Course Outline for 3rd and 4th year B.Sc. Honours in Chemistry

The weightage of assessment for theory course will be of 100 marks for 4 credit and 3 credit courses and 50 marks for two credit courses. 20 % of the marks of the theory courses are allotted to class assessment of which 15% marks for class test and 5 % marks are for class attendance. For 2 credit courses there will be one one-hour incourse examination and for 4 credit and 3-credit courses, it would be comprising of arithmetical mean of two one hour in-course examinations. There will be a 4-hour course final examination (for 4 credit course), 3-hour course final examination (for 3 credit course) and 2½ hour course final examination (for 2 credit courses) of 80% marks. The allocation of marks to each 4 credit practical course is 100 and 2 credit practical courses is 50. The duration of each practical examination will be 6 hours. Each student has to appear in a viva-voce examination of 2 (two) credits.

Third Year

Course Type	Course No.	Course Title	Credits
Major	CH 7301	Chemical Kinetics and Photochemistry	3
	CH 7302	Surface Chemistry, Colloid Science and Phase Equilibrium	2
	CH 7321	Organic Reaction Mechanism I	2
	CH 7322	Chemistry of Natural Products	2
	CH 7323	Bio-organic Chemistry	2
	CHL 7324	Organic Chemistry Laboratory II	4
	CH 7341	Advanced Concepts of Atomic Structure and Chemical bonding	2
	CH 7342	Transition Metals and Co-ordination Chemistry	3
	CHL 7343	Inorganic Synthesis and Characterization	2
	CH 7351	Nuclear Chemistry	2
	CH 7361	Instrumental Methods of Analysis	3
	CH 7371	Quantum Chemistry and Statistical Mechanics	2
	CH 7381	Chemical Spectroscopy I: Theory	3
	CH 7382	Oral / Seminar	2
3rd Year Total Credits [Theory = 26, Lab = 6 and Oral = 2]			**34**

Fourth Year

Course Type	Course No.	Course Title	Credits
Major	CH 7401	Physical Properties of Polymers	2
	CH 7402	Chemistry of Solids	2
	CHL 7403	Physical Chemistry Laboratory II	4
	CH 7421	Organic Reaction Mechanism II	4
	CH 7441	Selected Topics in Inorganic Chemistry	3
	CH 7442	Chemical Crystallography	2
	CH 7451	Chemical Spectroscopy II: Applications	3
	CH 7461	Organic Process Industries	3
	CH 7462	Inorganic Process Industries	3
	CHL 7463	Industrial Chemistry Laboratory	2
Major Optional Courses	*CH 7481	Environmental Chemistry	2
	*CH 7482	Applied Physical Chemistry	2
	*CH 7483	Medicinal Chemistry	2
	CH 7484	Oral / Seminar	2
4th Year Total Credits [Theory = 26, Lab = 6, Oral = 2]			**34**

- **Optional Courses**

Any two (2) of Courses CH 7481, CH 7481 and CH 7483 must be taken by the student.

3RD YEAR

CH 7301 Chemical Kinetics and Photochemistry (3 Credits)

Course Content

1. **Chemical Kinetics:** Review of elementary concepts: order, molecularity and rate constant. Integration of rate equations for model reaction systems: zero, first and 2nd order reactions. Parallel, consecutive, successive and opposing reactions: methods for determination of order and rate constants. Complex reactions. Steady state approximation. Kinetics of polymerization reactions. Chain reactions. Explosions.

2. **Techniques and Methods for Measuring Rates of Reactions:** Conventional chemical methods: conductance methods, polarimetry, spectrophotometry; methods based on gas pressure and volume measurements. Techniques for measuring rates of fast reactions: production and measurement of free radicals, flash photolysis, flow methods, relaxation techniques, relative methods.

3. **Temperature Dependence of Reaction Rates and Theories:** The Arrhenius equation. Bimolecular reactions: collision theory-its success and failures. Transition State Theory: elementary treatment, Eyring equation, Thermodynamic formulation. Reaction enthalpy and enthalpy diagrams.

4. **Reactions in Solution:** Diffusion and activation controlled reactions. Theories of reaction rate in solutions, Effect of dielectric constant and ionic strength on rates of reactions in solution.

5. **Theories of Unimolecular Reactions:** Unimolecular reactions: Lindemann theory, Hinshelwood treatment.

6. **Kinetics and Reaction Mechanism:** Principle of steady state approximation. Iodination of acetone. Decomposition of nitrogen pentoxide. Decomposition of ethane and acetaldehyde. Hydrogen-chlorine, and hydrogen bromine reaction. Hydrogenation of ethylene.

7. **Catalysis:** Homogeneous and heterogeneous catalysis, acid-base catalysis. Hinshelwood and Rideal mechanism. Enzyme catalysis: Michael-Menten equation. Autocatalysis. Oscillatory reactions.

8. **Photochemistry and Photochemical Reaction:** Laws of photochemistry. Quantum yield and its significance. Light source. Actinometer and its working principle. Fates of photo excited species. Photodissociation, photoionization. Some typical photochemical reactions. Photosensitization and photocatalysis. Mechanism of photocatalytic reactions. Formation and depletion of ozone in the stratosphere. Ozone hole.

9. **Radiation Chemistry:** Types of radiation, Deference between photochemistry and radiation chemistry. G-value and its significance.

Books Recommended

1. Chemical Kinetics, K. J. Laidler.
2. Atkins' Physical Chemistry, P. Atkins and J. De Paula.
3. Kinetics of Chemical Change, C. N. Hinshelwood.
4. Reaction Kinetics, M. J. Pilling and P. W. Seakins.
5. Chemical Kinetics and Dynamics, J. I. Steinfield, Joseph S. Francisco and William L. Hase.
6. Chemical Kinetics, K. A. Connors.
7. Chemical Kinetics and Reaction Mechanism, J. H. Espenson.
8. Fundamentals of Photochemistry, K. K. Rohatgi-Mukherjee.
9. Principles and Applications of Photochemistry, R. P. Wayne.
10. Introduction to Molecular Photochemistry, C. H. J. Wells.

CH 7302 Surface Chemistry, Colloid Science and Phase Equilibria (2 Credits)

Course Content

1. **Surface Chemistry:** Solid surfaces and their characterization. Adsorption on solid surfaces. Techniques for
2. measurement of adsorption on solids from the gas phase and solutions. Adsorption isotherms: Langmuir, Freundlich and BET. Enthalpy of adsorption. Role of adsorption in heterogeneous catalysis.

3. **Adsorption on the Surface of Liquid:** Gibb's adsorption equation. Determination of surface excess concentrations. Electrocapillary phenomenon. Surface films. Surface pressure. Determination of the cross sectional area of surface active molecules by surface tension measurements. Langmuir trough, Langmuir films, Langmuir-Blodgett films, preparation and characterization. Nanofabrication with self-assembled monolayers.

4. **The Colloidal State of Matter:** Classification, preparations and physical properties of colloids. Structure and stability of colloids. The electrical double layer. Zeta potential. Flocculation and coagulation. Electrokinetic phenomena. Colloidal electrolytes and their uses. Micelles and biological membranes. Emulsions: preparation, properties, stability and uses of emulsions. Micro-emulsions.

5. **Phase Equilibria:** Phase rule and its application in one component system like water, sulphur. Duhemm-Margules equation. Completely and partially miscible liquid pairs. Solid-liquid systems comprising two components. Efflorescence and deliquescence. Vapour pressure of saturated solutions. Solid-solid binary systems with reference to alloys. Cooling curves. Systems without compound formation, congruent and incongruent melting points. Introductory ideas about ternary systems and triangular phase diagram.

Books Recommended

1. Colloid Science, A. E. Alexander and P. Johnson.
2. Physical Chemistry, P. Atkins and J. de Paula.
3. A Short Textbook of Colloid Chemistry, B. Jirgensons and M. E. Straumains.
4. Colloid Chemistry: A Textbook, H. B. Weiser.
5. The Phase Rule, A. Findlay (revised by A. N. Campbell).
6. Physical Chemistry of Surfaces, A. W. Adamson and A. P. Gast.

CH 7321 Organic Reaction Mechanism I (2 Credits)

Course Contents

1. **Substitution Reactions**

   (i) Nucleophilic Substitution at a Saturated Carbon Atom: Mechanism of S_N2, $S_N1$and S_ni reactions, kinetics, thermodynamics, and stereochemistry. Effect of structure, solvent, leaving, attacking and neighbouring groups in substitution reactions.

