Syllabus of 3-Year Degree/4-Year Honours in Chemistry
National Education Policy-2020
With effect from 2023-2024

Semester I

Course Code	Course title	Name of the course	Credit of course	Class hours/ week	Evaluation	Internal Assessment	Total
CHEM-MAT-1	Inorganic -1A & Physical-1A	Major (Theory)	4	4	40	15	75
CHEM-MAP-1	Inorganic-1A & Physical-1A	Major (Practical)	2	4	20		
CHEM-MIT-1A	Inorganic-1& Organic-1	Minor-1(Theory)	3	3	25	10	50
CHEM-MIP-1A	Inorganic-1& Organic-1	Minor-1(Practical)	1	2	15		
CHEM-MDC-1	Chemistry in Daily Life	Multidisciplinary course	3	3	35	10	45
AEC	x	Ability Enhancement Course					
CHEM-SEC-1	Pharmaceutical Chemistry	Skill Enhancement course	3	3	35	10	45
To be determined		Value Added course	4	4	40	10	50
Total			20	25			265

Semester II

Course Code	Course title	Name of the course	Credit of course	Class hours/week	Evaluation	Internal Assessment	Total
CHEM-MAT-2	Organic-1	Major (Theory)	4	4	40	15	75
CHEM-MAP-2	Organic -1	Major (Practical)	2	4	20		
CHEM-MIT-2A	Inorganic -1 & Organic-1	Minor-2 (Theory)	3	3	25	10	50
CHEM-MIP-2A	Inorganic-1 & Organic-1	Minor-2 (Practical)	1	2	15		
CHEM-MDC-2	Basic Industrial Chemistry	Multidisciplinary course	3	3	35	10	45
AEC-1	Communicative English	Ability Enhancement course	4	4	40	10	50
CHEM-SEC-2	IT Skills for Chemist	Skill Enhancement course	3	3	35	10	45
		Summer Internship					
Total			20	23			265

Semester III

Course Code	Course title	Name of the course	Credit of course	Class hours/week	Evaluation	Internal Assessment	Total
CHEM-MAT-3	Inorganic-1B& Physical-1B	Major (Theory)	4	4	40	15	75
CHEM-MAP-3	Inorganic-1B& Physical-1B	Major (Practical)	2	4	20		
CHEM-MIT-1B	Physical-1&Inorganic-2	Minor-1 (Theory)	3	3	25	10	50
CHEM-MIP-1B	Physical-1 & Inorganic-2	Minor-1 (Practical)	1	2	15		
CHEM-MDC-3	Basic Concept of Clinical Biochemistry	Multidisciplinary course	3	3	35	10	45
AEC	x	Ability Enhancement Course					
CHEM-SEC-3	Basic Analytical Chemistry	Skill Enhancement course	3	3	35	10	45
To be determined		Value Added course	4	4	40	10	50
Total			20	23			265

Semester IV

Course Code	Course title	Name of the course	Credit of course	Class hours/week	Evaluation	Internal Assessment	Total
CHEM-MAT-4	Organic-2	Major (Theory)	4	4	40	15	75
CHEM-MAP-4	Organic -2	Major(Practical)	2	4	20		
CHEM-MAT-5	Physical-2	Major (Theory)	4	4	40	15	75
CHEM-MAP-5	Physical -2	Major(Practical)	2	4	20		
CHEM-MIT-2B	Physical-1& Inorganic -2	Minor-2 (Theory)	3	3	25	10	50
CHEM-MIP-2B	Physical-1& Inorganic-2	Minor-2(Practical)	1	2	15		
X	X	Multidisciplinary course	X				
AEC-2	NIL	Ability Enhancement course	4	4	40	10	50
X	X	Skill Enhancement course					
To be determined		Summer Internship					
Total			20	25			250

Semester V

Course Code	Course title	Name of the course	Credit of course	Class hours/week	Evaluation	Internal Assessment	Total
CHEM-MAT-6	Inorganic-2	Major (Theory)	4	4	40	15	75
CHEM-MAP-6	Inorganic -2	Major(Practical)	2	4	20		
CHEM-MAT-7	Physical-3	Major (Theory)	6	6	60	15	75
CHEM-MIT-3	Physical-2 & Organic-2	Minor-1/ Minor-2 (Theory)	3	3	25	10	50
CHEM-MIP-3	Physical-2 &Organic-2	Minor-1/ Minor-2 (Practical)	1	2	15		
Total			16	21			200

Semester VI

Course Code	Course title	Name of the course	Credit of course	Class hours/week	Evaluation	Internal Assessment	Total
CHEM-MAT-8	Inorganic-3	Major (Theory)	6	6	60	15	75
CHEM-MAT-9	Organic-3	Major (Theory)	6	6	60	15	75
CHEM-MAP-10	Inorganic-3 + Physical-3 + Organic-3	Major(Practical)	Inorganic-2 + Physical-2 + Organic-2	12	60	15	75
		Outreach/ Internship	2				
Total			20	24			225

Semester VII

Course Code	Course title	Name of the course	Credit of course	Class hours/week	Evaluation	Internal Assessment	Total
CHEM-MAT-11	Inorganic-4	Major (Theory)	5	5	50	15	75
CHEM-MAP-11	Inorganic-4	Major (Practical)	1	2	10		
CHEM-MAT-12	Physical-4	Major (Theory)	5	5	50	15	75
CHEM-MAP-12	Physical-4	Major(Practical)	1	2	10		
CHEM-MAT-13	Organic-4	Major (Theory)	5	5	50	15	75
CHEM-MAP-13	Organic-4	Major(Practical)	1	2	10		
CHEM-MIT-4	Physical-3 & Inorganic - 3	Minor-1/ Minor-2 (Theory)	3	3	25	10	50
CHEM-MIP-4	Physical-3 & Inorganic - 3	Minor-1/ Minor-2 (Practical)	1	2	15		
Total			22	29			275

Semester VIII

Course Code	Course title	Name of the course	Credit of course	Class hours/week	Evaluation	Internal Assessment	Total
CHEM-MAT-14	Inorganic-5	Major (Theory)	4	4	40	10	50
CHEM-MAT-15	Physical-5	Major (Theory)	4	4	40	10	50
CHEM-MAT-16	Organic -5	Major (Theory)	4	4	40	10	50
*CHEM-MAT-17	Inorganic -6 & Physical-6	Major (Theory)	6	6	60	15	75
*CHEM-MAT-18	Organic-6	Major (Theory)	3	3	30	15	75
*CHEM-MAP-18	Inorganic-6, Physical-6 & Organic-6	Major (Practical)	Inorganic -1 + Physical - 1 + Organic - 1	6	30		
Total			24	28			300

***Not applicable for UG Honours with Research Students but they will perform Research Poject / Dissertation of 12 credits.**

Semester – I

Course Code: CHEM-MAT-1

Course Title: Inorganic-1A & Physical -1A

Inorganic-1A

1. Atomic Structure:

(16L)

Bohr's model and atomic spectrum of hydrogen, Limitations of Bohr's model and Sommerfeld's modifications, de Broglie's concept, Heisenberg's uncertainty principle and its significance, Time independent Schrödinger's wave equation (without application and solution detail), Significance of ψ and ψ^2, Radial and angular wave functions for hydrogen atom (qualitative idea), radial probability distribution curves, shapes of s, p, d and f orbitals (qualitative idea), Quantum numbers and their significance, Pauli's exclusion principle, aufbau principle and limitations, Hund's rules, exchange energy, Electronic configurations of atoms. Elementary idea of microstates.

2. Periodic properties :

(14L)

Modern IUPAC periodic table and classification of elements in the table; Effective nuclear charge and its calculation using Slater's rules; Atomic radii, Ionic radii and Pauling's method for determining univalent ionic radii; Electronegativity (Pauling's, Mulliken's and Allred-Rochow's scale) and its applications, Ionization energy, Electron affinity and factors influencing these properties; Group trends and periodic trends of these properties with reference to s, p and d-block elements, Inert pair effect.

Reference Books:

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
3. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications, 1962.
4. Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
6. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
7. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
8. Atkins, P.W. & Paula, J. Physical Chemistry, Oxford Press, 2006.
9. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
10. Winter, M. J., The Orbitron, http:// winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
11. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).
12. Das, A. K., Fundamental Concepts of Inorganic Chemistry, Vol-1, Third Edition, CBS Publishers and Distributors.

Physical-1A

1. Kinetic Theory and Gaseous state
(18L)

Kinetic Theory of gases: Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules).

Maxwell's distribution of speed and energy: Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Calculation of number of molecules having energy $\geq \varepsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

Real gas and virial equation: Deviation of gases from ideal behavior; compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behaviour, other equations of state (Berthelot, Dieterici); Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; virial equation of state; van der Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard - Jones potential - elementary idea).

2. Chemical Thermodynamics - I
(12L)

Zeroth and 1st law of Thermodynamics: Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics; Concept of heat, work, internal energy and statement of first law; enthalpy, H; relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions; Joule's experiment and its consequence.

Thermochemistry: Standard states; Heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; Laws of thermochemistry; bond energy, bond dissociation energy and resonance energy from thermochemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions.

Reference Books:

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
2. Castellan, G. W. Physical Chemistry, Narosa.
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
4. Engel, T. & Reid, P. Physical Chemistry, Pearson.
5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
6. Maron, S. & Prutton Physical Chemistry.
7. Ball, D. W. Physical Chemistry, Thomson Press.
8. Mortimer, R. G. Physical Chemistry, Elsevier.
9. Laidler, K. J. Chemical Kinetics, Pearson.
10. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
11. Rakshit, P.C., Physical Chemistry Sarat Book House.
12. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.
13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
14. Clauze & Rosenberg, Chemical Thermodynamics

Course Code: CHEM-MAP-1
Course Title: Inorganic-1A & Physical -1A

Inorganic-1A

1. Preparation of primary standard solutions of titrants
2. Estimation of carbonate and hydroxide present together in a mixture
3. Estimation of carbonate and bicarbonate present together in a mixture

Reference Book

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

Physical-1A

1. Determination of pH of unknown solution (buffer), by color matching method.
2. Determination of heat of neutralization of a strong acid by a strong base.
3. Determination of heat of solution of oxalic acid from solubility measurement.

Reference Books

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009).
2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson.
3. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007).
4. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency.
5. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Course Code: CHEM-MIT-1A (Minor-1)
Course Title: Inorganic-1 & Organic-1

Inorganic-1

1. Atomic Structure (6L)

Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen and Bohr's model, Sommerfeld's model, quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many-electron atoms, Aufbau principle and its limitations.

