Semester-V

Chemistry MAJOR
Course code: CHEM5011 (3 and 4 Years)
Course title: Inorganic Chemistry
F.M. 75 (40+20+15)

Credit: 5

Course objective:
Development of knowledge for several basic and advanced topics of inorganicchemistry

Course outcome:
The course will help the students to develop a complete knowledge on radioactivity, co-ordination chemistry, transition elements, inorganic polymers as well as practical concept on chromatographic separation technique, gravimetric and spectrophotometric estimation

Theory (F.M. 40)
Credit 4

1. **Radioactivity**
   Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers. Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes.Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures. *12 hours*
2. **Co-ordination Chemistry-II**
   VB description and its limitations. Elementary Crystal Field Theory: splitting of dn configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion, Octahedral site stabilization energy (OSSE), spinel and inverted spinels, Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples). Magnetism and Colour: Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions. Racah parameter. Selection rules for electronic spectral

transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea). *24 hours*

3. **Chemistry of Transition Elements**
   General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry *12 hours*
4. **Inorganic Polymers**
   Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes. *12 hours*

Reference Books

1. Arnikar, H. J. Essentials of Nuclear Chemistry, New Age International, 1995.
2. Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008.
3. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
4. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
5. Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.
6. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.
7. Banerjee, S. P., Comprehensive Coordination Chemistry,Books& Allied Pvt. Ltd., 2019
8. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
9. Atkins, P., Overton, T., Rourke, J., Weller, M., Armstrong, F,. Shriver & Atkins, Inorganic Chemistry, Fifth Edition, Oxford University Press.

Practical (F.M. 20)

Credit 1

I. Chromatographic separation of metal ions

Paper chromatographic separation of following metal ions:

1. Ni (II) and Co (II)

2. Fe (III) and Al (III)

II. Gravimetric estimation

1. Estimation of nickel (II) using Dimethylglyoxime (DMG).

2. Estimation of copper as CuSCN

3. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminiumoxinate)

4. Estimation of chloride

III. Spectrophotometry

1. Measurement of 10Dq of 3d metal complexes by spectrophotometric method.

2. Determination of λmax of $KMnO_4$ and $K_2Cr_2O_7$.

Reference Books

1. Mendham, R.C., Denney, J.D., Baines, M. Thomas and Siva Sankar, B. Vogel's Text Book on Quantitative Chemical Analysis, 6/e, Pearson.
2. Nad, A.K., Mahapatra, B. & Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.
3. Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010.
4. Mukhopadhyay, R. & Chattejee, P. Advanced Practical Chemistry, Books & Allied(P) Ltd., 3rd Ed., 2007.

Chemistry MAJOR
Course code: CHEM5012 (3 and 4 Years)
Course title: Organic Chemistry
F.M 75 (40+20+15)

Credit: 5

Course objective:
Development of knowledge for several basic and advanced topics of organic chemistry

Course outcome:
The course will help the students to develop a complete knowledge on pericyclic reactions, retrosynthesis, polynuclear hydrocarbons and study of biomolecules as well as practical concept of volumetric estimation and chromatographic separation of organic sample

Theory (F.M. 40): Credit: 4

1. Pericyclic Reactions

Mechanism, stereochemistry, regioselectivity in case of

(i) Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.

(ii) Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.

(iii) Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

10 hours

2. The Logic of Organic Synthesis

(i) Retrosynthetic analysis: disconnections; synthons, donor and acceptor synthons; natural reactivity and umpolung; latent polarity in bifunctional compounds: consonant and dissonant polarity; illogical electrophiles and nucleophiles; synthetic equivalents; functional group interconversion and addition (FGI and FGA); C-C disconnections and synthesis: one-group and two group (1,2- to 1,6-diocarbonyl compounds), reconnection; protection and deprotection strategy (alcohol, amine, carbonyl, acid).

(ii) Strategy of ring synthesis: thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique.

(ii) Asymmetric synthesis: stereoselective and stereospecific reactions; diastereoselectivity and enantioselectivity (only definition); enantioselectivity: kinetically controlled MPV reduction; diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogenic centre: Cram's rule, Felkin-Anh model.

