

Warana University, Warananagar



Syllabus for Master of Science Part-II (M.Sc. II)

Analytical Chemistry

As Per National Education Policy 2020

To be implemented from AY 2026-27 onwards

Preamble:

Analytical Chemistry is a pervasive and a key subject not only for Chemistry, but all the branches of Science, Engineering and Technology which involves Chemistry. It is an experimental science and students need to be trained in theory and practical dealing with fundamental and advanced analytical skills of conventional analysis and instrumental analysis so as to get expertise in doing fine experiments and handle sophisticated instruments.

The M.Sc. Analytical Chemistry program offered by Warana University is a Two Years full time program. The first and second semester gives general background of analytical chemistry and its importance to all the branches of Chemistry to make a good theoretical background of students. The semester third and fourth is totally assigned to analytical chemistry and it covers most of the fundamental and advance aspects of modern analytical chemistry. In order to make students more career oriented and nurturing their scientific temperaments, students will get exposure to the depth of core understanding of various dimensions of analytical chemistry during these two years of study.

Program Outcomes (POs)

PO1: The M.Sc. analytical chemistry program at Shivaji University, Kolhapur provides the key knowledge base and laboratory resources to prepare students for careers as professionals in the field of chemistry and particularly in analytical chemistry, enabling them to interface not only with various branches of chemistry (organic, inorganic, physical, biological, industrial, environmental, pharmaceuticals etc.) but also with the related fields, and for professional courses and areas of research including medical, forensic, food, agriculture, dental, law, intellectual property, business programs etc.

PO2: Students will be able to solve various problems by identifying the essential parts of a problem, formulate strategy for solving the problem, applying appropriate techniques to arrive at a solution, test the precision and accuracy of the solution and interpret the results.

PO3: Students will be able to acquire domain specific knowledge and technical skills needed for employment in industries, teaching fields and pursue research. Students will be skilled in problem solving, critical thinking and analytical reasoning.

PO4: Students will be able to apply the fundamental knowledge to address the cross-cutting issues such as sustainable development.

PO5: Students will get perfect insight into qualitative and quantitative analytical chemistry and research ethics for production of quality research.

PO6: Students will be able to communicate effectively i.e. being able to articulate, comprehend and write effective reports, make effective presentations and documentation and capable of expressing the subject through technical writing as well as through oral presentation.

Program Specific Outcomes (PSOs)

PSO1: Students will be able to prepare and qualify subject specific competitive exams like NET, SET and GATE and also other general public administration exams like M.P.S.C. and U.P.S.C. etc.

PSO2: Student will be able to utilize the knowledge and analytical skills in QA-QC and R&D departments in almost all the industries enabling them to secure jobs where analytical chemistry is the core requirement to ensure and ascertain the quality of the product.

PSO3: Students will have opportunity for higher education leading to Ph.D. program.

PSO4: Students will be able to explore contemporary research in chemistry and allied fields of science and technology, collaborate in team projects, and communicate the results of scientific work in oral, written and electronic formats to both scientists and the public at large.

PSO5: Students can start their own laboratories/start-ups/chemical industry/business (entrepreneurship).

PSO6: Students will be able to interpret data from the state-of-art analytical instruments for ascertaining the product/material.

Framework of NEP-2.0 for M.Sc. Degree in Analytical Chemistry

Semester III

Class	Level	Mandatory Subjects	Elective (choose any one)	Research Project	Total Credit
M.Sc. II	6.5	ACH301 (4 Cr)	E-ICH304 (4 Cr) OR E-OCH304 (4 Cr) OR E-PCH304 (4 Cr) OR E-ACH304 (4 Cr)	RP-ACH306 (4 Cr)	22
		ACH302 (4 Cr)			
		ACH303 (4 Cr)			
		PR-ACH305 (2 Cr)			

Semester IV

Class	Level	Mandatory Subjects	Elective (choose any one)	Research Project	Total Credit
M.Sc. II	6.5	ACH401 (4 Cr)	E-ICH404 (4 Cr) OR E-OCH404 (4 Cr) OR E-PCH404 (4 Cr) OR E-ACH404 (4 Cr)	RP-ACH405 (6 Cr)	22
		ACH402 (4 Cr)			
		ACH403 (4 Cr)			

Cumulative Credits for 1-Year PG Degree: 26 Cr (Mandatory) + 8 Cr (Elective) + 10 Cr (Research Project) = 44 Credits.

Course Structure: M.Sc. Part-II, Analytical Chemistry

Semester III — Major Mandatory

Course Code	Course Title	Credits
ACH301	Advanced Analytical Techniques	4
ACH302	Organo Analytical Chemistry	4
ACH303	Electroanalytical Techniques in Chemical Analysis	4
PR-ACH305	Analytical Chemistry Practicals-V	2
RP-ACH306	Research Project	4

Semester III — Major Elective (Choose any one)

Course Code	Course Title	Credits
E-ICH304	Organometallic and Bioinorganic Chemistry	4
E-OCH304	Drug and Heterocycles	4
E-PCH304	Solid State Chemistry	4
E-ACH304	Environmental Chemical Analysis and Control	4

Semester IV — Major Mandatory

Course Code	Course Title	Credits
ACH401	Modern Separation Method in Analysis	4
ACH402	Organic Industrial Analysis	4
ACH403	Advanced Methods in Chemical Analysis	4
RP-ACH405	Research Project	6

Semester IV — Major Elective (Choose any one)

Course Code	Course Title	Credits
E-ICH404	Energy and Environmental Chemistry	4
E-OCH404	Applied Organic Chemistry	4
E-PCH404	Surface Chemistry	4
E-ACH404	Applied Analytical Chemistry	4

Detailed Syllabus — M.Sc. Part-II (Semester III), Analytical Chemistry

ACH301: Advanced Analytical Techniques

Course Code: ACH301 | Credits: 4 | Hours: 60 (15 hrs/unit)

Course Outcomes:

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Instrumental Analytical Techniques	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, useful as an analytical chemist and in R&D.
Mass Spectrometry	Acquire knowledge of mass spectrometry, types of MS, ionization types and specific practical applications of MS.
Nanochemistry	Acquire knowledge of the basics of nanochemistry, nanomaterials and nanotechnology, and application-oriented synthesis and characterization of nanomaterials.
Advanced Instrumentation	Gain a wide understanding of the instrumental analytical techniques (SEM, TEM, EDS, STM, AFM, Raman, XFS, ESR, XPS, AES, SIMS etc.) employed for qualitative and quantitative analysis in contemporary research.

Unit I: Advances in Mass Spectrometry — A (15 hrs.)

Sub-topic	Content
Content	Introduction to Mass spectrometry, diagram of a mass spectrometer and instrumentation, principles, history, concept of ion free path, classification of mass spectrometry based on nature of compound to be analyzed and the ion sources viz. Electron impact (EI), chemical ionization (CI), Fast ion or atom bombardment ionization (FID/FAB), field desorption (FD), laser desorption ionization (LDI), plasma desorption ionization (PDI), thermospray ionization (TSI), electrospray (ESI), atmospheric pressure ionization, Inductively coupled plasma (ICP) etc. Mass Analyzers, Quadrupolar Analyzers, Quadrupole ion trap or Quistor, Ion trap detector, development of high-mass, high-resolution ion trap, tandem mass spectrometry in the ion trap, time of flight analyzer, magnetic and electromagnetic analyzer.

Unit II: Introduction to Nanotechnology and Nano Chemistry (15 hrs.)

