School of Chemistry
Faculty of Sciences
University of the Punjab, Lahore
Course Outline

BS Chemistry Semester-VII					
Program	**BS Chemistry**	**Course Code**	**Chem-446**	**Credit Hours**	**2**
Course Title	**Electroanalytical Techniques-1**	**Course Type**	**Major (Elective)**		

Course Introduction

The course is organized to provide an adequate knowledge about electroanalytical techniques including potentiometry and conductometry

Potentiometry: Nernst equation; Electrode Potentials; different reference electrodes including glass and calomel electrode; working of a potentiometer and its applications including pH measurements and potentiometric titrations; ion-selective electrode systems; ion- exchange membrane electrode; gas-sensing electrode; solid-state membrane electrode and bio membrane electrode.

Conductometry: Conductance in Solutions; Specific conductance; molar conductance; factors upon which the conductance of solution depends; Measurement of conductance / Instrumentation; cell constant; Analytical applications of conductance measurement.

Learning Outcomes

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

1. Understand advanced analytical techniques named electroanalytical techniques.
2. Learn the principles and theories involved in Potentiometry and Conductometry.
3. Gain knowledge about measurements involving the potential and/or the conductance of various species using a number of versatile electrodes.
4. Practically apply the principle of conductance on real samples.

	Course Content	**Assignments/Readings**
Week 1	**Potentiometry,** Nernst equation, Electrode Potentials	Class based Learning/Test
Week 2	Different reference electrodes including glass and calomel electrode, Class Discussion	Class based Learning/Test
Week 3	Working of a potentiometer, Applications of a potentiometer including pH measurements and potentiometric titrations	Class based Learning/Test
Week 4	Ion-selective electrode systems, Quiz	Class based Learning/Test
Week 5	Ion- exchange membrane electrodes	Class based Learning/Test
Week 6	Class discussion, Gas-sensing electrodes	Class based Learning/Test
Week 7	Solid-state membrane electrode, Bio-membrane electrodes	Class based Learning/Test
Week 8	Mid Term Assessment	

Week 9	**Conductometry,** Introduction of conductometry, Conductance in Solutions	Class based Learning/Test
Week 10	Specific conductance, Basic concepts of molar conductance	Class based Learning/Test
Week 11	Factors affecting the conductance of solutions	Class based Learning/Test
Week 12	Measurement of conductance/Instrumentation	Class based Learning/Test
Week 13	Cell constant	Class based Learning/Test
Week 14	Analytical applications of conductance measurement	Class based Learning/Test
Week 15	Revision of analytical applications of conductance measurement	Class based Learning/Test
Week 16	Submission of assignments. If required, then discuss the whole chapter for final term exams preparation	

Textbooks and Reading Material

Recommended Books:

1. Gulaboski, R. (2012). Electrochemical Dictionary.
2. Kahlert, H. (2010). Potentiometry. Electroanalytical Methods: Guide to Experiments and Applications, 237-256.
3. Néher-Neumann, E. (2010). Advanced potentiometry: potentiometric titrations and their systematic errors. Springer Science & Business Media.
4. Skoog, D. A., & James, F. (2007). Holler, and Stanley R. Crouch. Principles of Instrumental.
5. Valcárcel, M. (2012). Principles of analytical chemistry: a textbook. Springer Science & Business Media.

Teaching Learning Strategies

- Lecturing using white/black board/Multimedia
- Written Assignments/presentations/ Task related to assigned topics
- Class activities and Discussion
- Quiz about last lecture
- Class Presentations Audio/visual Aids/ Tutorials

Assignments: Types and Number with Calendar

Assignments, quiz, Tasks, Presentation etc.

Assessment			
Sr. No.	**Elements**	**Weightage**	**Details**
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

BS Chemistry Semester-VII					
Program	**BS Chemistry**	**Course Code**	**Chem-447**	**Credit Hour**	**1**
Course Title	**Electroanalytical Techniques-1 (Lab I)**		**Course Type**	**Major (Elective)**	

Course Introduction

The course is organized to provide an adequate knowledge about electroanalytical techniques and determination of equivalence points for various types of acid-base titrations using conductometry and potentiometry.

