



**Federal Urdu University**  
of Arts, Science and Technology

**Syllabus**  
**Analytical Chemistry**  
**(BS & MSc)**  
**Department of Chemistry**  
**2012**

# BS: 2<sup>nd</sup> Year

Title of the Course  
Credit Hours: (3+1)

Analytical Chemistry

Code: CHEM-111  
Marks: 100

## 1- The Chemicals, Apparatus and Unit Operation of Analytical Chemistry (10 credits)

- The Selection and Handling of Reagents
- The Cleaning and Marking of Laboratory Ware
- The Evaporation of Liquids
- The Measurement of Mass
- The Equipment and Manipulations Associated with Weighing
- The Equipment and Manipulations for Filtration and Ignition
- The Measurement of Volume
- The Calibration of Volumetric Ware
- Safety in the Laboratory
- Preparation of Standard Base Solutions
- Preparation of Standard Acid Solutions

## 2- An Introduction to Analytical Chemistry (15 credits)

- Solution Concentrations
- Units of Concentrations
- Applications of Concentrations
- The Dilution of Solutions
- The Dilution Formula
- Mixing Solutions
- Concentrations in terms of pH
- The Self-ionization of Water
- The pH Scale
- Problems involving pH
- Dilution of Acidic or Basic Solutions
- Redox Reactions
- Oxidation Numbers
- Identifying the Oxidant Reductant
- Writing Balanced Redox Equations

## 3- Volumetric Analysis (10 credits)

- Calculations in Volumetric Analysis
- Acid-Base Theory
- Acid-Base Titrations
- pH Changes during Titrations
- Selecting an Indicator
- Primary Standards (Acids and Bases)
- Secondary Standards (Acids and Bases)
- Redox Titrations
- More Complex Volumetric Analysis
- Back Titrations

#### **4- Stoichiometric Analysis (10 credits)**

Mole relationships  
Reactions involving gases  
Gas Stoichiometry  
Mass-Volume or Concentration-Volume  
Volume-Volume Stoichiometry  
Gravimetric Analysis  
Drying and Ignition of Precipitate  
Gravimetric Calculations  
Application of Gravimetric Analysis

#### **Practical**

Fifteen experiments shall be conducted based on the following:

1. Cleansing of Glass Ware
2. Calibration of Volume Measuring Glassware
3. Calibration of Electronic Analytical Balance
4. Preparation of Solutions
5. Dilution of Solutions
6. Experiments demonstrating the use of Gravimetry in Quantitative Analysis
7. Experiments based on Acid-Base Titrations
8. Experiments based on Complexometric Titrations
9. Experiments based on Redox Titrations

#### **Recommended Literature**

1. Blackburn, Thomas, R., "Equilibrium- A Chemistry of Solutions", Holt, Rinehart and Winston, Inc., 1969.
2. Christian, G.D., "Analytical Chemistry" 6th ed., John Wiley & Sons, New York, 2003.
3. Harris D.C., "Quantitative Chemical Analysis" 4<sup>th</sup> Ed., Freeman (1995).
4. Miller J.C., and Miller J.N., "Statistics for Analytical Chemists"
5. Skoog D.A., West D.D., and Holler F.J., "Fundamentals of Analytical Chemistry" 6<sup>th</sup> Ed., Saunders College Publishing, 1992.

**BS 3<sup>rd</sup> Year, Semester-V**  
**M.Sc. (Previous), Semester-I**

Title of the Course  
Credit Hours: (3+1)

Analytical Chemistry

Code: CHEM-211  
Marks: 100

**1- Errors in Chemical Analysis and Sampling (10 credits)**

- Accuracy
- Precision
- Errors
- Deviation
- Variance
- Mean, median, mode
- Discarding an analytical result
- Comparison of result
- Confidence limit
- Minimization of errors
- Basis of sampling
- Sampling and physical states
- Crushing and grinding
- Hazards in sampling

