GUJARAT UNIVERSITY

MSc Analytical Chemistry Semester III and IV

Revised Syllabus

Design and Structure of Choice Based Credit System

(Effective from June 2023)

MSc SEMESTER III						
Course		**No. of hours per week (12 h for each unit and 48 h for each paper/course)**			**Total credits**	**Marks**
Paper Code	**Type**	**Lectures**	**Labs**	**Total**		
CHE(A) 501	Core Paper	4	--	4	4	100
CHE(A) 502	Core Paper	4	--	4	4	100
CHE(A) 503	Core Paper	4	--	4	4	100
CHE(EA) 504	Elective Paper	4	--	4	4	100
CHE(A) 505 PR	Lab Course-I	--	6	6	4	100
CHE(A) 506 PR	Lab Course-II	--	6	6	4	100
	Total	**16**	**12**	**28**	**24**	**600**
MSc SEMESTER IV						
Course		**No. of hours per week (12 h for each unit and 48 h for each paper/course)**			**Total credits**	**Marks**
Paper Code	**Type**	**Lectures/ Discussion**	**DISS/PW and IT**	**Total**		
CHE(A) 507	Core Paper	4	--	4	4	100
CHE(A) 508	Core Paper	4	--	4	4	100
CHE(A) 509	Industrial Training (IT) and Industrial Visit	--	4	4	4	100
CHE(A) 510	Core Paper [Professional Chemistry Test (Last 5 Years NET questions)]	4		4	4	100
CHE(A) 511	Dissertation (DISS)/ Project Work (PW)/ Lab Course	--	12	12	8	200
	Total	**12**	**16**	**28**	**24**	**600**

For each paper 30 % weightage is given to internal assessment and 70 % for external assessment.

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MSc SEMESTER III

ANALYTICAL CHEMISTRY

M.Sc. SEMESTER III

CHE(A) 501 SEPARATION TECHNIQUES AND BIOANALYTICAL CHEMISTRY

Learning Objective

- ☑ The main objective of this course is to familiarize students with the fundamental principles and working mechanism of separation tools/techniques used in analytical science such as, gas, liquid, and supercritical fluid chromatography, size exclusion, chiral, and affinity chromatography.
- ☑ Although modern chemical separation techniques are routinely practiced, the aim is to integrate all into one course.
- ☑ Although no hands-on training is provided, by completion of this course students are expected to gain theoretical method development skills in all separation techniques.
- ☑ The goal is to explain the chemical basis for stationary phase and mobile phase effects, to predict retention order given the relative dominance between stationary phase effects and mobile phase effects, to predict the effects of overloading, early and slow elution, baseline drift.
- ☑ Study in detail about quantitative bioanalysis, various stages of bioanalysis, bioanalytical method development and validation.

Learning Outcome

At the end of the course the students will be able to:

- ☑ Explain the principles of the most important liquid, supercritical fluid and gas chromatographic techniques.
- ☑ Evaluate strengths and limitations of the most important chromatographic separation and detection methods in relation to the properties of the sample.
- ☑ Interpret data from analytical separation methods.
- ☑ Choose and plan the use of suitable chromatographic technique for actual analytical problem solving with a reasonable degree of knowledge of potentially relevant methods.
- ☑ Be able to report and discuss chromatographic analyses in a scientifically sound, and understandable (intelligible) way.
- ☑ Account for the need of bioanalytical methods at projects within pharmacology, biopharmaceutics, pharmacokinetics, pharmacodynamics, metabolism, and toxicology
- ☑ Understand the basic principles of method construction and validation of bioanalytical methodology.

CHE(A) 501 Separation Techniques and Bioanalytical Chemistry

Unit 1 *Modern Liquid Chromatography*

- Principle, theory, and applications of ultra-performance liquid chromatography (UPLC), hydrophilic interaction liquid chromatography (HILIC), preparative high-performance liquid chromatography, flash chromatography, counter current chromatography, chiral chromatography, size/molecular exclusion/gel permeation chromatography and affinity chromatography, multidimensional liquid chromatography

Unit 2 *Gas Chromatography*

- Principle & theory, types of gas chromatography (GC) columns: packed and capillary columns, stationary phases-the key to different separations, temperature programming and carrier gas, types of sample injection, types of detectors: thermal conductivity, flame ionization, electron capture, flame photometric, flame thermionic and sulfur chemiluminescence detectors.
- Head space GC, pyrolysis GC, application in pharmaceutical, food, flavors, and fragrances analysis, multidimensional gas chromatography

Unit 3 *Supercritical Fluid Chromatography*

- Theory & historical development of supercritical fluid chromatography (SFC), carbon dioxide as the mobile phase, column selection, mobile phase additives & modifiers, effect of temperature & pressure, instrumentation for analytical and preparative SFC,
- Chiral & achiral SFC, applications in pharmaceuticals, food analysis and natural products

Unit 4 *Bioanalytical Chemistry*

- Quantitative bioanalytical method development: extraction from biological matrices, importance of internal standards, chromatography, and detection systems. Bioanalytical method validation parameters: sensitivity, selectivity, accuracy and precision, linearity (calibration curves), recovery, matrix effect, stability, dilution reliability, ruggedness
- Bioavailability and bioequivalence study, incurred sample reanalysis test for subject samples. US Food and Drug Administration (FDA) guidance for bioanalytical method validation, acceptance criterion

