Faculty of Sciences

Department of Chemistry

B.S (Chemistry)

Vision

The Department of Chemistry aspires to become a leading institute of higher education which is recognized for its innovation, excellence in promoting quality education to ensure well qualified graduates with high ethical and moral values to serve in national and international organization. By maintaining its research programs to meet the emerging challenges in agriculture, industries, and environment, the Department of Chemistry enhances the recognition and reputation of the University of Agriculture, Faisalabad, Pakistan globally.

Mission

The Department of Chemistry with excellence in academics and research, aims at providing conducive student-centered learning environment for imparting high-quality market-oriented education, conducting collaborative research, and producing highly qualified human resource. To make liaisons with local industry and conduct research to solve their problems. Integrating traditional technologies with innovative technologies in agriculture, health and chemical industry with the aim to meet the sustainable development goals.

Program Educational Objectives (PEOs)

After four years of graduation, diversified professional areas are available for the graduates of chemistry like:

1. Various industrial sectors like agricultural pesticides, fertilizers, textiles, pharmaceuticals, food, paint, leather, glass, cement, sugar, oil and gas, polymer, etc.
2. Research organizations like PCSIR, NFC, etc.
3. SPD organizations like PAEC, NDC, MTC, etc.
4. Laboratories working under government/semi-government authorities like forensic laboratories, drug testing laboratories, food authority, environmental laboratory, textile testing laboratory, etc.

Program Learning Course Outcomes (PLOs) (Graduate Attributes)

Knowledge: An ability to apply knowledge of Chemistry

Problem Analysis: An ability to identify, formulate, search literature, and analyze complex problems reaching substantiated conclusions using principles of Chemical Sciences

Design/Development of Solutions: An ability to design solutions for complex problems and design systems, with appropriate consideration for agriculture, health and chemical industry.

Investigation: An ability to investigate complex problems in a methodical way including literature survey, design and analysis to extract valid conclusions.

Modern Tool Usage: An ability to create, select and apply appropriate techniques, resources, latest software, like Chemoffice, chemsktech, Gauss view, Avogadro's, Gaussian.

The Scientist and Society: An ability to apply reasoning informed by contextual knowledge to assess societal, cultural issues and the consequent responsibilities relevant to professional practice and solution to environmental, agricultural, energy, water treatment, health issues.

Environment and Sustainability: An ability to understand the impact of professional solutions in societal and environmental contexts and demonstrate knowledge of, and need for, sustainable development.

Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of practice.

Individual and Teamwork: An ability to work effectively, as an individual or in a team, on multifaceted and /or multidisciplinary settings.

Communication: An ability to communicate effectively, orally as well as in writing, on projects, technical reports, thesis.

Project Management: An ability to demonstrate management skills and apply scientific principles to one's own work, as a member and/or leader in a team, to manage projects in a multidisciplinary environment.

Lifelong Learning: An ability to recognize the need for, and have the preparation and ability to engage in, independent and life-long learning in the broadest context of technological change.

DEPARTMENT OF CHEMISTRY
REVISED UNDERTGRADUATE CURRICULUM 2022

Sr.#	EXISTING			PROPOSED		
1	CHEM-310	FUNDAMENTALS OF INORGANIC CHEMISTRY	4(3-1)	CHEM-310	FUNDAMENTALS OF INORGANIC CHEMISTRY	4(3-1)
2	CHEM-311	FUNDAMENTALS OF ORGANIC CHEMISTRY	4(3-1)	CHEM-311	FUNDAMENTALS OF ORGANIC CHEMISTRY	4(3-1)
3	CHEM-407	CHEMISTRY OF ENVIRONMENT	3(3-0)	CHEM-407	CHEMISTRY OF ENVIRONMENT	3(3-0)
4	CHEM-408	FUNDAMENTALS OF PHYSICAL CHEMISTRY	4(3-1)	CHEM-408	FUNDAMENTALS OF PHYSICAL CHEMISTRY	4(3-1)
5	CHEM-409	FUNDAMENTALS OF ANALYTICAL CHEMISTRY	3(2-1)	CHEM-409	FUNDAMENTALS OF ANALYTICAL CHEMISTRY	3(2-1)
6	CHEM-410	APPLIED CHEMISTRY-I	3(2-1)	CHEM-410	APPLIED CHEMISTRY-I	3(2-1)
7	CHEM-506	CHEMISTRY OF d AND f-BLOCK ELEMENTS	4(3-1)	CHEM-411	INORGANIC CHEMISTRY-I	3(3-0)
8	CHEM-507	SUBSTITUTION AND ELIMINATION REACTIONS	4(3-1)	CHEM-412	ORGANIC CHEMISTRY-I	3(3-0)
9	CHEM-511	STEREOCHEMISTRY AND ORGANIC SPECTROSCOPY	4(3-1)	CHEM-413	EXPERIMENTAL PHYSICAL CHEMISTRY-I	2(0-2)
10	CHEM-508	ATOMIC STRUCTURE AND SOLUTION CHEMISTRY	4(3-1)	CHEM-506	PHYSICAL CHEMISTRY-I	3(3-0)
11	CHEM-509	ABSORPTION AND EMISSION SPECTROSCOPY	4(3-1)	CHEM-507	ABSORPTION AND EMISSION SPECTROSCOPY	3(2-1)
12	CHEM-510	INORGANIC REACTION MECHANISM	4(3-1)	CHEM-508	EXPERIMENTAL INORGANIC CHEMISTRY-I	2(0-2)
13	CHEM-512	THERMODYNAMICS AND SURFACE CHEMISTRY	4(3-1)	CHEM-509	INORGANIC CHEMISTRY-II	3(3-0)
14	CHEM-513	APPLIED CHEMISTRY-II	4(3-1)	CHEM-510	APPLIED CHEMISTRY-II	3(3-0)
15	CHEM-601	ADVANCED INORGANIC MATERIALS	3(3-0)	CHEM-511	ORGANIC CHEMISTRY-II	3(3-0)
16	CHEM-602	II- ACCEPTOR LIGANDS AND INORGANIC POLYMERS	3(3-0)	CHEM-512	EXPERIMENTAL ORGANIC CHEMISTRY-1	2(0-2)
17	CHEM-603	ELECTROANALYTICAL TECHNIQUES	3(3-0)	CHEM-513	PHYSICAL CHEMISTRY-II	3(3-0)
18	CHEM-604	EXPERIMENTS IN ANALYTICAL CHEMISTRY	2(0-2)	CHEM-514	ORGANIC REDOX REACTIONS	3(3-0)
19	CHEM-605	ORGANIC REDOX REACTIONS	3(3-0)	CHEM-515	CONDENSATION AND HETEROCYCLIC CHEMISTRY	3(3-0)
20	CHEM-606	MOLECULAR REARRANGEMENT AND REACTIVE INTERMEDIATES	3(3-0)	CHEM-516	POLYMER CHEMISTRY	2(2-0)
21	CHEM-607	HETEROCYCLIC COMPOUNDS	3(3-0)	CHEM-517	COLLOIDS AND SURFACE CHEMISTRY	3(3-0)
22	CHEM-608	EXPERIMENTAL ORGANIC CHEMISTRY	2(0-2)	CHEM-518	ORGANOMETALLIC COMPOUNDS	3(3-0)
23	CHEM-609	CHEMICAL KINETICS AND MOLECULAR SYMMETRY	3(3-0)	CHEM-519	CHROMATOGRAPHIC TECHNIQUES	3(2-1)
24	CHEM-610	COLLOIDS AND POLYMER CHEMISTRY	3(3-0)	CHEM-601	INORGANIC MATERIALS	3(3-0)
25	CHEM-611	QUANTUM CHEMISTRY AND SPECTROSCOPY	3(3-0)	CHEM-602	CHEMISTRY OF INORGANIC POLYMERS	3(3-0)
26	CHEM-612	EXPERIMENTAL PHYSICAL CHEMISTRY	2(0-2)	CHEM-603	KINETICS OF INORGANIC REACTION MECHANISM	3(3-0)
27	CHEM-613	CHROMATOGRAPHIC TECHNIQUES	3(3-0)	CHEM-604	ELECTROANALYTICAL TECHNIQUES	3(3-0)
28	CHEM-614	MATERIALS ANALYSIS	3(2-1)	CHEM-605	BIOINORGANIC AND ATMOSPHERIC CHEMISTRY	3(3-0)
29	CHEM-615	ORGANOMETALLIC COMPOUNDS	3(3-0)	CHEM-606	EXPERIMENTAL INORGANIC CHEMISTRY-II	2(0-2)
30	CHEM-616	CONDENSATION AND PERICYCLIC REACTIONS	3(3-0)	CHEM-607	MOLECULAR REARRANGEMENT AND REACTIVE INTERMEDIATES	3(3-0)
31	CHEM-617	MEDICINAL AND NATURAL PRODUCTS CHEMISTRY	3(3-0)	CHEM-608	EXPERIMENTAL ORGANIC CHEMISTRY-II	2(0-2)
32	CHEM-618	DESIGNING OF ORGANIC SYNTHESIS	3(3-0)	CHEM-609	MATERIAL S AND DRUG ANALYSIS	3(3-0)
33	CHEM-619	NUCLEAR AND PHOTOCHEMISTRY	3(3-0)	CHEM-610	PERICYCLIC REACTIONS AND REACTIVE INTERMEDIATES	3(3-0)

34	CHEM-620	ELECTROCHEMISTRY	3(3-0)	CHEM-611	MEDICINAL AND NATURAL PRODUCTS CHEMISTRY	3(3-0)
35	CHEM-621	TECHNICAL REPORT	3(0-3)	CHEM-612	DESIGNING OF ORGANIC SYNTHESIS	3(3-0)
36	CHEM-622	SPECIAL TOPICS IN PHYSICAL CHEMISTRY	3(3-0)	CHEM-613	QUANTUM CHEMISTRY AND SPECTROSCOPY	3(3-0)
37				CHEM-614	NUCLEAR AND PHOTOCHEMISTRY	3(3-0)
38				CHEM-615	ELECTROCHEMISTRY	3(3-0)
39				CHEM-616	SPECIAL TOPICS IN PHYSICAL CHEMISTRY	3(3-0)
40				CHEM-617	EXPERIMENTAL PHYSICAL CHEMISTRY-II	2(0-2)
41				CHEM-618	EXPERIMENTAL ANALYTICAL CHEMISTRY	2(0-2)
42				CHEM-619	THERMAL METHODS OF ANALYSIS	3(3-0)
43				CHEM-620	RADIOANALYTICAL TECHNIQUES	3(3-0)
44				CHEM-621	TECHNICAL REPORT/INTERNSHIP	6(0-6)
45				CHEM-622	SURFACE ANALYTICAL TECHNIQUES	3(3-0)
46		**ELECTIVE COURSES FOR OTHER DEPARTMENTS**				
47	CHEM-301	INTRODUCTION TO ORGANIC CHEMISTRY	3(3-0)	CHEM-301	BASIC ORGANIC CHEMISTRY	3(3-0)
48	CHEM-302	ENVIRONMENTAL CHEMISTRY AND BIOCHEMISTRY	4(3-1)	CHEM-302	ENVIRONMENTAL CHEMISTRY AND BIOCHEMISTRY	4(3-1)
49	CHEM-303	INTRODUCTION TO ANALYTICAL CHEMISTRY	4(3-1)	CHEM-303	INTRODUCTION TO ANALYTICAL CHEMISTRY	3(2-1)
50	CHEM-304	INTRODUCTION TO ORGANIC CHEMISTRY	3(3-0)	CHEM-304	INTRODUCTION TO ORGANIC CHEMISTRY	3(3-0)
51	CHEM-306	BASIC CHEMISTRY	3(3-0)	CHEM-306	BASIC CHEMISTRY	3(3-0)
52	CHEM-307	ORGANIC CHEMISTRY	3(2-1)	CHEM-307	ORGANIC CHEMISTRY	3(2-1)
53	CHEM-401	INDUSTRIAL CHEMISTRY	2(1-1)	CHEM-401	INTRODUCTORY INDUSTRIAL CHEMISTRY	2(1-1)
54	CHEM-403	ENVIRONMENTAL CHEMISTERY	3(2-1)	CHEM-403	ENVIRONMENTAL CHEMISTERY	3(2-1)
55	CHEM-405	PHOTOACTIVE MATERIALS AND THEIR CHARACTERIZATION	3(2-1)	CHEM-405	PHOTOACTIVE MATERIALS AND THEIR CHARACTERIZATION	3(2-1)
56				CHEM-406	INDUSTRIAL CHEMISTRY	2(1-1)
57	CHEM-501	PHYSCICAL CHEMISTRY	3(2-1)	CHEM-501	PHYSCICAL CHEMISTRY-I	3(2-1)
58	CHEM-503	FUNDAMENTALS OF CHEMISTRY	3(3-0)	CHEM-503	FUNDAMENTALS OF CHEMISTRY	3(3-0)

REVISED SCHEME OF STUDIES FOR BS-CHEMISTRY (4-YEARS)
Session 2022

COURSE NO.	COURSE TITLE	CREDIT HOURS
First Semester		
ENG-301	COMPOSITION AND COMMUNICATION SKILLS	3(3-0)
BOT-301	DIVERSITY OF PLANTS	4(3-1)
ZOOL-301	ANIMAL DIVERSITY-I	4(3-1)
MATH-301	ELEMENTARY MATHEMATICS	3(3-0)
CS-305	INTRODUCTION TO INFORMATION AND COMMUNICATION TECHNOLOGIES	3(2-1)
CHEM-310	FUNDAMENTALS OF INORGANIC CHEMISTRY	4(3-1)
	TOTAL:-	**21**
Second Semester		
ENG-303	ENGLISH-I (FUNCTIONAL ENGLISH)	2(2-0)
IS-401 **OR** SSH-402	ISLAMIC STUDIES **OR** ETHICS	3(3-0)
ZOOL-302	ANIMAL DIVERSITY-II	4(3-1)
BOT-302	PLANT SYSTEMATICS, ANATOMY AND EMBRYOLOGY	4(3-1)
STAT-301	INTRODUCTORY STATISTICS	4(4-0)
CHEM-311	FUNDAMENTALS OF ORGANIC CHEMISTRY	4(3-1)
	TOTAL:-	**21**
Third Semester		
IS-402	**ترجمہ قرآن**	1(1-0)
ENG-304	ENGLISH-II (COMMUNICATION SKILLS)	2(2-0)
SSH-302	PAKISTAN STUDIES	2(2-0)
BIOCHEM-302	BASIC BIOCHEMISTRY	3(3-0)
CHEM-407	CHEMISTRY OF ENVIRONMENT	3(3-0)
CHEM-408	FUNDAMENTALS OF PHYSICAL CHEMISTRY	4(3-1)
CHEM-409	FUNDAMENTALS OF ANALYTICAL CHEMISTRY	3(2-1)
	TOTAL:-	**18**
Forth Semester		
IS-403	**روحانیت**	1(1-0)
PY-401	RENEWABLE ENERGY RESOURCES	3(3-0)
MATH-512	MATHEMATICS FOR CHEMISTRY	3(3-0)
CHEM-410	APPLIED CHEMISTRY-I	3(2-1)
CHEM-411	INORGANIC CHEMISTRY-I	3(3-0)
CHEM-412	ORGANIC CHEMISTRY-I	3(3-0)
CHEM-413	EXPERIMENTAL PHYSICAL CHEMISTRY-I	2(0-2)

	TOTAL:-	**18**
Fifth Semester		
CHEM-506	PHYSICAL CHEMISTRY-I	3(3-0)
CHEM-507	ABSORPTION AND EMISSION SPECTROSCOPY	3(2-1)
CHEM-508	EXPERIMENTAL INORGANIC CHEMISTRY-I	2(0-2)
CHEM-509	INORGANIC CHEMISTRY-II	3(3-0)
CHEM-510	APPLIED CHEMISTRY-II	3(3-0)
CHEM-511	ORGANIC CHEMISTRY-II	3(3-0)
CHEM-512	EXPERIMENTAL ORGANIC CHEMISTRY-1	2(0-2)
	TOTAL:-	**19**
Sixth Semester		
CHEM-513	PHYSICAL CHEMISTRY-II	3(3-0)
CHEM-514	ORGANIC REDOX REACTIONS	3(3-0)
CHEM-515	CONDENSATION AND HETEROCYCLIC CHEMISTRY	3(3-0)
CHEM-516	POLYMER CHEMISTRY	2(2-0)
CHEM-517	COLLOIDS AND SURFACE CHEMISTRY	3(3-0)
CHEM-518	ORGANOMETALLIC COMPOUNDS	3(3-0)
CHEM-519	CHROMATOGRAPHIC TECHNIQUES	3(2-1)
TOTAL:-		**20**
Seventh Semester **SPECIALIZATION: (INORGANIC/ORGANIC/PHYSICAL/ANALYTICAL CHEMISTRY)**		
CHEM-601	INORGANIC MATERIALS	3(3-0)
CHEM-602	CHEMISTRY OF INORGANIC POLYMERS	3(3-0)
CHEM-603	KINETICS OF INORGANIC REACTION MECHANISM	3(3-0)
CHEM-604	ELECTROANALYTICAL TECHNIQUES	3(3-0)
CHEM-605	BIOINORGANIC AND ATMOSPHERIC CHEMISTRY	3(3-0)
CHEM-606	EXPERIMENTAL INORGANIC CHEMISTRY-II	2(0-2)
	TOTAL:-	**17**
	OR	
CHEM-607	MOLECULAR REARRANGEMENT AND REACTIVE INTERMEDIATES	3(3-0)
CHEM-608	EXPERIMENTAL ORGANIC CHEMISTRY-II	2(0-2)
CHEM-609	MATERIAL S AND DRUG ANALYSIS	3(3-0)
CHEM-610	PERICYCLIC REACTIONS AND REACTIVE INTERMEDIATES	3(3-0)
CHEM-611	MEDICINAL AND NATURAL PRODUCTS CHEMISTRY	3(3-0)
CHEM-612	DESIGNING OF ORGANIC SYNTHESIS	3(3-0)
	TOTAL:-	**17**
	OR	
CHEM-604	ELECTROANALYTICAL TECHNIQUES	3(3-0)
CHEM-613	QUANTUM CHEMISTRY AND SPECTROSCOPY	3(3-0)
CHEM-614	NUCLEAR AND PHOTOCHEMISTRY	3(3-0)

CHEM-615	ELECTROCHEMISTRY	3(3-0)
CHEM-616	SPECIAL TOPICS IN PHYSICAL CHEMISTRY	3(3-0)
CHEM-617	EXPERIMENTAL PHYSICAL CHEMISTRY-II	2(0-2)
	TOTAL:-	**17**
	OR	
CHEM-604	ELECTROANALYTICAL TECHNIQUES	3(3-0)
CHEM-609	MATERIAL S AND DRUG ANALYSIS	3(2-1)
CHEM-618	EXPERIMENTAL ANALYTICAL CHEMISTRY	2(0-2)
CHEM-619	THERMAL METHODS OF ANALYSIS	3(3-0)
CHEM-620	RADIOANALYTICAL TECHNIQUES	3(3-0)
CHEM-622	SURFACE ANALYTICAL TECHNIQUES	3(3-0)
	TOTAL	**17**
Eighth Semester **SPECIALIZATION: (INORGANIC/ORGANIC/PHYSICAL /ANALYTICAL CHEMISTRY)**		
CHEM-621	TECHNICAL REPORT/INTERNSHIP	6(0-6)
	TOTAL	**06**
	OR	
CHEM-621	TECHNICAL REPORT/INTERNSHIP	6(0-6)
	TOTAL:-	**06**
	OR	
CHEM-621	TECHNICAL REPORT/INTERNSHIP	6(0-6)
	Total:-	**06**
	OR	
CHEM-621	TECHNICAL REPORT/INTERNSHIP	6(0-6)
		06
	TOTAL CREDIT HOURS	**140**

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S. #	EXISTING	PROPOSED
1.	**CHEM-310 FUNDAMENTALS OF INORGANIC CHEMISTRY 4(3-1)** **Theory** Chemical Bonding: Types of chemical bonding, ionic and covalent bonding, localized bond approach, theories of chemical bonding; Valence bond theory (VBT); Hybridization and resonance; Prediction of molecular shapes using Valence Shell Electron Pair Repulsion (VSEPR) model; Molecular orbital theory (MOT) applied to diatomic molecules; Delocalized approach to bonding; Bonding in electron deficient compounds; Hydrogen bonding. Acids and Bases: Brief concepts of chemical equilibrium, acids and bases including soft and hard acids and bases (SHAB), concept of relative strength of acids and bases, significance of pH, pKa, pKb and buffer solutions, theory of indicators, solubility, solubility product, common ion effect and their industrial applications. p-Block Elements: Physical and chemical properties of p-block elements with emphasis on some representative compounds, inter-halogens, pseudo-halogens and polyhalides. **Practical** Lab safety and good laboratory practices; Knowledge about material safety data sheets (MSD); Disposal of chemical waste and first-aid practices; Qualitative analysis of salt mixtures; Quantitative analysis; Acid- base titrations; Preparation and standardization of acid and alkali solutions; Redox titrations; Preparation and standardization of potassium permanganate solution and its use for the determination of purity of commercial potassium oxalate or oxalic acid; Preparation and standardization of sodium thiosulfate solution and its use in determination of copper in a given sample; Gravimetric analysis; Determination of barium in a given sample; Determination of chloride in a given solution. **Suggested Readings** 1. Bhatti, H.N. 2020. Text Book of Inorganic Chemistry. The Caravan Book House, Lahore, Pakistan. 2. Bhatti, H.N. and R. Rehaman. 2020. Laboratory Manual of Inorganic Chemistry. Caravan Book House Lahore, Pakistan. 3. Catherine E. 2008. House Craft, Alan G. Sharpe, Inorganic Chemistry. 3rd Ed. Prentice Hall, USA. 4. Cotton, F.A. and G. Wilkinson. 2007. Advanced Inorganic Chemistry. 6th Ed. John-Wiley & Sons, NY, USA.	**CHEM-310 FUNDAMENTALS OF INORGANIC CHEMISTRY 4(3-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the periodicity of periodic table 2. Describe he classification of elements based on s p d and f block 3. Demonstrate the different theories of chemical bonding **4.** Demonstrate the properties of p-block elements **Theory** The periodic law and Periodicity development of periodic table; Diagonal and vertical relationship of first row element; Classification of elements based on s, p, d, and f orbitals; Group trends and periodic properties in s, p, d, and f block elements i.e., atomic radii, ionic radii, ionization potentials; Electron affinities, electronegativity, and redox potential; Types of chemical bonding; Ionic and covalent bonding, localized bond approach; Theories of chemical bonding; Valence bond theory (VBT), Hybridization and resonance, Prediction of molecular shapes using Valence Shell Electron Pair Repulsion (VSEPR) model, molecular orbital theory (MOT) applied to diatomic molecules. Delocalized approach to bonding; Bonding in electron deficient compounds; Hydrogen bonding. Physical and chemical properties of p-block elements with emphasis on some representative compounds, inter-halogens, and pseudo-halogens. **Practical** Lab safety and good laboratory practices; Knowledge about material safety data sheets (MSD); Disposal of chemical waste and first-aid practices; Separation and identification of two acid and two basic radicals from a mixture of two salts; Acid- base titrations; Preparation and standardization of acid and alkali solutions, Standardize the given NaOH solution. Redox titrations; Preparation and standardization of potassium permanganate solution and its use for the determination of purity of commercial potassium oxalate or

5. Kathleen A. H. and E.H. James. 2010. Descriptive Inorganic Chemistry. 2nd Ed. Brooks Cole, UK.
6. Mendham, J., R.C. Denny, J.D. Barnes, M. Thomas and B. Sivasankar. 2000. Vogel's Textbook of Quantitative Chemical Analysis. 6th Ed. Pearson Education, Ltd, UK.

oxalic acid; Gravimetric analysis; Determination of barium in a given sample; Determination of chloride in a given solution in given sample.

Suggested Readings

1. Bhatti, H.N. 2020. Textbook of Inorganic Chemistry. The Caravan Book House, Lahore, Pakistan.
2. Bhatti, H.N. and R. Rehaman. 2020. Laboratory Manual of Inorganic Chemistry. Caravan Book House Lahore, Pakistan.
3. Catherine, E. 2008. House Craft, Alan G. Sharpe, Inorganic Chemistry. 5th Ed. Prentice Hall, USA.
4. Cotton, F.A. and G. Wilkinson. 2007. Advanced Inorganic Chemistry. 6th Ed. John-Wiley & Sons, NY, USA.
5. Kathleen, A. H. and E.H. James. 2010. Descriptive Inorganic Chemistry. 6th Ed. Brooks Cole, UK.
6. Mendham, J., R.C. Denny, J.D. Barnes, M. Thomas and B. Sivasankar. 2000. Vogel's Textbook of Quantitative Chemical Analysis. 6th Ed. Pearson Education, Ltd, UK.