2. Chemical Periodicity (6L)

Classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and f-block elements. Positions of hydrogen and noble gases in the periodic table. Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group-wise variation of above properties in respect of s- and p- block elements.

3. Acids and bases (6L)

Brönsted–Lowry concept, conjugate acids and bases, relative strengths of acids and bases, effects of substituent and solvent, differentiating and levelling solvents. Lewis acid-base concept, classification of Lewis acids and bases, Lux-Flood concept and solvent system concept. Hard and soft acids and bases (HSAB concept), applications of HSAB process.

4. Redox reactions (4L)

Balancing of equations by oxidation number and ion-electron method, Standard electrode potential, formal potential, redox indicator and redox titrations.

Organic-1

1. Fundamentals of Organic Chemistry (5L)

Electronic displacements: Inductive effect, resonance and hyperconjugation; cleavage of bonds: homolytic and heterolytic; structure of organic molecules on the basis of VBT; nucleophiles and electrophiles; reactive intermediates: carbocations, carbanions and free radicals.

2. Stereochemistry (5L)

Different types of isomerism; geometrical and optical isomerism; concept of chirality and optical activity (up to two carbon atoms); asymmetric carbon atom; elements of symmetry (plane and centre); interconversion of Fischer and Newman representations; enantiomerism and diastereomerism, meso compounds; threo and erythro, D and L, cis and trans nomenclature; CIP Rules: R/S (upto 2 chiral carbon atoms) and E/Z nomenclature.

3. Nucleophilic Substitution and Elimination Reactions (4L)

Nucleophilic substitutions: S_N1 and S_N2 reactions; eliminations: E1 and E2 reactions (elementary mechanistic aspects); Saytzeff and Hofmann eliminations; elimination *vs* substitution.

4. Aliphatic Hydrocarbons (9L)

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structures.

Alkanes (up to 5 Carbons): Preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: mechanism for free radical substitution: halogenation.

Alkenes: (up to 5 Carbons): Preparation: elimination reactions: dehydration of alcohols and dehydrohalogenation of alkyl halides; *cis*- alkenes (partial catalytic hydrogenation) and *trans*- alkenes (Birch reduction). Reactions: cis-addition (alkaline $KMnO_4$) and trans-addition (bromine) with mechanism, addition of HX [Markownikoff's (with mechanism) and anti-Markownikoff's addition], hydration, ozonolysis, oxymercuration-demercuration and hydroboration-oxidation reaction.

Alkynes: (up to 5 Carbons): Preparation: acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides. Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$.

Reference Books

1. Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. Concepts and Models in Inorganic Chemistry, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education Ind
5. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
6. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
7. Madan, R. L. Organic Chemistry, S. Chand & Sons.
8. Wade, L. G., Singh, M. S., Organic Chemistry.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
12. Sengupta, Subrata. Basic Stereochemistry of Organic molecules.
13. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
14. Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.

Course Code: CHEM-MIP-1A (Minor-1)
Course Title: Inorganic-1 & Organic-1

Inorganic-1

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with $KMnO_4$.
3. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
4. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$.

Organic-1

Qualitative Analysis of Single Solid Organic Compounds

1. Detection of special elements (N, Cl, and S) in organic compounds.
2. Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH, dil. $NaHCO_3$)
3. Detection of functional groups: Aromatic-NO_2, Aromatic-NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), phenolic-OH in solid organic compounds.

Reference Books

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Das, S. C., Chakraborty, S. B., Practical Chemistry.
3. Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
4. Ghosal, Mahapatra & Nad, An Advanced course in practical Chemistry, New Central Book Agency.
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
6. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.
7. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.

Course Code: CHEM-MDC-1
Course Title: Chemistry in Daily Life

1. Food additives **(6L)**

Food flavour, food colour, food preservatives, artificial sweeteners, acidulants, alkalies, edible emulsifiers and edible foaming agents, sequestrants – uses and abuses of these substances in food beverages.

2. Vitamins **(4L)**

Basic idea on vitamins, uses of some vitamins: Vit-A, Vit-K, Vit-E, Vit-C, Vit-D and Vit-B_{12}

3. Drugs **(8L)**

Concept and necessity of drugs and pharmaceuticals; uses: aspirin, paracetamol, sulphadiazine, quinine, chloroquine, phenobarbital, metronidazole.

4. Fats and oils **(8L)**

Natural fat, edible and inedible oil of vegetable origin; common fatty acids; glycerides; hydrogenation of unsaturated oil, production of vanaspati and margarine.

5. Soaps and detergents **(6L)**

Production of toilet and washing soaps; enzyme-based detergents, detergent powder; liquid soaps.

6. Pesticides **(7L)**

Common pesticides: production, applications and residual toxicity of gammaxane, aldrin, parathion, malathion, DDT, paraquat, decamethrin.

7. Glass and ceramics **(6L)**

Definition and manufacture of glasses, optical glass and coloured glass; clay and feldspar, glazing and vitrification, glazed porcelain, enamel.

Reference Books

1. Gayatri Baidya, Textbook of Food Chemistry, Book Rivers.
2. Thapar, Food Chemistry, Pacific Book International.
3. Sengupta, S. Application Oriented Chemistry, Book Syndicate Pvt. Ltd., 2000.
4. Singh, K. Chemistry in Daily Life: Third Edition Kindle Edition.
5. Lassar-Cohn, Chemistry in Daily Life, Publisher, Read Books, 2007.
4. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
5. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
6. Madan, R. L. Organic Chemistry, S. Chand & Sons.
7. Ekambaram, S. General Chemistry, Pearson.
8. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
9. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Gangopadhyay, P. K. Application Oriented Chemistry, Book Syndicate.
11. Mondal, A. K & Mondal, S. Degree Applied Chemistry, Sreedhar Publications.
12. Banerjee, S. P. A Text Book of Analytical Chemistry, The New Book Stall.

Course Code: CHEM-SEC-1
Course Title: Pharmaceutical Chemistry

1. Drugs & Pharmaceuticals: (27L)

Basic concepts of drug discovery, design and development; Synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti- inflammatory agents (Aspirin, paracetamol, lbuprofen); antibiotics (Chloramphenicol); antibacterial and antifungal agents (Sulphonamides; Sulphanethoxazol, Sulphacetamide, Trimethoprim); antiviral agents (Acyclovir), Central Nervous System agents (Phenobarbital, Diazepam),Cardiovascular (Glyceryl trinitrate), antilaprosy (Dapsone), HIV-AIDS related drugs (AZT- Zidovudine).

2. Fermentation: (10L)

Aerobic and anaerobic fermentation. Production of (i) Ethyl alcohol and citric acid, (ii) Antibiotics; Penicillin, Cephalosporin, Chloromycetin and Streptomycin, (iii) Lysine, Glutamic acid, Vitamin B2, Vitamin B12 and Vitamin C.

3. Hands on Practical: (8L)

Preparation of Aspirin and its analysis.
Preparation of magnesium bisilicate (Antacid).

Reference Books

1. Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press, UK, 2013.
2. Singh, H. & Kapoor, V.K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi, 2012.
3. Foye, W.O., Lemke, T.L. & William, D.A.: Principles of Medicinal Chemistry, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.
4. Ghosh, J., A Textbook of Pharmaceutical Chemistry, S. Chand Publishers.

Semester II

Course Code: CHEM-MAT-2
Course Title: Organic-1

1. Bonding and Physical Properties: (18L)

Valence Bond Theory:

Concept of hybridisation, shapes of molecules, resonance (including hyperconjugation); calculation of formal charges and double bond equivalent (DBE); orbital pictures of bonding (sp^3, sp^2, sp: C-C, C-N & C-O systems and s-cis and s-trans geometry for suitable cases).

Electronic displacements:

Inductive effect, field effect, mesomeric effect, resonance energy; bond polarization and bond polarizability; electromeric effect; steric effect,steric inhibition of resonance.

MO theory:

Qualitative idea about molecular orbitals, bonding and antibonding interactions, idea about σ, σ*, π, π*, n – MOs; basic idea about Frontier MOs (FMO); concept of HOMO, LUMO and SOMO; interpretation of chemical reactivity in terms of FMO interactions; sketch and energy levels of π MOs of i) acyclic p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems), ii) cyclic p orbital system (neutral systems: [4], [6]-annulenes; charged systems: 3-, 4-, 5-membered ring systems); Hückel's rules for aromaticity up to [10]-annulene (including mononuclear heterocyclic compounds up to 6-membered ring); concept of antiaromaticity and homoaromaticity; non-aromatic molecules; Frost diagram; elementary idea about α and β; measurement of delocalization energies in terms of β for buta-1,3-diene, cyclobutadiene, hexa-1,3,5-triene and benzene.

Physical properties:

Influence of hybridization on bond properties: bond dissociation energy (BDE) and bond energy; bond distances, bond angles; concept of bond angle strain (Baeyer's strain theory); melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular forces; polarity of molecules and dipole moments; relative stabilities of isomeric hydrocarbons in terms of heat of hydrogenation, heat of combustion and heat of formation.

2. General Treatment of Reaction Mechanism – I : (24L)

Mechanistic classification:

Ionic, radical and pericyclic (definition and example); reaction type: addition, elimination and substitution reactions (definition and example); nature of bond cleavage and bond formation: homolytic and heterolytic bond fission, homogenic and heterogenic bond formation; curly arrow rules in representation of mechanistic steps; reagent type: electrophiles and nucleophiles (elementary idea); electrophilicity and nucleophilicity in terms of FMO approach.

Reactive intermediates:

Carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes, benzyne, nitrenes: generation and stability, structure using orbital picture and electrophilic/nucleophilic behavior of reactive intermediates (elementary idea).

3. Stereochemistry-I: **(18L)**

Bonding geometries of carbon compounds and representation of molecules:

Tetrahedral nature of carbon and concept of asymmetry; Fischer, sawhorse, flying-wedge and Newman projection formulae and their inter translations.

Concept of chirality and symmetry:

Symmetry elements and point groups (C_{nh}, C_{nv}, C_n, D_{nh}, D_{nd}, D_n, S_n (C_s, C_i); molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of epimers; concept of stereogenicity, chirotopicity and pseudoasymmetry; chiral centres and number of stereoisomerism: systems involving 1/2/3-chiral centre(s) (AA, AB, ABA and ABC types).

Relative and absolute configuration:

D/L and R/S descriptors; erythro/threo and meso nomenclature of compounds; syn/anti nomenclatures for aldols; E/Z descriptors for C=C, conjugated diene, triene, C=N and N=N systems; combination of R/S- and E/Z- isomerisms.