RECOMMENDED REFERENCES

1 *"Quantitative Chemical Analysis"*, Daniel C. Harris, 9th Edition, W.H. Freeman and Company, New York, 2015.
2 *"Analytical Chemistry"*, Gary D. Christian, 7th Edition, John Wiley and Sons Inc. New Jersey, 2004.
3 *"Fundamentals of Analytical Chemistry",* Douglas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Edition, Cengage learning, 2016.
4 *"Principles of Instrumental Analysis",* Douglas A. Skoog, F. James Holler, Stanley R. Crouch, 7th Edition, Cengage learning, 2017.
5 *"Modern HPLC for Practicing Scientists"*, Michael W. Dong, Wiley Interscience, 2006.
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7 "*Chiral Separation Techniques: A Practical Approach"*, 2nd Edition, edited by Ganapathy Subramanian, Wiley-VCH, 2001.
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13 *"Countercurrent chromatography: People and applications"*, A. Berthod, M.J. Ruiz-Ángel, S. Carda-Broch, Journal of Chromatography A, 1216 (2009) 4206–4217.
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17 *"Modern Supercritical Fluid Chromatography: Carbon Dioxide Containing Mobile Phases"* Larry M. Miller, J. David Pinkston, Larry T. Taylor, John Wiley & Sons, 2019.
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19 *"Bioanalysis of Pharmaceuticals: Sample Preparation, Separation Techniques and Mass Spectrometry",* Steen Honoré Hansen, Stig Pedersen-Bjergaard, eds., John Wiley & Sons, 2015.
20 "*Handbook of LC-MS bioanalysis: best practices, experimental protocols, and regulations*", Wenkui Li, Jie Zhang, L.S. Francis, eds., John Wiley & Sons, 2013.
21 US Food and Drug Administration, *Guidance for Industry: Bioanalytical Method Validation*. US Department of Health and Human Services, Food and Drug Administration Centre for Drug Evaluation and Research and Centre for Veterinary Medicine, 2018.

M.Sc. SEMESTER III

CHE(A) 502 TRENDS IN ANALYTICAL SCIENCE

Learning Objective

- ☑ The overall goal of this course is to provide a resource that can be used to facilitate familiarity with basic concepts of the automation in the analytical measurements, significance of artificial intelligence, fundamentals of mass spectrometry and its related hyphenated techniques and green analytical chemistry.
- ☑ Automation in the measurements unveils the black-box and provides information/principles about process control, automatic & automated instruments to handle many samples and/or process, in the environmental and clinical laboratories.
- ☑ The ultimate aspiration of green analytical chemistry is the democratization of analytical chemistry.

Learning Outcome

Upon completion of the course, students will be able to:

- ☑ Understand types of automated instruments and devices commonly used and the principles behind their operation. Their application to process control and the techniques of flow injection analysis that allow most common analytical measurements to be performed automatically using microliter volumes of samples and reagents.
- ☑ Explain the mass spectrometric technique covering the fundamentals, terminology, data interpretation, hyphenated techniques, instrumentation, ion sources, mass analysers, detectors, and its applications.
- ☑ Acquire the skills to evaluate strengths and limitations of different hyphenated techniques with respect to sample properties and to specific analytical problems.
- ☑ Acquire the skills to find, choose and plan the use of suitable hyphenated techniques for actual advanced analytical problems based on a sound knowledge of the relevant method.
- ☑ Understand the 12 principles of green chemistry for analytical chemistry, through use of green solvents in the sample preparation and green chromatography.
- ☑ Design, develop and run all these techniques in a sustainable manner.
- ☑ Develop abilities to apply the knowledge and skills acquired to solve analytical problems associated with applications in real life.

CHE(A) 502 Trends in Analytical Science

Unit 1 *Automation in Measurement and Artificial Intelligence*

- Principles of automation, automatic and automated devices, Process control: off-line, at-line and on-line analysis. Continuous and discrete analyzers, feed- back mechanism
- Flow injection analysis (FIA), principles, dispersion coefficient, factors affecting peak height-sample volume, channel length, flow rate and channel geometry, Applications of FIA (chloride and phosphate determination), FIA acid-base titration, stopped flow measurements and gradient FIA, Artificial intelligence in analytical chemistry, Laboratory Information Management Systems (LIMS)

Unit 2 *Mass Spectrometry and HRMS*

- Principles of mass spectrometry, Ion sources: electron ionization and chemical ionization, electrospray ionization, atmospheric pressure chemical ionization (APCI), atmospheric pressure photo ionization (APPI) and atmospheric pressure secondary ion (APSI) mass spectrometry; matrix assisted laser desorption ionization (MALDI)
- Mass analyzers- quadrupole, ion-trap, time of flight (TOF), ion-cyclotron resonance and Fourier transform mass analyzers, High resolution mass spectrometry (HRMS), Tandem mass spectrometry, Applications

Unit 3 *Advanced Hyphenated Techniques*

- Principle, theory, instrumentation, working and applications of liquid chromatography-nuclear magnetic resonance-mass spectrometry (LC-NMR-MS), liquid chromatography-mass spectrometry/tandem mass spectrometry (LC-MS & LC-MS/MS), gas chromatography- mass spectrometry/tandem mass spectrometry (GC-MS & GC-MS/MS) and inductively coupled plasma-mass spectrometry (ICP-MS), Applications of hyphenated techniques

Unit 4 *Green Analytical Chemistry*

- Principles of Green Analytical Chemistry, Green Methodology in Analytical Sciences: Characteristics of green methods, Greening Sample Preparation: Strategies/techniques, New Sorbents, Green Solvents for Analytical Chemistry
- Green aspects for gas and liquid chromatography: State-of-the-art, Opportunities and Future Perspectives, Eco-scale metric approaches for evaluation of the greenness of analytical procedures

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1 *"Quantitative Chemical Analysis"*, Daniel C. Harris, 9th Edition, W.H. Freeman and Company, New York, 2015.

2 *"Analytical Chemistry"*, Gary D. Christian, 7th Edition, John Wiley and Sons Inc. New Jersey, 2004.

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4 *"Principles of Instrumental Analysis",* Douglas A. Skoog, F. James Holler, Stanley R. Crouch, 7th Edition, Cengage learning, 2017.