   (ii) Electrophilic Substitution in Aromatic System: Electrophilic substitution in benzene, formation of π and σ- complexes. Electrophilic substitution in monosubstituted benzene.

   (iii) Nucleophilic Substitution in Aromatic System: Nucleophilic substitution in pyridine and diazonium salts. Nucleophilic substitution in substituted benzene through benzyne intermediates.

2. **Addition Reactions**

   (i) Electrophilic addition to carbon-carbon double bonds: Mechanism of electrophilic addition to carbon-carbon double bonds, 1,2- and 1,4- additions, their sterochemistry, kinetics and thermodynamics.

   (ii) Nucleophilic Addition to Carbonyl Compounds: Addition to conjugated system like conjugated dienes and conjugated unsaturated carbonyl compounds. Effect of structure on reactivity.

3. **Elimination Reaction:** E1 and E2 reactions. Stereoselectivity of E2 reactions. Mechanism of E1cB reaction. Orientation in E2 reaction; elimination vs substitution reaction. Saytzev vs Hofmann products in elimination reactions.

4. **Formation and Reaction of Esters and Related Compounds:** Acyl-oxygen and hydrolysis. Reactivity in the hydrolysis and formation of esters. Formation and hydrolysis of amides.

5. **Mechanism of Some Important Reactions:** Aldol condensation, Benzoin condensation, Cannizzaro reaction, Perkin reaction, Diels-Alder reaction, Michael and Mannich reactions, Reimer-Tiemann reaction, Meerwein-Ponndorf, Clemmensen, Wolf-Kishner reduction and Oppenauer oxidation reaction.

Books Recommended

1. Stereochemistry of Carbon Compounds, I. L. Eiel.
2. Organic Chemistry, T. Morrison and R. N. Boyd.
3. Organic Chemistry, S. H. Pine, J. B. Hendrickson, D. J. Cram, and G. S. Hammond.
4. A Guidebook to Mechanism in Organic Chemistry, Peter Sykes.
5. Organic Reaction Mechanism: An Introduction, R. Breslow.
6. Principles of Organic Synthesis, R. O. C. Norman and J. M. Coxon.
7. Organic Chemistry, Volume 2, I. L. Finar,

CH 7322 Chemistry of Natural Products (2 Credits)

Course Content

1. **Natural Products:** General methods of isolation, purification and determination of structure of natural products by chemical and spectroscopic methods with reference to alkaloids, terpenes, steroids and hormones, primary and secondary metabolites.
2. **Alkaloids:** Definition, isolation of alkaloids from plant sources, test of alkaloids, characterization of alkaloids by chemical, spectroscopic and synthetic methods with reference to ephedrine, adrenaline, nicotine, atropine, quinine and papaverine, biosynthesis of alkaloids.
3. **Terpenoids:** Terpenes and terpenoids, classification of terpenoids, isoprene rule, essential oils, detection, isolation and purification of terpenoids, determination of structure of citral, menthol cadenine and camphor by chemical, spectroscopic and synthetic methods, biogenesis of terpenoid compounds.
4. **Steroids and Hormones:** Introduction of steroids and hormones, nomenclature and functions of steroids and hormones, cholesterol and its effects in biological systems, steroidal hormones and glycosides, natural and synthetic hormones.
5. **Organic Colouring Materials:** A relationship between colour and constitution, anthocyanidines, flavones, xanthenes and other materials, naturally occurring coloured compounds: chlorophyll and hemoglobin.
6. **Pheromones:** Pheromones, their stereospecificity and actions in biological systems.

Books Recommended

1. Organic Chemistry (Vol. 2), I. L. Finar.
2. Organic Chemistry, T. Morrison and R. N. Boyd.
3. Organic Chemistry - Natural Products (Vol. I and II), O. P. Agarwal.

CH 7323 Bioorganic Chemistry (2 Credits)

Course Content

1. **Carbohydrates:** Definition, classification, constitution and configuration of monosaccharides, synthesis of monosaccharides, ring structure of monosaccharides and their conformations, action of acids and bases on sugars, epimers, anomers and anomeric configurations, reaction of mono-, di-, tri- and tetrasaccharides, their structures, chemical and physical properties.
2. **Polysaccharides:** Definition, constitution classification and importance of polysaccharides, isolation of polysaccharides and their purification using different physical and chemical methods, structural elucidation of polysaccharides using chemical and spectroscopic methods.
3. A brief introduction of some important polysaccharides such as starch, cellulose, pectin, algininc acid, chitin, glycogen, heparin and darmatan sulphates.
4. **Amino Acids, Peptides and Proteins:** Definition, sources, classification and importance of amino acids, its buffer action in biological system, structure and configuration of amino acids, isoelectric point, preparations

and reactions of amino acids, biosynthesis of amino acids, peptides - its occurrence, constitution and geometry, C-terminal and N-terminal residues of peptides, proteins, their classifications and functions, denatured and conjugated proteins, primary and secondary structure of proteins, a brief treatment of enzymes and coenzymes.

5. **Lipids:** Definition, occurrence, classification and function, composition of fats and oils, hydrolysis of fats, saturated and unsaturated fatty acids, phosphoglycerides, phosphate esters, phospholipids and cell membranes, biosynthesis of lipids.

6. **Nucleic acids:** Definition, sources and importance, structure of nucleic acid, nucleosides and nucleotides, DNA and RNA.

7. **Purines:** Chemistry of purines and uric acid, purine derivatives, xanthine bases.

8. **Glycoconjugates:** A brief introduction of glycoprotein, proteoglycan and glycolipid.

Books Recommended

1. Organic Chemistry (Vol. 2), I. L. Finar.
2. Organic Chemistry, R. T. Morrison and R. N. Boyd.
3. Organic Chemistry - Natural Products (Vol. I and II), O. P. Agarwal.
4. Introduction to Carbohydrate Chemistry, R. D. Guthrie and J. Honeyman.

CH 7341 Advanced Concepts of Atomic Structure and Chemical Bonding (2 Credits)

Course Content

Atomic Structure: Schrödinger's wave equation and its application to hydrogen atom, solutions of Schrödinger wave equation, quantum numbers and their properties, angular wave functions and shapes of the orbitals, radial wave functions, probability distribution, nodal surface – angular nodes and radial nodes, Aufbau's principle, Pauli's exclusion principle, Hund's rule, classification of elements, periodic properties - size of atoms or ions, ionization energy, electron affinity and electronegativity, shielding effect and effective nuclear charge, Slater's rule for calculating shielding effect and effective nuclear charge, applications of Slater's rules and concept of effective nuclear charge.

Chemical Bonds: Chemical bond, types of chemical bonds,

(i) *Ionic Bond:* Ionic bond, characteristics of ionic bonds and ionic compounds, structure of NaCl, lattice energy of ionic crystals, theoretical calculation of lattice energy of NaCl crystal, Madelung constant, experimental determination of lattice energy of NaCl crystal, factors affecting the magnitude of lattice energy of ionic solids, applications of lattice energy calculation.

(ii) Covalent Bond: Covalent bond, types of covalent bond, factors favoring the formation of covalent bond, characteristics of covalent bonds and covalent compounds, dipole moments, dipole moment and percentage ionic character, factors affecting the magnitude of dipole moment, resonance, valence shell electron pair repulsion theory and its limitations, valence bond theory, hybridization, mathematical formulation of hybrid orbitals, limitations of valence bond method, molecular orbital theory, the LCAO method, molecular orbital diagram, HOMO and LUMO, MO descriptions of homonuclear diatoms of He_2 to F_2, Mixing of MOs and the correlation diagrams, MO descriptions of heteronuclear diatoms, HF and CO, and polyatoms, H_2O, BeH_2, BH_3, NH_3, and CH_4, Walsh diagram, comparison and contrast between VBT and MOT, frontier orbital concept and its applications.

(iii) Bonding in Metals: Metallic bond, factors favoring the formation of metallic bond, theories of metallic bond - electron sea theory, molecular orbital theory, characteristics of metals, conductors, semiconductors and insulators.

(iv) Hydrogen Bond: Hydrogen bond, types of hydrogen bond, theories of hydrogen bond – electrostatic approach, molecular orbital approach, properties of hydrogen bond, and hydrogen bonded compounds.