Optical activity of chiral compounds:

Optical rotation, specific rotation and molar rotation; racemic compounds, racemisation (through cationic, anionic, radical intermediates and through reversible formation of stable achiral intermediates); resolution of acids, bases and alcohols via diastereomeric salt formation; optical purity and enantiomeric excess; invertomerism of chiral trialkylamines.

Reference Books:

1. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.
2. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
3. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
4. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
6. Finar, I. L. Organic Chemistry (Vol. II), Pearson (2002).
7. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
8. Eames, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
9. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
10. Graham Solomons, T. W.; Fryhle, C. B. & Snyder, S. A. *Organic Chemistry*, 12th Ed., John Wiley & Sons (2017).
11. McMurry, J. E. *Fundamentals of Organic Chemistry*, 7th Ed., Cengage Learning India Edition (2013).

Course Code: CHEM-MAP-2
Course Title: Organic-1

1. Separation:
Based upon solubility, by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. $NaHCO_3$, etc., of components of a binary solid mixture; purification of any one of the separated components by crystallization and determination of its melting point. The composition of the mixture may be of the following types: Benzoic acid/p-Toluidine; p-Nitrobenzoic acid/p-Aminobenzoic acid; p-Nitrotolune/p-Anisidine; etc.

2. Determination of boiling point:
Determination of boiling point of common organic liquid compounds e.g., ethanol, cyclohexane, chloroform, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide, etc. [Boiling point of the chosen organic compounds should preferably be less than 160 °C]

3. Identification of a Pure Organic Compound by chemical test(s):
Solid compounds: Oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.
Liquid Compounds: Formic acid, acetic acid, methyl alcohol, ethyl alcohol, acetone, aniline, N,N-dimethylaniline, benzaldehydeand nitrobenzene.

Reference Books:

1. Bhattacharyya, R. C, A Manual of Practical Chemistry.
2. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
3. Mann, F. G. & Saunders, B. C. Practical Organic Chemistry, Pearson Education (2009).
4. Furniss, B. S., Hannaford, A.J., Smith, P. W. G., Tatchell, A. R. Practical Organic Chemistry, 5th Ed., Pearson (2012).

Course Code: CHEM-MIT-2A (Minor-2)
Course Title: Inorganic-1 & Organic-1

Inorganic-1

1. Atomic Structure **(6L)**

Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen and Bohr's model, Sommerfeld's model, quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many-electron atoms, Aufbau principle and its limitations.

2. Chemical Periodicity **(6L)**

Classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and f-block elements. Positions of hydrogen and noble gases in the periodic table. Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group-wise variation of above properties in respect of s- and p- block elements.

3. Acids and bases **(6L)**

Brönsted–Lowry concept, conjugate acids and bases, relative strengths of acids and bases, effects of substituent and solvent, differentiating and levelling solvents. Lewis acid-base concept, classification of Lewis acids and bases, Lux-Flood concept and solvent system concept. Hard and soft acids and bases (HSAB concept), applications of HSAB process.

4. Redox reactions **(4L)**

Balancing of equations by oxidation number and ion-electron method, Standard electrode potential, formal potential, redox indicator and redox titrations.

Organic-1

1. Fundamentals of Organic Chemistry **(5L)**

Electronic displacements: Inductive effect, resonance and hyperconjugation; cleavage of bonds: homolytic and heterolytic; structure of organic molecules on the basis of VBT; nucleophiles and electrophiles; reactive intermediates: carbocations, carbanions and free radicals.

2. Stereochemistry **(5L)**

Different types of isomerism; geometrical and optical isomerism; concept of chirality and optical activity (up to two carbon atoms); asymmetric carbon atom; elements of symmetry (plane and centre); interconversion of Fischer and Newman representations; enantiomerism and diastereomerism, meso compounds; threo and erythro, D and L, cis and trans nomenclature; CIP Rules: R/S (upto 2 chiral carbon atoms) and E/Z nomenclature.

3. Nucleophilic Substitution and Elimination Reactions **(4L)**

Nucleophilic substitutions: S_N1 and S_N2 reactions; eliminations: E1 and E2 reactions (elementary mechanistic aspects); Saytzeff and Hofmann eliminations; elimination vs substitution.

4. Aliphatic Hydrocarbons (9L)

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structures.

Alkanes (up to 5 Carbons): Preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: mechanism for free radical substitution: halogenation.

Alkenes: (up to 5 Carbons): Preparation: elimination reactions: dehydration of alcohols and dehydrohalogenation of alkyl halides; cis alkenes (partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alkaline $KMnO_4$) and trans-addition (bromine) with mechanism, addition of HX [Markownikoff's (with mechanism) and anti-Markownikoff's addition], hydration, ozonolysis, oxymercuration-demercuration and hydroboration-oxidation reaction.

Alkynes: (up to 5 Carbons): Preparation: acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides. Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$.

Reference Books

1. Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. Concepts and Models in Inorganic Chemistry, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education Ind
5. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
6. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
7. Madan, R. L. Organic Chemistry, S. Chand & Sons.
8. Wade, L. G., Singh, M. S., Organic Chemistry.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
12. Sen Gupta, Subrata. Basic Stereochemistry of Organic molecules.
13. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
14. Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.

Course Code: CHEM-MIP-2A (Minor-2)
Course Title: Inorganic-1 & Organic-1

Inorganic-1

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with $KMnO_4$.
3. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
4. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$.

Organic-1

Qualitative Analysis of Single Solid Organic Compounds:

1. Detection of special elements (N, Cl, and S) in organic compounds.
2. Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH, dil. $NaHCO_3$)
3. Detection of functional groups: Aromatic-NO_2, Aromatic-NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), phenolic -OH in solid organic compounds.

Reference Books

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Das, S. C., Chakraborty, S. B., Practical Chemistry.
3. Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
4. Ghosal, Mahapatra & Nad, An Advanced course in practical Chemistry, New Central Book Agency.
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
6. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.
7. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.

Course Code: CHEM-MDC-2
Course Title: Basic Industrial Chemistry (Multidisciplinary Course)

1. Fuels **(9L)**

Classification of fuel; heating values; origin of coal, carbonization of coal, coal gas, producer gas, water gas, coal based chemicals; origin and composition of petroleum, petroleum refining, cracking, knocking, octane number, antiknock compounds, kerosene, liquefied petroleum gas (LPG), liquefied natural gas (LNG); petrochemicals (C1 to C3 compounds and their uses).

2. Fertilizers **(5L)**

Manufacture of ammonia and ammonium salts, urea, superphosphate, bio-fertilizers.

3. Cement **(5L)**

Portland cement: composition and setting of cement, white cement.

4. Polymers **(9L)**

Basic concept, structure and types of plastics, polythene, polystyrene, phenol-formaldehydes, PVC; manufacture, physical properties and uses of natural rubber, synthetic rubber, silicone rubber; synthetic fibres, nylon-66, polyester, terylene, rayon; foaming agents, plasticizers and stabilizers.

5. Paints and varnishes **(9L)**

Primary constituents; formulation of paints; binders and solvents for paints; oil based paints, latex paints, alkyd resin paint. Constituents of varnishes; formulation of varnishes.

6. Dyes and pigments **(8L)**

Basic idea on dyes and pigments, Natural and synthetic dyes, Ideas on some dyes such as methyl orange, congo red, malachite green, crystal violet.

Reference Books

1. Banerjee, S. P. A Text Book of Analytical Chemistry, The New Book Stall.
2. Gangopadhyay, P. K. Application Oriented Chemistry, Book Syndicate.
3. Mondal, A. K & Mondal, S. Degree Applied Chemistry, Sreedhar Publications.
4. Banerjee, S. P. A Text Book of Analytical Chemistry, The New Book Stall.
5. Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.

Course Code: CHEM-SEC-2
Course Title: IT Skills for Chemist

1. Mathematics **(15L)**

i. Fundamentals, mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs.

ii. Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities.

iii. Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).

iv. Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms). Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

v. Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

vi. Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

2. Computer programming **(15L)**

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis. BASIC programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

3. Hands On **(15L)**

i. Introductory writing activities: Introduction to word processor and structure drawing (ChemSketch) software. Incorporating chemical structures, chemical equations, and expressions from chemistry (e.g. Maxwell-Boltzmann distribution law, Bragg's law, van der Waals equation, etc.) into word processing documents.

ii. Handling numeric data: Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a spreadsheet (Planck's distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory- Maxwell-Boltzmann distribution curves as function of temperature and molecular weight), spectral data, pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

iii. Numeric modelling: Simulation of pH metric titration curves. Excel functions LINEST and Least Squares. Numerical curve fitting, linear regression (rate constants from concentration- time data, molar extinction coefficients from absorbance data), numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pKa of weak acid), integration (e.g. entropy/enthalpy change from heat capacity data).

iv. Statistical analysis: Gaussian distribution and Errors in measurements and their effect on data sets. Descriptive statistics using Excel. Statistical significance testing: The t test. The F test.

v. Presentation: Presentation graphics

Reference Books

1. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).
2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).
3. Steiner, E. The Chemical Maths Book Oxford University Press (1996).
4. Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007).
5. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.
6. Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.
7. Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).
8. Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

Semester III

Course Code: CHEM-MAT-3
Course Title: Inorganic-1B & Physical-1B

Inorganic -1B

1. Redox Reactions and precipitation reactions:
(15L)

Qualitative idea about complimentary, noncomplimentary, disproportionation and comproportionation reactions, standard redox potentials with sign conventions, Electrochemical series and its application to explore the feasibility of reactions and equilibrium constants, Nernst equation; effect of pH, complexation and precipitation on redox potentials, formal potential; Basis of redox titration and redox indicators, Redox potential diagrams (Latimer and Frost) of common elements and their applications.

Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulphides, carbonates, sulphates and halides.

2. Acid-Base Concepts and Solvents: (15L)

Recapitulation of Arrhenius concept, Bronsted-Lowry concept, Solvent system concept (in H_2O, liq. NH_3, liq. SO_2 and liq. HF), Lux-Flood concept, Lewis concept, Solvent levelling and differentiating effects, Relative strength of different acids and bases, Pauling's rules, Hammett acidity function and super acids, HSAB principle and its applications, Acid-base equilibria in aqueous solution, pH, Buffer, Acid-base neutralization curves and choice of indicators.

Reference Books:

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
3. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications, 1962.
4. Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
6. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
7. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
8. Atkins, P.W. & Paula, J. Physical Chemistry, Oxford Press, 2006.
9. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
10. Winter, M. J., The Orbitron, http:// winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
11. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).
12. Das, A. K., Fundamental Concepts of Inorganic Chemistry, Vol-1-6, Third Edition, CBS Publishers and Distributors.