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17 *"Handbook of GC-MS: fundamentals and applications",* Hans-Joachim Hübschmann, 3rd Edition, John Wiley & Sons, 2015.

18 *"Practical Guide to ICP-MS: A Tutorial for Beginners,* Robert Thomas,3rd Edition, CRC Press, 2013.

19 *"Handbook of Green Analytical Chemistry",* Miguel de la Guardia, Salvador Garrigues, eds., West Sussex, UK: John Wiley & Sons, 2012.

20 "*Challenges in Green Analytical Chemistry*", Salvador Garrigues, Miguel de la Guardia, RSC, 2020.

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M.Sc. SEMESTER III

CHE(A) 503 ELECTROANALYTICAL TECHNIQUES

Learning Objective

- ☑ The fundamental goal of this course is to explain the importance of electroanalytical techniques for the analysis of chemicals and biochemicals and to facilitate in identification of the most appropriate electroanalytical technique for a specific analysis.
- ☑ To provide proficiency at evaluating the electrode reaction mechanism from data obtained using different electroanalytical techniques.
- ☑ To develop familiarity with electroanalytical techniques that are used for sensing of targets in research and industry.

Learning Outcome

Upon completion of the course, students will be able to:

- ☑ Identify the basic concept of electrochemical quantities for the basis of qualitative or quantitative measurement.
- ☑ Understand the basic concept of electrolysis for electrogravimetry and coulometric techniques under various conditions.
- ☑ Understand the instrumentation of electrogravimetry, coulometry technique.
- ☑ Recognize the application of electrogravimetry and coulometric technique.
- ☑ Learn problem solving for analytical tasks.
- ☑ Comprehend the advantages and disadvantages of various voltametric technique for selective and sensitive microanalysis.
- ☑ Understand the design of Ion-selective electrode, potentiometric and amperometric biosensors for detection of gases, biomolecules, and ions.
- ☑ Become familiar with biosensor techniques used in research and industry for analysis of biochemicals and chemicals.
- ☑ Learn electrochemical methods for sensing, including potentiometric sensors and biosensors, ion selective electrodes, amperometric sensors and conductometric sensors based chemiresistors.
- ☑ Be familiar with modern biosensing techniques such as field-effect transistors, biosensors based on chemiresistors and semiconducting oxide sensors.

CHE(A) 503 Electroanalytical Techniques

Unit 1 *Electroanalytical Measurements*

- Introduction to potentiometry, galvanic measurements, potentiostatic measurements, voltage measurements with finite current, impedance measurements, electric double layer, electrocapillarity, current measurements, diffusion transport

Unit 2 *Electrodeposition and Coulometry*

- Fundamentals of electrolysis & current-voltage relationship,
- Electrogravimetry: principles, theory &types of electro gravimetric analysis at constant current, constant potential and at controlled potential, problems involved in electrogravimetry
- Coulometry: fundamentals, principle, theory& instrumentation, coulometric analysis at controlled potential coulometry, constant current coulometry, coulometric titration, applications of coulometric titration, comparison of constant current coulometry with conventional volumetric titration

Unit 3 *Voltammetry*

- Principle, theoretical consideration, basic experiment, instrumentation and applications of polarography, differential pulse polarography, square wave polarography, A.C. polarography, stripping analysis, cyclic voltammetry & amperometry titration

Unit 4 *Electrochemical and Biosensors*

- Potentiometric sensors and ion selective electrodes – concentration and activities, glass membrane type ISE, Gas sensing electrodes, Potentiometric biosensors linked with pH, NH_3, CO_2, Ag_2S and I_2
- Amperometric sensors- first generation, second generation and third generation, determination of glucose, lactate, cholesterol, phosphate, ethanol, starch, aspirin, and paracetamol using amperometric biosensor, amperometric gas sensors
- Conductometric sensors-chemiresistors, biosensors based on chemiresistors and semiconducting oxide sensors. Applications of Field-Effect Transistors sensors (Chemically Sensitive Field-Effect Transistors, Ion-Selective Field-Effect Transistors, FET-Based Biosensors)

RECOMMENDED REFERENCES

1 *"Quantitative Chemical Analysis"*, Daniel C. Harris, 9th Edition, W.H. Freeman and Company, New York, 2015.
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12 "*Analytical Chemistry*", Dhruba Charan Dash, PHI Learning Private Limited, New Delhi.

M.Sc. SEMESTER III

CHE(EA) 504 INDUSTRIAL ANALYTICAL CHEMISTRY
(Elective Analytical-1)

Learning Objective

- ☑ The aim of this course is to provide students with a broad understanding of the principles of analytical chemistry and their application in the areas of environmental, food and food products, industrial materials, and agriculture. Depending on their project, the students will have the opportunity to apply analytical chemical methods in any one of the aforementioned areas.
- ☑ To aware students critically about their roles and identities as a consumers and environmental actors in a complex, interconnected world.
- ☑ To provide knowledge on the key food safety, their methods of detection and the key food quality properties.
- ☑ To provide the knowledge of the proper procedures and regulations for safe handling and use of chemicals.

Learning Outcome

Upon completion of the course, students will be able to:

- ☑ Describe and compare a range of analytical chemistry methods and explain the underlying theoretical principles.
- ☑ Explain the broad role of analysts in quality control and assessment of experimental measurements from various application contexts especially environmental analysis, food analysis, analysis of industrial materials like alloys, cement, paints, pigments, & petrochemical products, and analysis of fertilizers, soaps & detergents.
- ☑ Employ a variety of analytical methods to prepare, separate and characterise samples from various matrices.
- ☑ As part of a team or individually, conduct, analyse and interpret results of a chemical analysis and effectively communicate these in written reports and other formats.
- ☑ Learn the ability to work safely and competently in an analytical laboratory setting.