Sub-topic	Content
Content	Definition of nanomaterials and nanotechnology, significance of nanotechnology, size and properties, types of nanomaterials like 0D (quantum dots), 1D, 2D and 3D, introduction to physical, chemical and biological synthesis of nanomaterials with suitable examples, top-down and bottom-up approach. Chemical synthesis of nanomaterials — different types and processes for synthesis of nanomaterials using wet chemical approaches. Fabricating nanomaterials with different morphology intended for specific applications. Applications of Nanotechnology.

Unit III: Advanced Instrumentation Techniques — A (15 hrs.)

Sub-topic	Content
Content	Scanning Electron Microscope (SEM) — Introduction, principle, instrumentation, applications. Transmission Electron Microscope (TEM) — Introduction, principle, instrumentation, applications. Electron Dispersion Spectroscopy (EDS) — Introduction, principle,

Sub-topic	Content
	instrumentation, applications. Energy Dispersive X-ray Analysis (EDAX) — Introduction, principle, instrumentation, applications. Scanning Tunneling Microscopy (STM) — Introduction, principle, instrumentation, applications. Atomic Force Microscopy (AFM) — Introduction, principle, instrumentation, applications. Practical applications and examples in analytical chemistry and research.

Unit IV: Advanced Instrumentation Techniques — B (15 hrs.)

Sub-topic	Content
Content	Raman Spectroscopy — Introduction, principle, instrumentation, applications. X-Ray Fluorescence Spectroscopy (XFS) — Introduction, principle, instrumentation, applications. Electron Spin Resonance Spectroscopy (ESR) — Introduction, principle, instrumentation, applications. X-Ray Photoelectron Spectroscopy (XPS) — Introduction, principle, instrumentation, applications. Auger Electron Spectroscopy — Introduction, principle, instrumentation, applications. Secondary Ion Mass Spectrometry (SIMS) — Introduction, principle, instrumentation, applications. Practical applications and examples in analytical chemistry and research.

Reference Books:

1. E. De Hoffmann, J. Charette, V. Stroobant, Mass Spectrometry: Principles and Applications, John Wiley & Sons, Masson, Paris, 1996.
2. J. H. Gross, Mass Spectrometry: A Textbook, Springer-Verlag, Berlin, 2004.
3. C. G. Herbert, R. A. W. Johnstone, Mass Spectrometry Basics, CRC Press, Boca Raton, Florida, 2002.
4. K. Benjamin: Mass Spectrometry.
5. A. I. Vogel: A Textbook of Quantitative Inorganic Analysis, Longmans.
6. G. H. Morrison and H. Freiser: Solvent Extraction in Analytical Chemistry, John Wiley, New York, 1958.
7. Willard, Merritt and Settle: Instrumental Methods of Analysis.
8. Principles of Instrumental Analysis — Holler, Skoog and Crouch.
9. Instrumental Methods of Chemical Analysis — H. Kaur.
10. Bhushan, Bharat, 2004. Handbook of Nanotechnology. Springer.
11. Niemeyer, C. M. & Mirkin, C. A., 2004. Nanobiotechnology — Concepts, Applications and Perspectives. Wiley-VCH Verlag.
12. Zander, C., Enderlein, J. & Keller, R. A., 2002. Single Molecule Detection in Solution. Wiley-VCH Verlag.
13. Avouris, P., Klitzing, K. Von, Sakaki, H. & Wiesendanger, R., 2003. NanoScience and Technology Series. Scanning Probe Microscopy — Analytical Methods (R. Wiesendanger, eds), Springer.
14. Instrumental Analysis by Skoog.
15. Nanochemistry, a Chemical Approach to Nanomaterials, G. A. Ozin and A. C. Arsenault, RSC Publishing, Cambridge, 2005. ISBN 0-85404-664-X.

ACH302: Organo Analytical Chemistry**Course Code: ACH302 | Credits: 4 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Analytical–Organic Interface	Gain knowledge of the instruments used at the interface of Analytical–Organic chemistry, useful for R&D and structural elucidation using UV-Visible, IR, ¹ H & ¹³ C NMR, Mass spectrometry data and interpretation of the same.
Drug Analysis	Acquire knowledge about drugs, their classification, sources of impurities (chemical, atmospheric and microbial contamination) in pharmaceutical raw materials, and analysis of the same.
Clinical and Hyphenated Analysis	Gain knowledge about the conventional and advanced analytical approaches for analysis of drugs, vitamins, body fluids and clinical samples.
Pesticide and Forensic Analysis	Gain an idea of commonly used pesticides and their analysis, and also about forensic science and forensic sample analysis.

Unit I — A) Drug Analysis (10 hrs.)

Sub-topic	Content
Content	Introduction to drugs, their classification, sources of impurities in pharmaceutical raw materials such as chemical, atmospheric and microbial contaminants etc. Limit tests: limit test for impurities for Pb, As, Fe, Se, etc. Estimation of moisture (K-F method), halide (Schoniger's oxygen flask method), sulfate, boron, etc. Analysis of commonly used drugs such as antihistamines, sulfa drugs, barbiturates, etc. using non-aqueous titrations, sodium nitrite titrations, differential UV methods, colorimetric and fluorimetric methods of analysis.

Unit I — B) Analysis of Vitamins (05 hrs.)

Sub-topic	Content
Content	Analysis of vitamins (thiamine, ascorbic acid, Vit. A, Vit. B6, Vit. K) — chemical, instrumental and biological assay, wherever applicable.

Unit II: Hyphenated Techniques (15 hrs.)

Sub-topic	Content
Content	Advanced techniques of analysis: UV-Visible, IR, ¹ H-NMR (recapitulation), ¹³ C NMR, mass spectrometry (basic fundamentals of mass spectrometry, ionization, advanced organic analysis examples); problems related to structure determination and applications of spectroscopic techniques as analytical tools.

Unit III: Clinical Analysis (15 hrs.)

Sub-topic	Content
Content	Biological significance, analysis of assay of enzymes (pepsin, monoamine oxidase, tyrosinase). Composition and detection of abnormal levels of certain constituents leading to diagnosis of diseases. Sample collection and preservation of physiological fluids; analytical methods for the constituents of physiological fluids (blood, urine and serum). Blood — estimation of glucose, cholesterol, urea, hemoglobin and bilirubin. Urine — urea, uric acid, creatinine, calcium, phosphate, sodium, potassium and chloride.

Unit IV — A) Pesticides Analysis (07 hrs.)

Sub-topic	Content
Content	Introduction, classification of pesticides, sampling, sample pretreatment and processing, analysis of DDT, gammexane, endosulphan, zinab, ziram, malathion, thiram, thiometon, simazine and chloridane. Applications of colorimetric and chromatographic techniques (GC-MS, HPLC-MS) in analysis of pesticide residue.

Unit IV — B) Forensic Analysis (08 hrs.)

Sub-topic	Content
Content	Special features of forensic analysis, sampling, sample storage, sample dissolution, classification of poisons, lethal dose, significance of LD-50 and LC-50. General discussion of poisons with special reference to mode of action of cyanide, organophosphate and snake venom. Estimation of poisonous materials such as lead, mercury and arsenic in biological samples. Practical applications and examples in analytical chemistry and research.