2.	**CHEM-311 FUNDAMENTAL OF ORGANIC CHEMISTRY 4(3-1)** **Theory** Basic Concepts in Organic Chemistry: Atomic orbitals; molecular orbitals and chemical bonding; Concept of resonance and stability of resonance hybrids, factor effecting the resonance; Inductive effect; Applications of inductive effect and resonance on various properties of organic compounds; Steric effect and its applications, Hydrogen bonding and its effects on various properties of organic compounds; Tautomerism, Hyperconjugation. Chemistry of Functional Groups: Preparation and properties of alcohols; Phenols; Ethers; and amines with focus on reaction mechanism and applications; Carbonyl compounds; Preparations and reaction mechanism of aldehydes and ketones and their applications; Carboxylic acids and their derivatives; Acidity of carboxylic acids and effect of substituents on their acidity; Preparation and reactions of carboxylic acids and their derivatives including esters; Amides; Acid halides and acid anhydrides. Chemistry of Hydrocarbons: Saturated; Unsaturated and aromatic hydrocarbons with emphasis on synthesis and free radical; Electrophilic; Addition and electrophilic substitution reactions. **Practical** Separation and purification of organic compounds by using crystallization; Sublimation; Solvent extraction; Distillation and chromatography. Analysis of simple organic compounds containing various functional groups. **Suggested Readings** 1. Ingold, C.K. 2000. Structure and Mechanism in Organic Chemistry. C.B.S. Ed. Wiley Inter Science, UK. 2. March, J. 2014. Advanced Organic Chemistry, Reaction, Mechanism and Structure, 6th Ed. John Wiley & Sons, Inc., Publication, USA. 3. Morison and Boyd. 1992. Organic Chemistry. 6th Ed. Prentice Hall, UK. 4. Peter, S. 2009. A Guide Book to Mechanism in Organic Chemistry". Special Edition, Pearson Education, Singapore. 5. Raza, A.M., A. Rehman and H.N. Bhatti. 2019. A Textbook of Organic Chemistry. The Caravan Book House, Lahore, Pakistan. 6. Rehman, A. and H.N. Bhatti. 2015. Laboratory Manual of Organic Chemistry. Caravan Book House, Lahore, Pakistan.	**CHEM-311 FUNDAMENTAL OF ORGANIC CHEMISTRY 4(3-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain various molecular theories. 2. Describe the fundamentals of bonding. 3. Demonstrate the knowledge about the resonance. 4. Explain different chemical functional groups. **Theory** Atomic orbitals; Molecular orbitals and chemical bonding; Concept of resonance and stability of resonance hybrids, factor effecting the resonance; Inductive effect; Applications of inductive effect and resonance on various properties of organic compounds; Steric effect and its applications, hydrogen bonding and its effects on various properties of organic compounds; Tautomerism, Hyperconjugation; Preparation and properties of alcohols; Phenols; Ethers; and amines with focus on reaction mechanism and applications; Carbonyl compounds; Preparations and reaction mechanism of aldehydes and ketones and their applications; Carboxylic acids and their derivatives; Acidity of carboxylic acids and effect of substituents on their acidity; Preparation and reactions of carboxylic acids and their derivatives including esters; Amides; Acid halides and acid anhydrides; Saturated; Unsaturated and aromatic hydrocarbons with emphasis on synthesis and free radical; Electrophilic; Addition and electrophilic substitution reactions. **Practical** Separation and purification of organic compounds by using crystallization; Sublimation; Solvent extraction; Distillation and chromatography; Analysis of simple organic compounds containing various functional groups. **Suggested Readings** 1. Ingold, C.K. 2011. Structure and Mechanism in Organic Chemistry. C.B.S. Ed. Wiley Inter Science, UK. 2. March, J. 2019. Advanced Organic Chemistry, Reaction, Mechanism and Structure. 6th Ed. John Wiley & Sons, Inc., Publication, USA. 3. Morison and Boyd. 2002. Organic Chemistry. 6th Ed. Prentice Hall, UK. 4. Raza, A.M., A. Rehman and H.N. Bhatti. 2019. A Textbook of Organic Chemistry. The Caravan Book House, Lahore, Pakistan.

		5. Rehman, A. and H.N. Bhatti. 2015. Laboratory Manual of Organic Chemistry. Caravan Book House, Lahore, Pakistan.

3.	**CHEM-407 CHEMISTRY OF ENVIRONMENT 3(3-0)** **Theory** The atmosphere: composition; Temperature and pressure profile; Role of free radicals in the atmosphere; Temperature inversion and photochemical smog; Particular matter in the atmosphere; Industrial pollutants; Atmospheric aerosols; Acid rain major sources; Mechanism; Control measures and effects on buildings and vegetation; Global warming; Major greenhouse gases; mechanism; Control measures and global impact; Stratospheric ozone- the ozone hole; CFCs, ozone protection; Biological consequences of the ozone depletion. Water pollution: municipal; Industrial and agriculture sources of pollution; Heavy metals contamination of water; Eutrophication, detergents and phosphates in water; Wastewater: primary; Secondary and tertiary treatment; Organic matter in water and its decomposition and removal. Land pollution: heavy metals contamination of soil; Bioaccumulation of heavy metal; Toxicity of heavy metals; Green chemistry for industrial management: green synthesis; Green processes, recycling; Overcoming disasters; Environmental management and disaster preparedness. **Suggested Readings** 1. Bhatti, H.N. and S. Noreen. 2017. Principles of Environmental Chemistry. Caravan Book House, Lahore, Pakistan. 2. Dara, S.S. 2009. A Text Book of Environmental Chemistry and Pollution Control. S. Chand Group, ND, India. 3. Manahan, S.E. 2009. Fundamentals of Environmental Chemistry. 9th Ed. CRC Press LLC, Taylor and Francis, NY, USA. 4. Matalack, A. 2010.Introduction to Green Chemistry. CRC press, Taylor & Francis Group, NY, USA. 5. Richard, W. and M.A. Holloway. 2010. Atmospheric Chemistry. Springerlink, London, UK.	**CHEM-407 CHEMISTRY OF ENVIRONMENT 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain different environmental layers. 2. Explain the fundamentals of environment. 3. Describe the knowledge about the atmosphere. 4. Present different pollution sources and factors. **Theory** The atmosphere: Composition; Temperature and pressure profile; Role of free radicals in the atmosphere; Temperature inversion and photochemical smog; Particular matter in the atmosphere; Industrial pollutants; Atmospheric aerosols; Acid rain major sources; Mechanism; Control measures and effects on buildings and vegetation; Global warming; Major greenhouse gases; Mechanism; Control measures and global impact; Stratospheric ozone- the ozone hole; CFCs, ozone protection; Biological consequences of the ozone depletion; Water pollution: Municipal; Industrial and agriculture sources of pollution; Heavy metals contamination of water; Eutrophication, detergents and phosphates in water; Wastewater: primary; Secondary and tertiary treatment; Organic matter in water and its decomposition and removal; Land pollution: Heavy metals contamination of soil; Bioaccumulation of heavy metal; Toxicity of heavy metals; Green chemistry for industrial management: Green synthesis; Green processes, recycling; Overcoming disasters; Environmental management and disaster preparedness. **Suggested Readings** 1. Bhatti, H.N. and S. Noreen. 2021. Principles of Environmental Chemistry. Caravan Book House, Lahore, Pakistan. 2. Dara, S.S. 2009. A Text Book of Environmental Chemistry and Pollution Control. S. Chand Group, ND, India. 3. Manahan, S.E. 2009. Fundamentals of Environmental Chemistry. 9th Ed. CRC Press LLC, Taylor and Francis, NY, USA. 4. Matalack, A. 2010.Introduction to Green Chemistry. CRC press, Taylor & Francis Group, NY, USA. 5. Richard, W. and M.A. Holloway. 2010. Atmospheric Chemistry. Springerlink, London, UK.

4.	**CHEM-408 FUNDAMENTALS OF PHYSICAL CHEMISTRY 4(3-1)** **Theory** **States of Matter**: **Gases;** Introduction; Law of equipartition of energy; Collision diameter; Collision number; Collision frequency and mean free path; Viscosities of gases; Measurements; Effect of temperature and pressure on viscosities of gasses; Critical phenomenon of gases and experimental determination of Pc; Vc and Tc; The Joule-Thomson Experiment; Liquefying Gases Using an Isoenthalpic Expansion.**Kinetic theory of Gases**: Maxwell distribution law of molecular velocities; Derivation of most probable; Mean and root mean square velocities; Transport properties; Effect of altitude; Molar mass and temperature on vertical distribution of particle; **Liquids:** The properties of liquids like surface tension; Viscosity; Refractive index and dipole moment; Parachor, Reheochor and molar refraction as additive and constitutive properties; Measurement of refractive index and dipole moment; **Solids:** Symmetry operations and Bravis lattices; Thermal Conduction. Ionic Conduction; Concept of X-Ray diffraction; Bragg's equation and crystal structure analysis; Crystal structure of metallic solids; Ionic solids; Molecular solids and covalent networks; Heat capacities of solids. **Chemical Equilibrium** Basic concepts; Law of mass action, relationship between different equilibrium constants ,homogenous and heterogeneous equilibria, Le-Chatelier's principle, Gibbs energies of formation and calculations of equilibrium constants, effect of temperature and pressure on the equilibrium constants/compositions, van't Hoff equation; Equilibria Involving Ideal Gases and Solid or Liquid Phases; **Practical** Preparation of standard molar, Normal and percentage solutions; Standardization of NaOH solution using Oxalic acid; Buffer solution preparation and measurement of pH value. Determine the surface tension of the given liquid by drop weight or stalagmometer. Determine the relative and absolute viscosities of given liquids using Ostwald′ s viscometer. Determination of molar refractivity. Determination of percentage composition of a solution by refractometric method. Determination of specific and molar rotation of optically active substances in solution by polarimetric method. Determination of percentage composition of unknown mixture by polarimetry. **Suggested Readings** 1. Alberty, R.A. and Silvey. 2002. Physical Chemistry. John Wiley & Sons, NY, USA. 2. Atkins, P and J. Paula. 2003. Atkins Physical Chemistry. Oxford university press, ND, India. 3. Bhatti, H.N and Z.H. Farooqi. 2016. Physical Chemistry Laboratory Manual. Caravan Book House, Lahore. 4. Bhatti, H.N. 2016. A Text Book of Physical Chemistry. Caravan Book House, Lahore. 5. Donald A. McQuarrie and J.D. Simon. 2016. Physical Chemistry: A Molecular Approach 1st Ed. University Science Book Publisher. Sausalito, CA, USA.	**CHEM-408 FUNDAMENTALS OF PHYSICAL CHEMISTRY 4(3-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various states of mater and their properties. 2. Explain the fundamentals of chemical thermodynamics. 3. Describe the knowledge about the chemical kinetics. 4. Demonstrate making different solutions. **Theory** Equation of states, ideal and real gases; Van der Waals equation for real gases; Critical phenomena and critical constants; Physical properties of liquids: Surface tension, viscosity, refractive index etc., and their applications, unit cells and crystal system; Method of crystal structure analysis (X-ray diffraction and electron diffraction); The Bragg Equation; Heat capacities of solids; Introduction; Extensive and intensive properties; Molar heat capacities; Second law of thermodynamics; Carnot cycle and concept of entropy; Entropy changes in reversible and irreversible processes; Entropy changes for an ideal gas; Effect of temperature and pressure on entropy; Concept of free energy; Effect of temperature and pressure on free energy; Relationship between standard free energy and equilibrium constant; General equilibrium expressions**;** Effect of temperature and pressure on equilibrium constant; van't Hoff equation; Rate of reaction, and rate law; Order and molecularity of the reactions; Integrated rate laws: Zero, pseudo first, second order reactions with same and different initial concentrations of reactants; Half-lives of reactions; Experimental techniques and methods for determination of rate and order of reaction (integration, half-life, initial rate, and graphical methods); Activation energy and Arrhenius equation; Types of solutions; Concentrations of solutions (molarity, molality, normality, ppm, ppb, percentage composition, mole fraction), Ideal and non-ideal solutions; Raoult's law; Henry law; Colligative properties of dilute solutions; Abnormal colligative properties; Fractional distillation and idea of azeotropes. **Practical** Preparation of standard molar, normal percentage and ppm solutions; Standardization of secondary standard acids and bases solutions by volumetric methods; Determination of refractive index, molar refractivity and percentage composition by refractive index method; Determination of surface tension, parachor and percentage composition by surface tension measurement, Determination of viscosity, rheochor and percentage composition by viscosity measurement;

	6. Nivaldo J.T. 2017. Chemistry: A Molecular Approach. 4th Ed. Pearson Education, Inc., USA.	Determination of heat of solution; Determination of heat of neutralization of a strong acid and base. Determination of molecular weight of a compound by elevation of boiling point (ebullioscopic method)/depression in freezing point method. **Suggested Readings** 1. Atkins, P., J. de Paula and J. Keeler. 2018. Eléments of Physical Chemistry. 11th Ed. Oxford University Press, Oxford, UK. 2. Bhatti, H.N. 2020. A Text Book of Physical Chemistry. Caravan Book House, Lahore, Pakistan 3. Bhatti, H.N., Z.H. Farooqi, and S. Noreen. 2021. Physical Chemistry Laboratory Manual. Caravan Book House, Lahore, Pakistan. 4. Donald,A.M. and J.D. Simon. 2016. Physical Chemistry: A Molecular Approach 1st Ed. University Science Book Publisher. Sausalito, CA, USA. 5. Nivaldo, J.T. 2017. Chemistry: A Molecular Approach. 4th Ed. Pearson Education, Inc., NJ, USA. 6. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G. A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

5.	**CHEM-409 FUNDAMENTALS OF ANALYTICAL CHEMISTRY 3(2-1)** **Theory** Introduction to analytical science and chemical analysis; Chemometrics; Accuracy of analysis; Type of errors and use of statistical analysis; Separation techniques: Basic principle and applications of solvent extraction; Solvent extraction of metals, multiple batch extraction, counter current distribution; Solid phase extraction; Solvent extraction by flow injection method; General theory and principles of chromatography; Important types of chromatography and their applications; Spectroscopy: Properties of light and its interaction with matter; Lambert- Beer's law and its limitations Development of spectroscopic techniques for analysis; Principles of atomic spectroscopy; Basic components, instrumentation and applications: Atomic absorption and flame photometer, UV-vis and IR techniques. **Practical** Laboratory materials, reagents and safety measures; Calibration of glassware used for volumetric analysis; Determination of chlorides by titrimetric titrations; Determination of sulfate using gravimetric analysis; Solvent extraction of organic/inorganic compounds; Separation of mixture of organic and inorganic compounds by chromatographic methods; Determination of metals using absorption and emission spectroscopic techniques; Separation and purification of compounds using column chromatography. **Suggested Readings** 1. Bhatti, H.N. 2017. Principles of Analytical Chemistry. Caravan Book House, Lahore. 2. Christian, G. D. 2006. Analytical Chemistry. 6th Ed. John-Wiley & Sons, NY, USA. 3. Harris, D. C. 2011. Quantitative Chemical Analysis. 8th Ed. W.H. Freeman and Company, NY, USA. 4. Matthios, O. 2007. Chemometrics-Statistics and Computed applications in Analytical Chemistry, 2nd Ed. Wiley-VCH, Germany. 5. Skoog, D.A., P.M. West, F.J. Holler and S.R. Crouch. 2013. Fundamentals of Analytical Chemistry. 9th Ed. Brooks Cole Publishing Company, UK.	**CHEM-409 FUNDAMENTALS OF ANALYTICAL CHEMISTRY 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain basic knowledge of analytical chemistry with a practical emphasis on basic analytical tools. 2. Present the recent approaches in problem solving in analytical chemistry. 3. Demonstrate insight into sample collection techniques. 4. Explain most recent developments in quality assurance and method validation. **Theory** Basic tools and operations of analytical chemistry including analytical balance, rules for weighing substances in various states; Sources of errors in weighing, various types of lab apparatus; Measurements in analytical chemistry: Fundamental units, units for expressing concentration, significant figures, stoichiometry and preparing solutions; Gas, liquid and solid sampling; Sample preparation for inorganic and organic analysis: Linear regression and calibration curve, data evaluations and comparisons; Chemical equilibrium in analytical chemistry; Classical methods of analysis; Separation techniques and methods; Quality assurance and method validation; Good laboratory practice; Validation, quality assurance, laboratory accreditation, electronic records. **Practical** Calibration of glassware (pipette, burette and flask) used for volumetric analysis; Use of analytical balance and calculation of standard deviation; Calibration of pH meter and determination of pH of various acidic and basic solution; Calibration of conductometer and determination of conductance of tap water, distilled water, conductivity water and canal water; Calculation of variance, mean, median, coefficient of variance of the data; Separation of ink components by paper chromatography; Separation of amino acids by thin layer chromatography; Separation of dyes by column chromatography; Separation of mixtures by circular paper chromatography. **Suggested Readings** 1. Bhatti, H.N. 2019. Principles of Analytical Chemistry. Caravan Book House, Lahore. 2. Christian, G.D. 2022. Analytical Chemistry. 7th Ed. John-Wiley & Sons, NY, USA.

3. Harris, D.C. 2011. Quantitative Chemical Analysis. 8th Ed. W.H. Freeman and Company, NY, USA.
4. Kealey, D. and P.L. Haines. 2002. BIOS Instant Notes in Analytical Chemistry.BIOS Scientific Publishers Limited, Oxford, UK.
5. Skoog, D.A. and D.M. West. 2008. Fundamentals of Analytical Chemistry. 8th Ed. Hot Reinehart Inc., London, UK.

6.	**CHEM-410 APPLIEDCHEMISTRY-I 3(2-1)** **Theory** Chemical Unit Processes: Brief introduction to Chemical Industry with reference to Pakistan; General unit operations commonly used in industry such as evaporation; Crystallization; grinding; screening; heat transfer; filtration and distillation. Industrial Chemical Synthesis: Raw materials; Unit operations/processes involved; flow sheet diagrams with all the important Steps/ parameters involved in the manufacturing of caustic soda; Washing soda; Sulphuric acid; Hydrochloric acid; Different applications of these chemicals in industry. Water Softening and Scale Removing: Water hardness; its measurement and removal; methods used for water softening including ion-exchange and reverse osmosis; distillation and precipitation; Types of boiler scales; Chemical and mechanical methods to eliminate the scaling. **Practical** Standard solutions: Preparation of standard molar, normal, molal, percentage, ppm and ppb solutions. Estimation of total water hardness by EDTA method; Estimation of total suspended solids in water; Estimation of total dissolved solids in water; Determination of carbonate, bicarbonate and total alkalinity of water sample; Determine the acidity of the sulphuric acid and its normality; Preparation of ferric alum or ferric ammonium sulphate; Determining the % age purity of sodium bicarbonate and sodium carbonate; Estimation of chloride in the tannery effluent; Estimation of percentage purity of the Commercial sodium chloride; Separation of benzoic acid from sodium benzoate by solvent extraction. **Suggested Readings** 1. Austin,G.T.2005.Shreve'sChemicalProcessIndustry.6th Ed.McGrawHillBookCompany, NY,USA. 2. Bhatti, H.N and M. Salman. 2017. Applied Chemistry. Caravan Book House, Lahore. 3. Bhatti, H.N. S. Ilyas and S. Noreen, 2016. Applied Chemistry Laboratory Manual. Caravan Book House, Lahore, Pakistan. 4. Kent, J.A. 2012. Riegel's Handbook of Industrial Chemistry. Springer Science & Business Media, London, UK. Vermani, O. P. 2006. Applied Chemistry: Theory and Practice, 2nd Ed. New Age International. ND, India.	**CHEM-410 APPLIEDCHEMISTRY-I 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe about various chemical industry. 2. Explain the fundamentals of industrial synthesis. 3. Present the knowledge about the Pakistani industries. 4. Describe different chemical treatments. **Theory** Chemical unit processes: Brief introduction to chemical Industry with reference to Pakistan; General unit operations commonly used in industry such as evaporation; crystallization; Grinding; Screening; Heat transfer; Filtration and distillation, Industrial chemical synthesis: Raw materials, unit operations/processes involved, flow sheet diagrams with all the important steps/ parameters involved in the manufacturing of caustic soda; Washing soda; Sulphuric acid; Hydrochloric acid; Different applications of these chemicals in industry;Water Softening and Scale Removing: Water hardness; its measurement and removal; Methods used for water softening including ion-exchange and reverse osmosis; Distillation and precipitation; Types of boiler scales; Chemical and mechanical methods to eliminate the scaling. **Practical** Standard solutions: Preparation of standard molar, normal, molal, percentage, ppm and ppb solutions; Estimation of total water hardness by EDTA method; Estimation of total suspended solids in water; Estimation of total dissolved solids in water; Determination of carbonate, bicarbonate and total alkalinity of water sample; Determine the acidity of the sulphuric acid and its normality; Preparation of ferric alum or ferric ammonium sulphate; Determining the % age purity of sodium bicarbonate and sodium carbonate; Estimation of chloride in the tannery effluent; Estimation of percentage purity of the Commercial sodium chloride; Separation of benzoic acid from sodium benzoate by solvent extraction. **Suggested Readings** 1. Austin,G.T.2005.Shreve'sChemicalProcessIndustry.6th Ed.McGrawHillBookCompany, NY,USA. 2. Bhatti, H.N and M. Salman. 2021. Applied Chemistry. Caravan Book House, Lahore. 3. Bhatti, H.N. M. Salman and S. Noreen, 2021. Applied Chemistry Laboratory Manual. Caravan Book House, Lahore, Pakistan.

4. Kent, J.A. 2012. Riegel's Handbook of Industrial Chemistry. Springer Science & Business Media, London, UK.
5. Vermani, O.P. 2006. Applied Chemistry: Theory and Practice. 2nd Ed. New Age International. ND, India.

7.	**CHEM-506 CHEMISTRY OF d AND f-BLOCK ELEMENTS 4(3-1)** **Theory** Chemistry of d-block elements and coordination complexes: Background of coordination chemistry; nomenclature and structure of coordination complexes with coordination number 2-6, chelates and chelate effect; theories of coordination complexes; Werner's theory; valence bond 23 theory (VBT); crystal field theory (CFT) and molecular orbital theory (MOT); Jahn-Teller theorem, magnetic properties, spectral properties, isomerism, stereochemistry and stability constants of coordination complexes. Chemistry of f-block elements: Actinides: General characteristics, electronic structure, oxidation state and position in the periodic table, half-life and decay law; Lanthanides; General characteristics; Occurrence; extraction and general principles of separation; Electronic structure and position in the periodic table; Lanthanides contraction; Oxidation states; Spectral and magnetic properties and uses. **Practical** Inorganic synthesis and separation: Preparations of following Inorganic Complexes; Tetraamminecopper (II) sulphate; Potassiumtrioxalatochromate (III); Potassiumtrioxalatoaluminate (III); cis-Potassium dioxalatodiaquachromate (III); Determination of zinc and cadmium by complexometric titration Chromatographic separations of transition metals; Separation of $Ni^{2+}$and Co^{2+}ions in a mixture by paper chromatography; Separation of $Ni^{2+}$and Cu^{2+}ions in a mixture by paper chromatography; Separation of $Cu^{2+}$and Fe^{2+} ions in a mixture by paper chromatography; Spectrophotometric determination of iron, manganese and nickel. **Suggested Readings** 1. Atkins, P. and L. Jones. 2010. Chemicals Principles, 5th Ed. W.H. Freeman & Company, UK. 2. Bhatti, H.N. and R. Rehman. 2015. Advanced Inorganic Chemistry. The Carvan Book Lahore, Pakistan. 3. Cotton, F. A., G. Wilkinson, C.A. Murillo and M. Bochmann. 1999. Advanced Inorganic Chemistry, 6th Ed. Wiley-Interscience, NY, USA. 4. Housecraft, C. and A.G. Sharpe. 2012. Inorganic Chemistry, 4th Ed. Prentice Hall. UK. 5. Miessler, G.L. and D.A. Tarr. 2010. Inorganic Chemistry, 4th Ed. Pearson-Prentice Hall International. 6. Svehla, G. 1979. Vogel's Textbook of Macro and Semimicro Qualitative Inorganic Analysis, 5th Ed. Longman Group Limited, UK.	**CHEM-411 INORGANIC CHEMISTRY -I 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to gain knowledge about: 1. Demonstrate geometrical structures followed by VSEPR 2. Describe parameters of molecular structures 3. Describe the details about X-ray spectra 4. Explain stereochemistry, preparation, and applications of coordination compounds **Theory** VSEPR model followed by VB theory (Hybridization, Resonance etc.,);Explanation of the structure of AB_2, AB_3, AB_2E, AB_4, AB_3E, AB_2E_2, AB_5, AB_3E_3, AB_6, AB_5E, AB_4E_2, AB_7, AB_6E; Discussion of molecular orbitals and molecular structures of homo nuclear molecules and ions, hetero nuclear diatomic and polyatomic molecules, and ions; Bent bond, bridge bond, four electrons-three center bonds; Metallic bond based on band model; X-ray spectra and N(E) curves, n(E) curves; Binding energy in metals, conductors, semi-conductors and insulators; Effect of temperature and impurities on conductivity. Nomenclature; theories of bonding (Werner's theory, Sigwick theory, VBT, CFT); Stereochemistry of coordination compounds; Coordination geometries (CN 2 to 6). Preparation of coordination compounds; Stability of coordination compounds; Application of coordination compounds in chemistry, life, and industry. **Suggested Readings** 1. Bhatti, H.N. and R. Rehman. 2020. Advanced Inorganic Chemistry. Volume-I. The Caravan Book Lahore, Pakistan. 2. Cotton, F.A. and Wilkinson, G. 1988. Advanced Inorganic Chemistry. 6th Ed. John Wiley, NY. 3. Greenwood, N.N. and A. Easnshaw. 1984. Chemistry of the Elements. 2nd Ed.Pergaman NY. 4. Joly, W.L. 1985. Principles of Inorganic Chemistry. McGraw Hill. 5. Sharpe, A.G. 1987. Inorganic Chemistry. 5thEd. John Wiley, NY.