Potentiometry:

Determine the amount of HCl by using strong base (NaOH) potentiometrically.
Determine the amount of HCl by using weak base (NH4OH) potentiometrically.
Determine the amount of CH_3COOH by using strong base (NaOH).
Determine the amount of HCl & CH_3COOH conductometrically by using strong base NaOH.
Simple acid base titrations using potentiometer.

Conductometry:

Determine the amount of HCl conductometrically by using strong base NaOH.
Determine the amount of base NH_4OH conductometrically by using strong acid.
Determine the amount of NH_4OH by using weak acid CH_3COOH conductometrically.
Determine the amount of NaOH conductometrically by using weak acid CH_3COOH.

Learning Outcomes

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

1. Understand advanced analytical techniques named electroanalytical techniques.
2. Learn the principles and theories involved in Potentiometry and Conductometry.
3. Gain knowledge about measurements involving the potential and/or the conductance of various species using a number of versatile electrodes.
4. Determine the equivalence points for various types of acid-base titrations using conductometry and potentiometry.

Course Content		Assignments/Readings
Week 1	Potentiometry, Determine the amount of HCl by using strong base (NaOH) potentiometrically.	Lab based Performance/Lab reports
Week 2	Determine the amount of HCl by using weak base (NH_4OH) potentiometrically.	Lab based Performance/Lab reports
Week 3	Determine the amount of CH_3COOH by using strong base (NaOH).	Lab based Performance/Lab reports
Week 4	Determine the amount of HCl & CH_3COOH conductometrically by using strong base NaOH.	Lab based Performance/Lab reports
Week 5	Determine the amount of HCl & CH_3COOH conductometrically by using strong base NaOH.	Lab based Performance/Lab reports

Week 6	Simple acid base titrations using potentiometer.	Lab based Performance/Lab reports
Week 7	Simple acid base titrations using potentiometer.	Lab based Performance/Lab reports
Week 8	MID TERM EXAMS	
Week 9	Conductometry, Determine the amount of HCl conductometrically by using strong base NaOH.	Lab based Performance/Lab reports
Week 10	Determine the amount of HCl conductometrically by using strong base NaOH.	Lab based Performance/Lab reports
Week 11	Determine the amount of base NH_4OH conductometrically by using strong acid.	Lab based Performance/Lab reports
Week 12	Determine the amount of base NH_4OH conductometrically by using strong acid.	Lab based Performance/Lab reports
Week 13	Determine the amount of NH_4OH by using weak acid CH_3COOH conductometrically.	Lab based Performance/Lab reports
Week 14	Determine the amount of NH_4OH by using weak acid CH_3COOH conductometrically.	Lab based Performance/Lab reports
Week 15	Determine the amount of NaOH conductometrically by using weak acid CH_3COOH.	Lab based Performance/Lab reports
Week 16	FINAL TERM EXAMS	

Textbooks and Reading Material

Recommended Books:

1. Gulaboski, R. (2012). Electrochemical Dictionary.
2. Kahlert, H. (2010). Potentiometry. Electroanalytical Methods: Guide to Experiments and Applications, 237-256.
3. Skoog, D. A., & James, F. (2007). Holler, and Stanley R. Crouch. Principles of Instrumental.
4. Valcárcel, M. (2012). Principles of analytical chemistry: a textbook. Springer Science & Business Media.
5. J. Mendham, R. C. Denney, J. D. Barnes, & M. Thomas. (2000). Vogel's textbook of quantitative chemical analysis. Prentice Hall.

Teaching Learning Strategies
• Lecturing using white/black board/Multimedia • Written Assignments/presentations/ Task related to assigned topics • Class activities and Discussion • Quiz about last lecture • Class Presentations Audio/visual Aids/ Tutorials • Laboratory performance
Assignments: Types and Number with Calendar
Assignments, quiz, Tasks, Presentation etc.
Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

BS Chemistry Semester-VII					
Program	**BS Chemistry**	**Course Code**	**Chem-448**	**Credit Hours**	**2**
Course Title	**Molecular Absorption Spectroscopy**	**Course Type**	**Major (Elective)**		

Course Introduction

The aim of the course is to enable the students to understand the principles and instrumentations of molecular absorption spectroscopic techniques like UV-Visible, IR and Raman spectroscopies. The students will also be able to apply the acquired knowledge for the spectral determination by these techniques. The students will learn these techniques and their applications in chemical analysis.