Books Recommended

1. Inorganic Chemistry, G. L. Miessler and D. A. Tarr.
2. Chemical Structure and Bonding, R. L. DeKock and H. B. Gray.
3. Atomic Structure and the Chemical Bond, M. Chanda.
4. Inorganic Chemistry, D. F. Shriver, P. W. Atkins and C. H. Langford.
5. Physical Chemistry, G. M. Barrow.
6. Valence and Molecular Structure, E. Cartmel and G. W. A. Fowles.

CH 7342 Transition Metals and Coordination Chemistry (3 Credits)

Course Content

1. **Transition and Inner Transition Elements:** General characteristics of transition metals and inner transition metals, shapes of *d* and f orbitals, energetics of d and f orbitals as functions of atomic numbers, magnetism in transition metal chemistry, origin of paramagnetism and diamagnetism, magnetic susceptibility, Curie's law, techniques of magnetic measurements, Gouy balance, lanthanides and actinides: oxidation states, atomic and ionic radii of M^{3+} ions, magnetic properties of M^{3+} ions, lanthanide contraction, chemical reactivity of lanthanides, separation of lanthanide and actinide compounds, comparison between 3d and 4f block elements.

2. **Bonding in Coordination Compounds:** Classical coordination compounds, double salts and coordination compounds, coordination number, ligand types, Werner's coordination theory, limitations of Werner's postulate, Sidgwick's electronic concept, application of EAN rule, limitations of Sidwick's concept, assumptions of valence bond theory (VBT), hybridization and geometry of complexes, inner orbital and outer orbital octahedral complexes, limitations of VBT, important features of crystal field theory (CFT), orbital splitting and electron spin, factors influencing the magnitude of 10dq, spectrochemical series, crystal field stabilizing energies of d^n configuration (n = 0 to 10), magnetic moments, colour of transition metal complexes, distortion of octahedral complexes and Jahn-Teller theorem, limitations of CFT, ligand field theory (LFT), molecular orbital theory (MOT), MOT as applied to octahedral complexes, comparison of different theories.

3. **Stability of Complex Compounds:** Stability, stepwise formation constants and overall formation constants, kinetic vs. thermodynamic stability, labile and inert octahedral complexes, factors affecting the stability of a complex, experimental determination of stability constant and composition of a complex.

4. **Nomenclature and Isomers in Coordination Compounds:** Names of coordination compounds, use of abbreviated names, four and six coordination preferences, isomerism – structural and stereoisomerism in complex compounds, geometrical and optical isomerisms in 4- and 6- coordinate complexes, chirality.

5. **Reactions and Mechanisms in Coordination Chemistry:** Substitution reactions in octahedral complexes, types of substitution reactions, nucleophilic substitution reactions, association, dissociation and interchange mechanisms, factors affecting the rate of substitution reactions, acid and base hydrolysis reactions, the conjugate base mechanism, stereochemistry of octahedral substitution, substitution in square planar complexes, trans effect – theories of trans effect, uses of trans effect, substitution in tetrahedral complexes, fluxionality in coordination compounds.

Books Recommended

1. Advanced Inorganic Chemistry, F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann.
2. Inorganic Chemistry – Principles of Structure and Reactivity, J. E. Huhee, E. A. Keiter and R. L. Keiter.
3. Selected Topics on Advanced Inorganic Chemistry, S. Z. Haider.
4. Inorganic Chemistry, D. F. Shriver, P. W. Atkins and C. H. Langford.
5. Complex and First-row Transition Elements, D. Nicholls.
6. Elements of Magnetochemistry, R. L. Dutta and A. Syamal.
7. Kinetics and Mechanism, A. A. Frost and R. G. Pearson.
8. Inorganic Reaction Mechanisms, M. L. Tobe.
9. Mechanism of Inorganic Reactions, F. Basolo and R. G. Pearson.
10. Ligand Substitution Process, C. H. Langford and H. B. Gray.

CH 7351 Nuclear Chemistry (2 Credits)

Course Content

1. **The Atomic Nucleus and Its Properties:** Atomic nucleus and its composition, nuclear radius and nuclear density, nuclear force, mass defect, packing fraction, binding energy, nuclear spin and moments, nuclear potential, concepts of nuclear structure - shell model, nuclear statistics, nuclear stability, nuclidic mass and atomic mass, nuclear mass and energy correlation, classification of nuclides.

2. **Radioactivity and Radioactive Decay Laws:** Radioactivity**,** units of radioactivity, natural and artificial radioactivity, radioactive decay, radioactive decay constant, kinetics of radioactive decay, half-life and average life, radioactive decay series, radioactive equilibria, comparison between radioactive equilibrium and chemical equilibrium.

3. **Nuclear Reactions and Fission:** Nuclear reactions and their comparison with chemical reactions, types of nuclear reactions, conservation laws, energetics of nuclear reactions, nuclear reaction cross-section, excitation function, nuclear reactions mechanisms, liquid drop model of nuclear fission and fissionability parameters, general features of mass, charge and kinetic energy distributions in thermal neutron induced fission of ^{235}U and ^{239}Pu.

4. **Interaction of Radiation with Matter and Detection of Nuclear Radiation:** Introduction, modes of interactions, interactions of gamma radiations with matters, interactions of charged particles with matters, Bremsstrahlung radiation, Ĉerenkov radiation, beta backscatter, the Auger process, radiation detection, measurements of radiations with ionization chambers, proportional counter, Geiger Müller counter, NaI(Tl) scintillation detectors, solid state semiconductor detector.

5. **Nuclear Reactors and Accelerators:** Nuclear reactors – principles, major components of reactors, types of reactors, application of reactors; working principles, basic components and utilization of Van de graaff, tandem Van de graaff and cyclotron accelerators.

6. **Safety:** Radiation exposure, radiation dose, dose equivalent, quality factor, simple calculation of radiation exposure and radiation dose for γ- and β-rays, radiation hazards, radioactive wastes and their management.

Books Recommended

1. Radiochemistry and Nuclear Methods of Analysis, W. D. Ehmann and D. E. Vance.
2. Nuclear and Radiochemistry, G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller.
3. Introduction to Nuclear Physics and Chemistry, B. G. Harvey.
4. Essentials of Nuclear Chemistry, H. J. Arnikar.
5. Nuclear Chemistry and its Applications, G. R. Choppin and J. Rydberg.

CH 7361 Instrumental Methods of Analysis (3 Credits)

Course Content

1. **Thermal Analysis:** Thermogravimetry (TG), types of TG, instrumentation, application of TG, derivative thermogravimetry (DTG), simultaneous TG and DTG, differential thermal analysis (DTA): working principle, instrumentation, factors affecting DTA, applications, differential scanning calorimetry (DSC): principle, instrumentation and applications.
2. **Atomic Spectrometric Methods:** Atomic absorption and atomic emission, absorption line width, choice of absorption line, flame emission spectrometry: instrumentation, flame emission analysis, atomic absorption spectrophotometry: principles, instrumentation and interferences, electro-thermal atomizers, sample requirements and general preparation techniques, the effect of different solvents, sensitivity, qualitative and quantitative analysis, hydride vapour generation technique, cold vapour technique, advantages and disadvantages of AAS.

Polarographic and Voltammetric Analysis: Current voltage relationship, mass transport processes, direct current polarography (DC), diffusion current, charging current, factors affecting the diffusion current, characteristics of dropping mercury electrode, three electrode potentiostat, polarographic maxima, oxygen interference, half wave potential, alternating current and pulse polarography, principle and advantages over dc polarography, voltammetry – ASV, CSV and CV, multicomponent analysis, quantitative applications.

Chromatographic Techniques: Overview, retention behaviour, efficiency, selectivity, resolution, chromatographic theory, measured chromatographic parameters, evaluation methods, and classification of chromatography.

(I) Liquid Chromatography: Types of liquid Chromatography;

(a) **Planar Chromatography*:*** Theories and mechanism of PC and TLC, nature of stationary phases, general properties required of a mobile phase, development of the chromatograms, location of spots, superiority of TLC, analytical applications.

(b) ***Column Chromatography****:* Column selectivity, efficiency, capacity factor etc.

(i) Ion-Exchange Chromatography: Ion-exchange resin, types of resins and their structure and properties, factors affecting the ion-exchange-equilibria, eluting solvents, effect of pH, effect of complexing agents, and application of ion-exchange chromatography.

(ii) Gel Chromatography: Mechanism of gel chromatography, advantages of gel chromatography, technique of gel chromatography, applications of gel chromatography.