8	**CHEM-507 SUBSTITUTION AND ELIMINATION REACTIONS 4(3-1)** **Theory** Acids and Bases: Concept of weak acids and bases; Organic acids and bases; Scale of acidity and basicity; pKa values; Predicting acid/base reactions from pKa values; Effect of resonance, inductive, electrostatic, steric and hydrogen bonding on acidity and basicity; Acidity of alkynes, alcohols and phenols; Linear free energy relationships; Determination of organic reaction mechanisms. Nucleophilic Substitution: Mechanism of S_N1, S_N2, S_Ni, S_NAr; The effect of substrate structure, attacking nucleophile, leaving group, neighbouring group and reaction medium on the rates and mechanisms of nucleophilic substitution reactions; Elimination Reactions: Study of E_1, E_2, E_1CB mechanisms; Structure and reactivity; Saytzeff and Hofmann's rule; Competition between elimination and substitution reactions; Electrophilic and nucleophilic substitution in aromatic system: mechanism and orientation in electrophilic substitution, nitration, sulphonation, Friedel-Craft reactions, Nucleophilic attack in aromatic species. **Practical** Identification of organic compounds; Carboxylic acids, carbohydrates; hydrocarbons, aldehydes, ketone, primary, secondary and tertiary amines, phenolics, amides and imines. Estimation of functional groups **Suggested Readings** 1. Bhatti, H.N. 2016. Advanced Organic Chemistry. The Caravan Book House, Lahore, Pakistan. 2. Chughtai, F.A. and Z.H. Nazli. 2010. Systematic Organic Analysis. Majeed Book Depot, Lahore. 3. Morrison, T.R. 2005. Organic Chemistry. 6thEd. Prentice Hall of India Private Limited. ND, India. 4. Solomon, T.W.G. 2014. Organic Chemistry. 11th Ed. John Wiley & Sons NY, USA. 5. Sykes, P. 2009. A Guide Book to Mechanism in Organic Chemistry. 6th Ed. Pearson Education, ND, India.	**CHEM-412 ORGANIC CHEMISTRT-I 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various acid base theories. 2. Explain the fundamentals of bonding. 3. Demonstrate the knowledge about the reaction mechanisms. 4. Describe different chemical reactions. **Theory** Concept of weak acids and bases; Organic acids and bases; Scale of acidity and basicity; pKa values; Predicting acid/base reactions from pKa values; Effect of resonance, inductive, electrostatic, steric and hydrogen bonding on acidity and basicity; Acidity of alkynes, alcohols and phenols; Linear free energy relationships; Determination of organic reaction mechanisms; Mechanism of S_N1, S_N2, S_Ni, S_NAr; The effect of substrate structure, attacking nucleophile, leaving group, neighbouring group and reaction medium on the rates and mechanisms of nucleophilic substitution reactions; Study of E_1, E_2, E_1CB mechanisms; Structure and reactivity; Saytzeff and Hofmann's rule; Competition between elimination and substitution reactions; Electrophilic and nucleophilic substitution in aromatic system: Mechanism and orientation in electrophilic substitution, nitration, sulphonation, friedel-Craft reactions, nucleophilic attack in aromatic species. **Suggested Readings** 1. Bhatti, H.N. 2020. Advanced Organic Chemistry. Volume-I. The Caravan Book House, Lahore, Pakistan. 2. Morrison, T.R. 2016. Organic Chemistry. 6thEd. Prentice Hall of India Private Limited. ND, India. 3. Solomon, T.W.G. 2017. Organic Chemistry. 11th Ed. John Wiley & Sons,NY, USA. 4. Sykes, P. 2009. A Guide Book to Mechanism in Organic Chemistry. 6th Ed. Pearson Education, ND, India.

CHEM-511 STEREOCHEMISTRY AND ORGANIC SPECTROSCOPY 4(3-1)

Theory

Stereochemistry: Chirality and enantiomers; Optical activity: Symmetry elements: R-S conventions; Racemic modifications and their resolution; Asymmetric synthesis; Optical activity in biphenyl and spiro compounds; Stereo specific and stereo selective reactions; Geometrical isomerism; Z and E convention; cis-trans isomerism in cyclic systems; Conformational analysis of disubstituted cyclohexanes and condensed rings.

Organic Spectroscopy: Basic principles of UV/Visible, IR, NMR spectroscopy and Mass spectrometry; Spectral interpretation of simple organic compounds with these techniques.

Practical

Experiments of both of qualitative and quantitative nature based on available spectroscopic techniques.

Suggested Readings

1. Bhatti, H.N. 2016. Advanced Organic Chemistry. The Caravan Book House, Lahore.
2. Eliel, E.L .2005. Stereochemistry of Carbon Compounds. Tata McGraw Hill. ND, India.
3. Morris, D.G. 2001. Stereochemistry. The Royal Society of Chemistry, London.
4. Pavia, D.L., G.M. Lampman and G.S. Kriz. 2014. Introduction to Spectroscopy. 5th Ed. Cengage Learning, NY, USA.
5. Silverstein, R.M., G.C. Bassler and T.C. Morrill. 2014. Spectrometric Identification of Organic Compounds, 8th Ed. John Wiley & Sons Inc., NY, USA.
6. Solomon, T.W.G. 2014. Organic Chemistry. 11th Ed. John Wiley &Son's, Inc., NY, USA.

CHEM-413 EXPERIMENTAL PHYSICAL CHEMISTRY-I 2(0-2)

Learning Objectives

By the end of this course students will be able to:

1. Demonstrate using different equipment in physical chemistry lab.
2. Describe practical applications of various physical chemistry techniques.
3. Demonstrate different physical chemistry parameters.
4. Describe the knowledge gained in previously studies courses.

Theory

Preparation of different standard solutions; Preparation of buffer solutions; Determination of wavelength of maximum absorption of compounds and unknown composition using spectrophotometer; Determination of specific and molar rotation of optically active substances in solution by polarimetric method; Determination of percentage composition of unknown mixture by polarimetry; Determination of cell constant and verification of Ostwald's dilution law; Conductometric titration of an acid against a base; Kinetics of hydrolysis of ethyl acetate; Determination of partition coefficient of benzoic acid; Study of the freundlich adsorption isotherm of acetic acid-charcoal system; Preparation of colloidal solution and determination of precipitation values of electrolytes; Determination of dissociation constant of weak acid using potentiometer; Determination of solubility of a sparingly soluble salt by conductivity measurements; Determination of sugar % by refractometer.

Suggested Readings

1. Beran, J.A. 2014. Laboratory Manual for Principles of General Chemistry. 10th Ed. Wiley & Sons, NY, USA.
2. Bhatti, H.N. and Z.H. Farooqi. 2020. Experimental Physical Chemistry. Caravan Book House, Lahore, Pakistan.
3. Garland, C.W., J.W. Nibgler and D.P. Shoemaker. 2017. Experiments in Physical Chemistry. 8th Ed. McGraw-Hill Science, Los Angeles, USA.
4. Palmer, W.G. 2009. Experimental Physical Chemistry. Cambridge University, London, U.K.

9.

CHEM-508 ATOMIC STRUCTURE AND SOLUTION CHEMISTRY 4(3-1)

Theory

Solution Chemistry: Introduction, Concentration units; Ideal and Real Solutions; Raoult's law and its applications; Henry's law, Deviation of solutions from ideal behavior; Fractional distillation and concept of azeotropic mixtures; Colligative properties; Lowering of vapor pressure; Elevation in boiling point; Depression in freezing point; osmotic pressure and its measurement; The Gibbs–Duhem Equation; Chemical Equilibrium in Solutions; Solutions Formed from Partially Miscible Liquids; The Solid-Solution Equilibrium.

Quantum Theory and Atomic Structure: Introduction to quantum chemistry, Theory of electromagnetic radiation, Compton effect and photoelectric effect; Bohr's Model and its defects; Somerfield's modification and evolution of azimuthal quantum number; Classical Waves and the Nondispersive Wave Equation; The Stern–Gerlach Experiment; Dual nature of matter; Verification of dual nature by Davisson and Germer's experiment; Heisenberg's uncertainty principle, Quantum numbers and atomic orbitals. Pauli's exclusion principle, Hund's rule of maximum multiplicity, Concepts of atomic orbitals and energy levels.

Phase Equilibrium: Gibbs phase rule, Phase diagrams of one component and two component systems, Gibbs energy and the phase diagram of a substance, location of phase boundaries, Clausius-Clapeyron equation, vapor-liquid equilibrium of binary liquid mixtures, binary phase diagrams and lever rule. The Pressure–Temperature Phase Diagram; The Phase Rule; Theoretical Basis for the P–T Phase Diagram; Chemistry in Supercritical Fluids; Liquid Crystals and their types.

Practical

Determine the heat of neutralization of a strong acid (HCl) by a strong base (NaOH). Determine the heat of solution of the given substance 'S' in water calorimetrically. Determination of λ_{max} for the given colour compound by spectrophotometric method. Verification of Beer-Lambert's law using a colored compound solution. Determination of absorbance and transmittance of various colored solutions. Determination of unknown percentage composition of a solution by spectrophotometery. Distribution coefficient of an acid between water and organic solvent by distribution method. Distribution coefficient of iodine between aqueous-organic system by distribution method. Determination of rate constant of hydrolysis of an ester catalysed by an acid. Determination of rate constant of hydrolysis of an ester catalysed by a base.

Suggested Readings

1. Bhatti, H.N. 2017, Text Book of Physical Chemistry. Caravan Book House, Lahore.
2. Bhatti, H.N. and Z.H. Farooqi. 2016. Experimental Physical Chemistry, Caravan Book House, Lahore, Pakistan.
3. Dor Ben-Amotz. 2014. Understanding Physical Chemistry. Wiley Press, NY, USA.

CHEM-506 PHYSICAL CHEMISTRY-I 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe about molecular velocities.
2. Explain the statistical thermodynamics.
3. Present an overview of advances in chemical kinetics.
4. Demonstrate the study the kinetics of various chemical reactions.

Theory

Virial equations, Maxwell's law of molecular velocities; Calculation of molecular velocities and binary collisions; Maxwell-Boltzmann's law of energy distribution; Barometric formula, effect of altitude, molar mass, and temperature on vertical distribution of particles; Determination of Avogadro's number. Thermodynamic functions; Second law of thermodynamics and Clausius inequality; Maxwell's relations and thermodynamics formula; Partial molar properties and their determination; Chemical potential; Nernst heat theorem its applications to solid and gases; Third law of thermodynamics and determination of entropy by third law; Clausius-Clapeyron equation; Sterling's approximation, statistical treatment of entropy; Partition function and its physical significance; Interpretation of thermodynamic functions in terms of translational, rotational vibrational and electronic partition functions; Free energy and equilibrium constant from partition function. Concept of rate law and order of reaction, kinetics of 3^{rd} order reaction with same and different concentrations and molecular identity; kinetics of opposing, parallel and consecutive reactions; Basic experimental techniques to study rate of reactions; Kinetics of thermally excited chain reactions like reaction of H_2 and Br_2; Kinetics of thermal decomposition of ozone, N_2O_5 and CH_3CHO; Mathematical treatment of collision and transition state theory of bimolecular reactions.

Suggested Readings

1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11^{th} Ed. Oxford UniversityPress, Oxford, UK.
2. Bhatti, H.N and Z.H. Farooqi. 2021. Modern Physical Chemistry. Volume-I. Caravan Book House, Lahore, Pakistan.
3. Donald,A.M. and J.D. Simon. 2016. Physical Chemistry: A Molecular Approach. 1^{st} Ed. University Science Book Publisher, Sausalito, CA, USA.

	4. Kurt W. Kolasinski. 2016. Physical Chemistry: How Chemistry Works, Wiley Books, NY, USA. 5. Sanjeev Chandra. 2016. Energy, Entropy and Engines: An Introduction to Thermodynamics Wiley, NY, USA.	4. Nivaldo, J.T. 2017. Chemistry: A Molecular Approach. 4th Ed. Pearson Education, Inc., NJ, USA. 5. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G. A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

10.	**CHEM-509 ABSORPTION AND EMISSION SPECTROSCOPY 4(3-1)** **Theory** Absorption Spectrophotometry: Principle of absorption spectrophotometry; Quantitative methodology; Instrumentation for molecular and atomic absorption spectrophotometry; Radiation sources; Atomizers, flames, graphite furnaces and electrochemical atomizers; monochromators, detectors, interferences in atomic absorption spectrophotometry, sample preparation; Applications of atomic absorption spectrophotometry; Principal of X-Ray spectroscopy; instrumentation and its applications. Emission Spectrophotometry: Introduction; Principle of emission spectrometry; Atomic emission spectrometry using flame; Plasma sources, plasma and its characteristics; Inductively coupled plasma, direct current plasma, microwave induced plasma, choice of argon as plasma gas, instrumentation for ICP-MS. Luminescence Spectrophotometry:Introduction, origin of fluorescence and phosphorescence spectra; Jablonski diagram, activation, deactivation, fluorescence spectrum, fluorescent and phosphorescent species; Photoluminescence and structure; Factors affecting fluorescence and phosphorescence; Fluorescence quenching, quantum yield, instrumentation for fluorescence measurement, sources, wavelength selectors, sampling, detectors, read out devices, instrumentation for phosphorescence measurement, sampling, recording procedure, applications of fluorescence and phosphorescence. Laser spectroscopy: Principles, fluorescence of laser light and its general applications; Ruby laser, nitrogen laser and dye laser; Use of laser radiation in absorption and fluorescence spectroscopic methods. **Practical** Determination Na, K by flame photometry; Sample preparation for AAS analysis; Determination of metals including, Cd, Pb, Fe, Cu in food samples; Determination of λmax of KMnO4 and K2Cr2O7 solutions and verification of Beer-Lambert's law; Determination of aspirin and caffeine in a proprietary analgesic by double beam UV-Vis, Spectrometer; Determination of metals like iron and nickel spectrophotometerically. **Suggested Readings** 1. Bhatti, H.N. 2017. Principlesof Analytical Chemistry. Caravan Book House, Lahore. 2. Christian, G.D. 2006. Analytical Chemistry, 6th Ed. John-Wiley & Sons, NY, USA. 3. Harris, D.C. 2011. Quantitative Chemical Analysis. 8th Ed. W.H. Freeman and Company, NY, USA. 4. Kealey, D. and P.L. Haines. 2002. BIOS Instant Notes in Analytical Chemistry, Bios Scientific Publishers Limited, Oxford, UK. 5. Skoog, D.A. and D.M. West. 2008. Fundamentals of Analytical Chemistry, 8th Ed. Hot Reinehart Inc., London, UK.	**CHEM-507 ABSORPTION AND EMISSION SPECTROSCOPY 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various quantum theories. 2. Explain the fundamentals of spectroscopy. 3. Demonstrate the knowledge about the spectra. 4. Describe different chemical phenomena. **Theory** Principle of absorption spectrophotometry; Quantitative methodology; Instrumentation for molecular and atomic absorption spectrophotometry; Radiation sources; Atomizers, flames, graphite furnaces and electrochemical atomizers; Monochromators, detectors, interferences in atomic absorption spectrophotometry, sample preparation; Applications of atomic absorption spectrophotometry; Principal of X-Ray spectroscopy, instrumentation and its applications;Introduction; Principle of emission spectrometry; Atomic emission spectrometry using flame; Plasma sources, plasma and its characteristics; Inductively coupled plasma, direct current plasma, microwave induced plasma, choice of argon as plasma gas, instrumentation for ICP-MS. Introduction, origin of fluorescence and phosphorescence spectra; Jablonski diagram, activation, deactivation, fluorescence spectrum, fluorescent and phosphorescent species; Photoluminescence and structure; Factors affecting fluorescence and phosphorescence; Fluorescence quenching, quantum yield, instrumentation for fluorescence measurement, sources, wavelength selectors, sampling, detectors, read out devices, instrumentation for phosphorescence measurement, sampling, recording procedure, applications of fluorescence and phosphorescence; Principles, fluorescence of laser light and its general applications; Ruby laser, nitrogen laser and dye laser; Use of laser radiation in absorption and fluorescence spectroscopic methods. **Practical** Determination Na, K by flame photometry; Sample preparation for AAS analysis; Determination of metals including, Cd, Pb, Fe, Cu in food samples; Determination of λ_{max} of $KMnO_4$ and $K_2Cr_2O_7$ solutions and verification of Beer-Lambert's law; Determination of aspirin and caffeine in a proprietary analgesic by double beam UV-Vis, Spectrometer; Determination of metals like iron and nickel spectrophotometerically. **Suggested Readings** 1. Bhatti, H.N. 2021. Principles of Analytical Chemistry. Caravan Book House, Lahore.

2. Christian, G.D. 2022. Analytical Chemistry, 6th Ed. John-Wiley & Sons, NY, USA.
3. Harris, D.C. 2011. Quantitative Chemical Analysis. 8th Ed. W.H. Freeman and Company, NY, USA.
4. Kealey, D. and P.L. Haines. 2010. BIOS Instant Notes in Analytical Chemistry, Bios Scientific Publishers Limited, Oxford, UK.
5. Skoog, D.A. and D.M. West. 2018. Fundamentals of Analytical Chemistry, 8th Ed. Hot Reinehart Inc., London, UK.

11.

CHEM-510 INORGANIC REACTION MECHANISM 4(3-1)

Theory

Inorganic reaction mechanism: Classification of reaction mechanisms; Rate laws; Steady state approximation; inert and labile complexes; Substitution reactions in octahedral complexes and square planar complexes; Acid hydrolysis; Base hydrolysis; Steric effects of inert ligands; nucleophilic reactivity; Trans-effect, *cis*-effect; Racemization reactions; Mechanism of electron transfer reactions; Oxidation reduction reactions of metal ions; Outer and inner sphere mechanisms; Factors affecting rate of electron transfer reactions; Two electrons transfer reactions; Complementary or non-complementary electron transfer reactions; Oxidative addition; Addition of oxygen; Hydrogen, HX, Organic halides and bimetallic species; Reductive Elimination Reactions.

Inorganic Analysis: Estimation of anions in mixtures; Chloride-phosphate; Chloride-nitrate; Oxalate-chloride; Sulphate-phosphate; Bromide-nitrate; Borate-acetate; Iodide-nitrate; Iodometric titration with potassium iodate; Gravimetric estimation of oxalate; Precipitation Titrations.

1. Determination of % age purity of KBr using Fluoresceine as indicator.
2. Determination of % composition of mixture of KI & KNO_3 using Eoscein as indicator.
3. Determination of strength of NaCl in given solution by $AgNO_3$ using Fluorescein as indicator.
4. Separation of heavy metals using solvent extraction technique.
5. Spectrophotometric determination of cerium.

Suggested Readings

1. Huheey, J.E., E.A. Keiter and R.L. Keiter. 1997. Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed. Prentice Hall, UK.
2. Jolly, W. L. 1991. Modern Inorganic Chemistry. 2nd Ed. McGraw-Hill Company, USA.
3. Jordan, R.B. 1998. Reaction Mechanisms of Inorganic and Organometallic Systems. 2nd Ed. Oxford University Press, NY, USA.
4. Sharma, S. K. 2007. Inorganic Reaction Mechanisms, Discovery Publishing House. ND, India.
5. Shriver, D.F.and P.W. Atkins. 2001. Inorganic Chemistry, 3rd Ed. Oxford University Press, London, UK.
6. Svehla, G. 1979. Vogel's Textbook of Macro and Semimicro Qualitative Inorganic Analysis, 5th Ed. Longman Group Limited, London, UK.

CHEM-508 EXPERIMENTAL INORGANIC CHEMISTRY- I 2(0-2)

Learning Course Outcomes

By the end of this course students will be able to :

1. Explain complex metric titrations (direct, back, masking, demasking, and indirect).
2. Demonstrate redox titrations for the estimation of different elements with the use of ceric sulphate
3. Demonstrate use of potassium for the determination of different elements
4. Demonstrate preparation of different complexes

Theory

Complexometric Titrations:Estimation of $Mg^{+2}$and Zn^{+2} with EDTA (Direct titration), Estimation of Ni^{+2} with EDTA (Back titration); Determination of Ca^{+2} and Zn^{+2} in mixture (Masking) (d) Determination of Cd^{2+} and Zn^{+2} in a mixture (Demasking); Determination of SO_4^{2-} and PO_4^{-3} with EDTA (Indirect titration). Redox Titrations:Use of Ceric sulphate solution for the estimation of the following: Determination of iron in an iron ore; Determination of nitrites; Use of potassium iodate for the determination of the followings: Copper, H_2O_2, Commercial Hypochlorite. Preparations:Tris (ethylenediamine) nickle (II) Chloride 2-hydrate, Sodium Cobaltinitrite, Pot. Trioxalato Aluminate, Ammonium sulphate Nickel (II) Sulphate, Hexa aqua Chromium (III) Chloride, Ammonium Sulphate Copper (II) Sulphate Pentahydrate.

Suggested Readings

1. Bassett, J., R.C. Denny, G.H. Jeffery and J. Mendham. 2008. Vogel's Textbook of Qualitative Inorganic Analysis. 7th Ed. the English Language Book Society and Longman, NY.
2. Bhatti, H.N. and R. Rehman. 2020. Experimental Inorganic Chemistry. Caravan Book House, Lahore. .
3. James, S. Pritz, G.H. Sehenk. 2020. Quantitative Analysis Chemistry. 10thEd. Alby and Becon Inc. London.
4. Schoeller,W.R. and A.R. Powell. 2005. The Analysis of Minerals and Ores of the Rarer Elements. 2nd Ed. Charles, Griffin and Company Limited.

12.

CHEM-512 THERMODYNAMICS AND SURFACE CHEMISTRY 4(3-1)

Theory

Chemical Thermodynamics:Introduction**;** State function;Zeroth law of thermodynamics; First law of thermodynamics; Enthalpy of system; Heat capacities and their dependence on temperature; Pressure and volume; Reversible and non-reversible processes; Spontaneous and non-spontaneous processes, Second law of thermodynamics, Kelvin-Planck and Clausius concept; Carnot cycle, efficiency of heat engine; Concept of entropy; Thermodynamics scale of temperature entropy for phase transition; Spontaneity and reversibility; Entropy change in reversible and irreversible processes; Temperature dependence of entropy; Variation of entropy with pressure and volume; Clausius inequality; Maxwell relations and thermodynamics formula; Third law of thermodynamics; Concept of free energy; Free energy functions; Free energy relationships with equilibrium constant of chemical reactions; Nernst heat theorem; Derivation of Gibbs and Helmholtz equation; Standard free energy of formation; Partial molar quantities, Chemical potential; Variation of chemical potential with pressure and temperature Calusius-Clapeyron equation; Fugacity and activity.

Surface Chemistry:Introduction; Surfaces and interfaces; Difference between adsorption and absorption; Types of adsorption; Forces of adsorption and factors affecting adsorption; adsorption isotherms; Freundlich, Langmuir and Tempkin adsorption isotherms; Applications of adsorptions; Colloids; Surface properties of colloidal materials; Emulsion and their industrial applications; Interfacial tension; Spreading of liquids and insoluble surface films; Adsorption at liquid surfaces; Gas reactions at solid surfaces; Determination of surface area of adsorbent; catalysis; Types of catalysis; Characteristics of catalytic reactions; Theories of catalysis; Enzyme catalysis and enzyme inhibition;

Practical

Determination of cell constant and molar conductance; Determination of molar mass of a polymer by viscosity method; Determination of precipitation value of electrolytes; Measurement of electronic and vibrational spectra of simple compounds and their interpretation; Evaluation of pKa value of an indicator by spectrophotometry; Determination of stoichiometry of a complex by jobs method; Determination of percentage composition of $KMnO_4$and $K_2Cr_2O_7$ in given solution by spectrophotometry; Determination of partial molar quantities; Determination of free energy changes and equilibrium constant; Sugar analysis and its inversion study by polarimetry; Determination of dissociation constant by potentiometry.

CHEM-509 INORGANIC CHEMISTRY -II 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Explain the chemistry and structure of lanthanides and actinides.
2. Describe the pi acceptor ligands and their synthesis
3. Explain detailed explanation of metal nitrosyls and their derivatives
4. Explain the non-aqueous solvent, their classification and chemical reactions.

Theory

Chemistry of Lanthanides and Actinides:Structure, occurrence, and preparation; Separation and electronic configuration, oxidation states, spectral and magnetic properties; Complex formation; Lanthanides contraction; Shapes of f-orbitals; Applications and uses of elements and their compounds. Pi- acceptor ligands: Transition metal carbonyls (Mononuclear, Binuclear, Polynuclear), synthesis, bonding situation based on spectroscopic evidence; Theoretical rationalization of molecular structures, (close, nido, erachno), Synthesis; Characteristics and reactivity of derivatives of metal carbonyls (carbonylate anions, carbonyl hydrides and carbonyl halides); Metal nitrosyls including halonitrosyl and their derivatives;Non-aqueous solvents: Introduction; classification of solvents; Types of reactions in non-aqueous solvents; effect of physical and chemical properties of solvents; study of reactions in liq. NH_3, liq. SO_2. liq. HF, CH_3COOH and liq. BrF_3; Reactions in molten salt system.

Suggested Readings

1. Bhatti, H.N. and R. Rehman.2020. Advanced Inorganic Chemistry. Volume-I. The Caravan Book Lahore, Pakistan.
2. Cotton, F.A. and, G. Wilkinson. 1988. Advanced Inorganic Chemistry. 6thEd. John Wiley, NY.
3. Greenwood, N.N. and A.Easnshaw. 1984 Chemistry of the Elements. 2nd Ed.Pergaman, NY.
4. Joly, W.L. 1985. Principles of Inorganic Chemistry. McGraw Hill.
5. Sharpe, A.G. 1987. Inorganic Chemistry. 5thEd. John Wiley, NY.