Introduction to Spectroscopy/Spectrophotometry, Introduction to Molecular spectroscopy, absorption in UV and Visible range; Basic principle of Spectrophotometry; Beer-Lambert's law; Deviations; Instrumentation and applications.

UV/Vis Spectroscopy, The Nature of Electromagnetic Radiation, The Electromagnetic Spectrum, Atomic Energy Levels, molecular Electronic Energy Levels, Instrumentation, Radiation Sources, Wavelength Selection, Cells and Sampling Devices, Detectors, Readout Modules and application.

FTIR/Raman Spectroscopy, Origin of Infrared Spectra; Different vibrational modes, Normal coordinate and normal vibrations, Symmetry of normal vibrations and selection rule, Raman Spectroscopy, Vibrational Spectra in gaseous phase and inert gas matrices; Comparison of Raman with Infrared spectroscopy; Applications for qualitative and quantitative chemical analysis; Instrumentation details and their function.

Learning Outcomes

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

1. Understand the principles and instrumentations of molecular absorption spectroscopic techniques like UV-Visible, IR and Raman spectroscopies.
2. Apply the acquired knowledge for the spectral determination by these techniques.
3. Learn these techniques and their applications in chemical analysis.

	Course Content	**Assignments/Readings**
Week 1	Introduction to Spectroscopy/ Spectrophotometry, Introduction to Molecular spectroscopy	Class based Learning/Test
Week 2	Absorption in UV and Visible range, Basic principle of Spectrophotometry	Class based Learning/Test
Week 3	Beer-Lambert's law; Deviations; Instrumentation and applications	Class based Learning/Test
Week 4	UV/Vis Spectroscopy, The Nature of Electromagnetic Radiation, The Electromagnetic Spectrum	Class based Learning/Test
Week 5	Atomic Energy Levels, Molecular Electronic Energy Levels	Class based Learning/Test
Week 6	Instrumentation, Radiation Sources, Wavelength Selection	Class based Learning/Test

Week 7	Cells and Sampling Devices, Detectors, Readout Modules and application	Class based Learning/Test
Week 8	**MID TERM ASSESSMENT**	
Week 9	FTIR / Raman Spectroscopy, Origin of Infrared Spectra	Class based Learning/Test
Week 10	Different vibrational modes, Normal coordinate and normal vibrations	Class based Learning/Test
Week 11	Symmetry of normal vibrations and selection rule	Class based Learning/Test
Week 12	Raman Spectroscopy	Class based Learning/Test
Week 13	Vibrational Spectra in gaseous phase and inert gas matrices	Class based Learning/Test
Week 14	Comparison of Raman with Infrared spectroscopy	Class based Learning/Test
Week 15	Applications for qualitative and quantitative chemical analysis; Instrumentation details and their function	Class based Learning/Test
Week 16	**FINAL TERM ASSESSMENT**	

Textbooks and Reading Material

Recommended Books:

1. Parker, F. (2012). Applications of infrared spectroscopy in biochemistry, biology, and medicine. Springer Science & Business Media
2. Christian, G. D. (2020). Evolution of Analytical Sciences in the United States: A Historical Account. Annual Review of Analytical Chemistry, 13(1), 475-496.
3. Advances in Infrared Group Frequencies by L.J. Bellacy, Mathuen & Col. Amsterdam (1968).
4. Gupta, P., Das, S. S., & Singh, N. B. (2023). Spectroscopy. Jenny Stanford Publishing
5. Kuptsov, A. H., & Zhizhin, G. N. (1998). Handbook of Fourier transform Raman and infrared spectra of polymers. Elsevier.

Teaching Learning Strategies

- Lecturing using white/black board/Multimedia
- Written Assignments/presentations/ Task related to assigned topics
- Class activities and Discussion
- Quiz about last lecture
- Class Presentations Audio/visual Aids/ Tutorials

Assignments: Types and Number with Calendar

Assignments, quiz, Tasks, Presentation etc.