**2- Molecular Spectroscopy (15 credits)**

- Properties of electromagnetic radiation
- Regions of electromagnetic radiation
- Molecular spectra
- Absorption spectroscopy (UV/ Visible)
- Components of spectrochemical measurement instrument
- Calorimeter
- Single-beam spectrophotometer
- Double-beam spectrophotometer
- Wave length choice for analysis
- Use of working curve
- Lambert Beer's laws of absorption of radiation
- Deviation from Beer's law
- Solution containing more than one absorbing species
- Photometric titration
- Determination of ligand to metal ratio in a complex

**3- Molecular Luminescence Spectroscopy (10 credits)**

- Theory of fluorescence and phosphorescence
- Instruments for measuring luminescence
- Use of luminescence for analysis

**4- Atomic Spectroscopy (10 credits)**

- Atomic spectra
- Atomic spectral line width
- Apparatus
- Radiation source

- Hollow cathode lamp
- Electrode less discharge lamp
- Cells
- Flames
- Furnaces
- Wave length selector
- Detector, Atomization method, Sample induction method
- Use of atomic spectroscopy or analysis.
- Interface in atomic absorption spectroscopy
- Flame emission spectroscopy

**Practical:**

Fifteen practical shall be conducted based on following:

- 1- Cleansing of Glass Wares
- 2- Calibration of Apparatus
- 3- To find out the  $\lambda_{\max}$  and  $\epsilon$  of  $\text{KMnO}_4$  Solution
- 4- Calculate the Concentration of Unknown Solution of  $\text{KMnO}_4$  Using Calibration Curve and Slope Method
- 5- To find out the  $\lambda_{\max}$  and  $\epsilon$  of  $\text{K}_2\text{Cr}_2\text{O}_7$  Solution
- 6- Calculate the Concentration of Unknown Solution of  $\text{K}_2\text{Cr}_2\text{O}_7$  Using Calibration Curve and Slope Method
- 7- Standardization of  $\text{KMnO}_4$  Solution performing Q - test and Statistical Analysis
- 8- Standardization of HCl Applying T- test

**BS 3<sup>rd</sup> Year, Semester-VI**  
**M.Sc. (Previous), Semester-II**

Title of the Course  
Credit Hours: (3+1)

Analytical Chemistry

Code: CHEM-311  
Marks: 100

**1. An introduction to Electrochemical Techniques (10 credits)**

- Electrochemical cell
- Electrolytic cell
- Galvanic cell
- Potential ( standard, formal, electrode, half cell, liquid junction)
- Electrochemical series
- Activity, activity coefficient, ionic strength
- Deby- Huckel theory
- Nernst equation

**2. Potentiometer (10 credits)**

- Kinds of electrode (first, second, third)
- Indicator electrode and calomel electrode
- Reference electrode
- Metallic electrode (Ag/AgCl)
- Membrane electrode (Glass electrode)
- Ion selective electrode
- Potentiometer
- pH meter / plon meter
- Determination of pH
- Alkaline, acidic, hygroscopic error
- Potentiometer titration
- End point location in potentiometric titration curves

**3. Conductometry (10 credits)**

- Conductivity, Molar conductivity
- Cell constant
- Conductivity cell
- Platinization of electrodes
- Conductivity meter
- Factors affecting conductivity
- Molar conductance at infinite dilutions
- Kolrausch's law
- Application
- Conductometric titration

**4. Introduction to Chromatography (5 credits)**

- Theory of chromatography
- Types of chromatography
- Paper chromatography
- Thin-layer chromatography
- Column chromatography

- Ion exchange chromatography
- Electrophoresis

### **5. Gas chromatography (10 credits)**

- Principle of chromatography
- Instrument
- Carrier gas
- Injection system
- Column
- Stationary phase
- Detectors
- Pumping system
- Instruments for liquid chromatography
- Applications