(iii) High-Performance Liquid Chromatography: The HPLC system, particle size and support material, filtration and degassing, HPLC columns, solvent requirements, solvent pumping systems, injection systems, HPLC detectors, applications.

(II) Gas Chromatography: Principles, GC columns, selection of materials and column design, stationary phases, carrier gas, sample injection system, general properties of detectors, detector types, scope of gas chromatography.

5. **Analytical Mass Spectrometry:** The general principles and basic instrumental aspects of mass spectrometry, interpretation of mass spectra, analytical-chemical aspects of mass spectrometry.

6. **Statistical Treatment of Data:** Population and sample mean, standard deviation, relative standard deviation, coefficient of variation, variance, confidence limit, Gaussian distribution, statistical tests, coefficient of correlation, regression lines, least square method.

Books Recommended

1. Instrumental Methods of Analysis, H. W. Willard, L. L. Merritt Jr., J. A. Dean and F. A. Settle Jr.
2. Modern Methods of Chemical Analysis, R. L. Pecsok, L. D. Shields, T. Cairns, and L. G. McWilliam.
3. Fundamentals of Analytical Chemistry, D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch.
4. Analytical Chemistry, G. D. Christian.
5. Modern Analytical Chemistry, D. Harvey.
6. Analytical Chemistry, R. Kellner, J. -M. Mermet, M. Otto and H. M. Widmer edited.
7. Analytical Chemistry Principles, J. H. Kennedy.
8. A Text Book of Quantitative Analysis, A. I. Vogel.
9. Quantitative Chemical Analysis, S. E. Manahan.

CH 7371 Quantum Chemistry and Statistical Mechanics (2 Credits)

Course Content

1. **Classical Mechanics:** Failures of classical mechanics. Black-body radiation, heat capacities of solids, photoelectric effect, the Compton effect, atomic spectra, Planck's quantum theory, Einstein's explanation of photoelectric effect, de Broglie's postulate, Heisenberg's uncertainty principle, wave equation.

2. **Time Independent Schrödinger Equation and Stationary State:** Interpretation of the wave functions: normalization of the wave functions. Orthogonality and completeness of the wave function. Significance of wave functions.

3. **Operators and Observables:** Constitution of quantum mechanical operator, some important operators: Hamiltonian operator, Laplacian operator, operator algebra. Eigen functions. Eigen values. Eigen value equation. Expectation values.

4. **Application of Quantum Mechanics:** Translational motion, particle in a box. Properties of solutions and the consequences, vibrational motion, one-dimensional harmonic oscillator: the formal solution, the energy levels, the wave functions, properties of the solutions. Rotational motion: rotation in two dimensions, the formal solution. Significance and application.

5. **The Structure of Hydrogen and Hydrogen-like Atom:** The formal solution of the Schrödinger equation; the separation of the R, Θ and Φ equations, total wave functions of the hydrogen and hydrogen-like atoms, probability density and radial distribution function, atomic orbitals and their shapes, orthonormality of atomic orbitals. Approximation methods. Variation principle, perturbation theory.

6. **Statistical Mechanics:** Basic concepts, macroscopic system, distribution of molecules, configuration, population, weight, most probable configurations, Boltzmann distribution, molecular partition function, internal energy of a system, the canonical ensemble, Fermi-Dirac and Bose-Einstein statistics, evaluation of partition functions, calculation of thermodynamic functions, applications of statistical mechanics, mean energies and the equipartition principle, heat capacities of solids, Einstein and Debye equations, chemical equilibrium: statistical treatment, evaluation of equilibrium constants.

Books Recommended

1. Quantum Mechanics in Chemistry, M. M. W. Hanna and W. A. Benjamin.
2. Quantum Chemistry, D. A. McQuarrie.
3. Atkins' Physical Chemistry, P. Atkins and J. D. Paula.
4. Introductory Quantum Chemistry, A. K. Chandra.
5. Molecular Quantum Mechanics, P. W. Atkins.
6. Quantum Chemistry, I. N. Levine.

CH 7381 Chemical Spectroscopy I: Theory (3 Credits)

Course Content

1. **Electromagnetic Radiation:** The nature of electro-magnetic radiation. Emission and absorption spectra; spectrometers; basic components of dispersive spectrometers; modulation technique: transmittance and absorbance. Beer-Lambert law: molar absorption cross section. Representation of spectra; spectral peaks; intensities, width and resolution; signal to noise ratio and signal averaging. Fourier transform technique and its advantages.

2. **Atomic Spectroscopy:** Atomic spectra. Spectra of hydrogen and hydrogen-like elements. Energy level diagrams. Angular momentum of atoms. Coupling of orbital and spin angular momenta. Term symbols. Fine structure of atomic spectra.

3. **Rotational Spectroscopy:** Rotation of molecules and their classification. Interaction of rotating molecules with radiation. Microwave spectrometer. Rotational energies of linear rotors. Distribution of molecules and rotational spectra. Centrifugal distortion. Effect of isotopic substitution. Stark effect and its use in microwave spectrometers. Determination of molecular geometry from microwave spectra.

4. **Infrared Spectroscopy:** Vibration in molecules; normal modes, harmonic and anharmonic. Potential-energy diagrams. Morse equation, vibrational energy, dissociation energy of diatomic molecules, population of vibrational levels. Transition probabilities. Fundamental, overtone and hot band transitions. Combination and difference bands, Fermi resonance. Vibration-rotation spectra of gaseous molecules. P, Q, and R branches. Infrared spectra of polyatomic molecules. Characteristic group vibrations and skeletal vibrations, shifts in group frequencies, Techniques: radiation sources, optics, monochromators, sample holders, detectors for

infrared spectrometers. Handling of samples: gaseous, liquid and solid samples. Principle of FTIR spectrometer and its advantages.

5. Ultraviolet-visible Spectroscopy: Electronic states of molecules. Spectra of simple gaseous diatomic species and their vibrational coarse structure. Franck-Condon principle and intensities of spectral lines. Dissociation energy; pre-dissociation spectra of species in condensed phase. Various electronic transitions in organic and inorganic species. Width of electronic bands, effect of solvent on band width and band position. Chromophores, bathochromic and hypsochromic shifts. Auxochromes. Fate of Excited Species: Spontaneous and stimulated emission; flurorescence and phosphorescence. Basic principle of LASER. Working principles of some common lasers.

6. Raman Spectroscopy: Raman effect. Classical theory of Raman scattering. Criterion of Raman activity. Raman spectrometers; use of laser in Raman spectroscopy. Vibrational and rotational Raman spectra. Use of polarized light. Applications of Raman spectroscopy.

7. Principles of Magnetic Resonance Spectroscopy: Nuclear spin. Effect of magnetic field on the energies of spinning nuclei. The Larmor precession. Resonance absorption of radiation through spin flipping. Electron density at the nucleus; the chemical shift; δ and τ-scale for chemical shift; the coupling of nuclear spins, the coupling constant, structures of simple compounds and NMR. The NMR spectrometer. Electron spin, Effect of magnetic field on the energies of spinning electrons, The g-factor, hyperfine splitting; determination of electron density from ESR spectroscopic studies. The ESR spectrometer.

8. Mass Spectroscopy: Basic principles. ionization techniques. Electron impact ionization. Appearance potential. photo-ionization. Mass filters. Sector magnet filter. Quadrupole filter. Fragmentation. Base peak. Metastable peaks. Application in structure, determination and quantitative analysis.

Books Recommended

1. Introduction to Molecular Spectroscopy, G. M. Barrow.
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash.
3. Molecular Structure and Spectroscopy, G. Aruldhas.
4. The Infrared Spectra of Complex Molecules, L. J. Bellamy.
5. Ultra-violet and Visible Spectroscopy, C. N. R. Rao.
6. Basic Principles of Molecular Spectroscopy, R. Chang.
7. Electronic Spectra and Electronic Structure of Polyatomic Molecules, G. Herzberg.
8. Atkins' Physical Chemistry, P. Atkins and J. De Paula.

CHL 7324 Organic Chemistry Laboratory II (4 Credits)

Course Contents

1. Identification of Organic Compounds: Detection and identification of different types of organic compounds both solid and liquid by physical and chemical methods, types of organic compounds: hydrocarbons, halogenated compounds, hydroxy compounds (alcohols and phenols), ethers, carbonyl compounds (aldehydes and ketones), carboxylic acids and the derivatives of alpha, beta-unsaturated carbonyl compounds and acids, keto and hydroxy acids, nitro compounds, amino compounds (primary, secondary and tertiary), organo sulphur compounds amides and N-substituted amides.