Assessment			
Sr. No.	**Elements**	**Weightage**	**Details**
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

BS Chemistry Semester-VII					
Program	**BS Chemistry**	**Course Code**	**Chem-449**	**Credit Hour**	**1**
Course Title	**Molecular Absorption Spectroscopy (Lab I)**		**Course Type**	**Major (Elective)**	

Course Introduction

The course is organized to apply theoretical knowledge about molecular spectroscopy, determine the characteristic wavelength and then application of the Beer's law for quantitative determination.
To determine λ_{max} of $KMNO_4$ using spectrophotometer.
To determine the concentration of $KMNO_4$ in the given sample using spectrophotometer.
To determine λ_{max} of $K_2Cr_2O_7$ using spectrophotometer.
To determine the concentration of $K_2Cr_2O_7$ in the given sample using spectrophotometer.
To determine the concentration of Iron (II) using 1, 10-phenanthroline method.
To determine the concentration of Iron (III) using thiocyanate method.
To determine the concentration of chromium by diphenylcarbazide method.
To determine the concentration of Ni by DMG method spectrophotometrically.
Determination of mixtures of complexes of Iron with Thiocyanide and 1, 10, phenanthroline
FTIR analysis of various organic molecules

Learning Outcomes

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

1. Apply theoretical knowledge about molecular spectroscopy.
2. Determine the characteristic wavelength.
3. Apply the Beer's law for quantitative determination.
4. Interpret the FTIR spectra of unknown compounds.

	Course Content	Assignments/Readings
Week 1	To determine λ_{max} of $KMNO_4$ using spectrophotometer.	Lab based Performance/Lab reports
Week 2	To determine the concentration of $KMNO_4$ in the given sample using spectrophotometer.	Lab based Performance/Lab reports
Week 3	To determine the concentration of $KMNO_4$ in the given sample using spectrophotometer.	Lab based Performance/Lab reports
Week 4	To determine λ_{max} of $K_2Cr_2O_7$ using spectrophotometer.	Lab based Performance/Lab reports
Week 5	To determine λ_{max} of $K_2Cr_2O_7$ using spectrophotometer.	Lab based Performance/Lab reports
Week 6	To determine the concentration of $K_2Cr_2O_7$ in the given sample using spectrophotometer.	Lab based Performance/Lab reports
Week 7	To determine the concentration of Iron (II) using 1, 10-phenanthroline method.	Lab based Performance/Lab reports
Week 8	MID TERM EXAMS	

Week 9	To determine the concentration of Iron (III) using thiocyanate method.	Lab based Performance/Lab reports
Week 10	To determine the concentration of chromium by diphenylcarbazide method.	Lab based Performance/Lab reports
Week 11	To determine the concentration of Ni by DMG method spectrophotometrically.	Lab based Performance/Lab reports
Week 12	To determine the concentration of Ni by DMG method spectrophotometrically.	Lab based Performance/Lab reports
Week 13	Determination of mixtures of complexes of Iron with Thiocyanide and 1, 10, phenanthroline.	Lab based Performance/Lab reports
Week 14	FTIR analysis of various organic molecules.	Lab based Performance/Lab reports
Week 15	FTIR analysis of various organic molecules.	Lab based Performance/Lab reports
Week 16	FINAL TERM EXAMS	

Textbooks and Reading Material

Recommended Books:

1. Parker, F. (2012). Applications of infrared spectroscopy in biochemistry, biology, and medicine. Springer Science & Business Media
2. Christian, G. D. (2020). Evolution of Analytical Sciences in the United States: A Historical Account. Annual Review of Analytical Chemistry, 13(1), 475-496.
3. Advances in Infrared Group Frequencies by L.J. Bellacy, Mathuen & Col. Amsterdam (1968).
4. Gupta, P., Das, S. S., & Singh, N. B. (2023). Spectroscopy. Jenny Stanford Publishing
5. Kuptsov, A. H., & Zhizhin, G. N. (1998). Handbook of Fourier transform Raman and infrared spectra of polymers. Elsevier.

Teaching Learning Strategies

- Lecturing using white/black board/Multimedia
- Written Assignments/presentations/ Task related to assigned topics
- Class activities and Discussion
- Quiz about last lecture
- Class Presentations Audio/visual Aids/ Tutorials
- Laboratory performance

Assignments: Types and Number with Calendar

Assignments, quiz, Tasks, Presentation etc.