Suggested Readings

1. Atkins, P. and J. de Paula. 2011. Physical Chemistry. 9th Ed. Oxford University Press, ND, India.
2. Ball, D.W. 2007. Physical Chemistry. Thomson Books, London, U.K.
3. Bhatti, H.N. and Z.H. Farooqi. 2016. Modern Physical Chemistry. Caravan Book House, Lahore, Pakistan.
4. Bhatti, H.N. and Z.H. Farooqi. 2016. Experimental Physical Chemistry. Caravan Book House, Lahore, Pakistan.

13.	**CHEM-513 APPLIEDCHEMISTRY-II 4(3-1)** **Theory** Elementary treatment of general unit Chemical unit processes; Nitration; Halogenation; Sulphonation; Hydration and Hydrogenation and Oxidation with real examples from industry;Agro-based industries; Sugar industry;Production and refining of sugar; Utilization of by-products and wastes; Manufacture of starch; Urea and phosphate fertilizers;Soap and detergentindustry;Fatsandoil industry; Glass Industry; Raw materials used for glass; Methods of manufacturing, various types of furnaces used for the manufacture of glass; different types of glass and their properties; Cement Industry; Raw materials; Different processes in cement manufacturing; Setting of cement and chemistry involved; Hydration of cement; Ceramicsandnew materials; Classification,structureandproperties; Classicalclay basedceramicsandadvanced ceramicmaterial; Dyes,paintandpigments;Introduction,classification; Synthesis andapplications;Industry Vision; Industrialtour. **Practical** Determinationofiodine; Saponificationvalue;Peroxidevalueandacid valueofoil/fat;Saponification ofoil/fat;Preparationofsoapsanddetergents;Synthesisof AzoDyes;Sugarqualityanalysis; Determinationofnitrogenandphosphoruscontentsoffertilizer. **Suggested Readings** 1. Austin,G.T.2005.Shreve'sChemicalProcessIndustry.6th Ed.McGrawHillBookCompany, NY,USA. 2. Bhatti, H.N and M. Salman. 2017. Applied Chemistry. Caravan Book House Lahore, Pakistan. 3. Bhatti, H.N., S. Ilyas and S. Noreen. 2016. Applied Chemistry Laboratory Manual. Caravan Book House Lahore, Pakistan. 4. Das,R.K.2001.IndustrialChemistry.Part.2. KalyaniPublishers,ND, India. 5. Kent, J.A. 2012. Riegel's Handbook of Industrial Chemistry. Springer Science & Business Media, London UK. 6. Shukla,S.P.andG.L.Trivedi.2000.ModernOrganicChemistry.S.Chand&Company,ND,India.	**CHEM-510 APPLIEDCHEMISTRY-II 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various chemical units. 2. Explain the fundamentals of industries. 3. Present the knowledge about the Pakistani industries. 4. Describe different chemical industries. **Theory** Elementary treatment of general unit chemical unit processes; Nitration; Halogenation; Sulphonation; Hydration and Hydrogenation and Oxidation with real examples from industry; Agro-based industries; Sugar industry; Production and refining of sugar; Utilization of by-products and wastes; Manufacture of starch; Urea and phosphate fertilizers; Soap and detergent industry; Fatsandoil industry; Glass Industry; Raw materials used for glass; Methods of manufacturing, various types of furnaces used for the manufacture of glass; Different types of glass and their properties; Cement Industry ,raw materials, different processes in cement manufacturing; Setting of cement and chemistry involved; Hydration of cement; Ceramics and new materials, classification, structure and properties; Classical clay based ceramics and advanced ceramic material; Dyes, paint and pigments; Introduction, classification; Synthesis and applications; Industry Vision; Industrial tour. **Suggested Readings** 1. Austin,G.T.2005.Shreve'sChemicalProcessIndustry.6th Ed.McGrawHillBookCompany, NY,USA. 2. Bhatti, H.N and M. Salman. 2021. Applied Chemistry. Caravan Book House Lahore, Pakistan. 3. Bhatti, H.N., M. Salman and S. Noreen. 2021. Applied Chemistry Laboratory Manual. Caravan Book House Lahore, Pakistan. 4. Das,R.K.2001.IndustrialChemistry.Part2. KalyaniPublishers,ND, India. 5. Kent, J.A. 2012. Riegel's Handbook of Industrial Chemistry. Springer Science & Business Media, London, UK. 6. Shukla,S.P.andG.L.Trivedi.2000.ModernOrganicChemistry.S.Chand&Company,ND,India.

14.		**CHEM-511 ORGANIC CHEMISTRY-II 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various optical compounds. 2. Explain the fundamentals of stereochemistry. 3. Present the knowledge about the optical activity. 4. Describe different spectroscopic conventions and its applications. **Theory** Stereochemistry: Chirality and enantiomers; Optical activity: Symmetry elements: R-S conventions; Racemic modifications and their resolution; Asymmetric synthesis; Optical activity in biphenyl and spiro compounds; Stereo specific and stereo selective reactions; Geometrical isomerism; Z and E convention; cis-trans isomerism in cyclic systems; Conformational analysis of disubstituted cyclohexanes and condensed rings. Organic Spectroscopy: Basic principles of UV/Visible, IR, NMR spectroscopy and Mass spectrometry; Spectral interpretation of simple organic compounds with these techniques. **Suggested Readings** 1. Bhatti, H.N. 2021. Advanced Organic Chemistry. Volume-I. The Caravan Book House, Lahore. 2. Eliel, E.L.2005. Stereochemistry of Carbon Compounds. Tata McGraw Hill. ND, India. 3. Morris, D.G. 2001. Stereochemistry. The Royal Society of Chemistry, London. 4. Pavia, D.L., G.M. Lampman and G.S. Kriz. 2014. Introduction to Spectroscopy. 5th Ed. Cengage Learning, NY, USA. 5. Silverstein, R.M., G.C. Bassler and T.C. Morrill. 2014. Spectrometric Identification of Organic Compounds. 8th Ed. John Wiley & Sons Inc., NY, USA. 6. Solomon, T.W.G. 2018. Organic Chemistry. 11th Ed. John Wiley &Son's, Inc., NY, USA.

15.		**CHEM-512 EXPERIMENTAL ORGANIC CHEMISTRY-I 2(0-2)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various functional groups. 2. Explain the fundamentals of organic chemistry. 3. Demonstrate the knowledge about the titration. 4. Describe different spectroscopic techniques and its applications. **Practical** Identification of organic compounds; Carboxylic acids, carbohydrates; Hydrocarbons, aldehydes, ketone, primary, secondary, and tertiary amines, phenolics, amides and imines. Physical & Chemical separations of organic compounds, Estimation of functional groups through titrimetric methods. Experiments of both of qualitative and quantitative nature based on available spectroscopic techniques. **Suggested Readings** 1. Chughtai, F.A. and Z.H. Nazli. 2010. Systematic Organic Analysis. Majeed Book Depot, Lahore. 2. Furniss, B.S., A.J. Hannaford, P.W.G. Smith, and A.R. Tatchell. 1989. Vogel's Textbook of Practical Organic Chemistry. 5th Ed. Longman, UK. 3. Leonard, J., B. Lygo and G. Procter. 2001. Advanced Practical Organic Chemistry. Nelson Thornes Ltd. UK. 4. Pavia, D.L., G.S. Kriz, G.M. Lampman and R.G. Engel. 2013. A Microscale Approach to Organic Laboratory Techniques. 5th Ed. Brooks/Cole Laboratory Series, Cengage Learning, UK. 5. Robert, T. M. and N.B. Robert. 1992. Organic Chemistry. 6th Ed. Prentice Hall, NY, USA.

16.

CHEM-513 PHYSICAL CHEMISTRY-II 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Explain quantum chemistry and related phenomena.
2. Describe the concepts of electrochemistry.
3. Describe the principles and theoretical background of electrochemical cell.
4. Describe the understandings of molecular symmetry.

Theory

Quantum Mechanics: Introduction, elementary treatment of photoelectric effect Compton effect; Dual nature of matter; Verification of dual nature by Davisson and Germer's experiment; Heisenberg's uncertainty principle; Brief introduction of operators; Derivation of time independent Schrodinger wave equation (SWE) for particle in one and three-dimensional system, postulates of quantum mechanics, eigen functions and eigenvalues, normalization of wave function; Application of SWE to hydrogen atom, Separation of variables and derivation of quantum numbers, tunnel effect. Electrochemistry: Introduction, electrolytic conduction and its measurement; Specific, equivalent and molar conductance; Determination of resistance; Cell content; Conductance ratio; Conduction of strong and weak electrolytes; Ionic motilities and their determination; Kohlrausch's law and its applications; Transport numbers; Hittort's rule; Determination of transport number by Hittort's method; Applications of conductance measurement; EMF of the chemical cells; Electrode potential and its measurement. Molecular symmetry: Introduction; Coordinate system; Symmetry operations and symmetry elements; The symmetry point groups; Multiplication of symmetry operators; Optical activity and dipole moments on basis of point group symmetry.

Suggested Readings

1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11th Ed. Oxford UniversityPress, Oxford, UK.
2. Bhatti, H.N and Z.H. Farooqi. 2021. Modern Physical Chemistry. Volume-I. Caravan Book House, Lahore, Pakistan.
3. Donald,A.M. and J.D. Simon. 2016. Physical Chemistry: A Molecular Approach. 1st Ed. University Science Book Publisher. Sausalito, CA, USA.
4. Nivaldo, J.T. 2017. Chemistry: A Molecular Approach. 4th Ed. Pearson Education, Inc., NJ, USA.

		5. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G.A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

17.	**CHEM-605 ORGANIC REDOX REACTIONS 3(3-0)** **Theory** Oxidation reactions: General principles; Oxidation of hydrocarbons, alcohols; Aromatics; Aldehydes and ketones autoxidation; Peroxidation, catalytic dehydrogenation; Oxidation of systems containing oxygen; Nitrogen and sulphur; Oxidative cleavage and decarboxylation; Reduction reactions; General principles; Hydrogenation, hydrogenolysis; Reduction with hydrides; Hydrazine and metals; Hofmann degradation and reductive alkylation. **Suggested Readings** 1. Bhatti, H.N. 2016. Advanced Organic Chemistry. The Caravan Book House, Lahore. 2. Bruice, P. 2013. Essentials of Organic Chemistry. 2nd Ed. Pearson Books. Berlin, Germany. 3. Francis, C.A. and R.G. Sundberg. 2007. Advanced Organic Chemistry. 5th Ed. Springer Science. Business Media, NY, USA. 4. March, J. 2013. Advanced Organic Chemistry: Reactions, Mechanisms, and Structure. 7th Ed. McGraw Hill Book Company, NY, USA. 5. Pine, S.H. 2008. Organic Chemistry. 5th Ed. Tata McGraw-Hill, ND, India. 6. Solomon, T.W.G. 2014. Organic Chemistry. 11th Ed. John Wiley and Son's Inc., NY, USA.	**CHEM-514 ORGANIC REDOX REACTIONS 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various organic reactions. 2. Explain the fundamentals of organic chemistry. 3. Demonstrate the knowledge about the mechanism. 4. Describe different organic reactions. **Theory** Oxidation reactions: General principles; Oxidation of hydrocarbons, alcohols; Aromatics; Aldehydes and ketones autoxidation; Peroxidation, catalytic dehydrogenation; Oxidation of systems containing oxygen; Nitrogen and sulphur; Oxidative cleavage and decarboxylation; Reduction reactions; General principles; Hydrogenation, hydrogenolysis; Reduction with hydrides; Hydrazine and metals; Hofmann degradation and reductive alkylation. **Suggested Readings** 1. Bhatti, H.N. 2021. Advanced Organic Chemistry. Volume-I. The Caravan Book House, Lahore. 2. Bruice, P. 2013. Essentials of Organic Chemistry. 2nd Ed. Pearson Books. Berlin, Germany. 3. Francis, C.A. and R.G. Sundberg. 2007. Advanced Organic Chemistry. 5th Ed. Springer Science. Business Media, NY, USA. 4. March, J. 2013. Advanced Organic Chemistry: Reactions, Mechanisms, and Structure. 7th Ed. McGraw Hill Book Company, NY, USA. 5. Pine, S.H. 2018. Organic Chemistry. 5th Ed. Tata McGraw-Hill, ND, India. 6. Solomon, T.W.G. 2018. Organic Chemistry. 11th Ed. John Wiley and Son's Inc., NY, USA.

18.	**CHEM-607 HETEROCYCLIC COMPOUNDS 3(3-0)** **Theory** Structure; Classification and nomenclature of heterocyclic compounds; Aromaticity; Reactions; Basicity, Acidity and synthesis of the heterocyclic compounds; Quinolines; Isoquinolines; Diazens; Furan, Pyrrole and thiophene; Pyridine; Pyrimidines; Azoles and purines; Reactivity of aromatic heterocyclic compounds; Electrophilic addition; Substitution at Nitrogen and Carbon; Reaction and synthesis of partially unsaturated heterocyclic compounds; Organo metallic compounds having heterocyclic ring. **Suggested Readings** 1. Bhatti, H.N. 2016. Advanced Organic Chemistry. The Caravan Book House, Lahore. 2. Claydem, J., N. Greeves and S. Warren. 2012. Organic Chemistry, 2nd Ed. Oxford University Press, UK. 3. Coxon, J.M. and R.O.C. Norman. 1993. Principles of Organic Synthesis. 3rd Ed. CRC Press, London, UK. 4. Crabtree, R.H. 2009. The Organometallic Chemistry of the Transition Metals. 5th Ed. John-Wiley & Sons, NY, USA. 5. Joule, J. A. 2010. Heterocyclic Chemistry. 5th Ed. John-Wiley & Sons, NY, USA.	**CHEM-515 CONDENATION AND HETEROCYCLIC CHEMISTRY 3(3-0)** **Learning Objectives** By the end of this course students will be able to: 1. Describe various heterocyclic compounds. 2. Explain the fundamentals of heterocyclic compounds. 3. Demonstrate the knowledge about the mechanism. 4. Describe different reactions and its mechanism. **Theory** Structure; Classification and nomenclature of heterocyclic compounds; Aromaticity; Reactions; Basicity, Acidity and synthesis of the heterocyclic compounds; Quinolines; Isoquinolines; Diazens; Furan, Pyrrole and thiophene; Pyridine; Pyrimidines; Azoles and purines; Reactivity of aromatic heterocyclic compounds; Electrophilic addition; Substitution at Nitrogen and Carbon; Reaction and synthesis of partially unsaturated heterocyclic compounds; Organo metallic compounds having heterocyclic ring.Condensation Reactions: Aldol condensation; Crossed and retro-aldol condensation; Cannizaro's and cross Cannizaro's reactions; Acid and base catalyzed condensations; Conditions; Mechanism and synthetic applications of the following reactions; Claisen, Claisen Schmidt; Knoevenagel; Perkin; Reformatsky and Stobbes condensations; Darzen's glycosidic ester synthesis; Mannich and Wittig Michealcondenation; Condensation of carbanions; Condensations involving acetylides and cyanides; Synthetic applications of condensation reactions. **Suggested Readings** 1. Bhatti, H.N. 2020. Advanced Organic Chemistry. Volume-I. The Caravan Book House, Lahore. 2. Clayden, J., N. Greeves and S. Warren. 2012. Organic Chemistry.2nd Ed. Oxford University Press, UK. 3. Coxon, J.M. and R.O.C. Norman. 1993. Principles of Organic Synthesis. 3rd Ed. CRC Press, London, UK. 4. Crabtree, R.H. 2009. The Organometallic Chemistry of the Transition Metals. 5th Ed. John-Wiley & Sons, NY, USA. 5. Joule, J.A. 2010. Heterocyclic Chemistry. 5th Ed. John-Wiley & Sons, NY, USA.

19.

CHEM-609 CHEMICAL KINETICS AND MOLECULAR SYMMETRY 3(3-0)

Theory

Fundamentals of kinetics, Concept of rate; Order and molecularity of reaction; Derivation of kinetic expression of zero order; First order; second order (with same and different concentration) and 3rd order reaction (with different concentration); Half-life of reactions; experimental techniques for rate determination and methods for determination of order of reaction (integration, half-life, initial rate and graphical methods); Kinetics of opposing; parallel and consecutive reactions; Basic experimental methods to study kinetics; Kinetics of thermally excited reactions of H_2 and Br_2, Kinetics of thermal decomposition of acetaldehyde and N_2O_5; Collision theory of uni-molecular, gas phase reactions (Lindeman mechanism); Introduction to transition state theory of reaction rates; Mathematical treatment of collision and transition state theory of bimolecular reactions; Bimolecular collision theory of reaction rates and its failures; Effect of temperature on reaction rates and Arrhenius equation; Interpretation of bimolecular reactions in solutions; Ionic reactions in solution; Fast reactions and their methods of studies.

Introduction; Symmetry elements and symmetry operations; Properties of groups and point groups; Special point groups; Multiplication tables; Matrices; Reducible and irreducible representation; Character tables, Vanishing integrals and selection rules.

Suggested Readings

1. Atkins, P. and J. de Paula. 2011. Physical Chemistry. 9th Ed. Oxford University Press, ND, India.
2. Ball, D.W. 2007. Physical Chemistry. Thomson Books, London, U.K.
3. Bhatti, H.N. and Z.H. Farooqi. 2016. Modern Physical Chemistry. Caravan Book House, Lahore, Pakistan.
4. Silbey, R.J., R.A. Alberty and M.G. Bawendi. 2011. Physical Chemistry. John Wiley & Sons, NY, USA.

CHEM-516 POLYMER CHEMISTRY 2(2-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Explain the classification of polymers.
2. Describe measurement of molecular weight of the polymers.
3. Describe understanding about the structure of polymers.
4. Demonstrate different application of polymeric materials.

Theory

Introduction to polymers; Classification of polymers; Kinetics of condensation and addition (free radical, cationic and anionic polymerization); Copolymers and their classification; Kinetics of copolymerization; Concept of molecular mass average in polymers and its determination; Molecular mass distribution; Determination of average molecular mass by different methods like Viscometry, Osmometr;. Gel permeation, Light scattering and sedimentation; Polymer analysis techniques like spectroscopic methods (UV visible and IR) and thermal analysis; Structure of polymer chain; Stereochemistry, configuration and conformation of polymers; Structure property relationship; Polymer rheology;

Suggested Readings

1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11th Ed. Oxford UniversityPress, Oxford, UK.
2. Ball, D.W. and B. Tomas. 2014. Physical Chemistry. 2nd Ed. Cengage Learning, Stamford, USA.
3. Bhatti, H.N. and Z.H. Farooqi. 2021. Modern Physical Chemistry.Volume-II. Caravan Book House, Lahore, Pakistan.
4. Bilmeyer, F.W. 2005. Text Book of Polymer Science. National Book Foundation, Islamabad, Pakistan
5. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G. A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

20.	**CHEM-610 COLLOIDS AND POLYMER CHEMISTRY 3(3-0)** **Theory** **Colloids**: Colloidal dispersions; Colloidal Stability; Lyophobic Sols; Systems containing lyophilic materials; Stability control; Sols and their preparations; Optical electrical and kinetic properties of sols; Determination of particle size; Sedimentation of suspensions; Stability of suspensoids; Precipitation of sols and their applications; Associated colloids; Gels and emulsions: Introduction; Methods of preparation of emulsions; Emulsifiers; Breaking of emulsions; Orientation theory; Emulsification and wetting; Rheology. Polymer chemistry; Classification of polymers; Kinetics of condensation, addition and co-polymerisation; Physical aspects of polymers; Molecular weight of polymers and distribution averages; Determination of molecular mass by different methods like viscometry; Osmometry; Gel permeation; Light scattering and sedimentation; Polymer characterization; Structure property relationship; Introduction; properties and applications of Elastomers; Plastics; Fibres; Blends and Alloys. **Suggested Readings** 1. Atkins, P. and J. de Paula. 2011. Physical Chemistry. 9th Ed. Oxford University Press, ND, India. 2. Ball, D.W. 2007. Physical Chemistry. Thomson Books, London, U.K. 3. Bhatti, H.N. and Z.H. Farooqi. 2016. Modern Physical Chemistry. Caravan Book House, Lahore. 4. Bilmeyer, F.W. 2005. Text Book of Polymer Science. National Book Foundation, Islamabad. Silbey, R.J., R.A. Alberty and M.G. Bawendi. 2011. Physical Chemistry. John Wiley & Sons, NY, USA.	**CHEM-517 COLLOIDS AND SURFACE CHEMISTRY 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the key concepts about colloids. 2. Demonstrate the preparation and key properties of colloidal solutions. 3. Describe basic principles of surface chemistry. 4. Explain the theoretical background about catalysts and catalytic reactors. **Theory** Colloids: Colloids, colloidal dispersions; Sols and their preparation; Properties of suspensions; Optional properties of sols; Determination of particle size, kinetic properties of sols; Sedimentation of suspensions; Electrical properties of sols; Electrophoresis and electro osmosis; Stability of suspensoids; Precipitation of sols; Associated colloids; Macromolecular properties in solutions and molecular weight determinations; Preparation and characterization of emulsions; Emulsifiers and their properties; Gibbs surface excess; Micellization; Theories of emulsion type; Stability of emulsions; Classification and properties of gels.Surface Chemistry: Introduction;Surface and interfacial tension; Spreading of liquids and insoluble surface films: Kelvin equation;Adsorption- types of adsorption and factors affecting adsorption; Adsorption isotherms; Single system, double system; Catalytic reaction of a gas on solid surface, catalytic reaction of two gases on solid surface; The Eley-Rideal and the Langmuir-Hinshelwood mechanism; Autocatalysis; Enzyme catalysis and enzyme inhibition. **Suggested Readings** 1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11th Ed. Oxford UniversityPress, Oxford, UK. 2. Ball, D.W. and B Tomas 2014. Physical Chemistry. 2nd Ed. Cengage Learning, Stamford, USA. 3. Bhatti, H.N. and Z.H. Farooqi. 2021. Modern Physical Chemistry Volume-II. Caravan Book House, Lahore, Pakistan. 4. Birdi, K.S., 2015. Hand book of Surface and Colloid Chemistry. 4th Ed. CRC Press. Boca Raton, USA Silbey, R.J., R.A. Alberty, M.G. Bawendi and G. A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

21.	**CHEM 618 DESIGNING OF ORGANIC SYNTHESIS 3(3-0)** **Theory** Introduction to Retrosynthesis: Retro-synthetic approach to organic synthesis; Functional group inter-conversation and convergent synthesis; Synthesis approach; Alkenes; alkynes; Alkyl halide; Alcohol; Ether; Aromatic compounds; Carbonyl and nitrogen containing compounds; C-C, C-N and C-O bond formation, 1,2; 1,3; 1,4; 1,5; and 1,6-cyclizations; Functional group protection; Hydroxyl; Amino; Carbonyl; Carboxylic; Sulfanyl, C=C; Solid phase synthesis; Application of synthetic chemistry in various industries. **Suggested Readings** 1. Clayden, J., N. Greeves and S. Warren. 2012. Organic Chemistry, 2nd Ed. Oxford University Press, NY, USA. 2. Fox, M. A. and J.K. Whitsell. 1997. Organic Chemistry, 3rd Ed. Jones & Bartlett, Publishers, Boston, UK. 3. Loudon, M. 2009. Organic Chemistry, 5th Ed. Roberts Company Publishers, London, UK. 4. Norman, R. O. C. and J.M. Coxon. 1993. Principles of Organic Synthesis, 3rd Ed. CRC Press, UK. 5. Smith, J. G. 2010. Organic Chemistry. 3rd Ed. McGraw-Hill, Los Angeles, USA. 6. Warren, S. and P. Wyatt. 2010. The Disconnection Approach, 2nd Ed. John-Wiley & Sons, Inc., NY, USA.	**CHEM-518 ORGANOMETALLIC COMPOUNDS 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe different organometallic compounds. 2. Explain the fundamentals of organometallic compounds. 3. Demonstrate the knowledge about the organometallic compounds. 4. describe different organometallic compounds. **Theory** Fundamentals of organometallic compounds; Historical background and current trends; 18-Electron rule: Rationalization, limitations. Classification of organometallic compounds and types of ligands, Types of bonding in organometallics; Single; Double and triple bonds to carbon (compound types, acyls, alkylidene complexes and alkylidyne complexes); Delocalized hydrocarbon systems (alkenes, olefins, allyl and butadienes); Alkyne complexes, Cyclic π-complexes (five and six membered rings); Carbido or carbide complexes; Homogeneous catalytic hydrogenation; Dimerization, oligomerization; Polymerization; Hydroformylation of olefins; Catalytic polymerization of acetylenes; Insertion reactions and uses of organometallic compounds in organic synthesis; Chemistry of organic compounds containing sulfur; Phosphorus, Boron and silicon; Synthesis; Reactions and applications of organometallic chemistry. Characterization of Organometallic compounds; Metal cluster and rationalization of their structures: electron counting schemes in clusters. **Suggested Readings** 1. Bhatti, H.N., and M.A. Iqbal. 2018. Organo-Transition metal Chemistry. Caravan Book house, Lahore. 2. Clayden, J., N. Greeves, and S. Warren. 2012. Organic Chemistry. 3rd Ed. Oxford University Press, Oxford, UK. 3. Cotton, F.A., G. Wilkinson, C.A. Murillo and M. Bochmann. 1999. Advance inorganic Chemistry. 6th Ed. Wiley-Interscience, NY, USA. 4. Crabtree, R. H. 2009. The Organometallic Chemistry of the Transition Metals. 5th Ed. John-Wiley & Sons, NY, USA. **5.** Pfennig, B.W. 2021. Principles of inorganic chemistry. John Wiley & Sons.