CHE(EA) 504 Industrial Analytical Chemistry

Unit 1 *Environmental Analysis*

- Analysis of Air: Sampling and examination of airborne solids, Direct instrumental methods for gaseous pollutants, Sampling of gases and the atmosphere, Gas chromatography, some chemical methods for determining trace gases
- Analysis of Water: The analysis of water, Selected analytical methods for water quality control, pH measurement – the glass electrode, Conductivity, Dissolved oxygen (DO), Biochemical oxygen demand (BOD), Chemical oxygen demand (COD), Methods for the determination of inorganic nitrogen, Determination of phosphate, Automation of colorimetric procedures, titrimetric determination of chloride, Ion-selective electrodes, Ion chromatography, The determination of heavy metals, The importance of chemical species – speciation, Trace organics in water – total organic carbon (TOC), Determination of some individual compounds or groups of compounds in polluted water, Gas chromatography/mass spectrometry (GC/MS)
- Soil Analysis: Sampling of soil, pH of Soil, moisture determination by Karl Fischer titration methods, Determination of total nitrogen, ammonia and nitrates, Estimation of available Nitrogen (Kjeldahl's Method), determination of total phosphates as P_2O_5, Soil analysis for micronutrients

Unit 2 *Food Analysis*

- Analysis of food: Introduction to food analysis, regulations and international standards related to food analysis, nutritional labeling, sampling, and sample preparation
- Compositional analysis of foods: moisture, proteins, fat, fiber, ash, vitamins and minerals, Adulteration of fats and oils, milk, and milk products
- Analysis of food products for flavoring agents, colour and various contaminants
- Analysis of Oils & Fats: Theory, Melting point of fats, Chemical Characteristics: saponification value, iodine value, acid value, thiocyanogen value, ketone, or perfume rancidity. Analysis of fatty acid composition in oils by GLC, Oxidation levels of fats by TLC

Unit 3 *Analysis of Industrial Materials*

- Analysis of Ferroalloys: Analysis of steel - Molybdenum, Phosphorous. Analysis of Ferromanganese, Ferrovanadium. Analysis of non- Ferrous alloys: Analysis of Tin, Zinc and Copper in Brass, Bronze. Analysis of Tin and lead in Solder
- Analysis of Cement: Composition of Portland cement, estimation of Aluminium

oxide and Ferrous oxide. Determination of Alumina in Cement by Polarography

- Paints and Pigments: Types of paints and pigments, determination of volatile and non-volatile components, Flash point (significance and method of determination), separation and analysis of pigments. Analysis of TiO_2 in Titanium dioxide pigments by XRD. Determination of Zn, Pb in Paint pigments by Polarographic method. Analysis of polyesters, acrylics by Gel permeation chromatography
- Petrochemical Products: Classification of Petrochemical products: crude oils, fuels, and calorific values, fractional distillation process and fractions, properties of fuel, composition of fuel, flashpoint, fire point, corrosion test, carbon residue

Unit 4 *Analysis of Pesticides, Fertilizers, Soaps, and Detergents*

- Pesticides: Introduction, Classification and properties of pesticides based on mode of action, targeted pest species and chemical composition, Physical and chemical properties of pesticides, Analysis of different pesticides by classical and instrumental methods
- Fertilizers: Types of fertilizers and analysis of different elements like nitrogen, phosphates, calcium, sodium, potassium, and ammonia
- Soaps and detergents: Classification of soaps and detergents with suitable examples, the chemistry of soaps and detergents, properties and characterization of soaps and detergents: Alkali and total fatty matter, active ingredients and oxygen releasing capacity

RECOMMENDED REFERENCES

1 *"Analytical Chemistry"*, Gary D. Christian, 7th Edition, John Wiley and Sons Inc. New Jersey, 2004.

2 *"Principles of Instrumental Analysis",* Douglas A. Skoog, F. James Holler, Stanley R. Crouch, 7th Edition, Cengage learning, 2017.

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M.Sc. SEMESTER III

CHE(EA) 504 THERMAL AND RADIOCHEMICAL METHODS
(Elective Analytical-2)

Learning Objective

- ☑ The aim of this course is to provide fundamental and practical aspects of thermal analysis and radiochemical methods.
- ☑ To give an overview of various thermal methods (TGA, DTA, DSC, TMA and EGA) and show how they can be used to measure different kinds of thermal events. Further, combined methods of thermal analysis and the interpretation of experimental results will be taught.
- ☑ The intent to incorporate radiochemical methods in this course is to give a thorough introduction to radioactivity as well as central concepts in radiochemistry. Radiochemical principles are seen in conjunction with chemical concepts and other fields where radiochemical principles can be utilized, such as the industry, the environment and medicine.
- ☑ The course shall relay knowledge about the role of radioactivity, both as a tool and its own scientific discipline. Applications where radiochemistry plays an integral part will be specifically treated.

Learning Outcome

After completing this course, students will be able to:

Thermal Methods

- ☑ Explain the basic principle and instrumentation of various thermal methods.
- ☑ Choose the experimental conditions for specific measurements.
- ☑ Identify the properties present in the various thermal methods.
- ☑ Consider factors, which affect thermal measurements.
- ☑ List the uses of each of the different thermal methods.
- ☑ Interprets related thermograms.

Radiochemical Methods

- ☑ Define radioactive decay processes and nuclear radiation.
- ☑ Know the principles of utilizing radioactivity applied to chemistry, chemical processes, and adjacent fields where chemistry is an integral part.
- ☑ Know the principles of radiation hygiene and the interaction of radiation and matter.
- ☑ Perform calculations in radiochemistry and utilize these in applied radiochemical sciences.
- ☑ Assess radiation and radiation exposure from a radiation protection point of view.