Assessment			
Sr. No.	**Elements**	**Weightage**	**Details**
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

BS Chemistry Semester-VII					
Program	**BS Chemistry**	**Course Code**	**Chem-450**	**Credit Hours**	**2**
Course Title	**Atomic Spectrochemical Analysis**		**Course Type**	**Major Elective**	

Course Introduction

In this course, the students will be able to learn about atomic emission, atomic absorption and atomic fluorescence spectroscopic techniques. The course will enable students to understand the theory and applications of atomic spectroscopy in various samples.

Atomic Emission/Atomic Florescence Spectroscopy, Basic principle of atomic emission spectroscopy; Source of atomization; Use of atomic spectra for detection and determination of elements; flame as a source of atomization and excitation; Instrumentation involved in FES; applications and limitations, Flame temperatures. Atomic Florescence Spectroscopy, Instrumentation, Applications, plasma sources and ICP-AES
Atomic Absorption Spectroscopy, Basic Principle of AAS, Flameless AA spectroscopy including graphite furnace and hydride generation, Interferences, Instrumentation and application and limitations

Learning Outcomes

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

1. Learn about atomic emission, atomic absorption and atomic fluorescence spectroscopic techniques.
2. Enable students to understand the theory of atomic spectroscopy in various samples.
3. Enable students to understand the applications of atomic spectroscopy in variety of samples.

	Course Content	**Assignments/Readings**
Week 1	Atomic Emission / Atomic Florescence Spectroscopy, Basic principle of atomic emission spectroscopy	Class based Learning/Test
Week 2	Source of atomization; Use of atomic spectra for detection and determination of elements	Class based Learning/Test
Week 3	Flame as a source of atomization and excitation	Class based Learning/Test
Week 4	Instrumentation involved in FES; applications and limitations	Class based Learning/Test
Week 5	Flame temperatures	Class based Learning/Test
Week 6	Atomic Florescence Spectroscopy, Instrumentation	Class based Learning/Test
Week 7	Applications, plasma sources and ICP-AES	Class based Learning/Test
Week 8	MID TERM ASSESSMENT	
Week 9	Atomic Absorption Spectroscopy Basic Principle of AAS	Class based Learning/Test

Week 10	Flameless AA spectroscopy	Class based Learning/Test
Week 11	Flameless AA spectroscopy including graphite furnace	Class based Learning/Test
Week 12	Flameless AA spectroscopy including hydride generation	Class based Learning/Test
Week 13	Interferences	Class based Learning/Test
Week 14	Instrumentation of AAS	Class based Learning/Test
Week 15	Application and limitations of AAS	Class based Learning/Test
Week 16	FINAL TERM ASSESSMENT	

Textbooks and Reading Material

Recommended Books:

1. Thomas, R. (2023). Practical Guide to ICP-MS and Other Atomic Spectroscopy Techniques: A Tutorial for Beginners.
2. Sultan, K. (2022). Practical Guide to Materials Characterization: Techniques and Applications. John Wiley & Sons.
3. Analytical Chemistry by Gary D. Christian, John Wiley and Sons (2014).
4. Stockwell, P. B. (1979). A total systems approach to laboratory automation. Journal of Analytical Methods in Chemistry, 1(4), 216-221.
5. Angino, E. (Ed.). (2012). Atomic absorption spectrometry in geology
6. Lai, W. F. (Ed.). (2023). Materials Science and Engineering in Food Product Development. John Wiley & Sons.

Teaching Learning Strategies

- Lecturing using white/black board/Multimedia
- Written Assignments/presentations/ Task related to assigned topics
- Class activities and Discussion
- Quiz about last lecture
- Class Presentations Audio/visual Aids/ Tutorials

Assignments: Types and Number with Calendar

Assignments, quiz, Tasks, Presentation etc.