Physical-1B

1. Chemical Thermodynamics - II (12L)

Second Law: Need for a Second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine and refrigerator; Kelvin –Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; Values of §dQ/T and Clausius inequality; Entropy change involved in various processes and transformations; Entropy and unavailable work; Free energy functions (G and A) and their variation with T, P and V. Criteria for spontaneity and equilibrium.

Thermodynamic relations: Maxwell's relations; Gibbs-Helmholtz equation, Joule-Thomson experiment and its consequences; inversion temperature; Joule-Thomson coefficient for a van der Waals gas; General heat capacity relations.

2. Chemical kinetics (18L)

Rate law, order and molecularity: Introduction of rate law, Extent of reaction; rate constants, order; Forms of rates of First, second and nth order reactions; Pseudo first order reactions (example using acid catalyzed hydrolysis of methyl acetate); Determination of order of a reaction by half-life and differential method; Opposing reactions, consecutive reactions and parallel reactions, kinetic and thermodynamic control of products.

Role of Temperature and theories of reaction rate: Temperature dependence of rate constant; Arrhenius equation, energy of activation; Rate-determining step and steady-state approximation – explanation with suitable examples; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment).

Homogeneous catalysis: Homogeneous catalysis with reference to acid-base catalysis; Primary kinetic salt effect; Enzyme catalysis; Michaelis-Menten equation, Lineweaver-Burk plot, turn-over number.

Reference Books

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
2. Castellan, G. W. Physical Chemistry, Narosa.
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
4. Engel, T. & Reid, P. Physical Chemistry, Pearson.
5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
6. Maron, S. & Prutton Physical Chemistry.
7. Ball, D. W. Physical Chemistry, Thomson Press.
8. Mortimer, R. G. Physical Chemistry, Elsevier.
9. Laidler, K. J. Chemical Kinetics, Pearson.
10. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
11. Rakshit, P.C., Physical Chemistry Sarat Book House.
12. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.
13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
14. Clauze & Rosenberg, Chemical Thermodynamics

Course Code: CHEM-MAP-3
Course Title: Inorganic-1B & Physical-1B

Inorganic-1B

i. Estimation of Fe(III) using $K_2Cr_2O_7$ solution
ii. Estimation of Ca^{2+} using $KMnO_4$ solution
iii. Estimation of Cu^{2+} iodometrically
iv. Estimation of Cr^{3+} using $K_2Cr_2O_7$ solution

Reference Book

Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

Physical-1B

i. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate.
ii. Study of kinetics of decomposition of H_2O_2.

Reference Books

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009).
2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson.
3. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007).
4. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency.
5. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Course Code: CHEM-MIT-1B
Course Title: Physical-1 & Inorganic-2

Physical-1

1. Kinetic Theory of Gases and Real gases (9L)

a. Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Rate of effusion

b. Nature of distribution of velocities, Maxwell's distribution of speed and kinetic energy; average velocity, root mean square velocity and most probable velocity; Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

c. Deviation of gases from ideal behavior; compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behaviour; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states

d. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only)

2. Liquids (4L)

Definition of Surface tension, its dimension and principle of its determination using stalagmometer; Viscosity of a liquid and principle of determination of coefficient of viscosity using Ostwald viscometer; Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only)

3. Solids (4L)

Forms of solids, crystal systems, unit cells, Bravais lattice types, Symmetry elements; Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices; Miller indices of different planes and interplanar distance, Bragg's law; Structures of NaCl, KCl and CsCl treatment only); Defects in crystals; Glasses and liquid crystals.

4. Chemical Kinetics (5L)

a. Introduction of qualitative rate law, order and molecularity; Extent of reaction; rate constants; Rates of First, second and nth order reactions and their Differential and integrated forms (with derivation); Pseudo first order reactions; Determination of order of a reaction by half-life and differential method; Opposing reactions, consecutive reactions and parallel reactions

b. Temperature dependence of rate constant; Arrhenius equation, energy of activation; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment)

Inorganic-2

1. Chemical Bonding and Molecular Structure (12L)

a. Ionic Bonding: General characteristics of ionic bonding. lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment.

b. Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples from s and p block elements of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.

c. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s- p mixing).

2. Coordination Chemistry (11L)

a. Werner's coordination theory, Valence Bond Theory (VBT): Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

b. Drawbacks of VBT. IUPAC system of nomenclature.

c. Crystal Field Theory (CFT):Postulates of CFT, splitting of d-orbitals in octahedral and tetrahedral fields, Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Factors affecting the magnitude of Δ. Spectrochemical series. Comparison of CFSE for O_h and T_d complexes.

Reference Books

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
6. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
7. Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.
8. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
9. Mandal, A. K. Degree Physical and General Chemistry Sarat Book House.
10. Pahari, S., Physical Chemistry New Central Book Agency.
11. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.
12. Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
13. Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
14. Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
15. Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008.

Course Code: CHEM-MIP-1B
Course Title: Physical-1 & Inorganic-2

Physical-1

1. Determination of the surface tension of a liquid or a dilute solution using a Stalagmometer
2. Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer
3. Study of the kinetics of acid hydrolysis of methyl acetate using hydrochloric acid.

Inorganic-2

Qualitative semi-micro analysis of mixtures containing three radicals. Emphasis should be given to the understanding of the chemistry of different reactions.

Acid Radicals: Cl^-, Br^-, I^-, NO_2^-, NO_3^-, S^{2-}, SO_4^{2-}, BO_3^{3-}, H_3BO_3.

Basic Radicals: K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cr^{3+}, Mn^{2+}, Fe^{3+}, Ni^{2+}, Cu^{2+}, NH_4^+.

Reference Books

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Palit, S.R., Practical Physical Chemistry Science Book Agency.
3. Mukherjee, N.G., Selected Experiments in Physical Chemistry J. N. Ghose & Sons.
4. Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall.
5. Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
6. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

Course Code: CHEM-MDC-3
Course Title: Basic Idea of Clinical Biochemistry (Multidisciplinary Course)

1. Biomolecules (30L)

Carbohydrates: Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle.

Proteins: Classification, biological importance; Primary and secondary and tertiary structures of proteins: α-helix and β- pleated sheets, denaturation of proteins, preliminary idea of enzymes,application of Biocatalyst in Chemical Industry.

Lipids: Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications. Properties and functions of steroid hormones.

2. Biochemistry of disease: A diagnostic approach by blood/ urine analysis (15L)

Blood: Composition and functions of blood, blood coagulation. Blood collection and preservation of samples. Anaemia, Regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

Urine: Sampling and preservation, composition and estimation of constituents of normal and pathological urine.

Reference Books

1. Cooper, T.G. Tool of Biochemistry. Wiley-Blackwell (1977).
2. Wilson, K. & Walker, J. Practical Biochemistry. Cambridge University Press (2009).
3. Varley, H., Gowenlock, A.H & Bell, M.: Practical Clinical Biochemistry, Heinemann, London (1980). 4. Devlin, T.M., Textbook of Biochemistry with Clinical Correlations, John Wiley & Sons, 2010.
5. Berg, J.M., Tymoczko, J.L. & Stryer, L. Biochemistry, W.H. Freeman, 2002.
6. Talwar, G.P. & Srivastava, M. Textbook of Biochemistry and Human Biology, 3rd Ed. PHI Learning.
7. Nelson, D.L. & Cox, M.M. Lehninger Principles of Biochemistry, W.H. Freeman, 2013.
8. O. Mikes, R.A. Chalmers: Laboratory Handbook of Chromatographic Methods, D. Van Nostrand & Co., 1961.

CHEM-SEC-3
Course Title: Basic Analytical Chemistry
(Skill Enhancement course)

1. Introduction **(3L)**

Strategies of Analytical Chemistry and its interdisciplinary applicability. Protocol of sampling. Variability and validity of analytical measurements. Presentation of experimental data and results from the point of view of significant figures.

2. Complexometry **(5L)**

Complexometric titrations, Chelation, Chelating agents, use of indicators. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

3. Soil Analysis **(3L)**

Composition, pH of soil samples, estimation of calcium and magnesium content.

4. Analysis of water **(5L)**

Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

Determination of pH, acidity and alkalinity of a water sample.

Determination of Biological Oxygen Demand (BOD).

5. Analysis of food products **(5L)**

Nutritional value of foods, idea about food processing and food preservations and adulteration.

Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.

Analysis of preservatives and colouring matter.

6. Chromatography **(5L)**

Definition, general introduction on principles of chromatography, paper chromatography, TLC etc. Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).

7. Ion-exchange **(4L)**

Column, ion-exchange chromatography etc., Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

8. Analysis of cosmetics **(5L)**

Major and minor constituents and their function

Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.

Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration

9. Suggested Applications (Any one) **(4L)**

To study the use of phenolphthalein in trap cases.

To analyse arson accelerants.

To carry out analysis of gasoline.

10. Suggested Instrumental demonstrations **(6L)**

Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.

Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.

Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drinks

Reference Books

1. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. Instrumental Methods of Analysis, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.
2. Skoog, D.A., Holler, F.J. & Crouch, S. Principles of Instrumental Analysis, Cengage Learning India Edition, 2007.
3. Skoog, D.A.; West, D.M. & Holler, F.J. Analytical Chemistry: An Introduction 6th Ed., Saunders College Publishing, Fort Worth, Philadelphia (1994).
4. Harris, D. C. Quantitative Chemical Analysis, 9th ed. Macmillan Education, 2016.
5. Dean, J. A. Analytical Chemistry Handbook, McGraw Hill, 2004.
6. Day, R. A. & Underwood, A. L. Quantitative Analysis, Prentice Hall of India, 1992.
7. Freifelder, D.M. Physical Biochemistry 2nd Ed., W.H. Freeman & Co., N.Y. USA (1982).
8. Cooper, T.G. The Tools of Biochemistry, John Wiley & Sons, N.Y. USA. 16 (1977).
9. Vogel, A. I. Vogel's Qualitative Inorganic Analysis 7th Ed., Prentice Hall, 1996.
10. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
11. Robinson, J.W. Undergraduate Instrumental Analysis 5th Ed., Marcel Dekker, Inc., New York (1995).
12. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.

Semester IV

Course Code: CHEM-MAT-4

Course title: Organic-2

1. Stereochemistry-II: (14L)

Chirality arising out of stereoaxis: Stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in allenes, spiro compounds, alkylidenecycloalkanes and biphenyls; related configurational descriptors (R_a/S_a and P/M); atropisomerism; racemisation of chiral biphenyls; buttressing effect.