CHE(EA) 504 Thermal and Radiochemical Methods

Unit 1 *Thermogravimetry and Derivative Thermogravimetry*

- Introduction to Thermogravimetric Analysis (TGA), basic principles of TGA, derivative TGA, modern TGA instrumentation, mechanisms of weight change in TGA, classification of TGA curves, simultaneous TGA techniques, applications of TGA

Unit 2 *Differential Thermal Analysis and Differential Scanning Calorimetry*

- Introduction to Differential Thermal Analysis (DTA), basic principles of DTA, modern DTA instrumentation, factors affecting DTA curve, applications of DTA
- Introduction to Differential Scanning Calorimetry (DSC), basic principles of DSC, modern DSC instrumentation: power compensated, heat flux, modulated DSC instruments, DSC sensors, applications of DSC

Unit 3 *Thermomechanical and Evolved Gas Analysis*

- Introduction of Thermomechanical Analysis (TMA), basic principles of TMA, modern TMA instrumentation, types and selection of probes, applications of TMA
- Basic Principles of Evolved Gas Analysis (EGA), instrumentation, evolved Gas detection, mass spectrometry, Fourier transform infrared (FTIR) spectroscopy, gas chromatography, coupling the TGA to gas analyzer, applications of EGA

Unit 4 *Radiochemical Methods*

- Radioactive Nuclides: Radioactive decay products, decay processes, radioactive decay rates, counting statistics
- Instrumentation: Measurement of alpha particles, beta particles and gamma radiation
- Neutron activation methods: Neutrons and neutron sources, interactions of neutrons with matter, theory of activation methods, experimental considerations in activation methods, applications of neutron activation
- Isotope dilution methods: Principles and application of the isotope dilution procedure
- Radiometric titrations: Principle, types, and application of Radiometric titrations

RECOMMENDED REFERENCES

1 *"Principles of Instrumental Analysis",* Douglas A. Skoog, F. James Holler, Stanley R. Crouch, 7th Edition, Cengage learning, 2017.

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8 *"Handbook of Radioactivity Analysis"*, M. F. L'Annunziata, ed., San Diego: Academic Press, 1998.

9 *"Chemical Analysis by Nuclear Methods",* Z. B. Alfassi, ed., Chichester, UK: Wiley, 1994.

10 *"Radiochemistry and Nuclear Methods of Analysis"*, W. D. Ehmann and D. E. Vance, New York: Wiley, 1991.

11 *"Radiochemistry and Nuclear Chemistry",* G. R. Choppin, J. Rydberg, J. O. Liljenzin, C. Ekberg, 4th Edition, Oxford, UK: Academic Press, 2013

12 *"Nuclear and Radiochemistry: Fundamentals and Applications",* Jens-Volker Kratz, Karl Heinrich Lieser, 3rd Edition, Wiley-VCH, 2013.

13 *"Nuclear and radiochemistry",*JózsefKónya, Noémi M. Nagy, 2nd Edition, Elsevier, 2018.

14 *"Handbook of Nuclear Chemistry"*: Vol. 1: Basics of Nuclear Science; Vol. 2: Elements and Isotopes: Formation, Transformation, Distribution; Vol. 3: Chemical Applications of Nuclear Reactions and Radiation; Vol. 4: Radiochemistry and Radiopharmaceutical Chemistry in Life Sciences; Vol. 5: Instrumentation, Separation Techniques, Environmental Issues; Vol. 6: Nuclear Energy Production and Safety Issues, Attila Vértes, Sándor Nagy, Zoltán Klencsár, Rezso György Lovas, Frank Rösch, eds., 2nd Edition, Springer Science & Business Media, 2010.

M.Sc. SEMESTER III

CHE(EA) 504
SPECTROSCOPIC TECHNIQUES FOR PHARMACEUTICAL AND BIOPHARMACEUTICAL INDUSTRIES
(SWAYAM ONLINE COURSE)
(Elective Analytical-3)

https://onlinecourses.nptel.ac.in/noc21_cy43/preview

About the Course

- ☑ A variety of spectroscopic techniques will be discussed along with their application in chemical, pharmaceutical and Bio-pharmaceutical Industries.
- ☑ Category: **1.** Chemistry
- ☑ Course Credit: **3**
- ☑ Course Duration:**12 weeks**

Course Certificate

- ☑ Average assignment score = 25% of average of best 8 assignments out of the total 12 assignments given in the course.
- ☑ Exam score = 75% of the proctored certification exam score out of 100
- ☑ Final score = Average assignment score + Exam score
- ☑ ELIGIBILITY CRITERIA FOR A CERTIFICATE: ONLY IF AVERAGE ASSIGNMENT SCORE >=10/25 AND EXAM SCORE >= 30/75. If one of the 2 criteria is not met, the certificate will not be provided even if the Final score >= 40/100.

CHE(EA) 504 Spectroscopic Techniques for Pharmaceutical and Biopharmaceutical Industries

(Swayam Online Course)

Course layout

- **Week 1:** Summary of spectroscopic techniques, electromagnetic radiation and its interaction with matter
- **Week 2:** Schrodinger Equation, Postulates of quantum mechanics, resolution, signal to noise ratio.
- **Week 3:** Rotational/ Rotational Raman and their application and Vibrational Spectroscopy
- **Week 4:** Application of Vibrational spectroscopy, Vibrational, Rotational-Vibration, Raman spectroscopy/Rotational-Raman/Vibrational-Raman
- **Week 5:** Atomic Spectroscopy
- **Week 6:** Flame photometry, AAS, ICP and its application, Molecular spectroscopy
- **Week 7:** Electronic spectroscopy, UV-Vis Spectroscopy and its application
- **Week 8:** Application of UV-Visible spectroscopy, Fluorescence spectroscopy
- **Week 9:** Fluorescence spectroscopy, Time resolved Spectroscopy
- **Week 10:** Microscopy
- **Week 11:** Mass spectroscopy, NMR spectroscopy
- **Week 12:** Application of FTIR, NMR and Mass in Pharmaceutical and Biopharmaceutical Industry