Assessment			
Sr. No.	**Elements**	**Weightage**	**Details**
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

BS Chemistry Semester-VII					
Program	BS Chemistry	**Course Code**	**Chem-451**	**Credit Hour**	**1**
Course Title	**Atomic Spectrochemical Analysis (Lab)**	**Course Type**	**Major (Elective)**		

Course Introduction

The course is organized so that students will be able to prepare the solutions of various concentrations, understand the hands-on use of atomic spectroscopic techniques for the practical determination of various elements in the given samples and use the atomic spectroscopy to obtain the valuable information.
Flame Emission / Spectrophotometry:
Determination of Sodium in tap water by using Flame Photometer.
Determination of Potassium in tap water by using Flame Photometer.
Find out the calcium in chalk sample by flame photometry.
Determination of Li by flame photometry.
Estimation of purity of various compounds on the base of flame emission Spectrophotometry.
Indirect determination of various compounds by flame photometric techniques.
Atomic Absorption/ Spectrophotometry:
Preparation of standard calibration graphs of Cd, Cu, Fe, Pb and Zn by AAS.
Determination of Cd, Cu, Fe, Pb and Zn in soil samples by AAS technique.

Learning Outcomes

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

1. Prepare the solutions of various concentrations.
2. Understand the hands-on use of atomic spectroscopic techniques for the practical determination of various elements in the given samples.
3. Use the atomic spectroscopy to obtain the valuable information.
4. Estimate the concentration of metals in unknown samples.

	Course Content	**Assignments/Readings**
Week 1	Flame Emission / Spectrophotometry: Determination of Sodium in tap water by using Flame Photometer.	Lab based Performance/Lab reports
Week 2	Determination of Potassium in tap water by using Flame Photometer.	Lab based Performance/Lab reports
Week 3	Find out the calcium in chalk sample by flame photometry.	Lab based Performance/Lab reports
Week 4	Determination of Li by flame photometry.	Lab based Performance/Lab reports
Week 5	Estimation of purity of various compounds on the base of flame emission Spectrophotometry.	Lab based Performance/Lab reports
Week 6	Estimation of purity of various compounds on the base of flame emission Spectrophotometry.	Lab based Performance/Lab reports
Week 7	Indirect determination of various compounds by flame photometric techniques.	Lab based Performance/Lab reports
Week 8	MID TERM EXAMS	

Week 9	Atomic Absorption/ Spectrophotometry: Preparation of standard calibration graphs of Cd, Cu, Fe, Pb and Zn by AAS.	Lab based Performance/Lab reports
Week 10	Preparation of standard calibration graphs of Cd, Cu, Fe, Pb and Zn by AAS.	Lab based Performance/Lab reports
Week 11	Determination of Cd, Cu, Fe, Pb and Zn in soil samples by AAS technique.	Lab based Performance/Lab reports
Week 12	Determination of Cd, Cu, Fe, Pb and Zn in soil samples by AAS technique.	Lab based Performance/Lab reports
Week 13	Determination of Cd, Cu, Fe, Pb and Zn in soil samples by AAS technique.	Lab based Performance/Lab reports
Week 14	Determination of Cd, Cu, Fe, Pb and Zn in soil samples by AAS technique.	Lab based Performance/Lab reports
Week 15	Determination of Cd, Cu, Fe, Pb and Zn in soil samples by AAS technique.	Lab based Performance/Lab reports
Week 16	FINAL TERM EXAMS	

Textbooks and Reading Material

Recommended Books:

1. Thomas, R. (2023). Practical Guide to ICP-MS and Other Atomic Spectroscopy Techniques: A Tutorial for Beginners.
2. Sultan, K. (2022). Practical Guide to Materials Characterization: Techniques and Applications. John Wiley & Sons.
3. Stockwell, P. B. (1979). A total systems approach to laboratory automation. Journal of Analytical Methods in Chemistry, 1(4), 216-221.
4. Angino, E. (Ed.). (2012). Atomic absorption spectrometry in geology
5. Lai, W. F. (Ed.). (2023). Materials Science and Engineering in Food Product Development. John Wiley & Sons

Teaching Learning Strategies

- Lecturing using white/black board/Multimedia
- Written Assignments/presentations/ Task related to assigned topics
- Class activities and Discussion
- Quiz about last lecture
- Class Presentations Audio/visual Aids/ Tutorials
- Laboratory performance

Assignments: Types and Number with Calendar

Assignments, quiz, Tasks, Presentation etc.

