysis of the same.

CO4: Student will learn about the analysis of cosmetics, face powder, hair dyes and hair care products, types of cosmetics, precautionary measures and composition of the cosmetics and specific roles of the ingredients. Will acquire knowledge about the paints, pigments and petroleum products, composition and analysis of the same using conventional and instrumental techniques.

Paper-XII, E-ACHT403(B): Industrial Analytical Chemistry (4 Cr, 60 hrs.)

Course Outcome (COs):

CO1: The students will acquire knowledge of analysis of metals, alloys, minerals and ores commonly used in the industry.

CO2: The students will be acquainted with the analysis of real samples like cement, plaster of Paris, different commercial ores, soil composition, soil fertility, fertilizers etc using conventional and instrumental methods of analysis.

CO3: Students will also gain the knowledge of analysis of commercial materials, explosives, polymers, resins, rubber, luminescent paints, lubricants and adhesives.

CO4: These would offer opportunity to the students to get employment in industries for quality assurance and quality control (QA-QC) of the product.

Paper-XII, E-ACHT403(C): Quality Assurance and Accreditation (4 Cr, 60 hrs.)

Course Outcome (COs):

CO1: Students will acquire knowledge of QA-QC which in essential for analytical chemist, This covers a variety of chemical fields and this knowledge would help students working on various materials, understanding the basics of samples, sampling, sample storage, and pre-post treatment of samples. CO2: Students will acquire knowledge of good laboratory practices, professional ethics, and instrumental analytical chemistry, awareness of health hazards, remedial measures, analytical method development and validation.

CO3: The students would be aware of the importance of documentation for raw materials and finished products, their monitoring, maintenance and management. World-wide agencies involved in regulating the analytical protocols and establishing standards.

CO4: Students will gain knowledge about the quality assurance and accreditation, evolution and significance of quality management, available accreditation agencies and advantages of accreditation.

Paper-XII, E-ACHT404 (D): Food, Fertilizer and Pesticides Analysis (4 Cr, 60 hrs.)

Course Outcome (COs):

CO1: Acquire knowledge of handling and investigating the characteristics of the food analysis. Students will also gain knowledge about the animal food stuff and the additives added in the animal food stuff as antibiotics, dietary supplements and growth promoting drugs, preservatives etc. and analysis of the same.

CO2: Student will gain knowledge and importance of food quality, probe for food adulteration and adulterants, food preservative, food flavors and analysis of their components.

CO3: Student will gain knowledge of analysis of fertilizers and Pesticides and their characterization techniques. Acquire knowledge of determination of micronutrients in fertilizers.

CO4: Student will learn about the analysis of vitamins including microbiological techniques. Biological values and estimation of enzymes, Carbohydrates, essential amino acids, proteins and lipids.

Analytical Chemistry Practical Course Mandatory Practical-VII: ACHP404 (4 Cr, 120 hrs.)

Course Outcomes (COs):

1. The students will acquire hands on training for conducting the representative experiments for the analysis of wide variety of samples of inorganic, organic and physical approaches by qualitative and quantitative analysis. Demonstrate professional and ethical attitude to serve the society

2. Students will have knowledge of safety signs on container of chemicals, safety in handling of chemicals, MSDS sheets; learn sample preparation and characterization for confirming the purity.

3. Students would acquire knowledge about the separation and estimation of amount of metal, metal ions, organic compounds etc. in given samples.

4. Based on the experience of project work, students will have ability to start their R & D laboratory.

Annexture-I

Research Project Paper Guidelines for all specializations (Analytical Chemistry)

Semester III RP-306 Credits= 04, 120 Hours, 100 Marks

• The students should write a synopsis of proposed research work.

• The students should perform a detailed literature survey related to the research problem.

• The students should design the problem and start experimental work. The students should complete at least 25% of their experimental work during semester III, and the same work should be continued in semester IV.

• The student should submit a spiral-bound copy of research work (Project) carried out during semester III. It Should include the Title page, certificate, index, synopsis, Literature survey write-up, experimental work and certified progress report. (Single Spiral Bound Copy containing all abovementioned documents)

• The Research Project will be examined by internal and external examiners separately during the practical examination at the end of the semester.

• The students should present their work during the evaluation in the form of power point presentation (PPT).

Annexure II Research Project Paper Guidelines for all specializations (Analytical Chemistry)

Semester IV RP-405, Credits= 06, 180 Hours, 150 Marks

• The student should submit the final hardbound dissertation copy of research work carried out during semesters III and IV.

• It Should include a title page, certificate, declaration, acknowledgement, abbreviations, index, Synopsis of proposed research work, Literature Survey write-up, abstract,

introduction, experimental section, results and discussion, conclusions, references, participation in conferences/seminars and publications if any and certified progress report. (Single hardbound Copy containing all the above mentioned documents)

• The final project should not be less than 25 pages and contain a minimum of 3000-4000 words.

• The students should present their work during the evaluation in the form of power point presentation (PPT).