22.

CHEM-519 CHROMATOGRAPHIC TECHNIQUES 3(2-1)

Learning Course Outcomes

By the end of this course students will be able to:

1. Explain theoretical basis, principles, and applications of chromatography.
2. Present skill to design chromatographic separations/purifications of samples.
3. Explain practical applications of solvent extraction and distillation systems.
4. Demonstrate gas chromatographic analysis for volatile compounds detection.

Theory

Classifications of chromatographic techniques; Theoretical background of chromatography processes; Resolution; Efficiency; Capacity factor; Selectivity factor; Plate theory and rate theory of chromatographic separation; Van-Deemter equation and its significance in evaluating column efficiency; Quantification of compounds using internal and external standard methods; Distillation and fractional distillation, paper and thin layer chromatography;Gas Chromatography: General principle, sample preparation/derivatization; Temperature programing and instrumental aspects including column; Stationary phases; Detectors and its applications. High Performance Liquid Chromatography: General principle; Instrumentation including column; Stationary phases; Detectors method development and applications; Electrophoresis: Theory and principle of CE; Mobility; Electro-osmotic flow separation by CE; Instrumentation; Modes of operation: Applications.

Practical

Solvent extraction and determination of caffeine or other high molecular weight compounds; Separation and purification of compounds using paper, TLC, Column, CG and HPLC; Extraction of essential oils using distillation and steam distillation, molecular and tripping crystallization of organic compounds, Spot test/TLC of arsons and explosive (i.e. picric acid, nitrobenzene and nitro-toluene); Calibration and validation of HPLC system as per requirements of British or US pharmacopoeia; Analysis of the binary mixture of pharmaceutical dosage by HPLC and statistical evaluation of data (RSD, CV, precision, accuracy, LOD, LOQ, resolution, Tailing factor).

Suggested Readings

1. Braitwaite, A. and F.J. Smith. 1999. Chromatographic Methods. 5th Ed. Kluwer Academic Publishers.

2. Camilleri, P. 1998. Capillary Electrophoresis: Theory and Practice. 2nd Ed. CRC Press, London, UK.
3. Christian, G.D. 2022. Analytical Chemistry. 7th Ed. John-Wiley & Sons, NY, USA.
4. Grob, R.L. and F.B. Eugene. 2004. Modern Practice of Gas Chromatography. 4th Ed. John-Wiley & Sons, USA.
5. Meyer, V.R. 2010. Practical High-Performance Liquid Chromatography. 5th Ed. John-Wiley & Sons, Ltd., USA.

23.	**CHEM-601 ADVANCED INORGANIC MATERIALS 3(3-0)** **Theory** Introduction to inorganic materials; Crystalline and amorphous states; Bonding in solids; Non-stoichiometric compounds; binary solid solutions; Mechanical, Electrical; Magnetic; Dielectric; Optical and chemical (corrosion) properties of advanced materials; Synthesis (e.g., sol-gel; Hydrothermal techniques; etc.) and design of inorganic materials and characterization; doping and purification of silicone; chemical vapour deposition and sputtering; introduction to nano materials. **Suggested Readings** 1. Cotton, F.A., G. Wilkinson, C.A. Murillo, and M. Bochmann. 1999. Advanced Inorganic Chemistry, 6th Ed. Wiley-Interscience. NY, USA. 2. Housecraft, C. and A.G. Sharpe. 2012. Inorganic Chemistry, 4th Ed. Prentice Hall. 3. Mendham, J., R.C. Denney, J.D. Barnes and M.J.K.Thomas. 2000. Vogel's Quantitative Chemical Analysis, 6th Ed., Prentice Hall, London, UK. 4. Müller, U. 2006. Inorganic Structural Chemistry, 2nd Ed. John-Wiley & Sons, NY, USA. 5. Rodgers G.E. 2012. Descriptive Inorganic, Coordination and Solid State Chemistry, 3rd Ed. Brooks Cole, London, UK.	**CHEM-601 INORGANIC MATERIALS 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain crystallography and catalysis 2. Describe bonding in solids and binary sloid solutions 3. Explain properties of advanced materials 4. Describe synthesis and designing of inorganic materials **Theory** Introduction to inorganic materials; Crystalline and amorphous states (crystallography); Molecular symmetry and group theory; Catalysis; Homogeneous and heterogeneous catalysis; Bonding in solids; Non-stoichiometric compounds; binary solid solutions; Mechanical, Electrical, Magnetic, Dielectric, Optical and chemical (corrosion) properties of advanced materials; Synthesis (e.g., sol-gel; Hydrothermal techniques; etc.) and design of inorganic materials and characterization; Doping and purification of silicone; Chemical vapour deposition and sputtering; Introduction to nano materials. **Suggested Readings** 1. Bhatti, H.N. 2020. Textbook of Inorganic Chemistry. The Caravan Book House, Lahore, Pakistan. 2. Cotton, F.A., G. Wilkinson, C.A. Murillo, and M. Bochmann. 1999. Advanced Inorganic Chemistry. 6th Ed. Wiley-Interscience. NY, USA. 3. Housecraft, C. and A.G. Sharpe. 2012. Inorganic Chemistry. 4th Ed. Prentice Hall. 4. Mendham, J., R.C. Denney, J.D. Barnes and M.J.K.Thomas. 2000. Quantitative Chemical Analysis. 6th Ed., Prentice Hall, London, UK. 5. Müller, U. 2006. Inorganic Structural Chemistry. 2nd Ed. John-Wiley & Sons, NY, USA. 6. Rodgers, G.E. 2012. Descriptive Inorganic, Coordination and Solid State Chemistry. 3rd Ed. Brooks Cole, London, UK.

24.	**CHEM-602 II- ACCEPTOR LIGANDS AND INORGANIC POLYMERS 3(3-0)** **Theory** π-Acceptor Ligands: Introduction to π-acceptor ligands; Effective atomic number (EAN) rule and chemistry of metal carbonyls; Nitrosyls and isocyanides; Structure elucidation based on spectroscopic evidences; Applications and uses of metal carbonyls and their derivatives for catalysis and organic synthesis. Inorganic Polymers: Introduction to homoatomic and heteroatomic inorganic polymers, chains and cages of boron; Silicon; Nitrogen; Phosphorous and sulphur; Synthesis and applications; Polyionicspecies; Isopoly and heteropoly; Anions of transition metals; Silicates; Borates; Condensed phosphates; Zeolites. **Suggested Readings** 1. Atkins, P. and L. Jones. 2010. Chemicals Principles: The Quest for Insight, 5th Ed. W.H. Freeman, NY, USA. 2. Bhatti, H.N. and R. Rehman. 2015. Advanced Inorganic Chemistry, The Caravan Book House, Lahore, Pakistan. 3. Billmeyer, F.W. 2003. A Text Book of Polymer Science. 3rd Ed. John-Wiley & Sons, NY, USA. 4. Brady, J. E. and F. Sense. 2009. Chemistry-The Study of Matter and Its Changes, 5th Ed. Wiley-Interscience, NY, USA. 5. Cotton, F. A., G. Wilkinson, C.A. Murillo, and M. Bochmann. 1999. Advanced Inorganic Chemistry, 6th Ed. Wiley-Interscience, NY, USA. 6. Crabtree, R.H. 2011. The Organometallic Chemistry of the Transition Metals, 5th Ed. John-Wiley and Sons, NY, USA.	**CHEM-602 CHEMISTRY OF INORGANIC POLYMERS 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain inorganic polymers under chain and cages of different elements 2. Explain the synthesis and applications of inorganic polymers 3. Explain preparation and properties of polymers 4. Describe metal coordination polymers **Theory** Introduction to homoatomic and heteroatomic inorganic polymers; Chains and cages of boron, carbon, silicon, nitrogen, phosphorous and sulphur; Synthesis and applications; Polyionic species; Isopoly and heteropoly; Anions of transition; Metals, silicates, borates, condensed phosphates, zeolites; Preparation and properties of polysiloxanes, polyphosphazenes, polythiazyl and transition-metal polymers; Metal coordination polymers; Metal catalyzed reactions of alkenes; Characterization of polymeric materials applications. **Suggested Readings** 1. Atkins, P. and L. Jones. 2010. Chemicals Principles: The Quest for Insight. 5thEd. W.H. Freeman, NY, USA. 2. Bhatti, H.N. and R. Rehman. 2021. Advanced Inorganic Chemistry. Volume-II. The Caravan Book House, Lahore, Pakistan. 3. Billmeyer, F.W. 2003. A Text Book of Polymer Science. 3rdEd. John-Wiley & Sons, NY, USA. 4. Brady, J.E. and F. Sense. 2009. Chemistry-The Study of Matter and Its Changes. 5thEd. Wiley-Interscience, NY, USA. 5. Cotton, F.A., G. Wilkinson, C.A. Murillo, and M. Bochmann. 1999. Advanced Inorganic Chemistry. 6thEd. Wiley-Interscience, NY, USA. 6. Walton,D. and P. Lorimer. 2001. Polymers. Oxford Chemistry Primers.

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CHEM-603 ELECTROANALYTICAL TECHNIQUES 3(3-0)

Theory

Potentiometry: Electrode potential, Nernst equation and its use for measuring half-cell potential; Different kinds of electrodes including glass and calomel electrodes; Working of potentiometer and its applications including pH measurements; Ion selective electrode systems; Ion exchange membrane electrode; Solid state membrane electrodes and bio-membrane electrodes; Potentiometric titrations.

Coulometry and Electrogravimetry: Basic electrochemistry; Principle; Instrumentation of coulometry; Principle; Instrumentation of electrogravimetry; Consequences of electrogravimetry; Ohmic drop; activation over potential; Concentration and gas polarization; Basic difference and merits/demerits of coulometry and electrogravimetry.

Voltammetry and Polarography: Basic principle; Voltammogram; Polarizable and non-polarizable electrodes; Solid electrodes; Their scope and limitations; Cyclic voltammetry; Anodic stripping voltammetry; Voltammetric equation; Basic concept of polarography and interpretation of various polarographic curves; Measurement of decomposition potential; Diffusion and limiting
currents; Derivation of Ilkovic equation; Logarithmic analysis of polarographic wave; Advantages and limitation of dropping mercury electrode.

Thermal Methods of Analysis: Thermogravimetric analysis (TGA); Differential thermal analysis (DTA); differential scanning colorimetry (DSC) and thermometric titration (TT); Principles; instrumental details and analytical applications; Automation in analytical methods; Automatic; automated and smart instruments and their applications with special emphasis on clinical; Industrial and quality control aspects.

Suggested Readings

1. Bhatti, H.N. 2017. Principles of Analytical Chemistry. The Carvan Book House, Lahore.
2. Christian, G.D. 2006. Analytical Chemistry, 6th Ed. John-Wiley & Sons, NY, USA.
3. Fritz, S. 2010. Electranalytical Methods: Guide to Experiments and Applications. 2nd Revised, Springer-Verlag Berlin, Germany.
4. Monk, P.M.S. 2001. Fundamentals of Electroanalytical Chemistry. John-Wiley & Sons Ltd, England.
5. Sharma, B.K. 2005. Instrumental Methods of Chemical Analysis, 24th Ed. Goel Publishing House, Meerut, India.
6. Skoog, D.A. and D.M. West. 2008. Fundamentals of Analytical Chemistry, 8th Ed. Hot Reinehart Inc., London, UK.

CHEM-603 KINETICS OF INORGANIC REACTION MECHANISMS 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Explain the inorganic reaction mechanism and their classifications
2. Describe the substitution reactions in octahedral and square planner complexes
3. Explain the electron transfer reaction mechanism
4. Describe specifically, the oxidative addition and reductive elimination in organometallic complexes

Theory

Kinetics and mechanism of inorganic reactions: Rate law; Stationary state approximation; Thermodynamic and kinetic stability; Inorganic reaction mechanism: Classification of reaction mechanisms; Rate laws; Steady state approximation; Inert and labile complexes; Substitution reactions in octahedral complexes and square planar complexes; Acid hydrolysis; Base hydrolysis; Steric effects of inert ligands; nucleophilic reactivity; Trans-effect, *cis*-effect; Racemization reactions; Mechanism of electron transfer reactions; Oxidation reduction reactions of metal ions; Outer and inner sphere mechanisms; Factors affecting rate of electron transfer reactions; Two electrons transfer reactions; Complementary or non-complementary electron transfer reactions; Oxidative addition; Addition of oxygen; Hydrogen, HX; Organic halides and bimetallic species; Reductive elimination reactions.

Suggested Readings

1. Bhatti, H.N. and R. Rehman. 2021. Advanced Inorganic Chemistry. Volume-II, The Caravan Book House, Lahore, Pakistan.
2. Huheey, J.E., E.A. Keiter and R.L. Keiter. 1997. Inorganic Chemistry: Principles of Structure and Reactivity. 4th Ed. Prentice Hall, UK.
3. Jolly, W. L. 1991. Modern Inorganic Chemistry. 2nd Ed. McGraw-Hill Company, USA.
4. Jordan, R.B. 1998. Reaction Mechanisms of Inorganic and Organomettalic Systems. 2nd Ed. Oxford University Press, NY, USA.
5. Sharma, S. K. 2007. Inorganic Reaction Mechanisms, Discovery Publishing House. 1st Ed. ND, India.

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CHEM-613 CHROMATOGRAPHIC TECHNIQUES 3(3-0)

Theory

Classifications of chromatographic techniques; Theoretical background of chromatography processes; resolution; Efficiency; Capacity factor; Selectivity factor; Plate theory and rate theory of chromatographic separation; Van-Deemter equation and its significance in evaluating column efficiency; Quantification of compounds using internal and external standard methods.

Gas Chromatography: General principle, sample preparation/derivatization; Temperature programing and instrumental aspects including column; Stationary phases; Detectors and its applications.

High Performance Liquid Chromatography: General principle; Sample preparation; Separation process (normal phase and reverse phase separation); Instrumentation including column; Stationary phases; Detectors method development and applications.

Capillary Electrophoresis: Theory and principle of CE; Mobility; Electro-osmotic flow separation by CE; Instrumentation; Modes of operation; Applications.

Suggested Readings

1. Braitwaite, A. and F.J. Smith. 1999. Chromatographic Methods. 5th Ed. Kluwer Academic Publishers.
2. Camilleri, P. 1998. Capillary Electrophoresis: Theory and Practice. 2nd Ed. CRC Press, London, UK.
3. Grob, R. L. and F.B. Eugene. 2004. Modern Practice of Gas Chromatography. 4th Ed. John-Wiley & Sons, USA.
4. Meyer, V.R. 2010. Practical High-Performance Liquid Chromatography. 5th Ed. John-Wiley & Sons, Ltd., USA.
5. Miller, J.M. 2005. Chromatography: Concepts and Contrasts. 2nd Ed. John-Wiley & Sons, Inc. NY, USA.
6. Skoog, D. A., P.M. West, F.J. Holler and S.R. Crouch. 2013. Fundamentals of Analytical Chemistry. 9th Ed. Cengage Learning.

CHEM-604 ELECTROANALYTICAL TECHNIQUES 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe principles of electroanalytical methods and their classification.
2. Explain spectroelectrochemistry (Uv-vis, IR, Raman) and sonoelectrochemistry.
3. Demonstrate electroanalysis using modern electrochemical methods.
4. Explain applications of ion selective electrodes.

Theory

Electroanalytical methods and their classification; Potentiometry; Ion Selective Electrodes; Electrolysis; Electrogravimetric analysis and its principles; Coulometry; Polarography and voltammetry; Cyclic voltammetry; Hydrodynamic electrodes and microelectrodes; Conductimetry and dielectrometry; Impedance method; Real and imaginary values of impedance, Nyquist diagram, equivalent circuit of electrochemical cell, electrochemical impedance spectrum (EIS), evaluation of EIS data, determination of heterogeneous rate constants; Electroanalysis using modern electrochemical methods: Quartz Crystal Microbalance QCM, Scanning Tunneling Microscopy STM, Atomic Force Microscopy - AFM), Spectroelectrochemistry (UV-vis, IR, Raman), Sonoelectrochemistry.

SuggestedReadings

1. Bard, A.J. and L.R. Faulkner. 2001. Electrochemical Methods: Fundamentals and applications. 2nd Ed. NY: John Wiley & Sons.
2. Bard, A.J., M. Stratman. 2001. Encyclopedia of Electrochemistry, Instrumentation and Electroanalytical Chemistry. Volume-3, Wiley-VCH.
3. Christian, G.D. 2022. Analytical Chemistry. 7th Ed. John-Wiley & Sons, NY, USA.
4. Latimer, Jr. and G.W. 2012. Official Methods of Analysis of AOAC International. 20thEd. NY, USA.
5. Ranganna, S. 1986. Handbook of Analysis and Quality Control for Fruits & Vegetables. 2ndEd. Tata McGraw-Hill Education, NY, USA.
6. Stuart, H.B. 2013. Forensic Analytical Techniques. 1stEd. John-Wiley & Sons, USA.

27.

CHEM-617 MEDICINAL AND NATURAL PRODUCTS CHEMISTRY 3(3-0)

Theory

Introduction; Classification; Isolation; Biosynthesis and general methods for the structure determination of alkaloids (Piperine, Nicotene, Cocaine, Morphine, Quinine); Steroids (cholesterol, VIt min D) and terpenoids (Triterpenes, α-amyrin, β-amyrin, Ursolic acid, Oleanolic acid); Medicinal Chemistry; Chemistry of biomolecules; Introduction to drugs and drug discovery; Sources of therapeutic agents; Structure activity relationship (SAR); Drug-receptor interaction; Drug formulation and its methods; Different types of drugs; Chemistry and modes of action of some common drugs

Suggested Readings

1. Sriram, D. and P. Vogeeswari. 2010. Medicinal Chemistry, 2nd Ed. BITS Pilani, Pearson, Publisher: Darling Kindernley, ND, India.
2. Finar, I. L. 2008. Organic Chemistry, Vol. 2, Stereochemistry and the Chemistry of Natural Products, 5th Ed., Pearson Education Ltd., ND, India.
3. Oyvind, M. A. and R.M. Kenneth. 2010. Flavonoids: Chemistry, Biochemistry and Applications, CRC, Taylor & Francis, NY, USA.
4. Paul, M.D. 2009. Medicinal Natural Products: A Biosynthetic Approach, 3rd Ed., Medicinal Natural Products, John-Wiley & Sons, Ltd., USA.
5. Sell, C.S. 2003. A Fragrant Introduction to Terpenoid Chemistry. The Royal Society of Chemistry, Cornwall, UK.

CHEM-605 BIOINORGANIC AND ATMOSPHERIC CHEMISTRY 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe different environmental layers.
2. Explain the fundamentals of environment.
3. Demonstrate the knowledge about the atmosphere.
4. Describe different pollution sources and factors.

Theory

Bioinorganic Chemistry: Development and background; Metals and Complexes; metals of biological importance; metallic-protein and enzymes in biological systems and processes; transport and carrier proteins; importance of metals, non-metals, and chelating agents in biological systems; redox properties of iron–ligand complexes; metal ions exhibiting outer sphere electron transfer; oxygen (o_2) storage and transport, hemoglobin, hemocyanin and hemerythrin; oxidation of ch_4, hydrocarbons, $nh_4^{+\cdot}$nitrogen cycle: **(**nitrate reduction, denitrification, and anammox); transport, transfer, and transcription; metal uptake pathways; ion channels for potassium, metal uptake by cells via ligands on membranes. chemistry of elements in medicines. inorganic compounds in environments: introduction; factors governing metal speciation in the environment and in organisms, transition metals essential for life. atmospheric chemistry; water treatment; bioaccumulation of heavy metals, organic matter in soil, macro- and micro-nutrients in soil, ion-exchange in soil, soil ph and nutrients availability.

Suggested Readings

1. Atkins, P. 2010. Inorganic Chemistry. 5thEd.Oxford University Press.
2. Cotton, F.A., G. Wilkinson, P.L.Gaus. 1995. Basic Inorganic Chemistry. 3rd Ed. Wiley.
3. Greenwood, N.N., and A. Earnshaw. 1997. Chemistry of the Elements. 2nd revised Ed. Royal Society of Chemistry.
4. Jones, J.C. 2001. d- and f-Block Chemistry. 1st Ed. Royal Society of Chemistry.
5. Pfennig, B.W. 2021. Principles of inorganic chemistry. John Wiley & Sons.
6. Sparks, D. 2003. Environmental Soil Chemistry. 2nd Ed. Academic Press.

28. **CHEM-619 NUCLEAR AND PHOTOCHEMISTRY 3(3-0)**

Theory

Nuclear Chemistry: Composition of the nucleus; Nuclear stability and energetics; Radioactivity; Kinetics of radioactivity decay; Half life and its determination; Radioactive equilibria; Nuclear reactions; Linear accelerators and cyclotron; Fission and fusion; Atomic and hydrogen bomb; Nuclear reactors; Radiation hazards and use of tracers in chemistry; Photochemistry: Laws; Quantum efficiency and its experimental determination; Excited state symbols; Kinetics of photochemical reactions; Fluorescence, Phosphorescence, Chemiluminescence and bioluminescence; Photosensitized reactions; Flash photolysis and LASER; Advanced approaches to kinetics of photochemical reactions, Absorption, vibronic coupling, relaxation phenomena, solvent effects. Electron and energy transfer, isomerisation and dissociation reactions, Excitons, polarons, solitons, Semiconductor junctions, Photocurrent and photovoltage, Photo-processes in organic, inorganic, and sensitized solar cells.

Suggested Readings

1. Atkins, P. and J. de Paula. 2011. Physical Chemistry. 9th Ed. Oxford University Press, New Delhi, India.
2. Ball, D.W. 2007. Physical Chemistry. Thomson Books, London, UK.
3. Bhatti, H.N. and Z.H. Farooqi. 2016, Modern Physical Chemistry. Caravan Book House, Lahore.
4. Castellan, G.W. 2004. Physical Chemistry. Narosa Publishing House, New Dehli, India.
5. Engel, T. and P. Reid. 2013. Thermodynamics, Statistical Thermodynamics and Kinetics. 3rd Ed. Pearson Publishing, NJ, USA.

CHEM-606 EXPERIMENTAL INORGANIC CHEMISTRY-II 2(0-2)

Learning Course Outcomes

By the end of this course students will be able to:

1. Explain the organic reagents, type, and nature.
2. Describe the applications of organic reagents
3. Explain the complexometric titrations
4. Explain the kinetics of inorganic chemical reactions

Theory

Organic Reagents used in Inorganic Analysis: Types of reagents, their specific nature, and methods of applications with specific examples; Complexometric titrations involving various reagents (EDTA etc.), chelates and chelate effect, role of organic reagents in different analytical techniques. Titrimetric and spectrophotometric determination of di and trivalent metal ions in complexes; Kinetics of inorganic chemical reactions such as reaction of iodine with persulphate ion; Determination of heat of neutralization of an acid with a base.

Suggested Readings

1. Daniel, C.H. and A.C. Lucy. 2020. Quantitative Analysis Chemistry. 10th Ed. Alby and Becon Inc. London.
2. Jaffar, M. 2006. Experimental Physical Chemistry. 8th Ed. University Grants Commission.
3. Levitt, B.P. 1972. Findlay's Practical Physical Chemistry. 9th Ed. Longman Group Limited.
4. Schoeller, W.R., A.R. Powell, Charles, Griffin. 2004. The analysis of minerals and ores of the rarer elements. Company Limited.
5. Shoemaker, D. 1989. Experiments in Physical Chemistry. 5th Ed. McGraw Hill Publishing Company Limited.

29.

CHEM-606 MOLECULAR REARRANGEMENT AND REACTIVE INTERMEDIATES **3(3-0)**

Theory

Molecular rearrangements: Classification of molecular rearrangements; Mechanism of intramolecular 1,2-shifts involving migration of a group from carbon to carbon; Carbon to nitrogen and carbon to oxygen; Mechanism and synthetic applications of Wagner-Meerwein; Pinacol-pinacolone; Benzidine, Benzyl, Benzylic acid; Favorski; Wolff, Beckmann, Hoffmann, Curtius, Lossen and Schmidt; Baeyer-Villiger; Dakin and Fries rearrangeme.

Free radical reactions: Free radicals, their generation through photolysis; Thermolysis; Redox reaction; Free radical reactions; Addition; Substitution; Rearrangements; Fragmentation; Dimerization, Autoxidation and antioxidants; Disproportionation; Free radical reactions in biological systems; Reactive intermediates; Introduction; Nomenclature; Generation and synthetic applications of carbocation; Carbanion; Carbenes; Nitrenes and arynes intermediates.

Suggested Readings

1. Bhatti, H.N. 2016. Advanced Organic Chemistry. The Caravan Book House, Lahore.
2. Francis, C.A. and R.G. Sundberg. 2007. Advanced Organic Chemistry. 5th Ed. Springer Science. Business media, NY, USA.
3. Kalsi, P.S. 2010. Organic Reaction and Their Mechanism. 3rd Ed. New Age International Publisher, ND, India.
4. March, J. 2013. Advanced Organic Chemistry: Reactions, Mechanisms, and Structure. 7th Ed. McGraw Hill Book Company, NY, USA.
5. Sehyan, E. 2004. Organic Chemistry: Structure and Reactivity. 5th Ed. Houghton Mifflin Company, NY, USA.
6. Solomon, T.W.G. 2014. Organic Chemistry. 11th Ed. John Wiley and Son's Inc., NY, USA.