Reference Books:

1. F. J. Welcher: Standard Methods of Chemical Analysis, 6th Ed., Vol. I and II (D. Van Nostrand Comp.).
2. I. M. Kolthoff: Treatise on Analytical Chemistry, Vol. I & II.
3. F. D. Snell: Encyclopedia of Industrial Chemical Analysis, Vol. 1 to 20 (John Wiley).
4. Reich: Outline of Industrial Chemistry.
5. K. H. Buchel: Chemistry of Pesticides (John Wiley).
6. Indian Pharmacopoeia, British Pharmacopoeia and U.S. Pharmacopoeia.
7. V. M. Parikh: Absorption Spectroscopy of Organic Molecules (Addison Wesley).
8. Willard, Merritt, Dean and Settle: Instrumental Methods of Analysis (CBS).
9. D. H. Williams and J. Fleming: Spectroscopic Methods in Organic Chemistry (McGraw Hill); Silverstein: Spectroscopic Identification of Organic Compounds (John Wiley).
10. Jackman and Sternhill: Applications of NMR Spectroscopy in Organic Chemistry (Pergamon Press).
11. J. D. Roberts: Nuclear Magnetic Resonance (McGraw Hill).
12. K. Benjamin: Mass Spectrometry.
13. Nicholls: Aids to the Analysis of Foods and Drugs.
14. A. H. Beckett and J. B. Stanlake: Practical Pharmaceutical Chemistry, Vol. I & II (CBS Publishers).

ACH303: Electroanalytical Techniques in Chemical Analysis**Course Code: ACH303 | Credits: 4 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Electrochemistry Foundations	Fundamental knowledge of electrochemistry, electrodes, types of electrodes and its construction will lay foundation for the course.
Electroanalytical Techniques	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.
Advanced Electrodes	Become familiar with the advanced electrodes used for chemical analysis, liquid-liquid membrane electrodes, enzyme and gas electrodes.
Electrophoresis	Learn about electrophoretic techniques, advances in electrophoresis techniques and its analytical applications.

Unit I: Voltammetry Techniques (15 hrs.)

Sub-topic	Content
Content	Introduction, principle, excitation signals in voltammetry, basic instrumentation based on operational amplifiers, voltammetric electrodes, modified electrodes. Hydrodynamic voltammetry — electrode profiles in stirred and unstirred solutions, applications. Cyclic Voltammetry: instrumentation, determination of analytes using cyclic voltammetry, applications. Pulse voltammetry: introduction, normal pulse voltammetry, reverse pulse voltammetry, differential pulse voltammetry, square wave voltammetry. Stripping voltammetry: cathodic and anodic stripping voltammetry, electrodeposition step, voltammetric completion of the analysis, adsorptive stripping methods. Voltammetry with microelectrodes. Practical applications in analytical chemistry and research.

Unit II: Coulometry (15 hrs.)

Sub-topic	Content
Content	Introduction: theory and instrumentation, current-voltage relationship, controlled potential coulometry, types of coulometric methods, coulometric titration, and applications. Practical applications in analytical chemistry and research.

Unit III: Particle Size Analysis (15 hrs.)

Sub-topic	Content
Content	Introduction, low angle LASER light scattering: instrumentation, theoretical models, Mie theory, Fraunhofer diffraction theory, particle size distribution analysis, applications. Dynamic Light Scattering: introduction, instrumentation, photodetector sample cell and sample handling, applications. Photosedimentation: settling velocity and particle size, Stokes equation, instrumentation, sedimentation modes, particle size distribution analysis, photometric measurements and applications. Comparison with particle size measurements using XRD, SEM and TEM. Practical applications in analytical chemistry and research.

Unit IV — A) Ion Selective Electrodes (10 hrs.)

Sub-topic	Content
Content	Terminology, types and construction of electrodes, glass electrode, solid state and precipitate electrodes, liquid-liquid membrane electrodes, enzyme and gas electrodes, and applications.

Unit IV — B) Electrophoresis (05 hrs.)

Sub-topic	Content
Content	Introduction: paper electrophoresis — technique, factors affecting migration of ions, capillary and zone electrophoresis and applications. Practical applications in analytical chemistry and research.

Reference Books:

1. R. D. Braun, Introduction to Instrumental Analysis.
2. D. A. Skoog, F. J. Holler, Principles of Instrumental Analysis, 6th edition.
3. Willard, Merritt, Dean and Settle, Instrumental Methods of Analysis.
4. F. J. Welcher, Standard Methods of Chemical Analysis, Vol. 3, Part A & B.
5. G. W. Ewing, Instrumental Methods of Analysis, 4th and 5th editions.
6. Chatwal and Anand, Instrumental Methods of Analysis.
7. Bassett, Denney, Jeffery and Mendham, Vogel's Textbook of Quantitative Inorganic Analysis, 5th edition.
8. Electro-analytical Chemistry, edited by H. W. Nurnberg.
9. Stulic, Ion Selective Electrodes (John Wiley).

PR-ACH305: Analytical Chemistry Practicals-V**Course Code: PR-ACH305 | Credits: 2 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Hands-on Analytical Training	Acquire hands-on training for conducting representative experiments for the analysis of a wide variety of samples of inorganic, organic and physical approaches by qualitative and quantitative analysis.
Sample Preparation	Learn the sample preparation and characterization for purity, and qualitative and quantitative analysis of samples.
Metal/Ion Estimation	Gain good experimental skills for separation and estimation of the amount of metal / metal ions in given samples.
Organic Compound Estimation	Become acquainted with the separation and estimation of organic compounds in given samples.

Major Experiments

1. Estimation of Sn, Cu and Pb from Bronze/Brass alloy (volumetric, gravimetric or colorimetric techniques can be used).
2. Analysis of Galena ore.
3. Analysis of Benzoic acid and salicylic acid from medicated powder.
4. Estimation of Aspirin.
5. Determination of pK value of an indicator.
6. Cement analysis.
7. Analysis of bauxite ore to estimate the amount of silica, aluminium and iron.
8. Estimation of salicylic acid and zinc oxide from medicated powder.
9. Determination of saponification value and iodine value of oil.
10. To determine stability constant of Ferric ammonium sulphate and sulphosalicylic acid by Job's variation method.
11. Studies on effect of substituent at ortho position of benzoic acid on its equilibrium constant pH-metrically.
12. Simultaneous spectrophotometric determination of Cr and Mn.
13. Analysis of milk.

Minor Experiments

1. Analysis of plaster of Paris for calcium content.
2. Estimation of copper fungicide.
3. Analysis of sulpha drug.
4. Analysis of vitamin-C in juices and squashes.
5. Analysis of ethambutol.
6. Identification of organic compounds by their IR spectra.

7. Determination of strength of acetic acid in commercial vinegar by conductometric method.
8. Determination of chloride content from saline water by potentiometry.
9. Estimation of bicarbonate and carbonate by potentiometric method.
10. Determination of pK of given dibasic acid pH-metrically.
11. Determination of pK of given dibasic acid potentiometrically.
12. Estimation of Fe from soil sample.
13. Analysis of Na and K from soil sample.
14. To estimate the amount of barium from given water sample by nephelometry.
15. To determine the ion exchange capacity of active group of given cation exchange resin.
16. Estimation of lactose from milk sample using flame photometer.
17. To determine the amount of alkali content of antacid tablet titrimetrically.
18. Determination of pK value of tribasic acid by potentiometry.
19. Estimation of acetylsalicylic acid in the given aspirin tablet by titrating against 0.1N alcoholic KOH potentiometrically.
20. To determine the acid-base dissociation constant and isoelectric point of amino acid pH-metrically.

Note: Students should perform their practical work in the laboratory for a minimum of 15 days in one semester for 2 credits.

RP-ACH306: Research Project (4 Cr, 120 Hrs)

See the Research Project Paper Guidelines (Semester III) section later in this document for full details.

Detailed Syllabus — M.Sc. Part-II (Semester IV), Analytical Chemistry

ACH401: Modern Separation Method in Analysis

Course Code: ACH401 | Credits: 4 | Hours: 60

Course Outcomes:

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Separation & Chromatographic Methods	Learn about modern separation and chromatographic methods used for analysis of different types of samples.
Instrumentation & Mechanism	Understand the instrumentation and mechanism of various separation techniques.
Instrument & Detector Selection	Acquire knowledge regarding the choice of instrument and detectors to be used for analysis depending on the sample and matrix.
Extraction Chromatography	Learn the fundamentals of extractive chromatography, types of extraction techniques, advances in extraction methods, and their hyphenation with chromatography for addressing challenging problems in analytical chemistry.