10 hours

3. Polynuclear aromatic hydrocarbons

Polynuclear hydrocarbons and their derivatives: synthetic methods include Haworth, Bardhan-Sengupta and other useful syntheses (with mechanistic details); fixation of double bonds and Fries rule; reactions (with mechanism) of naphthalene, anthracene, phenanthrene and their derivatives.

6 hours

4. Carbohydrates

Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions

(mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $–CH_2OH$ of aldoses, reduction to alditols, *Lobry de Bruyn-van Ekenstein* rearrangement; stepping–up (Kiliani-Fischer method) and stepping–down (Ruff's & Wohl's methods) of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.

12 hours

5. **Biomolecules**

(i) *Amino acids*: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction; resolution of racemic amino acids.

(ii) *Peptides*: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger & '*dansyl*' methods); partial hydrolysis; specific cleavage of peptides: use of CNBr.

(iii) *Nucleic acids*: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA.

12 hours

6. **Alkaloids and Terpenoids**

General studies of terpenenoids and alkaloids; biosynthesis of terpenes; determination of structures of citral, nerol, α-terpineol, piperin, ephedrine and coniine 10 *hours*

Reference Books

1. Warren, S, Organic Synthesis:The Disconnection approach, Wiley student Ed., 2013.
2. Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley, 2009.
3. Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.
4. Gilchrist, T. L. & Storr, R. C. Organic Reactions and Orbital symmetry, Cambridge University Press.
5. Nasipuri, D, Stereochemistry of organic compounds, New Age International Publishers, , 2014.

6. Sen Gupta, S, basic Stereochemistry of Organic molecules, Oxford University press, 2014.
7. Singh, S & Singh, J, Photochemistry and Pericyclic Reactions, New Age International Publishers, 3rd Ed., 2010.
8. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
9. Finar, I. L. Organic Chemistry (Volume 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press.
12. Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.
13. Kar, R. K. Fundamentals of Organic Synthesis: The Retrosynthetic Analysis, New Central Book Agency, 2007.
14.

Practical (F.M. 20)
Credit:1

I. Volumetric Estimation:

(i) Estimation of Glucose using Fehling's solution
(ii) Estimation of Ascorbic acid (Vitamin-C) in reduced form
(iii) Estimation of Aniline using $KBrO_3$-KBr mixture
(iv) Estimation of Phenol using $KBrO_3$-KBr mixture
(v) Estimation of saponification value of oil/fat/ester

II. Chromatographic Separations

(i) TLC separation of a mixture containing 2/3 amino acids
(ii) TLC separation of a mixture of dyes (fluorescein & methylene blue)
(iii) Column chromatographic separation of mixture of dyes
(iv) Paper chromatographic separation of a mixture containing 2/3 amino acids

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson.
2. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007).

3. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
4. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.
5. Mukhopadhyay, R & Chatterjee, P, Advanced Practical Chemistry, Books & Allied (P) Ltd., 3rd Ed., 2007.
6. Manna, A.K., Practical Organic Chemistry, Books & Allied (P) Ltd., 2nd Ed., 2020.

Chemistry MAJOR
Course code: CHEM5013 (3 and 4 Years)
Course title: Physical Chemistry

Credit: 5

F.M. 75 (40+20+15)

Course objective:
Development of theoretical and practical knowledge for several basic and advanced topics of physical chemistry
Course outcome:
The course will help the students to develop a complete knowledge on crystal structure, polymers, dipole moment, polarizability, applications of quantum mechanics, statistical thermodynamics and surface phenomena

Theory (F.M. 40) Credit 4

1. Crystal Structure

Bravais Lattice and Laws of Crystallography: Types of solid, Bragg's law of diffraction; Laws of crystallography (Haüy's law and Steno's law); Permissible symmetry axes in crystals; Lattice, space lattice, unit cell, crystal planes, Bravais lattice. Packing of uniform hard sphere, close packed arrangements (fcc and hcp); Tetrahedral and octahedral voids.

Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of d_{hkl}; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation)

Determination of crystal structure: Powder method; Structure of NaCl and KCl crystals

10 hours

2. Polymers

Classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers, Criteria for synthetic polymer formation; classification of

polymerization processes, Functionality, Extent of reaction and Degree of polymerization – relationship.