CHEM-607 MOLECULAR REARRANGEMENT AND FREE RADICAL REACTIONS **3(3-0)**

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe various organic reactions.
2. Explain the fundamentals of rearrangement reactions.
3. Demonstrate the knowledge about the mechanism.
4. Describe different reactions and its mechanism.

Theory

Molecular rearrangements: Classification of molecular rearrangements; Mechanism of intramolecular 1,2-shifts involving migration of a group from carbon to carbon; Carbon to nitrogen and carbon to oxygen; Mechanism and synthetic applications of Wagner-Meerwein; Pinacol-pinacolone; Benzidine, Benzyl, Benzylic acid; Favorski; Wolff, Beckmann, Hoffmann, Curtius, Lossen and Schmidt; Baeyer-Villiger; Dakin and Fries rearrangement.Free radical reactions: Free radicals, their generation through photolysis; Thermolysis; Redox reaction; Free radical reactions; Addition; Substitution; Rearrangements; Fragmentation; Dimerization, autoxidation, and antioxidants; Disproportionation; Free radical reactions in biological systems.

Suggested Readings

1. Bhatti, H.N. 2021. Advanced Organic Chemistry. Volume-II. The Caravan Book House, Lahore.
2. Francis, C.A. and R.G. Sundberg. 2007. Advanced Organic Chemistry. 5thEd. Springer Science. Business media, NY, USA.
3. Kalsi, P.S. 2010. Organic Reaction and Their Mechanism. 3rd Ed. New Age International Publisher, ND, India.
4. March, J. 2013. Advanced Organic Chemistry: Reactions, Mechanisms, and Structure. 7th Ed. McGraw Hill Book Company, NY, USA.
5. Sehyan, E. 2004. Organic Chemistry: Structure and Reactivity. 5th Ed. Houghton Mifflin Company, NY, USA.
6. Solomon, T.W.G. 2014. Organic Chemistry. 11th Ed. John Wiley and Son's Inc., NY, USA.

30.	**CHEM-608 EXPERIMENTAL ORGANIC CHEMISTRY 2(0-2)** **Practical** Quantitative estimation of important functional groups in organic compounds (Amino, phenolic, carboxylic and ketonic groups); Single and Multistep synthesis of organic compounds involving principles of organic chemistry; Oxidation; Reduction; Acetylation; Benzoin condensation; Beckmann rearrangement; Benzilic acid rearrangement; Cannizarro's reaction, Soapnification; Condensation polymerization and diazotization. Experiments of both of qualitative and quantitative nature based on available spectroscopic techniques **Suggested Readings** 1. Furniss, B. S., A.J. Hannaford, P.W.G. Smith and A.R. Tatchell. 1989. Vogel's Textbook of Practical Organic Chemistry, 5th Ed. Longman, UK. 2. Mayo, D.W., R.M. Pike and D.C. Forbes. 2011. Microscale Organic Laboratory with Multistep and Multiscale Syntheses. 5th Ed. John-Wiley & Sons, Inc. USA. 3. Pavia, D.L., G.S. Kriz, G.M. Lampman and R.G. Engel. 2013. A Microscale Approach to Organic Laboratory Techniques. 5th Ed. Brooks/Cole Laboratory Series, Cengage Learning, UK. 4. Robert, T. M. and N.B. Robert. 1992. Organic Chemistry. 6th Ed. Prentice Hall, NY, USA. 5. Tse-Lok, H. 1995. Symmetry: A Basis for Synthesis Design. John-Willey & Sons, Inc., NY, USA.	**CHEM-608 EXPERIMENTAL ORGANIC CHEMISTRY-II 2(0-2)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe various functional groups. 2. Explain the fundamentals of organic compounds. 3. Demonstrate the knowledge about the mechanism. 4. Describe different reactions and its mechanism. **Practical** Quantitative estimation of important functional groups in organic compounds (Amino, phenolic, carboxylic and ketonic groups); Single and Multistep synthesis of organic compounds involving principles of organic chemistry; Oxidation; Reduction; Acetylation; Benzoin condensation; Beckmann rearrangement; Benzilic acid rearrangement; Cannizarro's reaction, Saponification; Condensation polymerization and diazotization. Experiments of both of qualitative and quantitative nature based on available spectroscopic techniques **Suggested Readings** 1. Furniss, B. S., A.J. Hannaford, P.W.G. Smith and A.R. Tatchell. 2022. Vogel's Textbook of Practical Organic Chemistry.6th Ed. Longman, UK. 2. Mayo, D.W., R.M. Pike and D.C. Forbes. 2011. Microscale Organic Laboratory with Multistep and Multiscale Syntheses. 5th Ed. John-Wiley & Sons, Inc. USA. 3. Pavia, D.L., G.S. Kriz, G.M. Lampman and R.G. Engel. 2013. A Microscale Approach to Organic Laboratory Techniques. 5th Ed. Brooks/Cole Laboratory Series, Cengage Learning, UK. 4. Robert, T. M. and N.B. Robert. 1992. Organic Chemistry. 6th Ed. Prentice Hall, NY, USA. 5. Tse-Lok, H. 1995. Symmetry: A Basis for Synthesis Design. John-Willey & Sons, Inc., NY, USA.

31.

CHEM-615 ORGANOMETALLIC COMPOUNDS 3(3-0)

Theory

Fundamentals of organometallic compounds; Types of bonding in organometallics; Single; Double and triple bonds to carbon (compound types, acyls, alkylidene complexes and alkylidyne complexes); Delocalized hydrocarbon systems (alkenes, olefins, allyl and butadienes); Alkyne complexes, Cyclic π-complexes (five and six membered rings); Homogeneous catalytic hydrogenation; Dimerization, Oligomerization; Polymerization; Hydroformylation of olefins; Catalytic polymerization of acetylenes; Insertion reactions and uses of organometallic compounds in organic synthesis; Chemistry of organic compounds containing sulfur; Phosphorus, Boron and silicon; Synthesis; Reactions and application.

Suggested Readings

1. Claydem, J., N. Greeves and S. Warren. 2012. Organic Chemistry. 2nd Ed. Oxford University Press, Oxford, UK.
2. Cotton, F.A., G. Wilkinson, C.A. Murillo and M. Bochmann. 1999. Advance inorganic Chemistry. 6th Ed. Wiley-Interscience, NY, USA.
3. Coxon, J. M. and R.O.C. Norman. 1993. Principles of Organic Synthesis. 3rd Ed. CRC Press, London, UK.
4. Crabtree, R. H. 2009. The Organometallic Chemistry of the Transition Metals, 5th Ed. John-Wiley & Sons, NY, USA.

CHEM-609 MATERIALS AND DRUG ANALYSIS 3(2-1)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe various sample and its classification.
2. Explain the fundamentals of food sampling.
3. Demonstrate the knowledge about the drug and polymer.
4. Describe different chemical techniques.

Theory

Collection and processing of soil, water, fertilizer, pesticides, food and drug samples; Functional foods, nutraceuticals, classification of nutraceuticals, analysis of nutraceuticals, Natural antioxidants, classification and analysis, analysis of pharmaceuticals: Classification of drugs; Tests for analysis of different pharmaceuticals, biofuels, essential oils and their quality assessment, method of analysis for physico-chemical characteristics of polymers; Composites and other functional materials.

Practical

Separation of sugars by thin layer chromatography, estimation of free fatty acids of oils and total phenols; quantification of essential oils from commercial flowers and herbage; estimation of lime and gypsum requirements of soil, estimation of carbonate and bicarbonate contents of water, determination of fat content in milk; Quantification of Proteins; Determination of cholesterol in food; Determination of organic acids in juices; Determination of analgesic by HPLC; Thermal methods of analysis for characterization of materials. Determination of biofuel properties such fatty acid composition, acid value, densities, saponification value, iodine values, cloud point, pour point and centane numbers.

Suggested Readings

1. Christian, G.D. 2022. Analytical Chemistry. 7th Ed. John-Wiley & Sons, NY, USA.
2. Fritz, S. 2010. Electroanalytical Methods: Guide to Experiments and Applications. 2nd Ed. Springer-Verlag Berlin, Germany.
3. Latimer, Jr. and G.W. 2012. Official Methods of Analysis of AOAC International. 20th Ed. NY, USA.
4. Ranganna, S. 1986. Handbook of Analysis and Quality Control for Fruits & Vegetables. 2nd Ed. Tata McGraw-Hill Education, NY, USA.
5. Stuart, H.B. 2013. Forensic Analytical Techniques.1st Ed. John-Wiley & Sons, USA.

32.

CHEM-620 ELECTROCHEMISTRY 3(3-0)

Theory

Introduction, Electrolytic conduction and its measurement; Specific; Equivalent and molar conductance; Determination of resistance; Cell content; Conductance ratio; Conduction of strong and weak electrolytes; Ionic motilities and their determination; Kohlrausch's law and its applications; Faraday's law (first and second) and their significance; Transport number; Hittort's rule; Determination of transference number by Hittort's method. Applications of conductance measurement; EMF of the chemical cells; Electrode potential and its measurement with reference to Weston standard; Glass electrode; Calomel electrode and quinhydrone electrode; Nernst equation; Thermodynamics of cells; Concentration of cells with liquid junction and without liquid junction; Idea of conductance of electrolytes; Debye-Huckel theory of strong electrolytes; Ionic strength; Activity and activity coefficients and their determination by emf method; Debye-Huckel limiting law; Redox reactions; Standard electrode potential; Calculation of cell emf; Nernst equation; Thermodynamics of redox reactions; Butler-Volmer equation; Latimer diagram; Frost diagram; Concentration cells; Fuel cells and hydrocarbon cells.

Suggested Readings

6. Atkins, P. and J. de Paula. 2011. Physical Chemistry. 9th Ed. Oxford University Press, ND, India.
7. Bhatti, H.N. and Z.H. Farooqi. 2016, Modern Physical Chemistry. Caravan Book House, Lahore.
8. Castellan, G.W. 2004. Physical Chemistry. Narosa Publishing House, ND, India.
9. Silbey, R.J., R.A. Alberty and M.G. Bawendi. 2011. Physical Chemistry. John Wiley & Sons, NY, USA.

CHEM-610 PERICYCLIC REACTIONS AND REACTIVE INTERMEDIATES 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe different pericyclic reactions.
2. Explain the fundamentals of pericyclic reactions.
3. Demonstrate the knowledge about the pericyclic reactions.
4. Describe different pericyclic reactions.

Theory

Pericyclic Reactions: Introduction to pericyclic reactions; Frontier orbital theory; Mechanisms of electrocyclic; Cycloaddition and sigmatropic reactions. Reactive intermediates; Introduction; Nomenclature; Generation and synthetic applications of carbocation; Carbanion; Carbenes; Nitrenes and arynes intermediates.

Suggested Readings

1. Ansari, F.L., R. Qureshi, and M.L. Qureshi. 1999. Electrocyclic Reactions: From Fundamentals to Research.Wiley-VCH, Germany.
2. Bhatti, H.N. 2021. Advanced Organic Chemistry. Volume-II. The Caravan Book House, Lahore.
3. Carey, F.A. and R.M. Giuliano. 2013. Organic Chemistry. 9th Ed. McGraw-Hill, Los Angeles, USA.
4. Clayden, J., N. Greeves and S. Warren. 2012. Organic Chemistry. 2nd Ed. Oxford University Press, Oxford, UK.
5. Smith, M.B. 2013. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7th Ed. John-Wiley & Sons, Inc. NY, USA.
6. Sykes, P. 2009. A Guide Book to Mechanism in Organic Chemistry. 6th Ed. Pearson Education, ND, India.

33.

CHEM-622 SPECIAL TOPICS IN PHYSICAL CHEMISTRY 3(3-0)

Theory

Statistical thermodynamics: Introduction; Probability concepts; The Canonical Ensemble, Microstates and Configurations; Stirling's approximation; Maxwell-Boltzmann's statistics for the systems of independent particles; Statistical treatment of entropy; Partition functions and its physical significance; Interpretation of thermodynamic functions in terms of translational; Vibrational; Rotational and electronic partition functions; Free energy and equilibrium constant; The Equipartition Theorem.

Nonlinear Optical materials: Introduction; Nonlinear material response; Nonlinear polarization; Quantum-mechanical treatment of material response; Nonresonant 1st, 2nd and 3rd order nonlinear processes and devices; Photonic crystals and waveguide devices. Shape Memory Alloys: Introduction; Shape memory effect; Phase transformation between Martensite and Austenite; Patterns of Crystalline Phase Transformation; Hysteresis; Mechanical and physical properties; Functional stability; Applications.

Suggested Readings

1. Atkins, P. and J. de Paula. 2011. Physical Chemistry. 9th Ed. Oxford University Press, ND, India.
2. Bhatti, H.N. and Z.H. Farooqi. 2016. Modern Physical Chemistry. Caravan Book House, Lahore, Pakistan.
3. Castellan, G.W. 2004. Physical Chemistry. Narosa Publishing House. ND, India.
4. Silbey, R.J., R.A. Alberty and M.G. Bawendi. 2011. Physical Chemistry. John Wiley & Sons, NY, USA.

CHEM-611 MEDICINAL AND NATURAL PRODUCTS CHEMISTRY 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe about different alkaloids.
2. Explain the fundamentals of drugs and alkaloids.
3. Demonstrate the knowledge about the drugs and alkaloids.
4. Describe different types of drugs and alkaloids and its application.

Theory

Introduction; Classification; Isolation; Biosynthesis and general methods for the structure determination of alkaloids (piperine, nicotene, cocaine, morphine, quinine); Steroids (cholesterol, VIt min D) and terpenoids (triterpenes, α-amyrin, β-amyrin, ursolic acid, oleanolic acid); Medicinal Chemistry; Chemistry of biomolecules; Introduction to drugs and drug discovery; Sources of therapeutic agents; Structure activity relationship (SAR); Drug-receptor interaction; Drug formulation and its methods; Different types of drugs; Chemistry and modes of action of some common drugs

Suggested Readings

1. Finar, I.L. 2008. Stereochemistry and the Chemistry of Natural Products.5th Ed. Pearson Education Ltd., ND, India.
2. Oyvind, M.A. and R.M. Kenneth. 2010. Flavonoids: Chemistry, Biochemistry and Applications. CRC, Taylor & Francis, NY, USA.
3. Paul, M.D. 2009. Medicinal Natural Products: A Biosynthetic Approach, 3rd Ed., Medicinal Natural Products, John-Wiley & Sons, Ltd., USA.
4. Sell, C.S. 2003. A Fragrant Introduction to Terpenoid Chemistry. The Royal Society of Chemistry, Cornwall, UK.
5. Sriram, D. and P. Vogeeswari. 2010. Medicinal Chemistry. 2nd Ed. BITS Pilani, Pearson, Publisher: Darling Kindernley, ND, India.

34.

CHEM-612 DESIGNING OF ORGANIC SYNTHESIS 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe different retro-synthetic approach.
2. Explain the fundamentals of synthetic compounds.
3. Demonstrate the knowledge about the synthetic compounds.
4. Describe different synthetic compounds and its applications.

Theory

Introduction to Retrosynthesis: Retro-synthetic approach to organic synthesis; Functional group inter-conversation and convergent synthesis; Synthesis approach; Alkenes, alkynes; Alkyl halide; Alcohol; Ether; Aromatic compounds; Carbonyl and nitrogen containing compounds; C-C, C-N and C-O bond formation, 1,2; 1,3; 1,4; 1,5; and 1,6-cyclizations; Functional group protection; Hydroxyl; Amino; Carbonyl; Carboxylic; Sulfanyl, C=C; Solid phase synthesis; Application of synthetic chemistry in various industries.

Suggested Readings

1. Clayden, J., N. Greeves and S. Warren. 2012. Organic Chemistry. 2nd Ed. Oxford University Press, NY, USA.
2. Fox, M.A. and J.K. Whitsell. 1997. Organic Chemistry. 3rd Ed. Jones & Bartlett, Publishers, Boston, UK.
3. Loudon, M. 2009. Organic Chemistry.5th Ed. Roberts Company Publishers, London, UK.
4. Norman, R.O.C. and J.M. Coxon. 1993. Principles of Organic Synthesis.3rd Ed. CRC Press, UK.
5. Smith, J.G. 2010. Organic Chemistry. 3rd Ed. McGraw-Hill, Los Angeles, USA.
6. Warren, S. and P. Wyatt. 2010. The Disconnection Approach. 2nd Ed. John-Wiley & Sons, Inc., NY, USA.

35.	**CHEM-611 QUANTUM CHEMISTRY AND SPECTROSCOPY 3(3-0)** **Theory** Quantum Chemistry: Postulates of quantum theory; Comparison of classical and quantum mechanics; Eigen functions and Eigen values; Probability density; Operators and their properties; Schrodinger's wave mechanical model and its applications to one and three dimensional systems; Separation of variables and derivation of quantum numbers; Quantum mechanical tunnelling; Mathematical treatment of rigid rotator and calculation of bond length. Harmonic oscillator and calculation of vibrational frequencies; Valence bond and molecular orbital theories; Rotational and Vibrational Spectroscopy: Spectral regions and classification of spectroscopy; Rotational energies of diatomic molecules; Population of rotational energy levels; Rotational spectra of rigid linear molecules and determination of bond lengths; The Stark effect; Vibrational spectroscopy: The harmonic and anharmonic oscillator models and their potential energy curves; Relative population of energy levels and intensities of transition; Types of vibrational modes; Fermi-resonance; Vibration of polyatomic molecules; Interpretation of IR spectra of simple molecules; Applications and sampling techniques; Electronic and Raman spectroscopy; Types of electronic transitions; Characteristic chromophoric group absorptions and applications; Energies of atomic orbitals with reference to H-atom spectrum; Angular momentum and fine structure of H-atom; Idea of Raman Scattering; Rayleigh scattering; Molecular polarizability; Rotational Raman spectra of linear molecules; Symmetric top and spherical top molecules vibrational spectra. **Suggested Readings** 1. Atkins, P. and J. de Paula. 2011. Physical Chemistry. 9th Ed. Oxford University Press, ND, India. 2. Banwell, C.N. 2011. Fundamentals of Molecular Spectroscopy. McGraw Hill Book Company, London, UK. 3. Barrow, G.M. 2005. Introduction to Molecular Spectroscopy. McGraw Hill Book Company, London, UK. 4. Bhatti, H.N. and Z.H. Farooqi. 2016, Modern Physical Chemistry. Caravan Book House, Lahore. 5. Silbey, R.J., R.A. Alberty and M.G. Bawendi. 2011. Physical Chemistry. John Wiley & Sons, NY, USA.	**CHEM-613 QUANTUM CHEMISTRY AND SPECTROSCOPY 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Describe the role of quantum chemistry in describing physical properties. 2. Present physical aspects of rotational and vibrational spectroscopy. 3. Explain the key concepts of Raman spectroscopy. **4.** Describe about the electronic transition in the molecules. **Theory** Quantum Chemistry: Postulates of quantum theory; Comparison of classical and quantum mechanics; Eigen functions and Eigen values; Probability density; Mathematical treatment of rigid rotator and calculation of bond length; Harmonic oscillator and calculation of vibrational frequencies; Valence bond and molecular orbital theories; Rotational and Vibrational Spectroscopy: Spectral regions and classification of spectroscopy; Rotational energies of diatomic molecules; Population of rotational energy levels; Rotational spectra of rigid linear molecules and determination of bond lengths; The Stark effect; Vibrational spectroscopy: The harmonic and anharmonic oscillator models and their potential energy curves; Relative population of energy levels and intensities of transition; Types of vibrational modes; Fermi-resonance; Vibration of polyatomic molecules; Interpretation of IR spectra of simple molecules; Applications and sampling techniques; Idea of Raman Scattering; Rayleigh scattering; Molecular polarizability; Rotational Raman spectra of linear molecules; Symmetric top and spherical top molecules vibrational spectra.Electronic spectroscopy; Types of electronic transitions; Characteristic chromophoric group absorptions and applications; Energies of atomic orbitals with reference to H-atom spectrum; Angular momentum and fine structure of H-atom; Brief introduction of electron spin resonance spectroscopy. **Suggested Readings** 1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11thEd. Oxford UniversityPress, Oxford, UK. 2. Banwell, C.N. 2011. Fundamentals of Molecular Spectroscopy. McGraw Hill Book Company, London, UK. 3. Barrow, G.M. 2005. Introduction to Molecular Spectroscopy. McGraw Hill Book Company, London, UK. 4. Bhatti, H.N. and Z.H. Farooqi. 2021. Modern Physical Chemistry.Volume-II. Caravan Book House, Lahore. Pakistan

		5. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G. A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

36.

CHEM-612 EXPERIMENTAL PHYSICAL CHEMISTRY 2(0-2)

Practical

Determination of solubility curves of ternary system; Determination of enthalpy of dissolution of copper sulphate and potassium nitrate; Determination of enthalpy change for the interaction between acetone and chloroform; Determination of Heat of neutralization; Heat of combustion and heat of solution of a bimolecualar reaction of sodium thiosulfate and ethylbromoacetate; A simple investigation of permeability and osmosis; Determination of partial molar quantities; Determination of free energy changes and equilibrium constant; Determination of dissociation constant by potentiometry; Study of the Freundlich and Langmuir adsorption isotherm of acetic acid-charcoal system; Determination of specific area and pore size distribution of a material by using BET-BJH method; Evaluation of thermal stability of a compound by using thermogravimetry; Determination of order of reaction by spectrophotometery; Study of reaction kinetics of a compound by spectrophotometery; Preparation and purification of lyophilic sols by using egg albumin and starch gum; Preparation and purification of lyophobic sol by using ferric hydroxide or aluminium hydroxide; Study of phase transition behavior of magnesium sulphate and copper sulphate; Determination of linear free energy relation from the electrochemical reduction of substituted benzene; Determination of formation constant of I_3(salicylate) complex; Thermodynamics of denaturation of bovine serum albumin.

Suggested Readings

5. Beran, J.A. 2014. Laboratory Manual for Principles of General Chemistry, 10th Ed. Wiley & Sons, NY, USA.
6. Bhatti, H.N. and Z.H. Farooqi. 2016. Experimental Physical Chemistry, Caravan Book House, Lahore.
7. Garland, C.W., J.W. Nibgler and D.P. Shoemaker. 2017. Experiments in Physical Chemistry, 8th Ed. McGraw-Hill Science, Los Angeles, USA.
8. Palmer, W.G. 2009. Experimental Physical Chemistry. Cambridge University, London, U.K.
9. Ting, T.C. 2015. Laboratory Manual Physical Chemistry, 4th Ed. Utar Publisher, Malaysia.

CHEM-614 NUCLEAR AND PHOTOCHEMISTRY 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe the principles and theoretical aspects of nuclear chemistry.
2. Explain nuclear radiations and nuclear reaction.
3. Explain various aspects of photochemistry.
4. Describe different phenomena associate with excited state.

Theory

Nuclear Chemistry: Composition of the nucleus; Nuclear stability and energetics; Radioactivity; Kinetics of radioactivity decay; Half-life and its determination; Radioactive equilibria; Nuclear reactions; Linear accelerators and cyclotron; Fission and fusion; Atomic and hydrogen bomb; Nuclear reactors; Radiation hazards and use of tracers in chemistry; Photochemistry: Absorption of light by molecules; Laws of photochemistry; Quantum efficiency and its experimental determination; Photo physical processes and Jablonski diagram; Quantitative aspects of fluorescence and phosphorescence; Kinetics of photochemical reactions; Chemiluminescence and bioluminescence; Photosensitized reactions; Flash photolysis and LASER; Advanced approaches to kinetics of photochemical reactions; Absorption; Vibronic coupling; Relaxation phenomena; Solvent effects; Electron and energy transfer, isomerization, and dissociation reactions; Excitons, polarons and solitons; Semiconductor junctions; Photocurrent and photovoltage; Photo-processes in organic, inorganic, and sensitized solar cells.

Suggested Readings

1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11th Ed. Oxford UniversityPress, Oxford, UK.
2. Bahl, A., B.S. Bahl and G.D. Tuli 2019. Essentials of Physical Chemistry. 28th Ed. S Chand & Company, ND, India.
3. Ball, D.W. and B Tomas. 2014. Physical Chemistry. 2nd Ed. Cengage Learning, Stamford, USA.
4. Bhatti, H.N. and Z.H. Farooqi. 2021. Modern Physical Chemistry.Volume-II. Caravan Book House, Lahore, Pakistan.
5. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G.A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

37.

CHEM-615 ELECTROCHEMISTRY 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe the principles of electrochemical techniques.
2. Describe the reactions at electrode surface.
3. Explain variety of electrochemical cells.
4. Demonstrate comprehensive knowledge about fuel cell.

Theory

Idea of conductance of electrolytes and its determination; Debye-Huckle equation for all types of solution and limiting law; Ionic strength; Strong electrolytes and Debye-Huckle theory; Activity and activity coefficients of electrolytic solution; Determination of activities; Nernst equation; Thermodynamics of cells Concentration of cells with liquid junction and without liquid junction; Derivation of E.M.F of electrode and electrolyte concentration cells with and without transference; The idea of over potential, Butler-Volmer equation; Latimer diagram; Frost diagram; Fuel cells: Classification of fuel cells, alkaline fuel cells, molten carbonate fuel cells, phosphoric acid fuel cells, solid oxide fuel cells, Proton exchange membrane fuel cells and hydrocarbon fuel cells; Cyclic voltammetry, corrosion and its prevention.