Concept of prostereoisomerism: Prostereogenic centre; concept of pro^n-chirality: topicity of ligands and faces (elementary idea); pro-R/pro-S, pro-E/pro-Z and Re/Si descriptors; pro-r and pro-s descriptors of ligands on propseudoasymmetric centre.

Conformation: Conformational nomenclature: eclipsed, staggered, gauche, syn and anti; dihedral angle, torsion angle; Klyne-Prelog terminology; P/M descriptors; energy barrier of rotation, concept of torsional and steric strains; relative stability of conformers on the basis of steric effect, dipole-dipole interaction and H-bonding; butane gauche interaction; conformational analysis of ethane, propane, n-butane, 2-methylbutane and 2,3-dimethylbutane; haloalkane, 1,2-dihaloalkanes and 1,2-diols (up to four carbons); 1,2-halohydrin; conformation of conjugated systems (s-cis and s-trans).

2. General Treatment of Reaction Mechanism II : (18L)

Reaction thermodynamics: Free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change via BDE, intermolecular & intramolecular reactions.

Concept of organic acids and bases: Effect of structure, substituent and solvent on acidity and basicity; proton sponge; gas-phase acidity and basicity; comparison between nucleophlicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.

Tautomerism: Prototropy (keto-enol, nitro - aci-nitro, nitroso-oximino, diazo-amino and enamine-imine systems); valence tautomerism and ring-chain tautomerism; composition of the equilibrium in different systems (simple carbonyl; 1,2- and 1,3-dicarbonyl systems, phenols and related systems), factors affecting keto-enol tautomerism; application of thermodynamic principles in tautomeric equilibria.

Reaction kinetics: Rate constant and free energy of activation; concept of order and molecularity; free energy profiles for one-step, two-step and three-step reactions; catalyzed reactions: electrophilic and nucleophilic catalysis; kinetic control and thermodynamic control of reactions; isotope effect: primary and secondary kinetic isotopic effect (k_H/k_D); principle of microscopic reversibility; Hammond's postulate.

3. Substitution and Elimination Reactions: (28L)

Free-radical substitution reaction: Halogentaion of alkanes, mechanism (with evidence) and stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate.

Nucleophilic substitution reactions: Substitution at sp^3 centre: mechanisms (with evidence), relative rates & stereochemical features: S_N1, S_N2, S_N2', S_N1' (allylic rearrangement) and S_Ni; effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite); substitutions involving NGP; role of crown ethers and phase transfer catalysts; [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides]. Concept of aliphatic electrophilic substitution reactions (S_E1, S_E2, S_Ei).

Elimination reactions: E1, E2, E1cb and E_i (pyrolytic syn eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/ Hofmann) and stereoselectivity; comparison between substitution and elimination; importance of Bredt's rule relating to the formation of C=C.

Reference Books:

1. Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Second edition, Oxford University Press 2012.
2. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
3. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
4. Carey, F. A. & Guiliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education, 2012.
5. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press, 2008.
6. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
7. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
8. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar, I. L. Organic Chemistry (Volume 1) Pearson Education.
10. Graham Solomons, T.W., Fryhle, C. B. Organic Chemistry, John Wiley & Sons, Inc.
11. Eames, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
12. Robinson, M. J. T. Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
13. Maskill, H. Mechanisms of Organic Reactions, Oxford Chemistry Primer, Oxford University Press.
14. March, J. Advanced Organic Chemistry, Fourth edition, Wiley.

Course Code: CHEM-MAP-4
Course title: Organic-2

Organic Preparations:

A**.** The following reactions are to be performed, noting the yield of the crude product:

1. Nitration of aromatic compounds
2. Condensation reactions
3. Hydrolysis of amides/imides/esters
4. Acetylation of phenols/aromatic amines
5. Benzoylation of phenols/aromatic amines
6. Side chain oxidation of aromatic compounds
7. Diazo coupling reactions of aromatic amines
8. Bromination of anilides using green approach (Bromate-Bromide method)
9. Selective reduction of m-dinitrobenzene to m-nitroaniline

Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

B. Purification of the crude product is to be made by crystallisation from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.

C. Melting point of the purified product is to be noted.

Reference Books:

1. Vogel, A. I. Elementary Practical Organic Chemistry, Part 1: Small scale Preparations, CBS Publishers and Distributors.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003.
3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009).
4. Furniss, B.S., Hannaford, A.J., Smith, P.W.G. & Tatchell, A.R. Practical Organic Chemistry, 5th Ed. Pearson (2012).
5. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000).
6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

Course Code: CHEM-MAT-5
Course title: Physical-2

1. Transport processes (20L)

Viscosity: General features of fluid flow (streamline flow and turbulent flow); Newton's equation, viscosity coefficient; Poiseuille's equation; Principle of determination of viscosity coefficient of liquids by falling sphere method; Temperature variation of viscosity of liquids and comparison with that of gases.

Conductance and transport number: Ion conductance; Conductance and measurement of conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye–Huckel theory of Ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Ostwald's dilution law; Ionic mobility; Few applications of conductance measurement; Conductometric titrations.

Transport number, Principles of Hittorf's and Moving-boundary methods.

2. Applications of Thermodynamics –I (20L)

Partial properties and chemical potential: Chemical potential and activity, partial molar quantities, relation between chemical potential and Gibb's free energy and other thermodynamic state functions; variation of chemical potential (μ) with temperature and pressure; Gibbs-Duhem equation; fugacity and fugacity coefficient; Variation of thermodynamic functions for systems with variable composition; Equations of states for these systems, Change in G, S H and V during mixing for binary solutions.

Chemical Equilibrium: Thermodynamic conditions for equilibrium, degree of advancement; Van't Hoff's reaction isotherm (deduction from chemical potential); Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Definitions of K_P, K_C and K_X; Van't Hoff's reaction isobar and isochore from different standard states; Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant on addition of inert gas; Le Chatelier's principle.

Nernst's distribution law; Application-(finding out Keq using Nernst distribution law for $KI+I_2 = KI_3$ and dimerization of benzoic acid).

Chemical potential and other properties of ideal substances-pure and mixtures:

Pure ideal gas: Its chemical potential and other thermodynamic functions and their changes during mixing; Chemical potential of an ideal gas in an ideal gas mixture; Concept of standard states and choice of standard states of ideal gases.

Condensed Phase: Chemical potential of pure solid and pure liquids, Ideal solution–Definition, Raoult's law; Mixing properties of ideal solutions, chemical potential of a component in an ideal solution; Choice of standard states of solids and liquids.

3. Foundations of Quantum Mechanics (20L)

Advent of Quantum Mechanics: Wave-particle duality, light as particles: photoelectric and Compton effects; electrons as waves and the de Broglie hypothesis; Uncertainty relations (without proof).

Wave function: Schrodinger time-independent equation; nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function.

Concept of Operators: Elementary concepts of operators, eigenfunctions and eigenvalues; Linear operators; Commutation of operators, commutator and uncertainty relation; Expectation value; Hermitian operator; Postulates of Quantum Mechanics.

Particle in a box: Setting up of Schrodinger equation for one-dimensional box and its solution; Comparison with free particle eigenfunctions and eigenvalues. Wave functions of particle in a box (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.

Reference Books

1. Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press.
2. Castellan, G. W. Physical Chemistry, Narosa.
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
4. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
5. Rakshit, P.C., Physical Chemistry, Sarat Book House.
6. Moore, W. J. Physical Chemistry, Orient Longman.
7. Mortimer, R. G. Physical Chemistry, Elsevier.
8. Denbigh, K. The Principles of Chemical Equilibrium Cambridge University Press.
9. Engel, T. & Reid, P. Physical Chemistry, Pearson.
10. Levine, I. N. Quantum Chemistry, PHI.
11. Atkins, P. W. Molecular Quantum Mechanics, Oxford.
12. emansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.
13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
14. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics:Basic Concepts and Methods Wiley.
15. Glasstone, S. An Introduction to Electrochemistry, East-West Press.

Course Code: CHEM-MAP-5
Course title: Physical-2

1. Determination of viscosity of unknown liquids (aqueous solution of glycerol and sugar) with respect to water.
2. Determination of partition coefficient for the distribution of I_2 between water and CCl_4.
3. Determination of K_{eq} for $KI + I_2 = KI_3$, using partition coefficient between water and CCl_4.
4. Conductometric titration of an acid (strong, weak, monobasic, dibasic) against strong base.
5. Study of saponification reaction conductometrically.
6. Verification of Ostwald's dilution law and determination of K_a of weak acid.

Reference Books

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson.
3. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007).
4. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency.
5 .University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
6 .Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co.Ltd.

Course Code: CHEM-MIT-2B
Course Title: Physical-1 & Inorganic -2

Physical-1

1. Kinetic Theory of Gases and Real gases (9L)

a. Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Rate of effusion

b. Nature of distribution of velocities, Maxwell's distribution of speed and kinetic energy; Average velocity, root mean square velocity and most probable velocity; Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

d. Deviation of gases from ideal behavior; compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behaviour; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states

e. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only)

2. Liquids (4L)

Definition of Surface tension, its dimension and principle of its determination using stalagmometer; Viscosity of a liquid and principle of determination of coefficient of viscosity using Ostwald viscometer; Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only)

3. Solids **(4L)**

Forms of solids, crystal systems, unit cells, Bravais lattice types, Symmetry elements; Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices; Miller indices of different planes and interplanar distance, Bragg's law; Structures of NaCl, KCl and CsCl treatment only); Defects in crystals; Glasses and liquid crystals.

4. Chemical Kinetics **(5L)**

a. Introduction of qualitative rate law, order and molecularity; Extent of reaction; rate constants; Rates of First, second and nth order reactions and their Differential and integrated forms (with derivation); Pseudo first order reactions; Determination of order of a reaction by half-life and differential method; Opposing reactions, consecutive reactions and parallel reactions

b. Temperature dependence of rate constant; Arrhenius equation, energy of activation; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment)

Inorganic-2

1. Chemical Bonding and Molecular Structure **(12L)**

a. Ionic Bonding: General characteristics of ionic bonding. lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment.

b. Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples from s and p block elements of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.

c. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s- p mixing).

2. Coordination Chemistry **(11L)**

a. Werner's coordination theory, Valence Bond Theory (VBT): Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

b. Drawbacks of VBT. IUPAC system of nomenclature.

c. Crystal Field Theory (CFT):Postulates of CFT, splitting of d-orbitals in octahedral and tetrahedral fields, Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Factors affecting the magnitude of Δ. Spectrochemical series. Comparison of CFSE for O_h and T_d complexes.