2. Synthesis of Organic Compounds: Aromatic substitution: (a) Bromination of acetanilide and phenol, (b) sulphonation of aniline, (c) Diazotization of aromatic amines and preparation of (i) phenols, (ii) halobenzenes and azo dyes.

3. Hydroxylation: Hydroxylation of cyclohexene, stereospecific hydroxylation, isolation and purification of the products.

4. Preparation Involving Some Specific Reactions: Aldol condensation, Perkin reaction, Cannizzaro reaction, Michael reaction.

Books Recommended

1. Unitized Experiments in Organic Chemistry, R. Q. Brewster, C. A. Vanderwerf and W. E. McEwen.
2. Organic Experiments, W. W. Linstromberg and H. E. Baumgarten.
3. Textbook of Practical Organic Chemistry, A. I. Vogel.
4. A Hand Book of Organic Analysis, E. A. Clarke.
5. The Systematic Identification of Organic Compounds, R. Shriner, C. Hermann, T. Morrill, D. Curtin and R. Fuson.

CHL 7343 Inorganic Synthesis and Characterization (2 Credits)

Course Content

1. Recrystallization of NaCl crystals from crude NaCl and its characterization.

2. Preparation of $FeSO_4.7H_2O$ and its characterization including estimation of water of crystallization and determination of Fe^{3+} as impurity, if any.

3. Preparation of $CuSO_4.5H_2O$ from metallic copper and its characterization by elemental analysis, IR and UV-visible spectra, and thermal analysis.

4. Synthesis of $[Cu(NH_3)_4]SO_4.H_2O$ from $CuSO_4.5H_2O$ and its investigation by infrared spectrometer.

5. Preparation of $[Co(NH_3)_6]Cl_3$ and its characterization by chemical analysis, infrared spectroscopy and magnetic measurement.

6. Preparation and characterization of tris(thiourea)copper(I) chloride, $[Cu(NH_2CSNH_2)_3]Cl$.

7. Synthesis of an ethylenediamine complex of cobalt and its characterization by infrared and ^1H NMR spectroscopy.

8. Preparation and investigation of potassium tris(oxalato)ferrate(III), $K_3[Fe(C_2O_4)_3]$.

9. Preparation and characterization of the optical isomers of tris(ethylenediamine)cobalt(III) iodide, $[Co(en)_3]I_3$.

10. Synthesis and characterization of a saccharin complex.

11. Spectrophotometric determination of $Cr_2O_7^{2-}$ and MnO_4^- concentration from their solution.

12. Preparation of anhydrous $AlCl_3$ and anhydrous $FeCl_3$.

Books Recommended

1. A Text Book of Quantitative Inorganic Analysis, A. I. Vogel.
2. Microscale Inorganic Chemistry, Z. Szafran, R. M. Pike and M. M. Singh.
3. Inorganic Experiments, J. D. Woollins.

4TH YEAR

CH7401 Physical Properties of Polymers (2 Credits)

Course Content

1. **Structure of Synthetic and Biological Polymers:** Definitions, Difference between polymers and macromolecules; Classification of polymers, degree of polymerization, Nomenclature and Tacticity; Basic structure of polymers: linear and branched polymers; moderately cross linked polymers, Number average and

weight average molecular weight, Z-average and viscosity average molecular weight, distribution of molecular weight; Polydispersity, Measurement of number average molecular weight: end group analysis, colligative properties, Measurement of number average molecular weight: light scattering, ultracentrifugation, Viscometry and Gel permeation chromatography.

2. **Morphology and Order in Crystalline Polymers:** Configurations of polymer chains, crystal structures of polymers, Amorphous polymers, Liquid crystalline polymers, Morphology of polymer single crystals, Structure of polymers crystallized from melt and solution, Factors affecting crystallinity.

3. **Polymer Solution:** Criteria for polymer solubility; Size and shapes of polymers in solution; Conformation of dissolved polymer chain, Thermodynamics of polymer solutions; Flory-Huggins theory, theta temperature, Concepts of a thermodynamically good and poor solvent, Fractionation of polymers by solubility.

4. **Polymer Structure and Thermal Properties:** The crystalline melting point, the glass transition, factors affecting Tm and Tg, experimental determination of Tg and Tm.

5. **Rheology and Mechanical Properties of Polymers:** Introduction to Rheology, definition, Newton's and Hooke's laws, flow behaviour of polymers, the ideal fluid, non Newtonian fluids, viscous flow, relationship between stresses and stain, viscoelasticity, mechanical models – Maxwell and voigt Boltzmann's superposition principles. stress-strain behavior of elastomers, the mechanical properties of crystalline polymers.

6. **Other Polymer Properties:** Thermal stability, flammability and flame resistance, chemical resistance, degradability, electrical conductivity, conducting polymers, vulcanization, physical aspects of vulcanization.

Books Recommended

1. Polymer Chemistry - An Introduction, M. P. Stevens.
2. Polymer Science, V. R. Gowariker, N. V. Biswanathan and J. Sreadhar.
3. Polymer Chemistry, P. C. Hiemenz and T. P. Lodge.
4. Textbook of Polymer Science, F. W. Billmeyer.

CH 7402 Chemistry of Solids (2 Credits)

Course Content

1. **Chemistry of the Defect of Solids and Solid Surfaces:** Perfect crystal, defects in solids, vacancies, point defects: intrinsic and extrinsic point defects, line defects: edge and screw dislocations, plane defects, calculation of the Schottky and Frenkel defects in ionic solids, influence of defects on the physical properties of the solids, colour centers.

2. **Bonding in Solids and Electronic Properties of Solids:** Introduction, bonding in solids, the band theory, electrical conductivity, thermal conductivity, origin of band gap, the hole concept, semiconductors and their types, sensitization and doping, measurement of semiconductivity, Hopping conduction, Hall effect, non-stoichiometric metal oxides, electronic properties of non-stoichiometric oxides, superconductors, SQUID.

3. **Optical Properties:** Interaction of light with solids, colour and photoconductivity.

4. **Magnetic and Dielectric Properties:** Magnetic susceptibility, classification of magnetic materials, diamagnetism, paramagnetism, ferromagnetism, anti-ferrimagnetism.

5. **Preparative Methods in Solid State Chemistry:** Introduction, microwave synthesis, sol-gel method, precursor method, hydrothermal method, chemical-vapour deposition.

6. **Reactions of Solids:** Solid-state reactions, role of defects, kinetics of thermal decomposition of solids, the Wagner's theory, tarnishing reactions, kinetics of oxide film growth, photoconductivity, chemistry of photography, photocells for solar energy conversion, dye-sensitized solar cells based on nanocrystalline oxide semiconductor films.

Books Recommended

1. Solid State Chemistry: An Introduction, L. Smart and E. A. Moore.
2. Solid State Chemistry, N. B. Hannay.
3. Chemistry of Solids, A. K. Galwey.
4. Solid State Chemistry, D. K. Chakrabarty.
5. Fundamentals of Material Science and Engineering, W. D. Callister.

CH 7421 Organic Reaction Mechanism II (4 Credits)

Course Content

1. **Molecular Orbital Theory:** Phase of an orbital and its role in bonding and antibonding, Huckel molecular orbital theory, LCAO`S theory and M.O`s theory - their shapes and energy states, illustration with 1,3-butadiene, allyl
2. system and 1,3,5-hexatriene.

3. **Orbital Symmetry and Chemical Reactions:** Woodward and Hofmann rules and their applications in thermal and photochemical reactions, electrocyclic reactions, cycloaddition reactions and sigmatropic rearrangements.

4. **Kinetics and Energetics in Reaction Mechanism:** Mechanistic implication of rate-law, energy of activation and entropy of activation in chemical reactions, kinetic control and thermodynamic control over product formation, salt effects, primary and secondary kinetic isotope effects.

5. **Catalysis:** Electrophilic and nucleophilic catalysts, catalysts of non-ionic reactions, "physical catalysts", acid-base catalysts, intramolecular catalysts.

6. **Special Addition, Elimination and Substitution Reactions:**

7. **Addition:** 1,3-Dipolar addition and 1,4-addition reactions.

8. **Elimination:** Ionic elimination, thermal and syn-elimination (Chugaev and related reactions), detailed treatment of Saytzeff and Hofmann rules of elimination reaction leading to product formations.