Suggested Readings

1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11th Ed. Oxford UniversityPress, Oxford, UK.
2. Bahl, A., B.S. Bahl and G.D. Tuli. 2019. Essentials of Physical Chemistry. 28th Ed. S Chand & Company, ND, India.
3. Ball, D.W. and B. Tomas. 2014. Physical Chemistry. 2nd Ed. Cengage Learning, Stamford, USA.
4. Bhatti, H.N. and Z.H. Farooqi. 2021. Modern Physical Chemistry.Volume-I. Caravan Book House, Lahore, Pakistan.
5. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G.A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

38.

CHEM-616 SPECIAL TOPICS IN PHYSICAL CHEMISTRY 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe the different topics in solution chemistry.
2. Explain the separation of solids from solutions.
3. Present the chemical equilibria and phase rule.
4. Describe fundamental understanding of nanomaterials.

Theory

Solution Chemistry: The thermodynamic properties of solution; The solution process; Conditions of equilibrium between phases; Theoretical basis of Raoults equation; Deviation from ideal behavior; Compound formation and association; Separation of solid solutions; Semi Permeable membranes, the cause of semi-permeability; Mechanism of osmotic pressure; Dilute solutions and the Gas Laws; The Bombardment theory: Objections to the Bombardment theory, review of the theories; Determination of the molecular weight by osmometry. Phase equilibrium: Distribution law and its applications; Homogenous and heterogeneous equilibria; The phase rule and its derivation, phase diagrams; Applications of Phase rule to one and two component systems; Vapor-liquid equilibrium of binary liquid mixtures; Vapor pressure -composition diagram of binary mixture and Lever rule; Nanomaterials: Introduction; Properties of nanomaterials; Synthesis, characterization, and applications of nanomaterials,

Suggested Readings

1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11th Ed. Oxford UniversityPress, Oxford, UK.
2. Bahl, A., B.S. Bahl and G.D. Tuli. 2019. Essentials of Physical Chemistry. 28th Ed. S Chand & Company, ND, India.
3. Ball, D.W. and B. Tomas. 2014. Physical Chemistry. 2nd Ed. Cengage Learning, Stamford, USA.
4. Bhatti, H.N. and Z.H. Farooqi. 2021. Modern Physical Chemistry.Volume-II. Caravan Book House, Lahore, Pakistan.
5. Silbey, R.J., R.A. Alberty, M.G. Bawendi and G.A. Papadantonakis. 2021. Physical Chemistry. 5th Ed. John Wiley & Sons, NY, USA.

39.

CHEM-617 EXPERIMENTAL PHYSICAL CHEMISTRY-II 2(0-2)

Learning Course Outcomes

By the end of this course students will be able to:

1. Demonstrate different instruments available in physical chemistry lab.
2. Determine different physical chemistry parameters of molecules/solutions.
3. Describe practical applications spectrophotometer, chemical kinetics/ thermodynamics.
4. Present the knowledge gained in previously studies courses.

Theory

Determination of molar mass of a polymer by viscosity method; Measurement of electronic and vibrational spectra of simple compounds and their interpretation; Evaluation of pKa value of an indicator by spectrophotometry; Determination of stoichiometry of a complex by jobs method; Determination of percentage composition of $KMnO_4$ and $K_2Cr_2O_7$ in given solution by spectrophotometry; Determination of partial molar volume of water-methanol mixture; Determine the distribution coefficient of iodine between CCl_4 and water; Determination of free energy changes and equilibrium constant; Sugar analysis and its inversion study by polarimetry; Kinetic study of saponification of an ester; Validity of langmuir adsorption isotherm with given adsorbate; Determination of eutectic point for binary system of organic components; Determination of heat of solution of a given substance by solubility method; Kinetics of autocatalytic reaction between permanganate and oxalate ions.

Suggested Readings

1. Beran, J.A. 2014. Laboratory Manual for Principles of General Chemistry. 10th Ed. Wiley & Sons, NY, USA.
2. Bhatti, H.N. and Z.H. Farooqi. 2020. Experimental Physical Chemistry. Caravan Book House, Lahore, Pakistan.
3. Garland, C.W., J.W. Nibgler and D.P. Shoemaker. 2017. Experiments in Physical Chemistry. 8th Ed. McGraw-Hill Science, Los Angeles, USA.
4. Palmer, W.G. 2009. Experimental Physical Chemistry. Cambridge University, London, U.K.

40.

CHEM-614 MATERIALS ANALYSIS 3(2-1)

Theory

Analysis of Food Products: Introduction to food analysis; Sampling of food; General methods of analysis; Analysis of milk, butter, wheat flour, meat, beverages, tea, coca, honey and soft drinks; Analysis of Pharmaceuticals: Classification of drugs; Tests for analysis of different pharmaceuticals; Introduction to US and British pharmacopeia; Method of analysis for physico-chemical characteristics of polymers; Composites and other functional materials.

Practical

Determination of fat content in milk; Quantification of Proteins; Determination of cholesterol in food; Quantification of reducing sugars and total sugars; Determination of organic acids in juices; Determination of analgesic by HPLC; Thermal methods of analysis for characterization of materials.

Suggested Readings

1. Christian, G. D. 2006. Analytical Chemistry, 6th Ed. John-Wiley & Sons, NY, USA.
2. Jackson, A. R. W. and J.M. Jackson. 2008. Forensic Science, 2nd Ed. Pearson Education, UK.
3. Harris, D. C. 2011. Quantitative Chemical Analysis, 8th Ed. W.H. Freeman and Company, NY, USA.
4. Stuart H. B. 2013. Forensic Analytical Techniques, 1st Ed. John-Wiley & Sons.
5. Watson, D.G. 2012. Pharmaceutical Analysis: A Textbook for Pharmacy Students and Pharmaceutical Chemists, Elsevier.

CHEM-618 EXPERIMENTAL ANALYTICAL CHEMISTRY 2(0-2)

Learning Course Outcomes

By the end of this course students will be able to:

1. Demonstrate absorption and emission spectroscopic techniques.
2. Demonstrate water analysis.
3. Demonstrate determination of analytes using volumetric and gravimetric analysis.
4. Present analysis of atmospheric samples and pesticide residues.

Theory

Determination of metals using absorption and emission spectroscopic techniques; Separation and purification of compounds using column chromatography; Separation of heavy metals by solvent extraction; Determination of nickel spectrophotometrically; Determination of phosphate content in soil/human urine samples and nitrate in drinking water; Determination of carbon dioxide in soft drinks; Determination of sulphate and phosphate by complexometric titrations using EDTA; Determination of chemical oxygen demand in industrial waste water; Determination of iron in pharmaceutical samples by redox titration; Determination of total acidity in citrus fruits; Assay of vinegar samples by conductometric titration; Analysis of analgesics by HPLC; Analysis of different fruit juices for vitamin C by HPLC/ HPTLC; Separation of a mixture of organic solvents by GC; Analysis of fatty acids in vegetable oils and fats by GC; Separation of natural and synthetic chemicals using thin layer chromatography; Analysis of drinking water; Estimation of water quality (pollution) parameters of different industrial discharges; Analysis of atmospheric samples; Analysis of pesticide residues.

SuggestedReadings

1. Christian, G.D. 2022. Analytical Chemistry. 7th Ed. John-Wiley & Sons, NY, USA.
2. Fritz, S. 2010. Electroanalytical Methods: Guide to Experiments and Applications. 2nd Revised, Springer-Verlag Berlin, Germany.
3. Latimer, Jr. and G.W. 2012. Official Methods of Analysis of AOAC International. 20th Ed. NY, USA.
4. Ranganna, S. 1986. Handbook of Analysis and Quality Control for Fruits & Vegetables. 2nd Ed. Tata McGraw-Hill Education, NY, USA.
5. Stuart, H.B. 2013. Forensic Analytical Techniques.1st Ed. John-Wiley & Sons, USA.

41.

CHEM-616 CONDENSATION AND PERICYCLIC REACTIONS 3(3-0)

Theory

Condensation Reactions: Aldol condensation; Crossed and retro-aldol condensation; Cannizaro's and cross Cannizaro's reactions; Acid and base catalyzed condensations; Conditions; Mechanism
and synthetic applications of the following reactions: Claisen, Claisen Schmidt; Knoevenagel; Perkin; Reformatsky and Stobbes condensations; Darzen's glycosidic ester synthesis; Mannich and Wittig Michealcondenation; Condensation of carbanions; Condensations involving acetylides and cyanides; Synthetic applications of condensation reactions.
Pericyclic Reactions: Introduction to pericyclic reactions; Frontier orbital theory; Mechanisms of electrocyclic; Cycloaddition and sigmatropic reactions

Suggested Readings

1. Ansari, F. L., R. Qureshi, and M.L. Qureshi. 1999. Electrocyclic Reactions:From Fundamentals to Research, Wiley-VCH, Germany.
2. Bhatti, H.N. 2016. Advanced Organic Chemistry. The Caravan Book House, Lahore.
3. Carey, F. A. and R.M. Giuliano. 2013. Organic Chemistry. 9th Ed. McGraw-Hill, Los Angeles, USA.
4. Clayden, J., N. Greeves and S. Warren. 2012. Organic Chemistry. 2nd Ed., Oxford University Press, Oxford, UK.
5. Smith, M. B. 2013. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7th Ed. John-Wiley & Sons, Inc. NY, USA.
6. Sykes, P. 2009. A Guide Book to Mechanism in Organic Chemistry. 6th Ed. Pearson Education, ND, India.

CHEM-619 THERMAL METHODS OF ANALYSIS 3(3-0)

Learning Course Outcomes

By the end of this course students will be able to:

1. Describe various thermal analysis.
2. Explain the fundamentals of thermal analysis.
3. Demonstrate the knowledge about the different thermal analysis.
4. Describe different chemical and spectroscopic techniques.

Theory

Thermal analysis: Introduction, characteristics of thermal analysis; Calorimetry: types of calorimeters, applications of calorimetry, cone calorimetry: Apparatus, applications of cone calorimetry; Differential scanning calorimetry (DSC): Elements of thermodynamics in DSC, DSC measurements, Types of DSC instruments, recently developed DSC techniques, Applications of DSC, Differential thermal analysis (DTA): apparatus and experimental factors, modern instruments, Applications of DTA, Thermogravimetric analysis: apparatus, measurements and analysis, designing and performing a TGA experiment, Thermomagnetometry: applications of thermomagnetometry, Thermomechanical analysis (TMA) and Thermodilatometry (TD): instrumental components, applications; Dynamic mechanical analysis and "Rheology", Applications of DMA, Dielectric analysis, experimental conditions and dielectric techniques, applications of Dielectric Analysis; Thermoptometry: The atomic force microscopy; Scanning thermal microscopy, thermomicroscopy measurements, thermophotometry, applications of thermoluminescence, laser flash analysis; Thermal desorption spectroscopy; Evolved gas analysis; Recent techniques in thermal analysis; Thermometric titration; Applications of various thermal techniques.

SuggestedReadings

1. Christian, G.D. 2022. Analytical Chemistry. 7th Ed. John-Wiley & Sons, NY, USA.
2. Fritz, S. 2010. Electroanalytical Methods: Guide to Experiments and Applications. 2ndEd. Springer-Verlag Berlin, Germany.
3. Latimer, Jr. and G.W. 2012. Official Methods of Analysis of AOAC International. 20th Ed. NY, USA.
4. Ranganna, S. 1986. Handbook of Analysis and Quality Control for Fruits & Vegetables. 2nd Ed. Tata McGraw-Hill Education, NY, USA.
5. Stuart, H.B. 2013. Forensic Analytical Techniques.1st Ed. John-Wiley & Sons, USA.

42.		**CHEM-620 RADIOANALYTICAL TECHNIQUES 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Demonstrate most recent radioanalytical techniques. 2. Explain applications of radioanalytical methods of analysis. 3. Describe the spectral and microscopic interpretations of analytes samples. 4. Explain the procedures for results interpretations. **Theory** Introduction to Radioactivity; Forms of radioactive decay; Types of particles emitted in radioactive decay; Interactions of radioactivity with matter; Basic radioactive decay law and calculation of simple decay; Units of radioactivity and radioactivity concentration; Natural chain decay relationships impacting presence and measurement of commonly-encountered, regulated natural and anthropogenic radionuclides; Examples of decay chains and radioactive equilibrium; Principles of radioanalytical chemistry, Properties of radionuclides, radiation decay modes, Radioanalytical chemistry principles, sample loss by radiocollodial behavior, sample preservation, dissolution of solids, fusion, carrier of tracer addition, isotope dilution technique, carrier addition, tracer addition, sample purification, counting source preparation, radiation detection principles and detectors, Quality assurance in radioanalytical chemistry. Measurement of Gross Alpha and Beta Radioactivity; Alpha spectrometry; Instrument theory and operation; Typical uses – strengths and limitations; Detector Calibration; Alpha Spectral Features; Background activity; Basic equations for determining radioactivity from count data Gamma Spectrometry; Typical uses – strengths and limitations; Instrument theory and operation; Spectral features; Detection efficiency (response); Background activity; Basic equations for determining radioactivity from count data. **Suggested Readings** 1. Friedlander, G., J.W., E.S. Kennedy,and M.J. Miller. 1981. Nuclear and Radiochemistry. 3rd Ed. Wiley, NY. 2. Harvey, B.G. 1969. Nuclear Physics and Chemistry. 2nd Ed. Prentice Hall Inc. 3. Naqvil, I.I. and M.A. Farrukh. 2010. Radiotracers in Chemical Applications: Radiochemistry. VDM Verlog. 4. Bryan, J.C. 2000. Introduction to Nuclear Science. 2nd Ed. CRC Press.

		5. Knoll, G.F. 2013. Radiation Detection and Measurement. 3rd Ed. Wiley, NY.
43.	**CHEM-621 TECHNICAL REPORT 3(0-3)**	**CHEM-621 TECHNICAL REPORT/INTERNSHIP 6(0-6)**

44.		**CHEM-622 SURFACE ANALYTICAL TECHNIQUES 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the concepts and techniques involved in the surface analysis. 2. Describe a sound physical understanding of the techniques used to determine chemical composition. 3. Describe principle and how to use of instruments and handling method of experimental data generated in surface analysis. 4. Explain sampling and analysis of samples for surface analysis. **Theory** X-Ray interaction with matter; Electron interaction with matter; Ion interaction with matter; X-Ray detection based surface analysis techniques; Fluorescence; Diffraction; Electron detection based surface analysis techniques; XPS – X-ray photoelectron spectroscopy; Principles (Auger electron energy; Spectra derivation); Instrumentation; Qualitative and quantitative analysis (core levels, chemical shifts, Auger parameter, valence levels, imaging); AES – Auger Electron Spectroscopy; Principles (photoelectric effect, calibration, charge effect); Instrumentation; Qualitative and quantitative analysis (qualitative analysis, depth profiling, SAM, chemical shifts); Ion detection based surface analysis techniques; SIMS – Secondary Ion Mass Spectrometry; Sputtering & ionization; Instrumentation (ion sources, mass analyzers, detectors); Dynamic SIMS – static SIMS (ToF-SIMS); Applications; ISS – Ion Scattering Spectroscopy and RBS – Rutherford Backscattering; Low energy ion diffusion – ISS; High energy ion diffusion – RBS; Instrumentation; Applications; Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM). Application in specific area of research. **Suggested readings** 1. Christian, G.D. 2022. Analytical Chemistry. 7th Ed. John-Wiley & Sons, NY, USA. 2. John, C.V., I. Gilmore. 2009.Surface Analysis: The Principal Techniques. Wiley, NY. 3. John, F.W, J. Wolstenholme. 2003.An Introduction to Surface Analysis by XPS and AES. Wiley, NY, USA. 4. John, C., Rivière,S.Myhra. 1998.Handbook of Surface and Interface Analysis: Methods for Problem-Solving. CRC Press, Boca Raton.

		5. Gernot,F., H.Bubert. 2011. Surface and Thin Film Analysis: A Compendium of Principles, Instrumentation, and Applications. Wiley-VCH, Berlin.

	EELECTIVE COURSES FOR OTHER DEPARTMENTS	
45.	**CHEM-301 INTRODUCTION TO ORGANIC CHEMISTRY 3(3-0)** **Theory** Basic concepts of organic chemistry: inductive effect, the concept of resonance, resonance effect, stereoisomerism, optical isomerism, geometrical isomerism. Functional groups: chemistry of functional groups, alkyl halides; preparation, structure and synthetic applications of Grignard reagent. Hydroxyl group and ether; classification, methods of preparation and chemical reactions of alcohols, phenols and ethers. Carboxylic acids and their derivatives; chemical properties of carboxylic acid, formation and hydrolysis of acid anhydrides, introduction to acid amides, acid halides and esters. Aldehydes and ketones; structure and reactivity of carbonyl group and methods of preparation. Organic nitrogen compounds; amines; their preparation, properties and reactivity. **Suggested Reading** 1. Chaudhary, G.R. 2009. A text book of organic chemistry. Azeem Publishers, Faisalabad. 2. Clayden, J., N. Greeves, S. Warren and P. Wothers. 2007. Organic chemistry. Oxford University Press, London. 3. Ibne Rasa, K.M., M.A. Rehman and A. Rehman. 2010. Organic chemistry. The Carvan Book House, Lahore. 4. Norman, R.O.C. and D.J. Waddington. 2008. Organic chemistry. Bell and Hyman, London.	**CHEM-301 BASIC ORGANIC CHEMISTRY 3(3-0)** **3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain organic chemistry 2. Describe classification of functional groups. 3. Demonstrate the synthetic applications of Grignard reagent 4. Explain reactivity of different functional groups **Theory** Basic concepts of organic chemistry: inductive effect, the concept of resonance, resonance effect, stereoisomerism, optical isomerism, geometrical isomerism. Functional groups: chemistry of functional groups, alkyl halides; preparation, structure and synthetic applications of Grignard reagent. Hydroxyl group and ether; classification, methods of preparation and chemical reactions of alcohols, phenols and ethers. Carboxylic acids and their derivatives; chemical properties of carboxylic acid, formation and hydrolysis of acid anhydrides, introduction to acid amides, acid halides and esters. Aldehydes and ketones; structure and reactivity of carbonyl group and methods of preparation. Organic nitrogen compounds; amines; their preparation, properties and reactivity. **Suggested Reading** 1. Bhatti, H.N. 2021. Textbook of Inorganic Chemistry. Caravan Book House, Lahore, Pakistan. 2. Clayden, J., N. Greeves, S. Warren and P. Wothers. 2007. Organic chemistry. Oxford University Press, London. 3. Finar, I. L. 2008. Organic Chemistry, Vol. 2, Stereochemistry and the Chemistry of Natural Products, 5th Ed., Pearson Education Ltd., ND, India. 4. Ibne Rasa, K.M., A. Rehman and H.N. Bhatti. 2020. A Textbook Organic Chemistry. Caravan Book House, Lahore. 5. Norman, R.O.C. and D.J. Waddington. 2008. Organic chemistry. Bell and Hyman, London. 6.

46.	**CHEM-302 ENVIRONMENTAL CHEMISTRY AND BIOCHEMISTRY 4(3-1)** **Theory** Concept and scope of environmental chemistry and biochemistry; Chemistry and intensity of environment contaminants and effects on biodiversity; Segments of the environment; Chemical and biochemical progress of the particulates, aerosols, ions, radicals, and gases contaminant generation; Physical, chemical and biochemical characteristics of urban and rural wastes; chemical, biochemical and biological significance and implications of recycling wastes; chemical and photochemical reactions of organic and inorganic pollutants in various spheres; Greenhouse effects on global warming and ozone layer depletion; biochemical effects of contaminants on soils, waters and plants; Interaction effects of water, soil and air pollutants on plant metabolic processes; Technologies for environment decontamination for safe food production, Planning environment pollution control and sustainable development. **Practical** Determination of BOD, COD and DO of waste water; Determination of heavy metals from soils and plants; Air sampling techniques. **Suggested Readings** 1. Crosby, D.G. 1998. Environmental Toxicology and Chemistry. Oxford University Press, New York. 2. Khan, T.I. 2001. Environmental Policies for sustainable Development. Pointer Publishers, Jaipur, India 3. Miller, G. T. 2004, Environmental Science. Thomsan Learning. Mexico. 4. Prakash, R. and S.M. Chaubey. 1990. Environmental Pollution and Health Hazards. Publications of Society of Biochemistry, India. 5. Tyagi, C.D. and M. Mehra. 1990. Environmental Pollution. Anmol Publishers, New Dehli.	**CHEM-302 ENVIRONMENTAL CHEMISTRY AND BIOCHEMISTRY 4(3-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the scope of environmental chemistry and biochemistry 2. Describe intensity of environment contaminants and effects on biodiversity 3. Explain the physical, chemical and biochemical characteristics of urban and rural wastes 4. Demonstrate the different theories of chemical bonding **Theory** Concept and scope of environmental chemistry and biochemistry; Chemistry and intensity of environment contaminants and effects on biodiversity; Segments of the environment; Chemical and biochemical progress of the particulates, aerosols, ions, radicals, and gases contaminant generation; Physical, chemical and biochemical characteristics of urban and rural wastes; chemical, biochemical and biological significance and implications of recycling wastes; chemical and photochemical reactions of organic and inorganic pollutants in various spheres; Greenhouse effects on global warming and ozone layer depletion; biochemical effects of contaminants on soils, waters and plants; Interaction effects of water, soil and air pollutants on plant metabolic processes; Technologies for environment decontamination for safe food production, Planning environment pollution control and sustainable development. **Practical** Determination of BOD, COD and DO of wastewater; Determination of heavy metals from soils and plants; Air sampling techniques. **Suggested Readings** 1. Crosby, D.G. 1998. Environmental Toxicology and Chemistry. Oxford University Press, New York. 2. Khan, T.I. 2001. Environmental Policies for sustainable Development. Pointer Publishers, Jaipur, India 3. Miller, G. T. 2004, Environmental Science. Thomsan Learning. Mexico. 4. Oyvind, M. A. and R.M. Kenneth. 2010. Flavonoids: Chemistry, Biochemistry and Applications, CRC, Taylor & Francis, NY, USA.

5. Prakash, R. and S.M. Chaubey. 1990. Environmental Pollution and Health Hazards. Publications of Society of Biochemistry, India.
6. Tyagi, C.D. and M. Mehra. 1990. Environmental Pollution. Anmol Publishers, New Dehli.

47.	**CHEM-303 INTRODUCTION TO ANALYTICAL CHEMISTRY 4(3-1)** **Theory** **Basics of Chemical Analysis:** Sampling, weighing, volume measurements. Precipitation, washing, filtration and ignition, errors and use of statistical analysis, volumetric analysis. **Separation Techniques:** Basic principle of solvent extraction and its applications in chemical analysis. General theory and principles of chromatography. Important types of chromatography including, paper, thin layer and column chromatography and their applications. **Spectroscopic Analysis:** Introduction of electromagnetic radiation and their interaction with matter. Principles of emission and absorption spectroscopy. Basic components of spectrophotometer. **Practical** Calibration of glassware used for volumetric analysis. Determination of sodium and potassium in tap water/food/plant samples by flame photometery. Identification of metals in soil and other agriculture samples by atomic absorption spectrophotometer. Separation of mixture of organic and inorganic compounds by chromatography methods. Identification of typical organic compounds by spectroscopic techniques. **Suggested Readings** 1. Chairstian, G.D. 2006. Analytical Chemistry. Sixth edition, John Wiley and Sons, New York. 2. Harris, B.C. and W.H. Harris. 1991. Quantitative Chemical Analysis. Freeman and Company, New York. 3. Rouessac, F. and A. Rouessac. 2007. Chemical Analysis: Modern Instrumentation Methods and Techniques. John Wiley & Sons, England. 4. Sharma, b.K. 2005. Instrumental Methods of Chemical Analysis, Goel Publishing House, Meerut, India. 5. Vogel, A.I. 2006. A Text Book of Qualitative Inorganic Analysis, Longmans Green and Co., London.	**CHEM-303 INTRODUCTION TO ANALYTICAL CHEMISTRY 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain basics of chemical analysis 2. Describe Separation Techniques 3. Demonstrate the spectroscopic analysis **4.** Demonstrate Separation, Identification of compounds by chromatography methods **Theory** Sampling, weighing, volume measurements. Precipitation, washing, filtration and ignition, errors and use of statistical analysis, volumetric analysis: Basic principle of solvent extraction and its applications in chemical analysis. General theory and principles of chromatography. Important types of chromatography including paper, thin layer and column chromatography and their applications**:** Introduction of electromagnetic radiation and their interaction with matter. Principles of emission and absorption spectroscopy. Basic components of spectrophotometer. **Practical** Calibration of glassware used for volumetric analysis. Determination of sodium and potassium in tap water/food/plant samples by flame photometry. Identification of metals in soil and other agriculture samples by atomic absorption spectrophotometer. Separation of mixture of organic and inorganic compounds by chromatography methods. Identification of typical organic compounds by spectroscopic techniques. **Suggested Readings** 1. Bhatti, H.N. 2020. Textbook of Inorganic Chemistry. The Caravan Book House, Lahore, Pakistan. 2. Chairstian, G.D. 2006. Analytical Chemistry. Sixth edition, John Wiley and Sons, New York. 3. Harris, B.C. and W.H. Harris. 1991. Quantitative Chemical Analysis. Freeman and Company, New York.