RECOMMENDED REFERENCES

1 "*Engineering Chemistry*", P.B. Joshi and Shashank Deep, Oxford University Press, 2019.
2 "*Modern Spectroscopy*", J. M. Hollas, John Wiley & Sons, 2004.
3 "*Absolutely Small: How Quantum Theory Explains our Everyday World*", Michael D. Fayer, Amacom, 2010.
4 "*Fundamentals of Molecular Spectroscopy*", C. N. Banwell & E.M. McCash, 1972.
5 "*Organic Spectroscopy*", William Kemp, Springer, 1975.
6 "*Understanding light microscopy: Jeremy Sanderson*", John Wiley & Sons, 2019.
7 "*Understanding NMR spectroscopy*", James Keeler, John Wiley & Sons, 2005.
8 "Principle of Fluorescence Spectroscopy", J.R. Lakowicz (Ed.), Springer, 2013.

M.Sc. SEMESTER III

CHE(A) 505 PR ANALYTICAL CHEMISTRY PRACTICLAS

Lab Course-I

CHE(A) 505 PR

Experiments: *Ion-exchange Chromatography, Thin layer Chromatography, Solvent extraction, Cloud Point extraction (Minimum: 8)*

1. Determination of ion-exchange capacity of cation and anion exchangers.
2. Ion-exchange separation and determination of halides (chloride and bromide) on anion exchange column.
3. Ion-exchange separation and determination of zinc and magnesium on anion exchange column.
4. Ion-exchange separation and determination of cadmium and zinc on an anion exchanger column.
5. Separation and determination of multiple analytes (three or more drugs) using TLC and HPTLC.
6. Extraction and determination of food colours (tartrazine, erythrosine, sunset yellow) from commercially available food samples using cloud point extraction (confectionary items).
7. Determination of nitrogen content of fertilizers (Kjeldahl's method).
8. Determination of alkali content & total fatty matter in cleansing agents (Soaps and detergents)
9. Estimation of drugs by non-aqueous titration: pyridoxine hydrochloride or sulphamethoxazole.

RECOMMENDED REFERENCES

1. *"Vogel's Textbook of Quantitative Chemical Analysis",* I. Vogel, 5th Edition, Revised by G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denny, Longman House, Burnt Mill, Harlow. Essex CM20 2JE, England, 1989.
2. *"Vogel's Textbook of Quantitative Chemical Analysis",* I. Vogel, 6th Edition, Revised by J. Mendham, R.C. Denny, J.D. Barnes, M.J.K. Thomas, Pearson Education, India, 2000.
3. *"Analytical Chemistry"*, Gary D. Christian, 7th Edition, John Wiley and Sons Inc. New Jersey, 2004.
4. *"Quantitative Chemical Analysis"*, Daniel C. Harris, 9th Edition, W.H. Freeman and Company, New York, 2015.

M.Sc. SEMESTER III

CHE(A) 506 PR ANALYTICAL CHEMISTRY PRACTICLAS

Lab Course-II

CHE(A) 506 PR

Experiments: *Experiments on Spectrophotometry, Fluorescence Spectroscopy, Flame Photometry, and Infrared Spectroscopy (Minimum: 8)*

1. Spectrophotometric determination of binary mixture ($KMnO_4$ and $K_2Cr_2O_7$) when their spectra do not overlap.
2. Spectrophotometric determination of binary mixture (Titanium and Vanadium) when their spectra overlap.
3. Spectrophotometric determination of ionization constant of an indicator (bromothymol blue).
4. Spectrophotometric determination of pKa of methyl red indicator
5. Determination of stoichiometry of Fe(II)-1,10-phenanthroline complex by Job's method of continuous variation.
6. Ultraviolet spectrophotometric determination of aspirin, phenacetin and caffeine in APC tablet using solvent extraction.
7. Simultaneous determination of arsenic (III) and antimony (III) in a mixture using bromate/bromide solution by spectrophotometry.
8. Determination of stability constants/formation constants of metal-complexes by spectrophotometry (Scatchard Plot).
9. Determination of Na and K in commercial samples by flame photometry.

RECOMMENDED REFERENCES

1. *"Vogel's Textbook of Quantitative Chemical Analysis"*, I. Vogel, 5th Edition, Revised by G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denny, Longman House, Burnt Mill, Harlow. Essex CM20 2JE, England, 1989.
2. *"Vogel's Textbook of Quantitative Chemical Analysis"*, I. Vogel, 6th Edition, Revised by J. Mendham, R.C. Denny, J.D. Barnes, M.J.K. Thomas, Pearson Education, India, 2000.
3. *"Analytical Chemistry"*, Gary D. Christian, 7th Edition, John Wiley and Sons Inc. New Jersey, 2004.
4. *"Quantitative Chemical Analysis"*, Daniel C. Harris, 9th Edition, W.H. Freeman and Company, New York, 2015.

MSc SEMESTER IV
ANALYTICAL CHEMISTRY

M.Sc. SEMESTER IV

CHE(A) 507 SCIENTIFIC WRITING

Learning Objective

- ☑ The purpose of scientific writing is to help students analyse and clarify their thinking about a particular topic, synthesize their ideas, and communicate them with others. The different options offered to students are specific in nature and serve a distinct purpose.
- ☑ To generate scientific temper and understanding among students to articulate their thinking as they engage in the scientific practices. Scientific writing will serve as an effective means to increase student engagement in learning as well as to improve their academic success.
- ☑ The students are expected to design, execute, and publish a study through this writing-intensive course.