Unit I: Advanced Gas Chromatographic Techniques (15 hrs.)

Sub-topic	Content
Content	Principles, plate theory, instrumentation and working of a Gas Chromatograph, sampling, sample pretreatment, sample injection types, columns, detectors, programmed temperature G.C., applications. Gas Chromatography-Mass Spectrometry: interface, instrumentation and applications. Practical applications and examples in analytical chemistry and research.

Unit II: Advanced Liquid Chromatographic Techniques (15 hrs.)

Sub-topic	Content
Content	High Performance Liquid Chromatography (HPLC) and Ultra Performance Liquid Chromatography (UPLC) — principle, instrumentation, mobile phase, stationary support in HPLC, detectors and applications. Super critical fluid chromatography (SCFC): characteristics, instrumentation and applications. Comparison of HPLC and GLC with SCFC. Liquid Chromatography-Mass Spectrometry interface, instrumentation, advantages and applications. Practical applications and examples in analytical chemistry and research.

Unit III: Ion Chromatography (15 hrs.)

Sub-topic	Content
Content	Principles, structure and characteristics of resins, eluent, suppressor columns and detectors used in Ion Chromatography, commercial scope, analytical applications, environmental speciation by Ion Chromatography. Practical applications and examples in analytical chemistry and research.

Unit IV — A) Modern Extraction and Separation Techniques (08 hrs.)

Sub-topic	Content
Content	Basic principles, classification of solvent extraction systems, extraction equilibria, factors affecting extraction process, application of β -diketones, 8-hydroxyquinoline, dithiocarbamates, xanthates, thio-compounds, separation of nonmetals and metals.

Unit IV — B) Extractive Chromatographic Separations (07 hrs.)

Sub-topic	Content
Content	Introduction, theoretical aspects of extraction chromatography, extraction chromatography with chelating ligands, extraction chromatography by ion-pair formation, extraction chromatography by solvation, extraction equilibria, nature of stationary phase in extraction chromatography, inert support, techniques in extraction chromatography. Practical applications and examples in analytical chemistry and research.

Reference Books:

1. A. I. Vogel, A Text Book of Quantitative Inorganic Analysis.
2. W. H. Willard, L. L. Merritt and J. A. Dean, Instrumental Methods of Analysis.
3. S. M. Khopkar, Basic Concepts in Analytical Chemistry.
4. L. R. Snyder and C. H. Horvath, An Introduction to Separation Science, Wiley Interscience.
5. James S. Fritz and George H. Schenk Jr., Quantitative Analytical Chemistry, 2nd edition, Allyn and Bacon Inc., Boston.
6. J. G. Dick, Analytical Chemistry.
7. R. L. Pescok and L. D. Shield, Modern Methods of Chemical Analysis.
8. O. Samuelson: Ion Exchange Separation in Analytical Chemistry (John Wiley, 1963).
9. Y. Marcus and A. S. Kertes: Ion Exchange and Solvent Extraction of Metal Complexes (Wiley-Interscience, 1969).
10. J. A. Marinsky and Y. Marcus: Ion Exchange and Solvent Extraction (Marcel Dekker Inc., New York, 1973).
11. G. H. Morrison and H. Freiser: Solvent Extraction in Analytical Chemistry (John Wiley, New York, 1958).
12. A. K. De, S. M. Khopkar and R. A. Chalmers: Solvent Extraction of Metals (Von Nostrand Reinhold, 1970).

ACH402: Organic Industrial Analysis**Course Code: ACH402 | Credits: 4 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Oils, Fats & Detergents	Acquire knowledge of handling and investigating the characteristics of oils, fats, detergents and soap samples and analysis of the same, providing opportunity in cosmetic, pharmaceutical, dyes and polymer industries.
Food Quality & Adulteration	Gain knowledge and importance of food quality; probe for food adulteration and adulterants, food preservatives, food flavors, and analysis of their components.
Animal Food Additives	Gain knowledge about animal food stuff and additives added to it — antibiotics, dietary supplements, growth-promoting drugs, preservatives etc. — and analysis of the same.
Cosmetics, Paints & Petroleum	Learn about the analysis of cosmetics, face powder, hair dyes and hair care products, and their composition; acquire knowledge about paints, pigments and petroleum products, their composition and analysis using conventional and instrumental techniques.

Unit I — A) Analysis of Oils and Fats (08 hrs.)

Sub-topic	Content
Content	Introduction to natural fats and oils; isolation of oils from natural resources and their purification. Analysis of oils and fats: softening point, congeal point, titre point, cloud point, iodine value, saponification value, etc.

Unit I — B) Analysis of Detergents (07 hrs.)

Sub-topic	Content
Content	Classification of detergents, analysis of raw materials, separation as alcohol-soluble and alcohol-insoluble matter, additives in detergent formulation (chlorides, sulfates, phosphates, silicates, borates, oxygen-releasing substances, CMC, EDTA, etc.), their role and analysis; analysis of active ingredients in detergents (methylene blue and Hyamine-1622 method).

Unit II — A) Food Analysis (08 hrs.)

Sub-topic	Content
Content.	Food flavors, food colors, food preservatives, analysis of milk and milk products, adulterants in milk and their identification, analysis of honey, jam and their major components. Practical applications and examples in analytical chemistry and research.

Unit II — B) Food Additive Analysis (07 hrs.)

Sub-topic	Content
Content	Additives in animal food stuff: antibiotics — penicillin, chlorotetracycline, oxytetracycline in diet supplements; identification and estimation of growth-promoting drugs such as sulfaquinoxaline, methyl benzoate, sulfanitran, pyrimethamine, nitrovin, nitrofurazone, acinitrazole, etc.

Unit III: Analysis of Cosmetics Products (15 hrs.)

Sub-topic	Content
Content	Introduction to cosmetics, definition, types of cosmetics, background and development in the cosmetic industry. A) Analysis of cream and lotions (8 hrs.): composition of creams and lotions, determination of water, propylene glycol, non-volatile matter and ash content; estimation of borates, carbonates, sulphates, phosphates, chlorides, ammonia, nitromethane, oxalic acid, 4-hydroxy benzoic acid, sodium iodate, H₂O₂, mercaptoacetic acid, titanium and zinc oxides. Practical applications and examples in analytical chemistry and research. B) Analysis of face powder (7 hrs.): composition of face powder, estimation of boric acid, Mg, Ca, Zn, Fe, Al and Ba. Analysis of deodorants and antiperspirants — composition, titanium, aluminium, phenol, methenamine, hexachlorophene, sulphonates, urea, etc. Practical applications and examples in analytical chemistry and research.

Unit IV — A) Analysis of Paints and Pigments (08 hrs.)

Sub-topic	Content
Content	Composition of paint, preliminary inspection of sample, tests on the total coating, separation and estimation of pigments, binder and thinner of latex paints; modification of binder, flash point of paints. Practical applications and examples in analytical chemistry and research.

Unit IV — B) Analysis of Petroleum Products (07 hrs.)

Sub-topic	Content
Content	Introduction, constituents and petroleum fractionation, quality control — specific gravity, viscosity, cloud point, pour point, flash point, vapor pressure, Doctor test, sulphuric acid absorption, aniline point and colour determination. Determination of water, neutralization value (acid and base numbers), ash content, sulphur and mercaptan sulphur. Determination of lead in petroleum; analysis of coal and coke — types, composition, preparation of sample, proximate and ultimate analysis, calorific value by bomb calorimetry.