9. **Substitution:** Orbital picture of S_N1 and S_N2 reactions, combination of S_N1 and S_N2 in solvolysis reactions, ion-pairs in S_N^1 mechanism, role of complex in aromatic reactions (substitution).

10. **Molecular Rearrangements:** Base-catalysed rearrangements, rearrangements involving migration to electron-deficient nitrogen and oxygen atoms, aromatic rearrangement passing through "No mechanism pathways", Claisen, Cope and related rearrangements.

11. **Photochemistry:** Excited states (Generation of singlet and triplet states), energy transfer, photosensitizer, quantum yield, photochemical synthesis and degradation, photochemical cycloaddition, photopoly-merisation, flash photolysis.

12. **Conformational Analysis and Its Effect on Reactivity:** Conformational effects on stability and reactivity, Curtius-Hammet principle, transannular effects, the concept of I-Strain.

Books Recommended

1. Physical Organic Chemistry, T. H. Lowry and K. S. Richardson.
2. Problems in Physical Organic Chemistry, A. R. Butler.
3. Physical Organic Chemistry, J. S. Hine.
4. Organic Chemistry, H. S. Pine, J. B. Hendrickson, D. J. Cram and G. S. Hammond.
5. Symmetry in Organic Molecules, T. L. Gilchrist and R. C. Storr.
6. Frontier Orbital Theory, I. Fleming.
7. Organic Reaction Mechanism, E. S. Gould.

CH 7441 Selected Topics in Inorganic Chemistry (3 Credits)

Course Content

1. **Molecular Symmetry and Group Theory:** Symmetry elements and operations, point groups of molecules, multiplication of symmetry operations, rules for multiplications, symmetry point groups and molecular systems, groups of very high and low symmetry, use of flow chart to identify a point group, optical activity and dipole moments on the basis of point group symmetry, symmetry operations and matrix representations, reducible and irreducible representations, character tables for point groups.

2. **Metal Carbonyls and Nitrosyls:** Pi-acid ligands and pi-acid complexes, metal carbonyl and metal nitrosyl complexes, preparation and properties of metal carbonyl and nitrosyl complexes, M-C-O and M-N-O bonding, bridging and terminal COs and NOs, cluster carbonyls and nitrosyls, infrared and ^{13}C NMR analysis, side-on-bonding in carbonyls, nitrosyls, biological importance of carbonyls and nitrosyls.

3. **Organometallics and Their Catalytic Aspects:** Introduction, general characteristics, stability of organometallic compounds, ligands in organometallic chemistry, classification of organometallic compounds, preparative routes for metal-carbon bond formation, bonding between metal atoms and organic pi systems, structures of Zeise's salt and ferrocene, complexes containing M – C, M = C, and M ≡ C bonds, organometallic reactions – ligand dissociation and substitution, oxidative addition, reductive elimination, carbonyl insertion, homogeneous catalysis – hydrogenation by Wilkinson's catalyst, hydroformylation, heterogeneous catalysis – Ziegler-Nata polymerizations, water gas reactions, Fisher-Tropsch reaction.

4. **Nonaqueous Solvents:** Classification of solvents, general properties of ionizing solvents, leveling and differentiating solvents, types of chemical reactions in solvents, measurement of solvent strength, liquid ammonia, anhydrous sulfuric acid, liquid SO_2, molten salts as solvents.

5. **Inorganic Polymers:** Concept of inorganic polymers as distinct to organic polymers, classification of inorganic polymers, properties of inorganic polymers, studies of some typical inorganic polymers: (i) phosphazines, (ii) silicones, and (iii) S-N polymers.

6. **Non-stoichiometric Compounds:** Introduction, characteristics of non-stoichiometric compounds, structure of non-stoichiometric compounds, methods for studying non-stoichiometric compounds.

7. **Metal Clusters:** Introduction, synthesis, reactions of metal clusters, structures of metal clusters, applications.

Books Recommended

1. Chemical Applications of Group Theory, F. A. Cotton.
2. Inorganic Chemistry, D. F. Shriver and P. W. Atkins.
3. Concepts and Models of Inorganic Chemistry, B. E. Douglas, D. H. McDaniel, and J. J. Alexander.
4. Modern Aspects of Inorganic Chemistry, H. J. Emeleus and A. G. Sharpe.
5. Inorganic Chemistry, G. L. Miessler and D. A. Tarr.
6. The Organometallic Chemistry of the Transition Metals, R. H. Crabtree.
7. Chemistry in Non-aqueous Solvents, H. H. Sisler.
8. A Text Book of Inorganic Polymers, A. K. Bhagi and G. K. Chatwal.

CH 7442 Elements of Chemical Crystallography (2 Credits)

Course Content

1. **Solids:** The solid state, properties of solids, crystalline and amorphous solids, distinction between crystalline and amorphous solids, classification of crystalline solid, isomorphism, polymorphism and allotropy.

2. **Crystal lattice and Crystal Symmetry:** Crystal lattice, unit cell, unit cell volume, crystal systems, Bravais lattices, lattice types, Miller indices, symmetry and symmetry elements, point groups, the Laue classes, space groups, transformation theory, systematic absences and space groups.

3. **Elementary Crystal Optics:** Crystal forms, crystal zones and zone symbols, cleavage, parting and fracture, crystal habit, crystal projections, crystal twins.

4. **X-ray Diffraction by Crystals:** X-rays, generation of X-rays, properties of X-rays, X-ray filters, diffraction of X-rays by crystals, Bragg's equation, reciprocal lattice, Bragg's law in reciprocal lattice, sphere of reflection, limiting sphere.

5. **Powder Diffraction technique:** The powder method – principles and uses, the Debye-Scherrer powder camera, Guinier focusing camera, the powder diffractometer, comparison of diffractometry with film methods, high temperature powder diffraction, effect of crystal size on the powder pattern, measurement of d-values, refinement of unit cell parameters, indexing of powder patterns, structure determination from powder patterns.

6. **Single Crystals and Data Collection:** Single crystal, techniques of single crystals growth, choosing a crystal, crystal mounting and alignment, measurement of crystal properties, data collection, four-circle diffractometer, unique data, data reduction, structure factor, electron density mapping, Fourier synthesis, the phase problem, the Patterson synthesis, the overall procedure, computational task.

7. **Structures of Solids:** Close packing, closed-packed structures, packing coefficient, interstitial sites, radius ratio, radius ratio rule, structure of some inorganic solids – NaCl, CsCl, zinc blende, wurtzite, NiAs, CaF_2, TiO_2, perovskite, normal spinel and inverse spinel and ilmenite, Structure of some organic solids -flavones and isoflavones, alkaloids.

Books Recommended

1. X-ray Structure Determination – A Practical Guide, G. H. Stout and L. H. Jensen.
2. Structure Determination by X-ray Crystallography, M. F. C. Ladd and R.A. Palmer.
3. Solid State Chemistry and Its Applications, A. R. West.
4. Inorganic Solids, D. M. Adams.
5. An Introduction to Crystal Chemistry, R. C. Evans.
6. X-ray Methods - Analytical Chemistry by Open Learning, C. Whiston.
7. Optical Crystallography, E. E. Wahlstrom.

CH 7451 Chemical Spectroscopy II: Applications (3 Credits)

Course Content

1. **Ultra-violet and Visible Spectra of Organic and Inorganic Compounds:** Woodward-Hoffman rules for the calculation of λ_{max}, solvent effect on band position, conjugated system, chromophore - stereochemical aspects, kinetic studies using uv-visible spectroscopy, spectra of complex compounds - free ions, d-configuration and correlation diagrams, and Tanabe-Sugano diagrams, UPS and XPS.

2. **Infra-red Spectra of Organic and Inorganic Compounds:** Characteristics group frequencies, assignment of spectral bands, structural factors, including common organic functional groups, affecting group frequencies, frequency shifts associated with structural changes in the compounds containing hetero atoms, applications in structure elucidation and investigation of reaction mechanism, combined infra-red and Raman spectroscopic studies for structure determination, infra-red spectra of transition metal complexes, infra-red spectra of adsorbed species.