Reference Books

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).

6. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
7. Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.
8. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
9. Mandal, A. K. Degree Physical and General Chemistry Sarat Book House.
10. Pahari, S., Physical Chemistry New Central Book Agency.
11. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.
12. Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
13. Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
14. Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
15. Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008.

Course Code: CHEM-MIP-2B
Course Title: Physical-1 & Inorganic-2

Physical-1

1. Determination of the surface tension of a liquid or a dilute solution using a Stalagmometer
2. Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer
3. Study of the kinetics of acid hydrolysis of methyl acetate using hydrochloric acid.

Inorganic-2

Qualitative semi-micro analysis of mixtures containing three radicals. Emphasis should be given to the understanding of the chemistry of different reactions.

Acid Radicals: Cl^-, Br^-, I^-, NO_2^-, NO_3^-, S^{2-}, SO_4^{2-}, BO_3^{3-}, H_3BO_3.

Basic Radicals: K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cr^{3+}, Mn^{2+}, Fe^{3+}, Ni^{2+}, Cu^{2+}, NH_4^+.

Reference Books

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Palit, S.R., Practical Physical Chemistry Science Book Agency.
3. Mukherjee, N.G., Selected Experiments in Physical Chemistry J. N. Ghose & Sons.
4. Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall.
5. Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
6. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

Semester V

Course Code: CHEM-MAT-6
Course title: Inorganic-2

1. Chemical Bonding: (35L)

Ionic Bond: Lattice energy, Born-Lande equation with derivation, Born-Haber cycle and its applications, Polarising power and polarisability of ions, Fajan's rules and its applications, radius ratio rules – its applications and limitations, solvation energy and solubility energetics of dissolution process; Packing in crystals, voids in crystal lattice, packing efficiency, Structure of ionic solids: rock salt, zinc blende, wurtzite, fluorite, antifluorite, perovskite and layer lattice. Qualitativeidea about stoichiometric and non-stoichiometric crystal defects.

Covalent Bond: Lewis structures, formal charge; Qualitative idea of V.B.Theory, Concept of Equivalent and nonequivalent Hybridization and shapes of simple molecules and ions (examples from main groups), Stereochemically non-rigid molecules – Berry's pseudorotation, Resonance and Dipole moments of inorganic molecules and ions, VSEPR theory and Bent's rule and their applications; M.O. Theory (elementary pictorial approach), concept of bond order, MO diagram of homo-nuclear diatomics (1^{st} and 2^{nd} period elements), hetero-nuclear diatomics (HF, CO, NO, NO^+ and CN^-). Electron sea model and elementary idea about band theory, classification of inorganic solids and their conduction properties according to band theory; Hydrogen bonding: classifications, its effect on the properties of compounds and its importance in biological systems, van der Waal's forces.

2. Metal extraction and purification : Basic Metallurgy (5L)

Idea about ores and minerals, operations involved in metallurgy, Flow chart diagram for the extraction of pure Ti, Ni and U(including reactions) from their important ores and their uses.

3. Chemistry of s and p-block elements :
(20L)

Allotropy and catenation (examples of C, P and S compounds). Study of the following compounds with emphasis on preparation, properties, structure and bonding: Berylium hydrides and halides; diborane; borazine; boron nitride, boric acid, borax, fluorocarbons (with environmental effect); oxides and oxyacids of nitrogen, phosphorous, sulphur and chlorine; Peroxoacids of sulphur, interhalogens, pseudohalogens, fluorides and oxides of xenon, basic properties of iodine. Synthesis, structural aspects and applications of silicones and phosphazines. Structural properties of various silicates.

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008.
2. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
3. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
4. Porterfield, H. W., Inorganic Chemistry, Second Edition, Academic Press, 2005.
5. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.
6. Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.
7. Gillespie, R. J. and Hargittai, I., The VSEPR Model of Molecular Geometry, Prentice Hall (1992).

8. Albright, T., Orbital interactions in chemistry,JohnWileyandSons(2005).
9. Mingos,D.M.P.,Essentialtrendsininorganic chemistry.OxfordUniversityPress(1998).
10. Miessler,G.L.,Fischer,P.J.,Tarr,D.A.,InorganicChemistry,Pearson,5thEdition.
11. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.

Course Code: CHEM-MAP-6
Course title: Inorganic-2

Quantitative Estimation of Binary Mixture

i. EstimationofFe(II)andFe(III)inagivenmixtureusing$K_2Cr_2O_7$solution
ii. EstimationofFe(III)andCu(II)inagivenmixtureusing$K_2Cr_2O_7$solution
iii. EstimationofFe(III)andCr(VI)inagivenmixtureusing$K_2Cr_2O_7$solution
iv. EstimationofFe(III)andCa(II)inagivenmixtureusing$KMnO_4$solution
v. Estimation of Ca(II) and Mg(II) by complexometric method
vi. Estimationofchloride gravimetrically
vii. EstimationofNi(II)usingDMGgravimetrically

Reference Books

1. Mendham,J.,A.I.Vogel'sQuantitativeChemicalAnalysis6thEd.,Pearson,2009.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
3. Das, S. C., Chakraborty, S. B., Practical Chemistry.
4. Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
5. Ghosal, Mahapatra &Nad, An Advanced course in practical Chemistry, New Central Book Agency.

Course Code: CHEM-MAT-7
Course title: Physical – 3

1. Basic Concepts of Electrochemistry : (12L)

Ionic equilibrium: Chemical potential of an ion in solution; Activity and activity, coefficients of ions in solution; Debye-Huckel limiting law-brief qualitative description of the postulates involved, qualitative idea of the model, the equation (without derivation) for ion-ion atmosphere interaction potential. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law;

2. Electromotive Force: (20L)

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry; Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half- cells. Application of EMF measurements, Concentration cells with and without transference, liquid junction potential; Determination of activity coefficients and transference numbers; Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

3. Dipole moment and polarizability: (8L)

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.

4. Colligative properties (12L)

*Colligative properties:*Vapour pressure of solution; Ideal solutions, ideally dilute solutions and colligative properties; Raoult's law; Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) Osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution; Abnormal colligative properties.

5. Phase rule: (8L)

Definitions of phase, component and degrees of freedom; Phase rule and its derivations; Definition of phase diagram; Phase diagram for water, CO_2, Sulphur.

6. First order phase transition and Clapeyron equation; (15L)

Clausius-Clapeyron equation, water system. Three component systems, water-chloroform-acetic acid system, triangular plots. Binary solutions: Ideal solution at fixed temperature and pressure; Principle of fractional distillation; Duhem-Margules equation; Henry's law; Konowaloff's rule; Positive and negative deviations from ideal behavior; Azeotropic solution; Liquid- liquid phase diagram using phenol-water system; Solid-liquid phase diagram; Eutectic mixture.

7. Crystal Structure (15L)

Bravais Lattice and Laws of Crystallography: Types of solid, Bragg's law of diffraction; Laws of crystallography (Haüy's law and Steno's law); unit cell, crystal planes, Bravais lattice.close packed arrangements (bcc, fcc and hcp). Crystal planes: Indexing of planes, Miller indices; calculation of dhkl; Relation between molar mass and unit cell dimension for cubic system; Bragg's law.

Reference Books

1. Castellan, G.W. Physical Chemistry, Narosa.
2. Atkins, P.W. & Paula, J. de Atkins, Physical Chemistry, Oxford University Press.
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
4. Levine, I. N. Physical Chemistry,Tata McGraw-Hill.
5. Moore,W.J. Physical Chemistry,Orient Longman.
6. Mortimer, R. G. Physical Chemistry, Elsevier.
7. Engel, T. & Reid, P. Physical Chemistry, Pearson.
8. Levine, I. N. Quantum Chemistry, PHI.
9. Atkins, P. W. Molecular Quantum Mechanics, Oxford.
10. Engel,T. & Reid, P. Physical Chemistry, Pearson.
11. Maron, S. H., Prutton,C.F., Principles of Physical Chemistry, McMillan.
12. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Methods, Wiley.
13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics,Vikas.
14. Glasstone, S. An Introduction to Electrochemistry, East-West Press.

Course Code: CHEM-MIT- 3
Course title: Physical & Organic - 2

Physical Chemistry – 2

1. Chemical Energetics **(8L)**

a. Concept of heat, work, internal energy and statement of first law; enthalpy, H; relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases
b. Standard states; Heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; Laws of thermochemistry; bond energy, bond dissociation energy and resonance energy from thermochemical data.
c. Statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine, refrigerator and efficiency; Entropy change of systems and surroundings for various processes.

2. Chemical Equilibrium: **(6L)**

Equilibrium constant and standard Gibbs free energy change; Definitions of K_P, K_C and K_X and relation among them; van't Hoff's reaction isotherm, isobar and isochore from different standard states; Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant with addition to inert gas; Le Chatelier's principle

3. Ionic Equilibria: **(8L)**

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water; Ionization of weak acids and bases,pH scale, common ion effect; and pH for different salts; Buffer solutions; Solubility and solubility product of sparingly soluble salts–applications of solubility product principle.

Organic Chemistry – 2

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structures.

1. Aromatic Hydrocarbons **(6L)**

Benzene: Preparation from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid. Reactions: electrophilic substitution (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), sulphonation and Friedel-Craft's reaction (alkylation and acylation) (up to 4 carbons on benzene).

2. Organometallic Compounds **(4L)**

Introduction; Grignard reagents: Preparations (from alkyl and aryl halide); concept of umpolung; Reformatsky reaction.

3. Alcohols, Phenols and Ethers **(8L)**

a. *Alcohols:* (up to 5 Carbons). Preparation: 1°-, 2°- and 3°- alcohols: using Grignard reagent, reduction of aldehydes, ketones, carboxylic acid and esters; Reactions: With sodium, HX (Lucas test), oxidation (alkaline $KMnO_4$, acidic dichromate, concentrated HNO_3).

b. *Phenols:* Preparation: cumene hydroperoxide method, from diazonium salts; acidic nature of phenols; Reactions: electrophilic substitution: nitration and halogenations; Reimer-Tiemann reaction. Fries rearrangement and Claisen rearrangement.

c. *Ethers:* Preparation: Williamson's ether synthesis; Reaction: cleavage of ethers with HI.

4.Carbonyl Compounds **(5L)**

Aldehydes and Ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde): Preparation: from acid chlorides, from nitriles and from Grignard reagents; general properties of aldehydes and ketones; aldol condensation (with mechanism); Cannizzaro reaction (with mechanism), Wittig reaction, benzoin condensation; Clemmensen reduction, Wolff-Kishner reduction and Meerwein-Pondorff-Verley (MPV) reduction.