Reference Books:

1. S. R. Junk and H. M. Pancoast: Handbook of Sugars (AVI).
2. B. Bilot and B. V. Well: Perfumery Technology (JW).
3. I. M. Kolthoff: Treatise on Analytical Chemistry, Vol. I and II.
4. D. Pearson: Laboratory Techniques in Food Analysis.
5. S. Ranganna: Handbook of Analysis and Quality Control for Fruits and Vegetable Products, 2nd Ed. (McGraw Hill).
6. Nicholls: Aids to the Analysis of Foods and Drugs.
7. G. J. Mountney: Poultry Product Technology (AVI).
8. Karamer Twig: Quality Control for Food Industry (AVI).
9. G. F. Longonan: The Analysis of Detergents and Detergent Products (JW).
10. A. Davidsohn & B. M. Milwidsky: Synthetic Detergents (Book Center, Mumbai).
11. M. Ash and L. Ash: A Formulary of Cosmetic Preparations (G. Goodwin).
12. Kurl Bauer, Dorothea Garbe, Horst Surburg: Common Fragrance and Flavour Materials (VCH Publisher, New York).
13. F. J. Welcher: Standard Methods of Chemical Analysis, Vol. I & II (6th Ed.).
14. S. N. Mahendru: Analysis of Food Products (Swan Publishers).

ACH403: Advanced Methods in Chemical Analysis**Course Code: ACH403 | Credits: 4 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Luminescence Techniques	Become skilled in the techniques like fluorescence, phosphorescence, types of quenching, FRET and applications of the same in analytical chemistry and for addressing research problems.
Kinetic Methods	Gain knowledge of the kinetic methods of analysis supporting the analysis and data procured in research.
Advanced Spectroscopic Methods	Acquire the knowledge of advanced methods of chemical analysis — XPS, XRF, fluorescence and phosphorescence spectroscopy — which will be beneficial in research.
Plastics Analysis	Acquire knowledge of identifying types of plastic and determination of metallic impurities in plastics.

Unit I: Fluorescence and Phosphorescence Spectrophotometry (15 hrs.)

Sub-topic	Content
Content	Fluorimetry, types of luminescence, instrumentation, theories of fluorescence and phosphorescence, electronic transition, structural factors, solvatochromism, solvation dynamics, fate of excited molecules, solvent effect on fluorescence, effect of intermolecular process, fluorescence anisotropy and time-domain fluorescence lifetime measurements. Relation between concentration with fluorescence and phosphorescence intensity, fluorescence quenching mechanism, resonance energy transfer, chemiluminescence, fluorescence sensing, synchronous spectrum, fluorescent nanomaterials. Practical applications, examples and problems in analytical chemistry and research.

Unit II: Kinetic Methods (15 hrs.)

Sub-topic	Content
Content	Theoretical basis of kinetic methods of analysis, methods of determining amount of the substance — tangent method, fixed time and concentration method, addition method, oxidation reactions of H ₂ O ₂ with thiosulphate, iodide and amine, enzyme-catalyzed reactions, inhibitors and activators.

Unit III: Photoelectron Spectroscopy (15 hrs.)

Sub-topic	Content
Content	Basic principles, photoelectric effects, photoionization process, Koopman's theorem, photoelectron spectra of simple molecules, ESCA, chemical shift, Auger electron spectroscopy — basic idea.

Unit IV: X-ray Spectroscopy (15 hrs.)

Sub-topic	Content
Content	Introduction, X-ray generation, properties of X-radiation, interaction of X-rays with matter, instrumentation. X-Ray Absorption, X-ray Fluorescence, X-ray Diffraction methods — instrumentation and analytical applications.

Reference Books:

1. Gary D. Christian, Analytical Chemistry, 6th edition, John Wiley and Sons Inc. (2003).
2. H. Kaur, Instrumental Methods of Chemical Analysis, Pragati Prakashan, Meerut.
3. W. H. Willard, L. L. Merritt and J. A. Dean, Instrumental Methods of Analysis.
4. S. M. Khopkar, Basic Concepts in Analytical Chemistry.
5. D. Skoog and D. West, Principles of Instrumental Analysis, Holt Saunders.
6. E. Berlin, Principles and Practice of X-Ray Spectrometric Analysis, Plenum, New York.
7. J. Winefordner, S. Schulman and T. O'Haver: Luminescence Spectrometry in Analytical Chemistry, Wiley Interscience, New York.
8. Engineering Chemistry, R. Gopalan, G. S. Nagrajan.
9. Engineering Chemistry, B. K. Sharma.

NOTE: Study tour is compulsory for M.Sc. Part-II students to visit Chemical Industries in India.

See Annexure-I for details.

[Note 3:; note that no 'Annexure-I' is actually included anywhere in the source file provided, so its content could not be reproduced.]

RP-ACH405: Research Project (6 Cr, 180 Hrs)

See the Research Project Paper Guidelines (Semester IV) section later in this document for full details.

Major Elective Papers

Students of Inorganic / Organic / Physical / Analytical / Applied / Industrial Chemistry shall choose any one of the following elective papers, as applicable to each semester.

[Note 4: The document provided by you gives full unit-by-unit detail only for the Analytical-specific Semester III elective (E-ACH304). The other three Semester III electives (E-ICH304, E-OCH304, E-PCH304) are named in the course-structure table but their detailed unit-wise content is not included — Please Look into it.]

E-ACH304: Environmental Chemical Analysis and Control (Semester III Elective)

Course Code: E-ACH304 | Credits: 4 | Hours: 60

Course Outcomes:

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Sampling	Acquire knowledge about sampling, criteria of good sampling, handling, preservation and storage of samples, pre-treatment and post-treatment of samples.
Electrochemical & Spectral Analysis	Acquire knowledge of conditions and strategies required during sampling, and electrochemical and spectral methods for analysis of environmental samples.
Air & Water Pollution	Learn about air and water pollution, sources of pollution, and typical parameters and properties (physical, chemical and biological) to be measured, with relevance to specific case studies.
Organic Pollutants	Become acquainted with organic pollutants and their analysis, with special reference to pesticide analysis.

Unit I: Sampling in Analysis (15 hrs.)

Sub-topic	Content
Content	Definition, theory and techniques of sampling, sampling of gases, liquids and solids, criteria of good sampling, minimization of variables, transmission and storage of samples, high pressure ashing techniques (HPAT), particulate matter, its separation in gas stream, filtering and gravity separation. Analysis of particulate matter like asbestos, mica, dust and aerosols etc.

Unit II: Electrochemical and Spectral Methods — Environmental Analysis (15 hrs.)

Sub-topic	Content
Content	Introduction to instrumental techniques, principle, instrumentation and applications with respect to environmental analysis of Conductometry, Potentiometry, Ion selective electrodes, Cyclic voltammetry, Amperometry, Coulometry, Atomic absorption spectrometry, Atomic fluorescence spectrometry, Inductively coupled plasma spectrometry, Turbidimetry, Non-Dispersive Infrared Analysis (NDIR).

Unit III: Air and Water Pollutant Analysis (15 hrs.)

Sub-topic	Content
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Sub-topic	Content
Content	Chemistry of air pollutants, characterization, source, methods of analysis of air pollutants: CO, CO ₂ , NO _x , NH ₃ , H ₂ S, SO ₂ etc. Monitoring instruments; potable and industrial water, major and minor components, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and their measurements. Analysis of Pb, Cd, Hg, Cr, As and their physiological manifestations. Quality of industrial wastewater analysis for organic and inorganic constituents. Chemistry of odour and its measurement.