4. Rouessac, F. and A. Rouessac. 2007. Chemical Analysis: Modern Instrumentation Methods and Techniques. John Wiley & Sons, England.
5. Sharma, b.K. 2005. Instrumental Methods of Chemical Analysis, Goel Publishing House, Meerut, India.
6. Vogel, A.I. 2006. A Text Book of Qualitative Inorganic Analysis, Longmans Green and Co., London.

48.	**CHEM-304 INTRODUCTION TO ORGANIC CHEMISTRY 3(3-0)** **Basic Concepts of Organic Chemistry:** Inductive effect, The concept of resonance, Resonance effect, Stereoisomerism, Optical isomerism, Geometrical isomerism. **Functional Groups:** Chemistry of functional groups, **Alkyl Halides**; preparation, structure and synthetic applications of Grignard Reagent. **Hydroxyl Group and Ether,** classification, methods of preparation and chemical reactions of alcohols, phenols and ethers. **Carboxylic Acids and Their Derivatives**; chemical properties of carboxylic acid, formation and hydrolysis of acid anhydrides, introduction to acid amides, acid halides and esters. **Aldehydes and Ketones**; structure and reactivity of carbonyl group and methods of preparation. **Organic Nitrogen Compounds:** Amines; their preparation, properties and reactivity. **Suggested Readings** 1. Chaudhary, G.R. 2009. A Text Book of Organic Chemistry. Azeem Publishers, Faisalabad. 2. Clayden, J., N. Greeves, S. Warren and P. Wothers. 2007. Organic Chemistry. Oxford University Press, London. 3. Ibne Rasa, K.M., A. Rehman and H.N. Bhatti. 2015. A Textbook of Organic Chemistry. The Carvan Book House, Lahore. 4. Norman, R.O.C. and D.J. Waddington. 2008. Organic Chemistry. Bell and Hyman. London.	**CHEM-304 INTRODUCTION TO ORGANIC CHEMISTRY 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain basic concepts of organic chemistry 2. Describe physical properties of different functional groups 3. Describe chemical properties of different functional groups 4. Demonstrate organic nitrogen compounds Basic Concepts of Organic Chemistry: Inductive effect, The concept of resonance, Resonance effect, Stereoisomerism, Optical isomerism, Geometrical isomerism. Functional Groups: Chemistry of functional groups, Alkyl Halides; preparation, structure and synthetic applications of Grignard Reagent. Hydroxyl Group and Ether**,** classification, methods of preparation and chemical reactions of alcohols, phenols and ethers. Carboxylic Acids and Their Derivatives; chemical properties of carboxylic acid, formation and hydrolysis of acid anhydrides, introduction to acid amides, acid halides and esters. Aldehydes and Ketones; structure and reactivity of carbonyl group and methods of preparation. Organic Nitrogen Compounds**:** Amines; their preparation, properties and reactivity. **Suggested Readings** 1. Clayden, J., N. Greeves, S. Warren and P. Wothers. 2007. Organic Chemistry. Oxford University Press, London. 2. Ibne Rasa, K.M., A. Rehman and H.N. Bhatti. 2020. A Textbook of Organic Chemistry. Caravan Book House, Lahore. 3. Norman, R.O.C. and D.J. Waddington. 2008. Organic Chemistry. Bell and Hyman. London. 4. Smith, J. G. 2010. Organic Chemistry. 3rd Ed. McGraw-Hill, Los Angeles, USA. 5. Warren, S. and P. Wyatt. 2010. The Disconnection Approach, 2nd Ed. John-Wiley & Sons, Inc., NY, USA.

49.	**CHEM-306 BASIC CHEMISTRY 3(3-0)** Periodic table, Nature of chemical bonding, State of matter, Properties of solutions; properties of liquid vapour pressure, Surface tension, viscosity, Optical activity, Refractometry, Liquid properties of water as solvent, Structure and interaction, Chemical reactivity, Acids, Bases, Oxidation-reduction reactions, Chemical kinetics, first, second, and third order reactions, Influence of temperature on reaction rates, Polymers and colloids, Introduction to organic chemistry, Organic chemicals and polymers. **Suggested Readings** 1. Bhatti, H.N. 2014.Modern inorganic chemistry. Carawan book house, Lahore. 2. Bhatti, H.N. 2014. Principles of physical chemistry. Carawan book house, Lahore. 3. Brown. 2006. Chemistry the central Science Pearson Printing Hall. 4. Christopher, J. C., 2004. Computational Chemistry Theories and Models. John Willey & Sons. 5. Raymond C. 2005. Chemistry. 8th Ed. McGraw Hill.	**CHEM-306 BASIC CHEMISTRY 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the periodicity of periodic table 2. Describe the Properties of solutions 3. Demonstrate the different theories chemical kinetics and Acid base **4.** Explain the physical and chemical properties of organic compounds **Theory** Periodic table, Nature of chemical bonding, State of matter, Properties of solutions; properties of liquid vapour pressure, Surface tension, viscosity, Optical activity, Refractometry, Liquid properties of water as solvent, Structure and interaction, Chemical reactivity, Acids, Bases, Oxidation-reduction reactions, Chemical kinetics, first, second, and third order reactions, Influence of temperature on reaction rates, Polymers and colloids, Introduction to organic chemistry, Organic chemicals and polymers. **Suggested Readings** 1. Bhatti, H.N. 2021. A Textbook of Inorganic Chemistry. Carawan Book House, Lahore. 2. Bhatti, H.N. 2020. A Textbook of Physical Chemistry. Carawan book house, Lahore. 3. Brown. 2006. Chemistry the central Science Pearson Printing Hall. 4. Christopher, J. C., 2004. Computational Chemistry Theories and Models. John Willey & Sons. **5.** Kathleen A. H. and E.H. James. 2010. Descriptive Inorganic Chemistry. 2nd Ed. Brooks Cole, UK.Raymond C. 2005. Chemistry. 8th Ed. McGraw Hill

50.	**CHEM-307 ORGANIC CHEMISTRY 3(2-1)** **Theory** Introduction to organic chemistry, organic energy systems and their environmental impacts, renewable and non-renewable energy sources. Biofuels (biodiesel, bioethanol, biomethanol): Introduction, synthesis and physiochemical characteristics. Fossil fuels; Introduction, historical background, mining of petroleum, fractional distillation, detailed chemistry and characteristics (octane number, cracking etc.) of petrol, Diesel, Gasoline, Kerosine oil, Terpene Oil and Furnace oil; Liquid Petroleum Gas, Compressed Natural Gas, their chemistry and characteristics, Organic Fuel cells; Introduction, Classification, reactions and Configurations **Practical** Trans-esterification of vegetable oil Separation of organic compounds by distillation Synthesis of bioethanol Determination of calorific value of fuel Estimation of sulphur contents of fuel Assessment of flash point of fuel Measurement of Density of fuel Measurement of viscosity of fuel Other practical related to the topic covered in theoretical part and fields Visits. **Suggested Readings** 1. Dara, S. S. Text Book of Engineering Chemistry. S. Chand Publication. New Delhi, India. 2. Dash, D.C. 2011 Analytical Chemistry. PHI Learning Pvt Limited. New Dehli, India. 3. Harris, D.C. 2010. Quantitative Chemical Analysis. Freeman and Company. New York. 4. Kent, A.J. 2012. Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology. 12th ed. Springer. New York Heidelberg Drodrecht London 5. Rieger, P.H. 2010. Electrochemistry. Second Edition, Springer. UK.	**CHEM-307 ORGANIC CHEMISTRY 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the introduction of organic chemistry 2. Describe renewable and non-renewable energy sources 3. Demonstrate the chemistry of biofuels **4.** Demonstrate mining of petroleum, fractional distillation **Theory** Introduction to organic chemistry, organic energy systems and their environmental impacts, renewable and non-renewable energy sources. Biofuels (biodiesel, bioethanol, biomethanol): Introduction, synthesis and physiochemical characteristics. Fossil fuels; Introduction, historical background, mining of petroleum, fractional distillation, detailed chemistry and characteristics (octane number, cracking etc.) of petrol, Diesel, Gasoline, Kerosine oil, Terpene Oil and Furnace oil; Liquid Petroleum Gas, Compressed Natural Gas, their chemistry and characteristics, Organic Fuel cells; Introduction, Classification, reactions and Configurations **Practical** Trans-esterification of vegetable oil, Separation of organic compounds by distillation, Synthesis of bioethanol, Determination of calorific value of fuel, Estimation of sulphur contents of fuel, Assessment of flash point of fuel, Measurement of Density of fuel, Measurement of viscosity of fuel, Other practical related to the topic covered in theoretical part and fields Visits. **Suggested Readings** • Dara, S. S. Text Book of Engineering Chemistry. S. Chand Publication. New Delhi, India. • Dash, D.C. 2011 Analytical Chemistry. PHI Learning Pvt Limited. New Dehli, India. • Harris, D.C. 2010. Quantitative Chemical Analysis. Freeman and Company. New York. • Kent, A.J. 2012. Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology. 12th ed. Springer. New York Heidelberg Drodrecht London • Ranganna, S. 1986. Handbook of Analysis and Quality Control for Fruits & Vegetables. 2nd Ed. Tata McGraw-Hill Education, NY, USA. • Rieger, P.H. 2010. Electrochemistry. Second Edition, Springer. UK.

51.	**CHEM-401 INDUSTRIAL CHEMISTRY 3(2-1)** **Theory** Impurities in natural water, hardwater, water softening, boiler scales and deposits, industrial, irrigation and municipal water, metallic corrosion and its inhibition, paints and varnishes, fats and oils, extraction, refining and hydro- genation of oils, sugar industry and its by-products, nitrogenous, phosphatic and potassic fertilizers. Aerobic & non aerobic fermentation. **Practical** 1. Determination of carbonates and bicarbonates in industrial water 2. Determination of chlorides and sulphates in industrial water 3. Determination of pH and TSS in water 4. Estimation of nitrogen, phosphorus and potassium in fertilizers 5. Analysis of an oil for acid, saponification and iodine value. **Suggested Readings** 1. Agarwal, O.P., A. Agarwal, 2001. Engineering Chemistry. Khana Publishers, India. 2. Kent, A.J. 1997. Riegel's Hand Book of Industrial Chemistry. CBS Publisher New Delhi, India. 3. Shreve, R.H. 1987. The Chemical Process Industries. McGraw Hill Book Co., New York.	**CHEM-401 INTRODUCTORY INDUSTRIAL CHEMISTRY 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the introduction to industrial chemistry 2. Demonstrate water softening techniques 3. Demonstrate industrial water purification techniques **4.** Demonstrate estimation of fertilizer contents **Theory** Impurities in natural water, hardwater, water softening, boiler scales and deposits, industrial, irrigation and municipal water, metallic corrosion and its inhibition, paints and varnishes, fats and oils, extraction, refining and hydrogenation of oils, sugar industry and its by-products, nitrogenous, phosphatic and potassic fertilizers. Aerobic & non aerobic fermentation. **Practical** Determination of carbonates and bicarbonates in industrial water, Determination of chlorides and sulphates in industrial water, Determination of pH and TSS in water, Estimation of nitrogen, phosphorus and potassium in fertilizers, Analysis of an oil for acid, saponification and iodine value. **Suggested Readings** 1. Austin,G.T.2005.Shreve's Chemical Process Industry.6th Ed. McGraw Hill Book Company, NY,USA. 2. Bhatti, H.N and M. Salman. 2021. Applied Chemistry. Caravan Book House Lahore, Pakistan. 3. Kent, A.J. 1997. Riegel's Hand Book of Industrial Chemistry. CBS Publisher New Delhi, India.

52.	**CHEM-403 ENVIRONMENTAL CHEMISTERY 3(2-1)** **Theory** Introduction to environmental chemistry, Acids and bases. pH diagrams, pH buffer, Types of chemical reactions, Carbonate chemistry. Carbonate system. Hardness and removal of hardness. Precipitation and dissolution, Solubility product, factors affecting solubility, Effect of temperature on chemical reactions, Ion association and dissociation reactions, Redox reactions, Greenhouse gases, Transfer and fate of pollutants in soil, air and water. Soil chemistry and environmental contaminants. Pesticides and herbicides. PCBs. PAHs and dioxins, heavy metals and other chemical pollutants. Primary and secondary pollutants. Applications of chemistry in resolving environmental problems. **Practical** Principles of titration, filtration, distillation, paper chromatography, spectroscopy, atomic absorption, determination of pH, DO. Eh. EC, Water hardness, Turbidity, BOD and COD. **Suggested Readings** 1. Brimble combe, P, Jickells T.D, Liss, P. S. 2006. An Introduction to Environmental Chemistry. 2. Clair N. Sawyer, Perry L, McCarly & Geve F Partern. 2006. Chemistry for Environmental Engineering. McGraw-Hill, Inc. 3. Harrison R M, De Mora S J. 2008. Introductory Chemistry for the Environmental Sciences, Cambridge Environmental Series No. 17, Macmillan Press Ltd. 4. Stumm, W. and. Morgan, J. 2002. Aquatic Chemistry, Chemical Equilibria and Rates in Natural Waters, John Wiley and Sons, Inc, ISBN 0-471-51185-4.	**CHEM-403 ENVIRONMENTAL CHEMISTERY 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the fundamentals of environment. 2. Describe the knowledge about the atmosphere. 3. Present different pollution sources and factors. 4. Demonstrate effect of carbonate chemistry **Theory** Introduction to environmental chemistry, Acids and bases. pH diagrams, pH buffer, Types of chemical reactions, Carbonate chemistry. Carbonate system. Hardness and removal of hardness. Precipitation and dissolution, Solubility product, factors affecting solubility, Effect of temperature on chemical reactions, Ion association and dissociation reactions, Redox reactions, Greenhouse gases, Transfer and fate of pollutants in soil, air and water. Soil chemistry and environmental contaminants. Pesticides and herbicides. PCBs. PAHs and dioxins, heavy metals and other chemical pollutants. Primary and secondary pollutants. Applications of chemistry in resolving environmental problems. **Practical** Principles of titration, filtration, distillation, paper chromatography, spectroscopy, atomic absorption, determination of pH, DO. Eh. EC, Water hardness, Turbidity, BOD and COD. **Suggested Readings** 1. Bhatti, H.N. and S. Noreen. 2021. Principles of Environmental Chemistry. Caravan Book House, Lahore, Pakistan. 2. Dara, S.S. 2009. A Text Book of Environmental Chemistry and Pollution Control. S. Chand Group, ND, India. 3. Manahan, S.E. 2009. Fundamentals of Environmental Chemistry. 9th Ed. CRC Press LLC, Taylor and Francis, NY, USA. 4. Matalack, A. 2010.Introduction to Green Chemistry. CRC press, Taylor & Francis Group, NY, USA. 5. Richard, W. and M.A. Holloway. 2010. Atmospheric Chemistry. Springerlink, London, UK.

53.	**CHEM-405 PHOTOACTIVE MATERIALS AND THEIR CHARACTERIZATION** **3(2-1)** **Theory** Introduction to Solid State Physics and Chemistry, Fabrication of nanostructure materials using semi conductor oxides, sulphides etc. Principles for measuring the band gap of semi conductors materials. Strategies to manufacture different morphologies of photoactive materials. Characterization of photoactive materials using spectroscopy, microscopy (SEM, TEM) and X-ray diffraction. Measurement of current voltage characteristics of the solar cells. Basics of Crystallography. Basic principles of electrochemistry, Role of electrolytes in the formation of the photovoltaic cells. Types of electrolytes and their limitations. Photo electrochemical cell. Electrodes and their selection. Dark current and light current. Concept of recombination of charges. Forward and reverse biasing. **Practical** Photometric measurement, preparation of their films of photoactive materials, measurement of conductance, surface area demonstration, light intensity measurement. **Suggested Readings** 1. Christopher M.A.B. and A. Maria Brett. 1992. Electrochemistry Principles, Methods, and Application. Publisher Oxford University Press. 2. John McHardy and F. Ludwig. 1992. Electrochemistry of Semiconductor and Electronics Publisher Noyes Publications, USA. 3. Kurla, S.P. 2013. Essentials of solid state physics. Publisher New Central Book Agency (P) Ltd. London. 4. Nelson, J. 2003. The Physics of Solar Cells. Imperial College Press, UK. 5. Wong, J. 2006. Analytical electrochemistry (3rd ed.). Publishers John Willey & Sons, USA.	**CHEM-405 PHOTOACTIVE MATERIALS AND THEIR CHARACTERIZATION 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the fundamentals of nanomaterial 2. Describe the knowledge fabrication and characterization of nanomaterials 3. Explain morphology of photoactive material **4.** Demonstrate Basic principles of electrochemistry **Theory** Introduction to Solid State Physics and Chemistry, Fabrication of nanostructure materials using semiconductor oxides, sulphides etc. Principles for measuring the band gap of semiconductors materials. Strategies to manufacture different morphologies of photoactive materials. Characterization of photoactive materials using spectroscopy, microscopy (SEM, TEM) and X-ray diffraction. Measurement of current voltage characteristics of the solar cells. Basics of Crystallography. Basic principles of electrochemistry, Role of electrolytes in the formation of the photovoltaic cells. Types of electrolytes and their limitations. Photo electrochemical cell. Electrodes and their selection. Dark current and light current. Concept of recombination of charges. Forward and reverse biasing. **Practical** Photometric measurement, preparation of their films of photoactive materials, measurement of conductance, surface area demonstration, light intensity measurement. **Suggested Readings** 1. Christopher M.A.B. and A. Maria Brett. 2005. Electrochemistry Principles, Methods, and Application. Publisher Oxford University Press. 2. John McHardy and F. Ludwig. 1992. Electrochemistry of Semiconductor and Electronics Publisher Noyes Publications, USA. 3. Kurla, S.P. 2013. Essentials of Solid-State Physics. Publisher New Central Book Agency (P) Ltd. London.

4. Nelson, J. 2003. The Physics of Solar Cells. Imperial College Press, UK.
5. Wong, J. 2006. Analytical electrochemistry (3rd ed.). Publishers John Willey & Sons, USA.

54.

CHEM-406 INDUSTRIAL CHEMISTRY 2(1-1)

Learning Course Outcomes

By the end of this course students will be able to:

1. Explain the industrial process involve in sugar and fertilizers industries
2. Describe the method of water treatments
3. Demonstrate classification and synthesis of Polymer
4. Explain Classification, natural fertilizers

Theory

Sugar Industry: Introduction to carbohydrates, Processes involved in sugar industry. Fertilizers: Classification, natural fertilizers, synthetic fertilizers: processes involved in the manufacture of nitrogen, phosphate fertilizers. Polymer and adhesives; introduction, classification synthesis and Application Water Softening and Scale Removing: Water hardness; its measurement and removal; methods used for water Types of boiler scales; Chemical and mechanical methods to eliminate the scaling.

Practical

Practicals will be arranged according to theory contents

Suggested Readings

4. Austin,G.T.2005.Shreve'sChemicalProcessIndustry.6thEd.McGrawHillBookCompany, NY,USA.
5. Bhatti, H.N and M. Salman. 2021. Applied Chemistry. Caravan Book House Lahore, Pakistan.
6. Kent, A.J. 1997. Riegel's Hand Book of Industrial Chemistry. CBS Publisher New Delhi, India.

55.	**CHEM-501 PHYSCICAL CHEMISTRY 3(2-1)** **Theory** **Chemical Thermodynamics:** Basic concept thermodynamics. First and second laws of thermodynamics. Various state functions. Relationship between free energy and equilibria constant. **Chemical Kinetics:** Order and molecularity. Kinetics of zero, first and second order reactions. Activation energy and its determination. **Solution Chemistry:** Type of solution and concept of concentration such as ppm and ppb. The ideal and non ideal solution. Theory of ionization. Hydrolysis of acids, bases and salts. pH and buffers. **Surface Phenomena and Colloids:** Physical adsorption and chemisorption. Type of adsorption, isotherm, applications of adsorption. Colloids, preparation, properties and uses. **Practical** Preparation of buffer and determination of pH values. Determination of specific and molar conductance of the given samples of water. Measurement of refractive index and viscosity of a given liquid. Determination of specific and molar rotation of the given optical active compound. Preparation of colloidal solution. **Suggested Readings** 1. Bhatti, H.N. 2012. Principles of Physical Chemistry. The Caravan Book House, Lahore. 2. Levitt, B.P. 1987. Findlay's Practical Physical Chemistry, 9th Ed., Longman Group Limited, London. 3. Maron, S.H. and b. Jerome. 1995. Fundamentals of Physical Chemistry, National Book Foundation, Islamabad. 4. Moore, W.I. 1997. Basic Physical Chemistry, Prentice Hall Inc., U.K.	**CHEM-501 PHYSCICAL CHEMISTRY-I 3(2-1)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the basic concept of thermodynamics 2. Describe the different order of reactions 3. Explain the preparation of Solutions **4.** Demonstrate the Physical adsorption and chemisorption. and Colloids, **Theory** Chemical Thermodynamics: Basic concept thermodynamics. First and second laws of thermodynamics. Various state functions. Relationship between free energy and equilibria constant. Chemical Kinetics**:** Order and molecularity. Kinetics of zero, first and second order reactions. Activation energy and its determination. Solution Chemistry: Type of solution and concept of concentration such as ppm and ppb. The ideal and non-ideal solution. Theory of ionization. Hydrolysis of acids, bases and salts. pH and buffers. Surface Phenomena and Colloids**:** Physical adsorption and chemisorption. Type of adsorption, isotherm, applications of adsorption. Colloids, preparation, properties and uses. **Practical** Preparation of buffer and determination of pH values. Determination of specific and molar conductance of the given samples of water. Measurement of refractive index and viscosity of a given liquid. Determination of specific and molar rotation of the given optical active compound. Preparation of colloidal solution. **Suggested Readings** 1. Atkins, P., J. de Paula and J. Keeler. 2018. Elements of Physical Chemistry. 11th Ed. Oxford University Press, Oxford, UK. 2. Bhatti, H.N and Z.H. Farooqi. 2021. Manual of Physical Chemistry. Caravan Book House, Lahore, Pakistan. 3. Bhatti, H.N. 2020. A Textbook of Physical Chemistry. The Caravan Book House, Lahore. 4. Levitt, B.P. 1987. Findlay's Practical Physical Chemistry, 9th Ed., Longman Group Limited, London.

		5. Maron, S.H. and b. Jerome. 1995. Fundamentals of Physical Chemistry, National Book Foundation, Islamabad. 6. Moore, W.I. 1997. Basic Physical Chemistry, Prentice Hall Inc., U.K.

56.	**CHEM-503 FUNDAMENTALS OF CHEMISTRY 3(3-0)** **Chemical Bonding:** Introduction, types of chemical bond, bond energy and bond length, sigma and pi bonds, geometries of inorganic and organic molecules on the basis of various theories of chemical bonding. Hydrogen bonding. **Chemistry of Organic Compounds:** Introduction of organic function groups, inter-conversion of function groups. Organic reactions and their mechanism. **Isomerism:** Basic concept, type of isomerism, conformational analysis. **Petrochemicals:** Introduction to petrochemicals, their chemistry and uses as intermediates in synthesis of dyes, textile auxiliaries, plastic and synthetic polymer. **Water Treatment:** Introduction, sources of water, nature of impurities in water, various treatment methods. **Suggested Readings** 1. Agarwal, O. P. 1993. Engineering Chemistry, Khanna Publishers, Dehli. 2. Bhatti, H. N. and B. A. Nasir. 2000. Modern Inorganic Chemistry, The Carvan Book House Lahore. 3. Cakrabarty, B. N. 1994. Industrial Chemistry, Oxford and IBH Publishing Co., New Dehli. 4. Ibne Rasa, K. M., M.A. Rehman and A. Rehman. 2000. Organic Chemistry, The Caravan Book House, Lahore. 5. Younas, M. 2010. A Textbook of Organic Chemistry, Ilmi Katabkhana Lahore.	**CHEM-503 FUNDAMENTALS OF CHEMISTRY 3(3-0)** **Learning Course Outcomes** By the end of this course students will be able to: 1. Explain the properties and reactions of functional groups 2. Describe the method of water treatments 3. Demonstrate the different theories of chemical bonding **4.** Demonstrate the properties and applications of petrochemicals Chemical Bonding: Introduction, types of chemical bond, bond energy and bond length, sigma and pi bonds, geometries of inorganic and organic molecules on the basis of various theories of chemical bonding. Hydrogen bonding. Chemistry of Organic Compounds**:** Introduction of organic function groups, inter-conversion of function groups. Organic reactions and their mechanism. Isomerism: Basic concept, type of isomerism, conformational analysis. Petrochemicals: Introduction to petrochemicals, their chemistry and uses as intermediates in synthesis of dyes, textile auxiliaries, plastic and synthetic polymer. Water Treatment**:** Introduction, sources of water, nature of impurities in water, various treatment methods. **Suggested Readings** 1. Ingold, C.K. 2011. Structure and Mechanism in Organic Chemistry. C.B.S. Ed. Wiley Inter Science, UK. 2. March, J. 2019. Advanced Organic Chemistry, Reaction, Mechanism and Structure. 6th Ed. John Wiley & Sons, Inc., Publication, USA. 3. Morison and Boyd. 2002. Organic Chemistry. 6th Ed. Prentice Hall, UK. **4.** Ibne Rasa, K.M., A. Rehman and H.N. Bhatti. 2020. A Textbook Organic Chemistry. Caravan Book House, Lahore