### **Practical:**

Fifteen practical shall be conducted based on following

1. To find out the  $R_f$  values of ink sample by using Paper Chromatography
2. To find out the Capacity of Cation-Exchange Resin and Concentration of Metal ion Solution
3. To Calculate the Acidity of Water Sample by Cation-Exchange Chromatography
4. To Calculate the Alkalinity of Water Sample by Cation-Exchange Chromatography
5. To Calculate the Concentration of Acids/Bases by Conductometry
6. To Calculate the Concentration of Acids/Bases by Potentiometry

### **Recommended Literature**

- 1- Skoog, Principles of instrument analysis
- 2- Braun, Introduction to chemical analysis
- 3- Text book of quantitative chemical analysis by Vogel
- 4- Principles of Chemical Instrumentation by Bendor
- 5- Basic Instrumental Analysis by Pease
- 6- Quantitative Chemical Analysis by HERRIS
- 7- Fundamentals of Analysis Chemistry by Skoog

# BS 4<sup>th</sup> Year Semester-VII

## M.Sc. (Final), Semester-I

Title of the Course: Molecular Spectroscopy  
Credit Hours: (4+0)

Code: CHEM-412  
Marks: 100

### **1-Applications of Ultraviolet/Visible Molecular Absorption Spectrometry (15 credits)**

Molar Absorptivity  
Absorbing Species  
Chromophores  
Effect of Conjugation of Chromophores  
Absorption Involving d and f electrons  
Charge Transfer Absorption  
Qualitative Analysis  
Detection of Functional Group  
Quantitative Analysis  
Applications to Non-absorbing Species  
Variables that Influence Absorbance  
Standard Addition Method  
Analysis of Mixtures  
Photometric Titrations

### **2- Infrared Spectrometry (15 credits)**

Theory of Infrared Absorption Spectrometry  
Dipole Changes during Vibration  
Types of Molecular Vibrations  
Simple Harmonic Oscillator  
An Harmonic Oscillator  
Vibrational Modes  
Infrared Instruments  
Mid-Infrared Absorption Spectrometry  
Sample Handling  
Qualitative Analysis  
Group Frequencies  
Finger Print Region  
Near-Infrared Spectroscopy  
Applications of Near-Infrared Spectrometry  
Far-Infrared Spectroscopy

### **3- Nuclear Magnetic Resonance Spectroscopy (15 credits)**

Theory of Nuclear Magnetic Resonance  
Precession of Nuclei  
Relaxation  
Free Induction Decay  
Chemical Shift



Effect of Magnetic Anisotropy  
Spin-Spin Splitting  
NMR Spectrometer  
Locking the Magnetic Field  
Shimming  
Sample Spinning  
Applications of Proton NMR

#### **4-Molecular Mass Spectrometry (15 credits)**

Ion Sources  
The Electron Impact Source  
Chemical Ionization  
Mass Spectrometer  
Quadropole Mass Spectrometer  
Applications  
Identification of Pure Compounds  
Molecular Formula  
Structural Information

**BS 4<sup>th</sup> Year Semester-VII**  
**M.Sc. (Final), Semester-I**

Title of the Course: Separation Techniques  
Credit Hours: (4+0)

Code: CHEM-413  
Marks: 100

**1-Solvent Extraction (15 credits)**

Distribution Coefficient  
Distribution Ratio  
Percent Extracted  
Single Step Solvent Extraction  
Multiple Steps Solvent Extraction or Counter Current Distribution  
Liquid-Solid Extraction (Introduction)

**2-Gas Chromatography (15 credits)**

Principle of Gas-Liquid Chromatography  
Retention Volume  
Retention Times  
Effect of Mobile-Phase Flow Rate  
Instrument for Gas-Liquid Chromatography  
Carrier Gas System  
Sample Injection System  
Column Configurations and Column Ovens  
Detection Systems  
Applications of Gas-Liquid Chromatography  
Gas-Solid Chromatography