3. **Nuclear Magnetic Resonance Spectroscopy:** Nuclear spin, common nuclei with spin (^{1}H, ^{13}C, ^{15}N, ^{19}F, ^{31}P), interaction of magnetic field with nuclear spin, Larmour precession, resonance absorption of radiation, the nmr spectrometer, nmr spectrum, chemical shift, shielding and deshielding of nuclei, spin-spin coupling, coupling constant, vicinal, geminal, ortho, para and meta coupling, proton exchange reactions, rotation about single bonds, variable temperature spectra, geminal coupling non-equivalence of protons, relaxation, NOE, simplification of complex spectra, double irradiation, Fourier transform spectra, two-dimensional nmr - a brief treatment of COSY and NOESY.

4. **Mass Spectroscopy:** Techniques of ionization, electron impact, fast atom bombardment, field desorption, photoionization, multiphoton ionization, thermal methods, principles of mass separation, sector magnet technique, quadrupole mass separator; time of flight in mass spectrometer, ion optics, sampling for mass spectrometric measurements, molecular beam sampling, ionization potentials and measurements, fragmentation of ions, rearrangement of ions, base peak, molecular mass determination, mass spectra of various classes of compounds, CI, EI and FAB mass spectroscopy.

5. **Combination of spectroscopic methods:** Structure elucidation of compounds by combined application of UV, IR, NMR (^{1}H and ^{13}C) and mass spectroscopy.

Books Recommended

1. Introduction to Spectroscopy: A Guide for Students of Organic Chemistry, D. L. Pavia, G. M. Lampman and G. S. Kriz.
2. Spectrometric Identification of Organic Compounds, R. M. Silverstein, G. C. Bassler and T. C. Morrill.
3. Spectroscopic Methods in Organic Chemistry, D. H. Williams and I. Fleming.
4. Spectroscopy, B. K. Sharma.

CH 7461 Organic Process Industries (3 Credits)

Course Contents

1. **Sugar and Starch Industries:** Steps in the industrial extraction of cane sugar and inversion of sugar, refining of sugar, production of sugar from sugar beet, by products of sugar industries, management of industrial waste of sugar industries, production of starch from corn., production of glucose and dextrin from starch, Starch derivatives and its importance.

2. **Cellulose and Allied Industries:** Natural sources of cellulose, its constituents and estimation, different processes for the manufacture of paper from pulp, production of paperboard, viscose rayon and other modified cellulose fiber, wood chemistry and wood chemicals.

3. **Fuels:** Solid, liquid and gaseous fuels, coal and its constituents, different stages of coal formation, analysis and calorific value of coal and other fuels, carbonization, distillation of coal tar, hydrogenation of coal, manufacture of producer gas and water gas, refining and distillation of crude oil, motor and aviation fuels, thermal and catalytic cracking, production of motor fuels by alkylation, cyclization and polymerization, lubricating agents, hydrocarbons and petroleum, their distribution in Bangladesh, methods of harnessing hydrocarbons in Bangladesh, petrochemicals from liquid and gaseous hydrocarbons, natural gas and its utilization.

4. **Natural Oils, Fats and Waxes:** Extraction and refining of vegetable oils, analysis of fats and oils and their uses, hydrogenation of oils, cotton seed, soybean, sunflower and linseed oils and their uses.

5. **Soaps and Detergents:** Methods of fat splitting, manufacture of laundry and toilet soaps, recovery and refining of glycerin, detergent: definition, classification and their manufacture, comparison between soaps and detergents, biodegradability of detergents.

6. **Biotechnology Related Industries:** Enzymes and micro-organism, production and application of enzyme, microbial activity, fermentation unit processes and unit control, instrumentation and control, recovery of fermentation products and waste treatment, manufacture of industrial alcohol and absolute alcohol, principle and production of citric acid, lactic acid, butyl alcohol, acetone and acetic acid.

7. **Surface Coating Industries:** Pigment - its classification and manufacture, paints - its constituents, functions and manufacturing process paint application and paint failure, printing ink - its classification and manufacture, varnishes, lacquers and enamels and its functions, industrial polishes.

8. **Chemical Explosives:** Definition, objective, classification and characteristics, principles of explosives technology, toxic chemical agents and propellants, industrial explosives (nitroglycerine, dynamite), military explosives - TNT, tertyl, picric acid, nitrocellulose, toxic chemicals and chemical vapors, propellants of rocket guided missiles.

9. **Rubber Industries:** Natural rubber - its production and processing, synthetic rubber - its classification, production of monomers and their polymerization processes, latex compounds, rubber compounding, vulcanization of rubber, different rubber processing chemicals and their functions.

10. **Agrochemical Industries:** Agrochemicals, their characteristics and composition, chemical pesticides manufacture and formulation of pesticides.

Books Recommended

1. Shreve's Chemical Process Industries, G. T. Austin.
2. Riegel's Handbook of Industrial Chemistry, J. A. Kent.
3. Industrial Organic Chemistry, K. Weissermel and H. J. Arpe.

CH 7462 Inorganic Process Industries (3 Credits)

Course Content

1. **Fundamentals in the Development of Chemical Industries:** General ideas about unit processes and unit operations, raw materials, process design, commercial energy sources, skilled manpower, catalysts, water as the basic process fluid, heat transfer, mass transfer, separation processes, concepts of consumption, production, and market evaluation, the balance of supply and demand, safety, environmental considerations, site and technology selection criteria, cost-benefit analysis.

2. **Chlor-alkali Industries:** Raw materials, manufacture of caustic soda, soda ash, sodium bicarbonate, chlorine, bleaching powder, sodium chlorite, environmental hazards of these chemicals.

3. **Fertilizer Industries:** Plant nutrients, classification of fertilizers, natural inorganic fertilizers, nitrogen fixation, artificial fertilizers, manufacture of ammonia, urea, ammonium sulfate, ammonium nitrate, action of urea as fertilizer, potassium fertilizer, calcium phosphate and other phosphatic fertilizers, potassium fertilizer, NPK fertilizer.

4. **Cement Industries:** Portland cement, raw materials, important process parameters for manufacturing a good cement clinker, methods of manufacturing Portland cement, sequence of operations, additives for cement, properties of cement, testing of cement, setting of cement, other types of cement, manufacture of gypsum, Plaster of Paris.

5. **Glass Industries:** Properties of glass, raw materials and fundamentals of glass industries, methods of manufacture, choice of the furnace, chemical reactions in the furnace, annealing, special glasses.

6. **Ceramic Industries:** Ceramics, properties of ceramics, basic raw materials, manufactures of ceramics, refractories, requisites of a good refractory, classification of refractories, properties of refractories, manufacture of refractories, types of refractory products.

7. **Acids:** Raw materials, manufacturing of hydrochloric, phosphoric, sulfuric acids, concentration and purification of acids, industrial uses of mineral acids, safety and hazards.

8. **Iron and Steel Industry:** Fundamentals of metallurgy, ores of iron, three commercial forms of iron, construction and operation of blast furnace, reactions in blast furnace, byproduct in blast furnace, classification of steel, steel manufacturing processes, effects of impurities on steel, phases in Fe-C system.

9. **Composite Materials:** Introduction, constitution, classification, fiber-reinforced composites.

10. **Inorganic Drugs:** Introduction, antacids, antimicrobials and astringents, arsenicals and cisplatin.

11. **Water treatment:** Water quality parameters, types of impurities present in water, effects of impurities in natural waters, methods of treatment of water for domestic and industrial purposes.

Books Recommended

1. Chemical Process Industries, R. N. Shreve and J. A. Brink, Jr.
2. Industrial Chemistry, B. K. Sharma.
3. Reagel's Handbook of Industrial Chemistry, J. A. Kent edited.
4. Shreve's Chemical Process Industries, G. T. Austin edited.
5. Materials Science and Engineering – An Introduction, W. D. Callister, Jr.
6. Inorganic Medicinal and Pharmaceutical Chemistry, J. H. Block and E. B. Roche.
7. Environmental Chemistry (Vol. 1 – 3), H. J. M. Bowen.

CH 7481 Environmental Chemistry (2 Credits)

Course Content

1. **Basic Concept of Environmental Chemistry and Its Scope:** Fundamental components and structure of the environment, lithosphere, hydrosphere, atmosphere and biosphere and their natural, chemical compositions, structure of the biosphere.

2. **Water Pollution:** General causes of water pollution, types of chemical pollutants in water, inorganics, organics, nutrients, pesticides, PCBs, PAHC, toxic heavy metals, radioactivity in water, detergents, etc.

3. **Water Treatment:** Coagulation, flocculation and filtration techniques, ion exchange purification of water, photo-oxidation, adsorption of chemical pollutants from dilute solution, electrochemical processes for water purification and reverse osmosis technology, sewerage and industrial waste water treatment.