Unit IV: Organic Pollutants and Their Analysis (15 hrs.)

Sub-topic	Content
Content	Sources, disposal, treatment and analysis of phenolic residues, methods of recovery of phenols from liquid effluents, organomercurials and its analysis, analysis of organochlorine pesticides, volatile organic pollutants and their analysis.

Reference Books:

1. A. K. De: Standard Methods of Waste and Wastewater Analysis.
2. P. M. S. Monk: Fundamentals of Electroanalytical Chemistry, John Wiley & Sons (2001).
3. Instrumental Methods of Chemical Analysis, H. Kaur.
4. S. M. Khopkar, Environmental Chemistry; Environmental Pollution Analysis.
5. M. S. Cresser and Morr, Environmental Chemical Analysis, American Publication (1988).
6. A. K. De, Environmental Chemistry, New Age International Publishers.
7. Moghe and Ramteke, Water and Wastewater Analysis: (NEERI).
8. A. C. Stern, Air Pollution: Engineering Control, Vol. IV (AP).
9. P. N. Cheremisinoff and R. A. Young, Air Pollution Control and Design Handbook, Vol. I & II (Dekker).
10. R. B. Pohasek, Toxic and Hazardous Waste Disposal, Vol. I & II (AAS).
11. M. Sittig, Resources Recovery and Recycling, Handbook of Industrial Waste.
12. B. K. Sharma, Industrial Chemistry.
13. S. P. Mahajan, Pollution Control in Process Industries.
14. R. A. Horne, Chemistry of our Environment.

E-ICH404: Energy and Environmental Chemistry (Semester IV Elective)**Course Code: E-ICH404 | Credits: 4 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Solid Waste Management	Learn basic concepts of solid waste management, from source generation to waste disposal.
Waste Characterization	Characterize solid waste in terms of hazardous waste components; understand the impact of waste management on health and environment, and steps towards solid waste management — reduction at source, recovery/recycling, treatment and disposal techniques.
Energy Conversion Devices	Explain advanced energy conversion devices such as fuel cells, and the various techniques involved in the production of hydrogen (a future fuel).
Energy Storage Devices	Demonstrate the reactions involved in advanced energy storage devices, predict the theoretical energy storage capacities of such devices, and understand the chemistry of various batteries.

Unit I: Energy Conversion Devices (15 hrs.)

Sub-topic	Content
Content	Fuel Cells: working of fuel cells, types of fuel cells, current capabilities/uses, fuel cell stacks and systems, hydrogen as a fuel. Production of hydrogen: electrolysis, thermochemical processes, steam reformer processes, water gas processes, Bosch process, biosynthesis and photochemical processes, coal gasification, steam iron process, partial oxidation processes. Storage, transport and handling of hydrogen.

Unit II: Energy Storage Devices — Batteries (15 hrs.)

Sub-topic	Content
Content	Li-ion batteries: principle of operation, battery components and design, electrode materials (LiCoO ₂ , LiNiO ₂ , LiNi _{1/3} Mn _{1/3} Co _{1/3} O ₂ , LiMn ₂ O ₄ , LiFePO ₄ , graphitic carbon), their synthesis and characterization, theoretical capacity, energy density, power density, cycle life, electrode and battery fabrication, battery modules and packs. Li-polymer batteries and applications, electrolytes for Li-ion batteries, all-solid-state batteries. Future developments and beyond-lithium batteries: Li-S battery, Li-Air battery, advanced lead-acid batteries, sodium battery, magnesium battery, aluminium battery, silicon battery, battery recycling technologies.

Unit III — A) Waste Treatment (08 hrs.)

Sub-topic	Content
Content	Electronic waste recycling programs, e-waste — non-recycling impacts, materials used in manufacturing electrical and electronic products, solid waste management: gas-to-energy projects, incandescent vs. compact fluorescent light bulbs, value-added material recovery, cost-effective treatment of refractory organics.

Unit III — B) Air and Water Pollution Control (07 hrs.)

Sub-topic	Content
Content	Control of NO _x , SO _x and particulate pollution, sewage and industrial wastewater treatment, water softening, municipal water purification.

Unit IV — A) Monitoring, Sampling and Analysis of Air and Water Pollutants (08 hrs.)

Sub-topic	Content
Content	Methods of monitoring and sampling of gaseous, liquid and solid pollutants, analysis of CO, CO ₂ , NO ₂ , SO ₂ , H ₂ S, analysis of toxic heavy metals — Cd, Cr, Hg, As, Pb, analysis of anions SO ₄ ²⁻ , PO ₄ ³⁻ , NO ₃ ⁻ , estimation of COD and BOD.

Unit IV — B) Techniques in Environmental Analysis (07 hrs.)

Sub-topic	Content
Content	ND-IR Spectroscopy, FTIR, AAS, ICP-AES, GC, GC-MS, HPLC, Anodic Stripping Voltammetry, with case studies.

Reference Books:

1. Lithium Ion Batteries: Basics and Applications, R. Korthauer, Springer.
2. Lithium Ion Batteries: Fundamentals and Applications, Yuping Wu, CRC Press, Taylor & Francis Group.
3. Lithium Ion Batteries: Materials, Technology and New Applications, K. Ozawa, Wiley.
4. 30 Years of Lithium-Ion Batteries, Advanced Materials, M. Li et al., Vol. 30, Issue 33, 2018, 1800561.
5. Fuel Cell Fundamentals, R. O'Hayre et al., John Wiley & Sons, 2016.
6. George Tchobanoglous et al., Integrated Solid Waste Management, McGraw-Hill, 1993.
7. Environmental Chemistry, H. Kaur, Pragati Prakashan, 10th edition, 2016.
8. Environmental Pollution, A. K. De.
9. Environmental Pollution Analysis, S. M. Khopkar.
10. Compendium of R&D Projects, Waste Management Technologies (WMT) Programme, Technology Development and Transfer Division, Department of Science and Technology, New Delhi, 2018–2019.
11. Environmental Waste Management, Ed. Ram Chandra, CRC Press, 2015, 1st Edition.
12. Electronic Waste Management, RSC Publishers, Editors: R. E. Hester, R. M. Harrison, 2009.

E-OCH404: Applied Organic Chemistry (Semester IV Elective)**Course Code: E-OCH404 | Credits: 4 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Agrochemicals	Learn about the synthesis and uses of different types of agrochemicals such as carbamates and organophosphorous insecticides, and natural and synthetic pyrethroids; learn the synthesis of some plant growth regulators as well as applications of juvenile hormones and pheromones.
Perfumery	Learn about perfumery compounds, commercial processes, preparation and importance of essential oils; learn the synthesis of 2-phenylethanol, yara-yara, vanillin, synthetic musk, jasmine, ionone etc. from citral, phenylacetate ester and benzyl acetate ester.
Dyes	Understand the classification and synthesis of azo dyes, reactive dyes, optical brighteners and dispersed dyes.
Polymers	Understand the mechanism of polymerization; study the manufacturing processes of synthetic rubber, plasticizers, and anti-oxidants required for natural polymers like starch and cellulose; gain knowledge about the Oxo and Wacker processes necessary for soap and synthetic detergents.

Unit I — A) Agrochemicals (07 hrs. (part of 15 hrs.))

Sub-topic	Content
Content	(i) Organochlorine pesticides: introduction, synthesis, and mode of action of endrin, aldrin, dieldrin. (ii) Herbicides: synthesis and mode of action of triazines, triazoles, pyridazinones, and bipyridylum compounds — diquat, paraquat. (iii) Juvenile hormone: introduction and structures, JHA importance, synthesis, IPM.