**3- High-Performance Liquid Chromatography (15 credits)**

Scope of HPLC  
Column Efficiency  
Instrument for Liquid Chromatography  
Mobile-Phase Reservoirs and Solvent Treatment Systems  
Pumping Systems  
Sample-Injection Systems  
Columns for HPLC (Analytical Columns and Guard Columns)  
Column Temperature Control  
Detectors  
Applications of HPLC

**4-Electrophoresis (15 credits)**

Capillary Electrophoresis  
Instrumentation for Capillary Electrophoresis  
Electro-Osmotic Flow  
Applications of Capillary Electrophoresis  
Capillary Electrochromatography

# BS 4<sup>th</sup> Year Semester-VII

## M.Sc. (Final), Semester-I

Title of the Course: Electroanalytical Techniques Code: CHEM-414  
Credit Hours: (4+0) Marks: 100

### 1-An Introduction to Electroanalytical Chemistry (30 credits)

#### i- Electrochemical Cells

Conduction in a Cell  
Structure of Solution, Double Layer  
Faradic and Non-Faradic Currents  
Mass Transfer  
Galvanic and Electrolytic Cells  
Anodes and Cathodes  
Schematic Representation of Cells

#### ii- Potentials in Electrochemical Cells

Thermodynamics of Cell Potential  
Liquid Junction Potential  
Electrode Potential  
Formal Potential  
Standard Hydrogen Electrode Potential  
Reference Electrodes  
Effect of Activity on Electrode Potential  
Effect of Equilibrium on Potential  
Effect of Rate Constant on Potential  
Measurement of Electrode Potential  
Calculation of Half-Cell Potential from  $E^\circ$  Values  
Calculation of Half-Cell Potential from Electrode Potentials

#### iii- Currents in Electrochemical Cells

IR Drop  
Polarization  
Concentration Polarization  
Charge Transfer Polarization  
Polarized and Non-Polarized Electrodes  
Overvoltage

### 2-Voltammetry (15 credits)

Voltammetric Current  
Current Voltage Relationship  
Voltammograms  
Voltammetric Sensors  
Microelectrodes  
Types of Voltammetry  
Cyclic Voltammetry

### 3- Coulometry (15 credits)

Current Voltage Relationship during Electrolysis  
Constant Potential Electrolysis  
Constant Current Electrolysis  
Potentiostats  
Potentiostatic Coulometry  
Amperometric Coulometry  
Applications

**BS 4<sup>th</sup> Year Semester-VII**  
**M.Sc. (Final), Semester-I**

Title of the Course: Advanced Practical  
Credit Hours: (0+4)

Code: CHEM-411  
Marks: 100

**1- Quantitative Analysis (30 credits)**

Experiments to be designed relevant to theory course.

**2- Quantitative Analysis (30 credits)**

Experiments to be designed relevant to theory course.

**BS 4<sup>th</sup> Year Semester-VIII**  
**M.Sc. (Final), Semester-II**

Title of the Course: Atomic Spectroscopy  
Credit Hours: (4+0)

Code: CHEM-512  
Marks: 100

**1-Introduction to Atomic Spectrometry (20 credits)**

Atomic Line Widths  
Line Broadening from the Uncertainty Effect  
Doppler Broadening  
Pressure Broadening  
Effect of Temperature  
Atomization Methods  
Sample Introduction Methods  
Nebulizers

**2- Atomic Absorption Spectrometry (20 credits)**

Flame Atomization  
Electrothermal Atomization  
Atomic Absorption Instrument  
Hollow Cathode Lamp  
Source Modulation  
Spectral Interferences  
Background Correction  
Continuum-Source Correction  
Zeeman Effect  
Source Self- Reversal  
Chemical Interferences  
Releasing Agents  
Protective Agents  
Ionization Suppressor  
Applications

**3-Atomic Emission Spectrometry (20 credits)**

Plasma  
Coupled Plasma Source  
Direct Current Plasma Source  
Applications of Plasma Sources  
Arc Source Emission Spectroscopy  
Cyanogens Spectral Bands  
Spark Sources  
Applications of Spark Source Spectroscopy