Reference Books

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry3rdEd.Narosa(1998).
5. Ekambaram,S.GeneralChemistry,Pearson.
6. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
7. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
8. Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.
9. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
10. Mandal, A. K. Degree Physical and General Chemistry Sarat BookHouse.
11. Pahari, S., Physical Chemistry New Central Book Agency.
12. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central BookAgency.
13. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
14. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
15. Madan, R. L. Organic Chemistry, S. Chand & Sons.
16. Wade, L. G., Singh, M. S., Organic Chemistry, Pearson.
17. Finar, I. L. Organic Chemistry (Volume1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
18. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
19. Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.

Course Code: CHEM-MIP - 3
Course title: Physical & Organic – 2

Physical Chemistry – 2

(Minimum five experiments to complete)

Thermochemistry

1. Determination of heat capacity of calorimeter for different volumes
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide
3. Determination of enthalpy of ionization of acetic acid
4. Determination of enthalpy of hydration of copper sulphate

Ionic Equilibria

1. Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH- meter and compare it with the indicator method
2. Preparation of buffer solutions and find the pH of an unknown buffer solution by colour matching method (using following buffers)

a. Sodium acetate-acetic acid
b. Ammonium chloride-ammonium hydroxide

3. Study of the solubility of benzoic acid in water.

Organic Chemistry – 2

Identification of a pure organic compound

1. Solid compounds: oxalic acid, tartaric acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.
2. Liquid Compounds: methyl alcohol, ethyl alcohol, acetone, aniline, dimethyl aniline, benzaldehyde, chloroform and nitrobenzene.

Reference Books

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Palit, S.R., Practical Physical Chemistry, Science Book Agency.
3. Mukherjee, N.G., Selected Experiments in Physical ChemistryJ. N. Ghose & Sons.
4. Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall.
5. Bhattacharyya, R. C, A Manual of Practical Chemistry.
6. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Text book of Practical Organic Chemistry, Prentice-Hall, 5th edition,1996.
7. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman,1960.

Semester VI

Course Code: CHEM-MAT-8
Course title: Inorganic – 3

1. Coordination Chemistry-I: (38L)

Idea about double salts and complex salts, Werner's theory, EAN rule, classification of ligands and the IR binding modes, IUPAC nomenclature of coordination compounds (up to two metal centres). Structure and bonding of coordination compounds on the basis of V.B.Theory and its limitations. Elementary idea about CFT, splitting of d^n configuration in ML_4 to ML_6 and ML_8 systems, factors affecting, measurement of Δ_o, spectrochemical series of ligands, CFSE in weak and strong fields, OSSE, High spin and low spin complexes, spin isomerism, tetragonal distortion, Jahn Teller theorem and applications, achievements and limitations of CFT, nephalauxetic effect, stabilisation of unusually high and low oxidation states of 3d series elements, Stereochemistry and isomerism (constitutional and stereo) of complexes with coordination no. 4 and 6. Colour and electronic spectra of complexes: selection rules for electronic transitions, d-d transition, charge transfer transition (qualitative idea), qualitative ORGEL diagram for $3d^1 – 3d^9$ ions with appropriate symbols for the energy levels.

2. Magnetochemistry: (12L)

Classification of magnetic substances, Origin of para magnetic moments, temperature dependence of para magnetism – Curie and Curie-Weiss law, TIP, magnetic susceptibility and its measurement (Gouy method), diamagnetic correction, effective magnetic moment, spin only moment for 3d metals, Orbital contribution to magnetic moment, spin-orbit coupling, quenching of orbital contribution, Sub-normal magnetic moments and antiferromagnetic interactions (elementary idea with examples). Magnetic properties of metal complexes when multiple widths are large compared to kT.

3. **Chemistry of d- and f-block elements :**
(15L)

d-block elements: Characteristic properties, Comparison among the elements of 3d series with reference to electronic configuration, oxidation states and E^0 values; General comparison between 3d, 4d and 5d series elements in term of electronic configuration, oxidation states, ionization energy, magnetic properties and coordination chemistry.

f-block elements: Comparison between d and f-block elements; Electronic configuration, oxidation states, variation of magnetic properties (Ln^{3+}), atomic and ionic (3+) radii of lanthanoids; consequences of lanthanide contraction, separation of lanthanides by ion exchange and solvent extraction methods; comparison between lanthanoids and actinoids.

4. Reaction Kinetics and Mechanism: (10L)

Introduction to inorganic reaction mechanisms, substitution reactions in square planar complexes; *trans*-effect - theories and applications; lability and inertness in octahedral complexes towards substitution reactions. Elementary concept of *cis*-effect.

5. Radioactivity and nuclear chemistry : (15L)

Atomic nucleus – nuclear stability, n/p ratio and different modes of decay, mass defect, packing fraction and nuclear binding energy. Nuclear forces: Meson exchange theory, magic numbers. Fission, fusion and spallation reactions, artificial radioactivity, superheavy elements. Moderators, slow and fast neutrons, Applications of radio-isotopes in: determination of structures, establishment of reaction mechanisms and radio-carbon dating, hazards of radiation and safety measures.

Reference Books

1. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
2. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann. 1997.
3. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.
4. Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
5. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.
6. Sinha, S. P., Ed., Lanthanide and Actinide Research (Journal,Vol.1,1986).
7. Wulfsberg, G., Principles of Descriptive Inorganic Chemistry, Brooks/Cole: Monterey, CA, 1987.

Course Code: CHEM-MAT-9
Course title: Organic – 3

1. Chemistry of alkenes and alkynes: (14L)

Addition to C=C: mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenations, iodolactonisation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, *syn* and *anti* hydroxylation, ozonolysis, addition of singlet and triplet carbenes; electrophilic addition to diene (conjugated dienes and allene); radical addition: HBr addition; mechanism of allylic and benzylic bromination in competition with brominations across C=C; use of NBS; dissolving metal reduction of alkenes; interconversion of E - and Z - alkenes; contra thermodynamic isomerization of internal alkenes, Wagner-Meerwein rearrangement.

Addition to C≡C (in comparison to C=C): mechanism, reactivity, regioselectivity (Markownikoff and anti-Markownikoff addition) and stereoselectivity; reactions: hydrogenation, halogenations, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity; interconversion of terminal and non-terminal alkynes.

2. Aromatic Substitution: (8L)

*Electrophilic aromatic substitution***:** mechanisms and evidences in favour of it; orientation and reactivity; reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction; one-carbon electrophiles (reactions: chloromethylation, Gatterman-Koch, Gatterman, Houben Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt, Dakin reaction), Cumene hydroperoxide-phenol rearrangement, Fries rearrangement, Claisen rearrangement, Dienone-phenol rearrangement, Ipso substitution.

Nucleophilic aromatic substitution: addition-elimination mechanism and evidences in favour of it; SNAr mechanism; cine substitution (benzyne mechanism), structure of benzyne.

3. Carbonyl and Related Compounds: (16L)

Addition to C=O: structure, reactivity and preparation of carbonyl compounds; mechanism (with evidence), reactivity, equilibrium and kinetic control; Burgi-Dunitz trajectory in nucleophilic additions; formation of hydrates, cyanohydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen- based nucleophiles; reactions: benzoin condensation, Benzil-benzilic acid rearrangement, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement.

Oxidations and reductions: Clemmensen, Wolff Kishner, $LiAlH_4$, $NaBH_4$, MPV, Oppenauer, Bouveault-Blanc, acyloin condensation; Bayer Villigir oxidation, oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols, Pinacol-pinacolone rearrangement.

Exploitation of acidity of α-H of C=O: formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence): halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H. V. Z.) reaction, nitrosation, SeO_2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Knoevenagel, Claisen-Schmidt, Claisen ester including Dieckmann, Stobbe; Mannich reaction, Perkin reaction, Favorskii rearrangement; alkylation of active methylene compounds; preparation and synthetic applications of diethyl malonate and ethyl acetoacetate; specific enol equivalents (lithium enolates, enamines, aza-enolates and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction.

Nucleophilic addition to α,β-unsaturated carbonyl system: general principle and mechanism (with evidence); direct and conjugate addition, addition of enolates (Michael reaction), Stetter reaction, Robinson annulations.

Substitution at sp^2 carbon (C=O system): mechanism (with evidence): $B_{AC}2$, $A_{AC}2$, $A_{AC}1$, $A_{AL}1$ (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

4. Organometallics: (6L)

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organolithium to carbonyl compounds; substitution on -COX; directed *ortho* metalation of arenes using organolithiums, conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; Blaise reaction; concept of umpolung and base-nucleophile dichotomy in case of organometallics.

5. Nitrogen compounds: (10L)

Amines: Aliphatic & Aromatic: preparation, separation (Hinsberg's method) and identification of primary, secondary and tertiary amines; reaction (with mechanism): Eschweiler–Clarke methylation, diazo coupling reaction, Mannich reaction; formation and reactions of phenylenediamines, diazomethane and diazoacetic ester, Hofmann, Curtius, Lossen, Schmidt and Beckmann. rearrangements, rearrangements of alkyl anilines (Hofmann-Martius rearrangement) and derivatives of anilines (Fischer-Hepp and Orton rearrangement)

Nitro compounds (aliphatic and aromatic): preparation and reaction (with mechanism): reduction under different conditions; Nef carbonyl synthesis, Henry reaction and conjugate addition of nitroalkane anion.

Alkylnitrile and isonitrile: preparation and reactions (with mechanism): Thorpe nitrile condensation, von Richter reaction.

Diazonium salts and their related compounds: reactions with mechanisms involving replacement of diazo group; reactions: Gomberg, Meerwein, Japp-Klingermann, Demjanov rearrangement.

6. Organic Spectroscopy: (12L)

*UV Spectroscopy***:** Introduction; types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic and Hypsochromic shifts; intensity of absorptions (Hyper-/Hypochromic effects); application of Woodward's Rules for calculation of λ_{max} for the following systems: conjugated diene, α,β-unsaturated aldehydes and ketones (alicyclic, homoannular and heteroannular); extended conjugated systems (dienes, aldehydes and ketones); relative positions of λ_{max} considering conjugative effect, steric effect, solvent effect, effect of pH; effective chromophore concentration: keto-enol systems; benzenoid transitions.