4. **Atmospheric Chemistry and Air Pollution:** Nature of chemical pollutants in the atmosphere and their sources, chemical and photochemical reactions and their consequent effects - ozone depletion, greenhouse effect and damage to physical structures, climate change, acid rain and photochemical smog, control of atmospheric pollution.

5. **Solid Waste Management:** Major sources of solid wastes – industry, municipality, household, nuclear and hospital waste etc., incineration process and filtration, sanitary landfills and oxidation ponds, composting and sewerage treatments.

6. **Toxic Effect of Chemical Pollutants on Living Systems:** Toxic chemicals, metals: Pb, Cd, Hg, As, Cu etc., pesticides, chlorinated hydrocarbons, polyaromatic hydrocarbons, toxic gases like CO, H_2S, NO_2, HCN etc.

7. **Environmental Chemical Analysis:** Importance of analytical methods in environmental chemistry, uses of analytical methods in analyzing environmental samples.

8. **National Policy for the Protection of the Environment:** International laws of the seas, clean air and clean water acts, national environment quality standards (EQS), EEC and WHO guidelines for air and water quality.

Books Recommended

1. Environmental Chemistry, S. E. Manahan.
2. Air Quality, T. Godish.
3. Fundamental Concepts of Environmental Chemistry, G. S. Sodhi.
4. Environmental Analytical Chemistry, F. W. Fifield and P. J. Haines edited.
5. Environmental Chemistry, A. K. De.
6. Environmental Toxicology, M. Satake, Y. Mido, M. S. Sethi, S. A. Iqbal, H. Yasuhisa and S. Taguchi.

CH7482 Applied Physical Chemistry (2 Credits)

Course Content

1. **Fundamentals of Material Balances**: Process classification, balances, material balance calculations, balances on multiple-unit processes, recyle and bypass, balances on reactive systems, balances on reactive processes, combustion.

2. **Energy and Energy Balances**: Forms of Energy, Energy Balances on Closed Systems, Energy Balances on Open Systems at Steady State, Energy Balance Procedures.

3. **Homogeneous and Heterogeneous Catalysis in Chemical Industries**: Commonly Used Catalysts; Zeolites; Mixed Oxides, Noble Metal Catalysts, Preparation and Characterization, New Trends in Catalyst Development, Nano-Cluster Preparation; Micro-Porous Supports.

4. **Energy**: Conventional Sources; Coal, Petroleum, Natural Gases; Fuel Cells, Modern Need of Energy Forms; Commercial Production of Electricity, Gasoline, LPG.

5. **Energy of the Future**: The Energy Crisis; Coal Gasoline and Natural Gas-Gasoline; Underground Gasification of Coal.

6. **Alternative and Renewable Sources of Energy**: Solar Energy, Solar Cells, Bio-Gas, Gasohol, Wind Energy, Energy from Waves, Geothermal Energy.

Books Recommended

1. Elementary Principles of Chemical Processes, R. M. Felder and R. W. Rousseau.
2. Energy and Problems of a Technical Society, J. J. Kraushaar and R. A. Ristinen.
3. Energy Systems and Sustainability: Power for a Sustainable Future, G. Boyle, B. Everett and J. Ramage edited.

CH 7483 Medicinal Chemistry (2 Credits)

Course Content

1. Physico-chemical properties and biological activity.

2. Structural features and pharmacological activity.

3. Drug Metabolism.

4. Receptor site theory.

5. Theoretical Aspects of drug design.

6. **Chemical and Biological Aspects of the Following Classes of Drugs:** (a) Anaesthetics (Cocaine, Ecgonine, Procaine, Tetracacine, Lidocaine), (b) Antibacterial agents (Sulfamethoxazole, Sultanilamide, Sulfadiazine), (c) Antibiotics (β-lactam antibiotics ampicillin, amoxycillin, cloxacillin, floxacillin). (d) Anti cancer agents (Busulfan, mechloromethamine, 5-flurouracil, Methotrexale, (e) Doxorubicin, Duanorubicin, Dactinomycin, Vincristin, Venblastin). (f) Antidiabetic agents (Tolbutamide, Chlorpropamide, Tolazamide, Acetohexamide, Glyburide). (g) Cardiac agents (Cardiac glycosides and Related Drugs, Digitoxin, Digoxin, Diglialis, Gitalin) (h) Central nervous system stimulants (Amphetamine, Strychnine, Brucine). and (i) Depressants (Diazepam, Oxazepam, Clobazam, Nitrazepam, Barbiturates)

Book Recommended

1. Burger's Medicinal Chemistry, M. E. Wolff edited.
2. Principles of Medicinal Chemistry, W. O. Foye, T. L. Lemke and D. A. Williams edited.

CHL7403 Physical Chemistry Laboratory II (4 Credits)

Course Content

1. **Electrochemical Measurements:** (a) Potentiometric titration involving oxidation-reduction reactions, and acid-base neutralization (b) Determination of activity coefficients of electrolyte (c) Determination of transport numbers (d) Determination of decomposition potentials of the electrolytes (e) Determination of equilibrium constants from e. m. f. measurements.

2. **Study of Kinetics of Chemical Reactions:** Using (a) Polarimeter (b) Dilatometer (c) Conductance bridge (d) Manometer (e) Spectrophotometer and (f) Chemical analysis.

3. **Study of Phase Equilibria:** (a) Study of partially miscible system in presence and absence of impurities (b) Boiling temperature vs. composition diagram of completely miscible binary liquid pairs (c) Determination of cooling curves of binary solid system.

4. **Study of Surface Phenomena:** (a) Study of adsorption on solids from solutions (b) Study of adsorption at liquid surface by surface tension measurements (c) Study of surface films using Langmuir trough.

5. **Thermochemical Measurements:** Measurement of enthalpies of (a) combustion and (b) reaction.

6. **Spectroscopic Experiments:** (a) Study of electronic spectra of selected species (b) Verification of Beer-Lambert law and its application in quantitative analysis (c) Determination of the composition of a complex compound (d) Determination of stability constant of a complex compound (e) Study of atomic and molecular spectra (f) Determination of isosbestic point.
7. Measurement of quantum yields of some photochemical reactions.

Books Recommended

1. Practical Physical Chemistry, A. Faraday.
2. Experimental Physical Chemistry, G. P. Mathews.
3. Experiments in Physical Chemistry, F. Daniels, J. H. Matthews, P. Bender and R. A. Alberty.
4. Experiments in Physical Chemistry, J. M. Wilson, R. J. Newcomb, A. R. Denoro and R. M. W. Rickett.
5. Findlay's Practical Physical Chemistry, Edition revised by B. P. Levitt.
6. Experiments in Physical Chemistry, D. P. Shoemaker, C. W. Garland and J. W. Nibler.
7. Chemistry Experiments for Instrumental Methods, D. T. Sawer, W. R. Heinman and J. M. Beebe

CHL 7463 Industrial Chemistry Laboratory (2 Credits)

Course Contents

1. **Water Analysis:** Analysis of water for temporary and permanent hardness, total suspended solids, chloride content, dissolve oxygen, arsenic and lead.

2. **Industrial Materials:** Analysis of an iron and a calcium compound, analysis of coal for sulphur and quality specifications in terms of carbon content and inorganic residues.

3. **Environmental Samples:** Air particulate matters for total suspended solids, analysis of lead, calcium, copper and sulphur, air pollutants: SO_x and NO_x levels in air.

4. **Metals and Alloys:** Analysis of steel for manganese and sulphur.

5. **Analysis of Fats and Oils:** Fats and oil analysis for acid value, iodine value and saponification value.

6. **Analysis of Carbohydrates:** Analysis of cane sugar for glucose by Fehling's solution and Benedict solution methods, analysis of molasses for glucose content.

7. **Soaps and Detergents:** Analysis of soap for total acid and alkali, and free acid or free alkali values for quality control.

8. **Food and Drinks:** Analysis of milk for sugar and protein.

9. **Polymers:** Preparation of polymers, determination of molecular weight of a polystyrene sample by viscometer.

10. **Cosmetics:** Analysis of cosmetics.

Books Recommended

1. Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF.
2. A Text Book of Quantitative Inorganic Analysis, A. I. Vogel.
3. Comprehensive Practical Organic Chemistry, V. K. Ahluwalia and R. Aggarwal.
4. Preparative Methods of Polymer Chemistry, W. R. Sorenson and T. W. Campbell.