Kinetics of Polymerization – Condensation and free-radical Addition Polymerization (only), Molecular weights of polymers, Determination of molecular weights by viscometry and osmometry methods, Molecular weight distribution and its significance. Polydispersity index

Preparation, Structures, Properties of few polymers (Physical, Thermal, Flow & Mechanical Properties) - polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride), Polyamides, Phenol formaldehyde resins (Bakelite, Novalac)

8 hours

3. Dipole moment and Polarizability

Polarizability of atoms and molecules, dielectric constant and polarisation, molar polarisation for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation (both without derivation) and their application; Determination of dipole moments

6 hours

4. Surface phenomena

Adsorption: Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm (no derivation required); Gibbs adsorption isotherm and surface excess; Heterogenous catalysis (single reactant); Zero order and fractional order reactions

Colloids: Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, Coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method; Stability of colloids and zeta potential; Micelle, surfactants, reverse micelleand emulsions

12 hours

5. Quantum mechanics-II

Particle in a box: setting up of Schrödinger equation for one-dimensional particle in box and its solution; comparison with free particle eigenfunctions and eigenvalues. properties of PB wave functions (normalisation, orthogonality, probability distribution); expectation values of x, x^2, p_x and p_x^2 and their significance in relation to the uncertainty principle; extension of the problem to two and three dimensions and the concept of degenerate energy levels.

Simple Harmonic Oscillator: setting up of the Schrödinger stationary equation, energy expression (without derivation), expression of wave function for n = 0 and n = 1 (without derivation) and their characteristic features

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component

Rigid rotor model of diatomic molecule: Schrödinger equation, transformation to spherical polar coordinates, Separation of variables, Spherical harmonics, Discussion of solutions

Qualitative treatment of hydrogen atom and hydrogen-like ions: Setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression); Average and most probable distances of electron from nucleus; Setting up of Schrödinger equation for many-electron atoms (He, Li)

16 hours

6. Statistical Thermodynamics

Configuration: Macrostates, microstates and configuration; calculation with harmonic oscillator; variation of W with E, equilibrium configuration, Boltzmann distribution, thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation), applications to barometric distribution; concept of ensemble - canonical ensemble; Partition function, molecular partition function and thermodynamic properties, Maxwell's speed distribution; Gibbs' paradox

8 hours

Reference Books

1. Rakshit, P.C., Physical Chemistry, Sarat Book Distributors, 7th Ed.
2. Kapoor, K. L., A Textbook of Physical Chemistry, Volume-4, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.
3. Kapoor, K., A Textbook of Physical Chemistry, Volume-5, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.
4. Castellan, G. W. Physical Chemistry, Narosa
5. Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press.
6. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
7. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
8. Moore, W. J. Physical Chemistry, Orient Longman.
9. Mortimer, R. G. Physical Chemistry, Elsevier.

10. Engel, T. & Reid, P. Physical Chemistry, Pearson.
11. Maron, S.H., Prutton, C. F., Principles of Physical Chemistry, McMillan.
12. Puri, B.R., Sharma, L.R., and Pathania, M.S., Principles of Physical Chemistry, Vishal Publishing Co.
13. Levine, I. N. Quantum Chemistry, PHI.
14. Atkins, P.W. Molecular Quantum Mechanics, Oxford.

Practical (F.M. 20) Credit 1

1. Conductometric titration with standardization of
   (i) Strong acid-strong base
   (ii) Weak acid-strong base
   (iii) Precipitation reaction
2. Kinetics of saponification of ester by conductometric method
3. Conductometric verification of Ostwald dilution law and determination K_a for a weak acid
4. Determination of solubility product of a sparingly soluble salt by titrimetric method
5. Determination of Equilibrium constant (K_c) of the reaction $KI + I_2 = KI_3$ by partition method
6. Determination of partition co-efficient (K_d) of a solute in two immiscible solvents

Reference Books

1. Nad, A.K., Mahapatra, B. &Ghosal, A.An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.
2. Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010.
3. Mukhopadhyay, R. & Chatterjee, P. Advanced Practical Chemistry, Books &Allied (P) Ltd., 3rd Ed., 2007.
4. Maity, S. K. & Ghosh, N. K. Physical Chemistry Practical, New Central Book Agency (P) Ltd. 2012