Unit I — B) Synthesis and Applications of Perfumery (08 hrs. (part of 15 hrs.))

Sub-topic	Content
Content	2-Phenylethanol, vanillin, and other food flavors, synthetic musk, and ionones.

Unit II: Unit Processes (15 hrs.)

Sub-topic	Content
Content	Introduction to unit operations and unit processes. Nitration: introduction, nitrating agents, kinetics and mechanism, oxynitration, typical industrial nitration process. Amination: introduction, Bechamp reduction. Halogenation: introduction, kinetics and mechanism, catalytic chlorination, manufacturing process for chlorobenzene and monochloroacetic acid. Sulfonation: introduction, sulphonating agents, kinetics and mechanism, manufacturing process for benzene sulphonic acid.

Unit III: Dyes and Intermediates (15 hrs.)

Sub-topic	Content
Content	Classification and synthesis of important dye intermediates using nitration, sulphonation, diazotization reactions. Synthesis of nitro dyes, xanthenes, reactive dyes, fluorescent brightening agents, thermal-sensitive

Sub-topic	Content
	dyes, dispersed dyes and reactive dyes.

Unit IV: Polymers (15 hrs.)

Sub-topic	Content
Content	Mechanism of polymerization. Industrial process for synthesis of polyethylene, acrylonitrile, acrylate and methacrylate polymer, biomedical polymer, polymer processing, plasticizers and anti-oxidants for polymers.

Reference Books:

1. Allan: Colour Chemistry.
2. K. Venkataraman: Chemistry of Synthetic Dyes, Vol. 1 to 7.
3. G. R. Chatwal: Synthetic Dyes.
4. Abrahart: Dyes & Their Intermediates.
5. N. N. Melikov: The Chemistry of Pesticides and Formulations.
6. K. H. Buchel: Chemistry of Pesticides.
7. R. Cremlyn: Pesticides.
8. H. R. Alcock and F. W. Lambe: Contemporary Polymer Chemistry.
9. J. M. G. Cowie, Blackie: Physics & Chemistry of Polymers.
10. I. M. Campbell: Introduction to Synthetic Polymers.
11. A. L. Gupta: Polymer Chemistry.
12. M. S. Bhatnagar: A Textbook of Polymers.
13. F. W. Billmeyer: Textbook of Polymer Science.

E-PCH404: Surface Chemistry (Semester IV Elective)

E-PCH404 — Surface Chemistry

Course Code: E-PCH404 | Credits: 4 | Hours: 60

Unit I: Surface Chemistry of Interfaces (15 hrs.)

Sub-topic	Content
Content	Types of interfaces, liquid-vapour interface, surface tension and interfacial tension, surface tension across curved surfaces, capillary action, methods of determination of surface tension, vapor pressure of droplet (Kelvin equation), surface activity and adsorption phenomenon, Traube's rule, liquid-liquid interfaces, work of cohesion and adhesion. Surface spreading: spreading of one liquid on the surface of another liquid, spreading coefficient and derivation for its relation with surface tension, surface films on liquids, criteria for spreading of one liquid on another. Experimental techniques for the study of monomolecular films, states of monomolecular films, reactions on monomolecular films, heterogeneous catalysis.

Unit II: Solid-Liquid and Solid-Solid Interfaces (15 hrs.)

Sub-topic	Content
Content	Solid-liquid interfaces: introduction, wetting phenomenon, contact angle and wetting, heat of wetting, methods of determination of contact angle, contact angle hysteresis, wetting agents, selective wetting, applications in detergency and pesticide effectivity. Solid-solid interfaces: introduction, surface energy of solids, adhesion and adsorption, sintering and sintering mechanism, Tammann temperature, importance of impurities, surface structure and surface composition. Friction and lubrication, mechanism of lubrication, solid-state lubricants.

Unit III: Solid-Gas Interfaces (15 hrs.)

Sub-topic	Content
Content	Adsorption, mechanism of adsorption, adsorption of gases by solids, surface area measurement, factors affecting adsorption, experimental methods of determining gas adsorption, adsorption of solutes from solution, heat of adsorption, measurement of heat of adsorption. Chemisorption: kinetics of chemisorption, heat of chemisorption, surface film. Catalysis of gas reactions by solid surfaces — one reactant gas slightly/strongly/moderately adsorbed, retarded reaction, ion exchange adsorption, applications.

Unit IV: Colloids and Emulsion (15 hrs.)

Sub-topic	Content
Content	Colloidal solution, classification of colloids, theories of origin of charge on sol particles, determination of charge on a colloidal particle, stability of sols, properties of colloids, spontaneous ageing of colloids, factors affecting spontaneous ageing, theories of spontaneous ageing, coagulation, kinetics of coagulation. Emulsion: types of emulsion, preparation, properties, characteristics, identification test between two types of emulsions, emulsifiers, demulsification. Gels: classification, methods for the preparation of gels, properties of gels, applications of colloids.

Course Outcomes:

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Interfaces	Understand concepts of solid-liquid, solid-gas, and liquid-gas interfaces.
Interfacial Processes	Apply fundamental principles of chemistry to chemical processes occurring at interfaces.
Spectroscopic Study of Interfaces	Apply spectroscopic methods to study interfaces and interfacial phenomena.
Surface Chemistry Fundamentals	Learn and understand the importance, applications and basic aspects of surface chemistry.
Solid-Gas Interfaces	Focus on the fundamentals of surface chemistry, with the main

Topic	Expected Course Outcome
	emphasis on solid surfaces in contact with the gas phase.
Adsorption & Colloids	Apply knowledge of adsorption, desorption and colloidal applications of surface chemistry in understanding and designing surface chemistry processes.

Reference Books:

1. Physical Chemistry of Surfaces: A. W. Adamson.
2. Introduction to Colloid and Surface Chemistry by D. J. Shaw.
3. Surface Chemistry by J. J. Bikerman.
4. The Surface Chemistry of Solids, by S. J. Gregg, Second Edition, Chapman & Hall Ltd., London.
5. Advanced Physical Chemistry, by Gurdeep Raj, Goel Publishing House, Krishna Prakashan Media (P) Ltd., Meerut.
6. Physical Chemistry by Pahari S., New Central Book Agency (P) Ltd., Kolkata.
7. Advanced Physical Chemistry, J. N. Gurtu, A. Gurtu, 11th Edition, Pragati Prakashan.
8. Advanced Physical Chemistry, D. N. Bajpai, S. Chand Publications.
9. Essentials of Physical Chemistry by Arun Bahl, B. S. Bahl, G. D. Tuli, S. Chand Publications.
10. Principles of Physical Chemistry by S. H. Maron and C. F. Prutton.
11. Physical Chemistry, P. W. Atkins.

E-ACH404: Applied Analytical Chemistry (Semester IV Elective)**Course Code: E-ACH404 | Credits: 4 | Hours: 60****Course Outcomes:**

After successful completion of this course, the students will be able to:

Topic	Expected Course Outcome
Metals, Alloys, Minerals & Ores	Acquire knowledge of analysis of metals, alloys, minerals and ores commonly used in industry.
Real-Sample Analysis	Become 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.
Commercial Materials	Gain knowledge of analysis of commercial materials — explosives, polymers, resins, rubber, luminescent paints, lubricants and adhesives.
Industrial QA-QC Employability	Gain opportunities for employment in industries for quality assurance and quality control (QA-QC) of the product.

Unit I: Spectrochemical Methods of Analysis (15 hrs.)

Sub-topic	Content
Content	Introduction to spectrochemical methods. Electronic spectra and molecular structure, NIR spectrometry for non-destructive testing. Solvents for spectrometry, FTIR spectrometer, fluorometry, optical sensors. Analysis of ores — bauxites, dolomites, monazites.