Assessment			
Sr. No.	**Elements**	**Weightage**	**Details**
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

BS Chemistry Semester-VII					
Program	**BS Chemistry**	**Course Code**	**Chem-452**	**Credit Hours**	**3**
Course Title	**Hyphenated Chromatographic Techniques**		**Course Type**	**Major (Elective)**	

Course Introduction

This course deals with the advanced chromatographic techniques like HPLC and GC. The students will learn about the instrumentation, applications and the sensitivities etc of these techniques. Furthermore, basic principle and applications of Potentiometry along with the various electrodes will be studied. The role of thermal methods in the analysis of various samples will be studied.

Gas Liquid Chromatography / Gas Solid Chromatography: Gas Chromatographs, Derivative Formation, Gas Chromatographic Columns, Liquid Phases and Column Selection, Detectors for Gas Chromatography, Optimization of Experimental Condition, Gas-Solid Chromatography, Interfacing Gas Chromatography with Mass Spectrometry, Interfacing Gas Chromatography with Infrared Spectrometry,

High Performance Liquid Chromatography: Optimization of Column Performance, Gradient Elution and Related Procedures, Derivation, HPLC Instrumentation, Mobile-Phase Delivery System, Sample Introduction, Separation Columns, Detectors, Interfacing HPLC with Mass Spectrometry, Instrumentation, detectors, sensitivity, precisian, sample types and qualitative and quantitative analysis.

Learning Outcomes

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

1. Learn about the instrumentation, applications and the sensitivities etc. of HPLC and GC techniques.
2. Understand the basic principle and applications of Potentiometry along with the various electrodes.
3. Comprehend the role of thermal methods in the analysis of various samples.
4. Interpret the graph of HPLC, GC, Potentiometric and TGA results.

	Course Content	**Assignments/Readings**
Week 1	Gas Liquid Chromatography / Gas Solid Chromatography, Gas Chromatographs	Class based Learning/Test
Week 2	Derivative Formation, Gas Chromatographic Columns	Class based Learning/Test
Week 3	Liquid Phases and Column Selection, Detectors for Gas Chromatography	Class based Learning/Test
Week 4	Optimization of Experimental Condition	Class based Learning/Test
Week 5	Gas-Solid Chromatography	Class based Learning/Test
Week 6	Interfacing Gas Chromatography with Mass Spectrometry	Class based Learning/Test

Week 7	Interfacing Gas Chromatography with Infrared Spectrometry	Class based Learning/Test
Week 8	**MID TERM ASSESSMENT**	
Week 9	High Performance Liquid Chromatography, Optimization of Column Performance	Class based Learning/Test
Week 10	Gradient Elution and Related Procedures, Derivation, HPLC Instrumentation	Class based Learning/Test
Week 11	Mobile-Phase Delivery System, Sample Introduction	Class based Learning/Test
Week 12	Separation Columns, Detectors	Class based Learning/Test
Week 13	Interfacing HPLC with Mass Spectrometry, Instrumentation	Class based Learning/Test
Week 14	Detectors, Sensitivity, and Precision	Class based Learning/Test
Week 15	Sample types, qualitative and quantitative analysis.	Class based Learning/Test
Week 16	**FINAL TERM ASSESSMENT**	

Textbooks and Reading Material

1. Fulekar, M. H., & Pathak, B. (2017). Environmental nanotechnology.
2. Grob, R. L., & Barry, E. F. (Eds.). (2016). Modern practice of gas chromatography. John Wiley & Sons.
3. Smith, C. G. (2020). Handbook of Chromatography: Volume II: Polymers. CRC Press.
4. Snyder, L. R., Kirkland, J. J., & Dolan, J. W. (2011). *Introduction to modern liquid chromatography*. John Wiley & Sons.

Teaching Learning Strategies

- Lecturing using white/black board/Multimedia
- Written Assignments/presentations/ Task related to assigned topics
- Class activities and Discussion
- Quiz about last lecture
- Class Presentations Audio/visual Aids/ Tutorials

Assignments: Types and Number with Calendar

Assignments, quiz, Tasks, Presentation etc.

Assessment			
Sr. No.	**Elements**	**Weightage**	**Details**
2.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.