Learning Outcome

Upon completion of the course, the students

- ☑ Will understand the importance of literature survey in research.
- ☑ Will learn to carry out investigations, analysing and interpreting data, and constructing explanations.
- ☑ Shall start to become better readers, thinkers, and learners in their discipline by processing their ideas through writing.
- ☑ Benefit in preparing the day-in and day-out communicative tasks that they face on the job.
- ☑ Will build new scientific understanding as it provides students the opportunity to articulate their thinking as they engage in the science practices during an investigation.

CHE(A) 507 Scientific Writing

- Writing of Research Article/Review Article/Commentary Article/Case Study/ Monograph/Book Chapter/Book Review/Research Proposal or any other scientific article type.
- The student can select any one scientific writing type or research proposal and submit a copy (hard and soft) of the same for internal and external evaluation.
- Evaluation will be centered around on novelty, relevance, significance, and impact.
- Additional weightage will be given for submission/publishing of any article type in any journal (University journal or a journal that is indexed in the UGC CARE list/Web of Science/ SCOPUS/SCI/SCIE etc.) or a research proposal.

Guidelines for Scientific Writing

Research Article

Presents a full report with new results on a specific topic. Complete experimental details with proper justification. Generally not limited in length, with figures, tables, and references. Format…Title, Authors, Abstract, introduction, experimental, results, discussion, conclusion, acknowledgment, references

Review Articles/Commentary Article

Gives an overview of research in a particular field. It can be on one's own research or any other topic of general and current interest. Organized differently from communications or research articles as it does not have primary experimental data. Data of existing literature can be presented in a tabular format, graphs, diagrams, figures, charts etc. Should be referenced as thoroughly as possible. Format…Title, Authors, Abstract, introduction, discussion, conclusion, acknowledgment, references

Case Study

This study represents person, group, or situation that has been studied over time. Format depends upon the type of study.

Monograph

Title, Author, Introduction: Reason to select a topic; History, timeline, and Scientific/social significance; Benefits to the scientific community, teaching, and research, Development: Exposition of ideas into paragraphs or chapters.
"Quote that author endorse these ideas." Conclusion: Status and future perspectives, References: Should be referenced as thoroughly as possible

Book Chapter

Title, Authors, Abstract, Introduction/Background on the topic, Discussion (with subdivisions): Text with tables, figures, charts etc., Summary/Conclusion: Status and future perspectives, References

Book Review

A book review is a thorough description, critical analysis, and/or evaluation of the quality, meaning, and significance of a book, often written in relation to prior research on the topic.
Scope/Purpose/Content, Note the Method/Methodology of writing, Critically Evaluate the Contents, Examine the Front Matter and Back Matter, Summarize and Comment.

Research Proposal

Title, Research Problem/Problem Statement, Rational/Purpose of the Study Review of the Literature, Proposed Research Framework, Research Questions/Proposed Hypothesis, Significance, Proposed Methods and Procedures, Deliverables/Expected Outcomes, Execution timelines, year wise breakup, financial aspects, References

RECOMMENDED REFERENCES

1 *"A Manual for Writers of Research Papers, Theses, and Dissertations"*, Kate Turabian, University of Chicago Press, 8th Edition, 2013.

2 "*Concise Guide to Writing Research Papers (Perfect Phrases Series)"*, Carol Ellison**,** McGraw-Hill Education; 1st Edition, 2010.

M.Sc. SEMESTER IV

CHE(A) 508 REPORT WRITING

Learning Objective

- ☑ The main purpose of writing a conference/seminar report is to provide an opportunity to the students to participate, present new findings through oral/poster presentations, interact with researchers/experts in different areas of Chemistry, and develop skill to summarise an event.
- ☑ It can serve as a platform for sharing experiences.

Learning Outcome

Upon completion of the course, students will be able to:

- ☑ Sharpen writing skills when it comes to details with good accuracy.
- ☑ Learn the best practices, methods and resources in research, presentation of own ideas.
- ☑ Learn from the experts.
- ☑ Expand network with researchers working in their areas of interest, for fulfilling career goals.
- ☑ Keep with the current trends.
- ☑ Build confidence as presenting at a conference is the perfect opportunity.

CHE(A) 508 Report Writing

- Report Writing for Participation and/or presentation (Poster/Oral/Invited talk as applicable) in University/State level/National/International Seminar/ Conference/Webinar/ Symposium/Workshop/Hands-on training /Software learning of at least 2 days. In case of one day seminar/ webinar/ conference/workshop, it is mandatory to participate in two such events.
- Evaluation will be based on detailed technical report prepared on the conference/seminar/workshop participated and for Poster/Oral presentation, as applicable.
- Additional weightage will be given for Oral or Poster Presentation.

Guidelines for Report Writing

It aims to summarise the most important talks/research presented. It is not usually feasible to attempt comprehensive coverage of the conference. More focus should be on those presentations that are most topical, interesting, or thought-provoking.

Points to consider when writing the report:

- Name of Institute/Department/University that organized the conference
- Title and theme of the conference
- Information regarding number of attendees, where and when it was held (date), name of the convener, organizing secretary etc.
- Include a copy of the brochure
- A brief about the Inaugural Session
- Details of all the technical sessions
- List of main speakers, their position/designation, topic, expertise, and their institutional affiliation
- Highlight research paper(s) or work with major significance and impact
- A brief about the Concluding/Valedictory Session

- Embed the text with photographs wherever possible
- The outcome/summary: Your learning

RECOMMENDED REFERENCES

1 *"Writing for Conferences: A Handbook for Graduate Students and Faculty"*, Leo Mallette, Clare Berger, Greenwood; Illustrated Edition, 2011.
2 *"The Creative Writing Handbook"*, John Singleton (Editor), Mary Luckhurst (Editor), Red Globe Press; 2nd Edition, 1999.