**BS 4<sup>th</sup> Year Semester-VIII**  
**M.Sc. (Final), Semester-II**

Title of the Course: Environmental Analytical Chemistry and Sampling

Code: CHEM-513

Credit Hours: (4+0)

Marks: 100

**1-Environmental Analytical Chemistry (20 credits)**

Aquatic, Soil and Atmospheric Chemistry  
Problems of Water, Soil and Air Pollution  
Causes of Pollutants  
Methods of Analysis  
Study of Contaminant in Food  
Study of City Water Supply  
Study of Solid Waste  
Getting a Sample  
Air Sample Collection and Analysis  
Water Sample Collection and Analysis  
Soil and Sediment Sampling  
Sample Preparation for Trace Organics  
EPA Methods and Analysis

**2-Analysis of Real Samples (20 credits)**

Real Samples  
Choice of Analytical Methods  
Accuracy in the Analysis of Complex Materials

**3-Preparing Samples for Analysis (20 credits)**

Preparing Laboratory Samples  
Moisture in Samples  
Determining Water in Samples  
Decomposing and Dissolving the Samples  
Decomposing Samples with Inorganic Acids  
Microwave Decomposition  
Combustion Methods for Decomposing Organic Samples  
Decomposition of Inorganic Materials by Fluxes

**BS 4<sup>th</sup> Year Semester-VIII**  
**M.Sc. (Final), Semester-II**

Title of the Course: Automated Methods of Analysis and Evaluation of Analytical Data

Code: CHEM-514

Credit Hours: (4+0)

Marks: 100

**1-Automation in Measurements (15 credits)**

Principles of Automation  
Automated Instruments: Process Control  
Automatic Instruments  
Flow Injection Analysis  
Microprocessors and Computers

**2-Evaluating Analytical Data (15 credits)**

Measure of Spread  
Measure of Central Tendency  
Gaussian Distribution  
Confidence Limit  
Confidence Interval  
Propagation of Uncertainty  
Probability Distribution for Sample and Population  
Confidence Interval for Sample and Population  
Probability in Statistics

**3-Statistical Analysis of Data (15 credits)**

Significant Testing  
Rejection of a Result  
Hypothesis Testing  
Analysis of Variance  
Comparing Two Sample Variances

**4-Linear Regression and Calibration Curves (15 credits)**

Linear Regression of Straight Line Calibration Curves  
Linear Regression with Error in Y-axis  
Linear Regression with Error in Both X and Y-axis  
Slope, Intercept, and Coefficient of Determination (Correlation)  
Using Spreadsheets for Plotting Calibration Curves  
Statistics Software Packages



## Recommended Literature

1. Analytical Chemistry by Gary D. Christian; 6<sup>th</sup> ed. 2004; John Wiley & Sons, Inc.
2. Fundamentals of Analytical Chemistry by Douglas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch; 8<sup>th</sup> ed. 2003; Saunders College Publishing, Philadelphia.
3. Instrumental Methods of Analysis by Hobert H. Willard D.L. Merrit & J.R.J.A. Dean, Frank A. Settle; 7<sup>th</sup> Sub edition 1988; Wadsworth Publishing Company.
4. Skoog, Principles of instrument analysis
5. Braun, Introduction to chemical analysis
6. Text book of quantitative chemical analysis by Vogel
7. Principles of Chemical Instrumentation by Bendor
8. Basic Instrumental Analysis by Pease
9. Quantitative Chemical Analysis by Hennis
10. Fundamentals of Analysis Chemistry by Skoog

**BS 4<sup>th</sup> Year Semester-VIII**  
**M.Sc. (Final), Semester-II**

Title of the Course:

Advanced Practical

Code: CHEM-511

Credit Hours: (0+4)

Marks: 100

**1- Quantitative Analysis (30 credits)**

Experiments to be designed relevant to theory course.

**2- Quantitative Analysis (30 credits)**

Experiments to be designed relevant to theory course.