Unit II: Analysis of Metals and Alloys (15 hrs.)

Sub-topic	Content
Content	Foundry materials, ferroalloys and special steels, slags, fluxes. Analysis of alloys — bronze, brass, Alnico and Nichrome.

Unit III: Analysis of Soil and Fertilizers (15 hrs.)

Sub-topic	Content
Content	Methods of soil analysis, soil fertility and its determination, determination of inorganic constituents of plant materials, chemical analysis as a measure of soil fertility, analysis of fertilizers, applications.

Unit IV: Analysis of Commercial Materials (15 hrs.)

Sub-topic	Content
Content	Analysis of explosive materials — TNT, RDX, lead azide, EDNA (ethylene dinitramine). Analysis of conducting polymer, resins and rubber. Analysis of luminescent paints. Analysis of lubricants and adhesives.

Reference Books:

1. Hillebrand, Lundell, Bright and Hoffman, Applied Inorganic Analysis, John Wiley.
2. Snell and Biffen, Commercial Methods of Analysis.

3. P. G. Jeffery, Chemical Methods of Rock Analysis, Pergamon.
4. Buchel, Chemistry of Pesticides, J. Wiley.
5. Rieche, Outlines of Industrial Organic Chemistry, Butterworth.
6. F. A. Henglein, Chemical Technology, Pergamon.
7. Kent, Riegel's Industrial Chemistry, Reinhold.
8. Chopra and Kanwar, Analytical Agriculture Chemistry, Kalyani Publishers.
9. Aubert and Pinta, Trace Elements in Soils.
10. Bear, Chemistry of Soil.
11. Hauson, Plant Growth Regulators, Noyes.
12. P. G. Jeffery and D. J. Hutchinson, Chemical Methods of Rock Analysis.
13. F. J. Welcher, Standard Methods of Chemical Analysis, A Series of Volumes, Robert E. Krieger Publishing Company.
14. I. M. Kolthoff and P. J. Elving, Treatise on Analytical Chemistry, A Series of Volumes.
15. R. D. Reeves and R. R. Brooks, Trace Element Analysis of Geological Materials, John Wiley & Sons, New Delhi.
16. W. M. Johnson and J. A. Maxwell, Rock and Mineral Analysis, John Wiley and Sons, New York.
17. W. F. Hildebrand, G. E. F. Lundell and H. A. Bright, Applied Inorganic Analysis, John Wiley, 2nd Ed.
18. K. J. Das, Pesticide Analysis (MD).

Research Project Paper Guidelines for All Specializations

(Inorganic, Organic, Physical, Analytical, Applied and Industrial Chemistry)

Semester III — RP-ICH306, RP-OCH306, RP-PCH306, RP-ACH306, RP-APCH306, RP-INDCH306

Credits: 04 | Hours: 120 | Marks: 100

- The students should write a synopsis of the proposed research work.
- The students should perform a detailed literature survey related to the research problem.
- The students should write a review article related to the research problem.
- It is expected to publish the review article either in a Shivaji University journal or a peer-reviewed journal.
- 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 is to be continued in Semester IV.
- The student should submit a spiral-bound copy of research work carried out during Semester III, including the synopsis, research proposal, review article and certified progress report.
- The Research Project will be examined jointly by internal and external examiners during the practical examination at the end of the semester.
- The students should present their work during the evaluation in the form of a PowerPoint presentation (PPT).

Marking Scheme

Sr. No.	Description	Marks
1	Synopsis	10
2	Research Proposal	20
3	Review article on proposed work	20
4	Daily lab notebook record	10
5	Progress of experimental work	20
6	Quality and effectiveness of presentation	20
	Total	100

Broad Guidelines for Preparation of Synopsis

- A. The proposed synopsis for research should be self-contained and should cover the rationale for carrying out the research.
- B. There should not be repetition of the work, topic or theme.
- C. The synopsis of the proposed research shall contain the following points:
 1. Title of the Research Proposal.
 2. Motivation with reasoning and significance of the proposed research.
 3. Statement of the problem.
 4. Review of the relevant literature.

5. Objectives of the study.
6. The methodology, comprising: (a) methods of research; (b) sampling design and assumptions; (c) conceptual framework, if any; (d) research design (explanation of how the research is being conducted and the tools used for the same); (e) methods of data collection; (f) methods of data analysis (use of parametric and non-parametric tools and techniques as the case may be).
7. Expected outcome.
8. Bibliography.

Template for Research Proposal

- Title
- Introduction
- Origin of the research problem
- Interdisciplinary relevance
- Review of Research and Development in the Subject
- Significance of the study
- Objectives
- Plan of research work

Semester IV — RP-ICH405, RP-OCH405, RP-PCH405, RP-ACH405, RP-APCH405, RP-INDCH405

Credits: 06 | Hours: 180 | Marks: 150

- The student should submit the final bound dissertation/thesis copy of research work carried out during Semester III and IV.
- It should include: title page, certificate, declaration, acknowledgement, abbreviations, index, abstract, introduction, experimental section, results and discussion, conclusions, references, and participation in conferences/seminars and publications, if any.
- The students should present their work during the evaluation in the form of a PowerPoint presentation (PPT).

Marking Scheme

Sr. No.	Description	Marks
1	Dissertation/thesis bound copy	30
2	Quality of work (innovative concepts, social relevance, extent of work etc.)	50
3	Publications	20
4	Participation in conferences — (a) Oral/Poster Presentation (10 marks); (b) Only attended (7 marks)	10 maximum
5	Final dissertation/thesis defence	40
	Total	150

Note: The Project will be examined jointly by internal (Project Supervisor) and external examiners (preferably Associate Professor and above with Ph.D.) at the end of the semester.

The project can be given individually or to a maximum group of three students (not more than three students allowed).

Scheme of Examination

To be implemented from June 2024 onwards.

[Note: Just Check it.]

Total Marks: 80.

Instructions:

1. Attempt in all, five questions.
2. Question No. 1 is compulsory.
3. Attempt any two questions from Section-I and any two questions from Section-II.
4. All questions carry equal marks. Figures to the right indicate marks.

Q.1 Solve the following (Compulsory, 1 Mark each) — 16 Marks. (Sub-questions a through p), one from each topic across the syllabus, to be set by the paper-setter.)

Section I

Q.2 Two sub-questions (8 marks each) OR three sub-questions (6 + 6 + 4 marks) = 16 Marks.

Q.3 Two sub-questions (8 marks each) OR three sub-questions (6 + 6 + 4 marks) = 16 Marks.

Q.4 Two sub-questions (8 marks each) OR three sub-questions (6 + 6 + 4 marks) = 16 Marks.

Section II

Q.5 Two sub-questions (8 marks each) OR three sub-questions (6 + 6 + 4 marks) = 16 Marks.

Q.6 Two sub-questions (8 marks each) OR three sub-questions (6 + 6 + 4 marks) = 16 Marks.

Q.7 Write short notes on any four of the following (out of six) — 16 Marks. (Sub-questions a through f.)

M.Sc. II Syllabus (NEP-2.0) — Nature of Practical Examination

To be implemented from June 2024 onwards.

Semester III

Practical Paper V — 50 Marks. Number of Examination Days: 01.

Q.1 Major Experiment = 25 marks.

Q.2 Minor Experiment = 15 marks.

Q.3 Oral = 5 marks.

Q.4 Journal = 5 marks.

Semester IV

[Note: The document provided by you ends immediately after the Semester III practical-examination pattern above — it does not include a Semester IV practical examination pattern at all. Nothing has been invented to fill this gap; please supply the missing Semester IV practical exam details from the department.]