M.Sc. SEMESTER IV

CHE(A) 509 INDUSTRIAL TRAINING AND INDUSTRIAL VISIT

CHE(A) 509 Industrial Training and Industrial Visit

Guidelines for Industrial Training

1 Each student must undergo a minimum of 1 (one) week of industrial training under the supervision of a member of staff from the concerned department.
2 The industry may be in Ahmedabad, Gujarat or anywhere in India.
3 The training may be obtained at any R&D, QA, QC, Production or any other relevant department in different instrumental techniques or other laboratory equipment.
4 The industry tour/visit must be of minimum of two days anywhere in India and same can be submitted in a form of report.
5 The students must submit a report on the training obtained from the industry which may include (a) introduction about the industry (b) various activities of the industry (c) the process which are used in the industry (d) the products of the industry and (e) summary and conclusion. The report must be written date-wise. The minimum number of hours/per day for industrial training is 6. The industry visit/tour can be reported separately. The industrial tour certificate will be issued by the in-charge faculty/head/principal, while the visit certificate can be from the

	industry.
6	The report submitted by each student would be assessed by the branch in-charge and the supervising teacher.
7	The student must discuss/present the details of the training through a power point presentation

M.Sc. SEMESTER IV

CHE(A) 510 PROFESSIONAL CHEMISTRY TEST

CHE(A) 510 Professional Chemistry Test (PCT)

Guidelines for Professional Chemistry Test

1	Prepare questions from the last five years of CSIR-NET Examinations.
2	Preparation should be as per sections A, B, and C from the paper format.
3	Examination will be based on MCQ based exam will be conducted.
4	(Part A maximum 10 out of 15 questions, Part B maximum 13 out of 20 questions and Part C maximum 6 out of 16 questions. If more than the specified number of questions are answered then the first 10, 13 and 16, respectively will be considered for assessment.)
5	No negative marks for wrong answers.

M.Sc. SEMESTER IV

CHE(A) 511 DISSERTATION/PROJECT WORK

CHE(A) 511 Dissertation/Project Work

Guidelines for Dissertation/Project Work

1. Each student must carry out a project of minimum 30 days duration under the supervision of a faculty from the concerned department.
2. The project can be carried out either in the department or in any other industry, institute or organizations located in Ahmedabad, Gujarat or anywhere in India.
3. The topics of the dissertation can be selected from any of the four branches of chemistry i.e., Organic, Inorganic, Physical or Analytical. The topic can be related to (a)synthesis, purification, characterization, application of organic compounds or (b)metal complexes preparation and applications or (c)physical studies of various systems (d) method development and validation (e) green chemistry (f) nanomaterials preparation and applications (g) functionalized supramolecules (h) electro analytical methods (i) environmental analysis and decontamination or any other related to the subject.
4. Each student must submit a dissertation on the topic of their study comprising of (a) an introduction on the topic along with literature survey and justification for the selection of the topic (b) materials and methods (c) methodology (d) results and discussion and (e) summary and conclusion along with the references.
5. Each student must give monthly report and a midterm presentation of their work at the department.
6. The student must discuss/present the details of dissertation through a power point presentation.
7. Dissertation would be examined by the supervising teacher and external examiner.

CHE(A) 511 PR

Experiments: *Thin layer Chromatography, Solvent extraction, Fluorescence Spectroscopy, and Infrared Spectroscopy (Minimum: 8)*

1. Determination of glucose from glucon D by titration with Fehling solution.
2. Determination of silica by molybdenum blue method
3. Estimation of caffeine in tea
4. Determination of calcium in milk powder using EDTA.
5. Determination of strength of commercial phosphoric acid by pH titration
6. Determination of ammonia in household cleaners by conductometric titrations.
7. Isolation/extraction of casein and lactose from milk and separation by TLC
8. Determination of iron in mustard sugar, phosphorus in peas, ascorbic acid in tomato, benzoic acid in food products
9. Analysis of the composition of a mixture of nitroanilines by thin-layer chromatography and ultraviolet-visible spectrometry
10. Simultaneous spectrophotometry (zero order, first and second derivative) determination of drugs.
11. Spectrophotometric determination of nitrate nitrogen in water.
12. Quantitative analysis of charge transfer complexes of iodine with drugs by spectrophotometry (linearity, accuracy, and precision).
13. Spectrophotometric determination of lead in leaves using solvent extraction.
14. Quantitative analysis of riboflavin (Vitamin B_2) in energy drinks by fluorescence spectroscopy.
15. IR Spectroscopy for detection of primary, secondary, and tertiary amines
16. IR Spectroscopy for detection of carbonyl functionality in acid, amide, aldehyde, and ketone.
17. Analysis of pesticides in environmental samples by Gas Chromatography-Mass Spectrometer
18. Pre-concentration of copper, cobalt, nickel, and zinc from brine/sea water on Chelex-100 resin and their simultaneous determination using atomic absorption spectrophotometry.

RECOMMENDED REFERENCES

5 *"Vogel's Textbook of Quantitative Chemical Analysis"*, I. Vogel, 5th Edition, Revised by G.H.

Jeffery, J. Bassett, J. Mendham, R.C. Denny, Longman House, Burnt Mill, Harlow. Essex CM20 2JE, England, 1989.

6 *"Vogel's Textbook of Quantitative Chemical Analysis",* I. Vogel, 6th Edition, Revised by J. Mendham, R.C. Denny, J.D. Barnes, M.J.K. Thomas, Pearson Education, India, 2000.

7 *"Analytical Chemistry"*, Gary D. Christian, 7th Edition, John Wiley and Sons Inc. New Jersey, 2004.

8 *"Quantitative Chemical Analysis"*, Daniel C. Harris, 9th Edition, W.H. Freeman and Company, New York, 2015.