*IR Spectroscopy***:** Introduction; modes of molecular vibrations (fundamental and non-fundamental); IR active molecules; application of Hooke's law, force constant; fingerprint region and its significance; effect of deuteration; overtone bands; vibrational coupling in IR; characteristic and diagnostic stretching frequencies of C-H, N-H, O-H, C-O, C-N, C-X, C=C (including skeletal vibrations of aromatic compounds), C=O, C=N, N=O, C≡C, C≡N; characteristic/diagnostic bending vibrations are included; factors affecting stretching frequencies: effect of conjugation, electronic effects, mass effect, bond multiplicity, ring-size, solvent effect, H-bonding on IR absorptions; application in functional group analysis

7. Carbocycles (6L)

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

8. Cyclic Stereochemistry: (6L)

Alicyclic compounds: concept of I-strain; conformational analysis: cyclohexane, mono and disubstituted cyclohexane; symmetry properties and optical activity; topomerisation; ring-size and ease of cyclisation; conformation.

9. Carbohydrates: (12L)

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 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; end-group-interchange of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose. Disaccharides: Glycosidic linkages, concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose, inversion of cane sugar. Polysaccharides: starch (structure and its use as an indicator in titrimetric analysis).

Reference Books:

1. Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Second edition, Oxford University Press 2012.
2. Sykes, P. A guide book to Mechanism in Organic Chemistry, Pearson Education, 2003.
3. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
4. Carey, F. A., Guiliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education, 2012.
5. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press, 2008.

6. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, Nelson Thornes, 2003.
7. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Finar, I. L. Organic Chemistry (Volume 1), Pearson Education.
9. Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Graham Solomons, T.W., Fryhle, C. B. Organic Chemistry, John Wiley & Sons, Inc.
11. March, J. Advanced Organic Chemistry, Fourth edition, Wiley.
12. Jenkins, P. R., Organometallic Reagents in Synthesis, Oxford Chemistry Primer, Oxford University Press.
13. Ward, R. S., Bifunctional Compounds, Oxford Chemistry Primer, Oxford University Press.
14. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London.
15. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
16. Sengupta, Subrata. Basic Stereochemistry of Organic molecules.
17. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
18. Eames, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
19. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
20. Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.

Course Code: CHEM-MAP-10
Course title: Inorganic - 3, Physical - 3 & Organic – 3

Inorganic – 3

Qualitative semi micro analysis

Qualitative semi micro analysis of mixtures containing four radicals (excluding oxide and carbonate). Emphasis should be given to the understanding of the chemistry of different reactions and to assign the most probable composition.

Basic Radicals: K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Al^{3+}, Cr^{3+}, Mn^{2+}, Fe^{2+}/Fe^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}, Sb^{3+}/Sb^{5+}.

Acid Radicals: Cl^-, Br^-, I^-, S^{2-}, SO_4^{2-}, $S_2O_3^{2-}$, NO_3^-, NO_2^-, BO_3^{2-}, PO_4^{3-}, AsO_4^{3-} and H_3BO_3.

Insoluble Materials: Cr_2O_3(ig), Fe_2O_3(ig), Al_2O_3, SnO_2, $PbSO_4$, $BaSO_4$, $SrSO_4$.

Analysis of other Specific elements: Ti, W, V, Mo and Ce.

Reference Books

1. Mendham,J.,A.I.Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
3. Das, S. C., Chakraborty, S. B., Practical Chemistry.
4. Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
5. Ghosal, Mahapatra & Nad, An Advanced course in practical Chemistry, New Central Book Agency.

Physical – 3

i) Study of phenol-water phase diagram.
ii) Effect of ionic strength on the rate of Persulphate –Iodide reaction.
iii) pH-metric titration of acid (mono-and di-basic) against strong base.
iv) Verification of Beer and Lambert's Law for $KMnO_4$and $K_2Cr_2O_7$solution.
v) Study of kinetics of $K_2S_2O_8$+ KI reaction, spectrophotometrically.
vi) Determination of pH of unknown buffer, spectrophotometrically.

Reference Books

1. Palit, S.R., De, S. K.Practical Physical Chemistry Science Book Agency.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
3. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
4. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Organic – 3

Qualitative Analysis of Single Solid and Liquid Organic Compounds:

1. Detection of special elements (N, S, Cl, Br) by Lassaigne's test
2. Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
3. Detection of the following functional groups by systematic chemical tests:
4. Aromatic amino (Ar-NH_2), aromatic nitro (Ar-NO_2), amido (-$CONH_2$, including imide), phenolic hydroxyl (Ph–OH), carboxylic acid (-COOH), carbonyl (-CHO and >C=O); only one test for each functional group is to be reported.
5. Melting/Boiling point of the given compound
6. Preparation, purification and melting point determination of at least one solid crystalline derivative of the given compound
7. Identification of the compound through literature survey.

Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups with relevant derivatisation in known and unknown (at least six) organic compounds containing different functional groups

Reference Books:

1. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003.
3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009).
4. Furniss, B.S., Hannaford, A.J., Smith, P.W.G., Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012).
5. Clarke, H. T., A Handbook of Organic Analysis (Qualitative and Quantitative), Fourth Edition, CBS Publishers and Distributors (2007).
6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

Semester VII

Course Code: CHEM-MAT-11
Course title: Inorganic – 4

1. Theories of Bonding: (18L)

Hydrogen molecule: Linear Combination of atomic orbitals (LCAO) method-normalizing constant, overlap integral. Bonding, non-bonding and anti-bonding orbitals. The variational principle-coulomb integral, resonance integral. Qualitative MO treatment to understand the bonding in triatomic (H_3^+, BeH_2, H_2O), tetraatomic (BH_3, NH_3) systems and CH_4. Qualitative MO energy level and orbital diagrams. Rationalization of structures.

2. Metal – ligand Equilibria in Solution (22L)

Stability of mononuclear, polynuclear and mixed ligand complexes in solution. Stepwise and overall formation constants and their relations. Trends in stepwise formation constants, factors affecting the stability of metal complexes with reference to the nature of the metal ions and ligands. Statistical and non-statistical factors influencing stability of complexes in solution. Stability and reactivity of mixed ligand complexes with reference to chelate effect and thermodynamic considerations. Macrocyclic effect. Determination of composition and stability constants of complexes.

3. **Bioinorganic Chemistry**

(25L)

Essential elements of Life, Role of metal ions in living systems-a brief review, Na^+ ion pump and transport of Na^+ and K+ across the cell membrane, Porphyrin and related ligands, ATP as energy source, oxidative phosphorylation and phosphorylation of glucose. Transport and storage of dioxygen: Structure and function of hemoglobin, myoglobin, hemocyanin and hemerythrin,Synthetic oxygen carriers. Active site structures and bio-functions of carboxy peptidaseA, carbonic anhydrase B, cytochrome c and chlorophyll. Biological nitrogen fixation, toxic metals (Pb, Cd and Hg) and their effects.Wilson disease, chelation therapy, platinum and gold complexes as drugs (examples only).

4. Polyoxo metalate (10L)

Iso and Hetero poly acids: Synthesis, Structure and Bonding. Types and classification of Heteropolymetallates (Dawson, Keggin etc.). Polyoxometallates, heteropoly blue. Utilities and application.

Recommended Books

1. F. A. Cotton, G. Wilkinson, C. M. Murillo and M. Bochmann, *Advanced Inorganic Chemistry*, 6th Edn, John Wiley & Sons, Inc, New York, 1999.
2. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorgnic Chemistry: Principles of Structures and Reactivity*, 4th Edn, Pearson, New Delhi, 2006.
3. N. N. Greenwood and A. Earnshaw, *Chemistry of the Elements*, 2nd Edn, Pergamon, New York, 1997.
4. K. L. Purcell, J. C. Kotz, *An Introduction to Inorganic Chemistry*.
5. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models of Inorganic Chemistry*, 3rd Edn, John Wiley & Sons, Inc., New York, 2001.
6. G. Wulfsberg, *Inorganic Chemistry*, Viva Books Pvt Ltd, New Delhi, 2001.
7. S. F. A. Kettle, *Coordination Chemistry*
8. G. Wilkinson, R. A.Gillard, J. A. McCleverty (eds) *Comprehensive Coordination Chemistry.*
9. J. Ronald, Paul L. A. Gillespie, Popelier, *Chemical Bonding and Molecular Geometry. From Lewis to Electron,* 2001, Oxford University Press.

10. C.J. Balehausen, H. B. Gray, *Molecular Orbital Theory: An Introductory LectureNote and Reprint Volume*, 1965, W.A. Benjamin INC.
11. Nouredine Zettili, *Quantum Mechanics: Concepts and Applications*, 2nd Edn. Wiley.
11a. P.M. Mathews, K. Venkatesan, *A Textbook of Quantum Mechanics*, 2nd Edn., McGraw Hill Education.
12. B.H. Bransden, *Quantum Mechanics*, 2nd Edn., Pearson Education. Karl T. Hecht, *Quantum Mechanics*, 2008, SPRINGER.
13. S. F. A. Kettle, J. N. Murrall, S. Teddler, *Valence Theory*.
14. A. Williams, *Theoretical Approach to Inorganic Chemistry*
15. D. F. Shriver, P. W. Atkins, C. H. Langford, *Inorganic Chemistry*.
16. C. E. Housecraft and A. G. Sharpe, *Inorganic Chemistry*, 3rd Edn, Pearson Education Ltd, Essex, England, 2008.
17. R. W. Hay, *Bioinorganic Chemistry*.
18. D. R. Williams, *Introduction to Bioinorganic Chemistry*
19. L. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine, *Bioinorganic Chemistry*
20. Jeremy M Berg, Stephen J Lippard*Principles of Bioinorganic Chemistry*, Panima Publishing Corporation, 1997
21. Asim K Das, *Bioinorganic Chemistry*, New Central Publisher.
22. Wolfgang Kaim, Brigitte Schwederski, *Bioinorganic Chemistry*: *Inorganic Elements in the Chemistry of Life*: *An Introduction and Guide*, John Wiley India Pvt Ltd.
23. Dieter Rehder, Ebbe Nordlander, *Bioinorganic Chemistry*, Oxford University Press; Illustrated edition, 2014.
24. Robert Crichton, *Biological Inorganic Chemistry: A New Introduction to Molecular Structure and Function*, 3rd Edition, Academic Press.
25. *Bioinorganic Chemistry: An Inorganic Perspective of Life*, Editors: Kessissoglou, D.P. (Ed.), Springer.
26. Ivano Bertini, Harry B. Gray, Stephen J. Lippard, Joan Selverstone Valentine, *Bioinorganic Chemistry*, University Science Books.
27. G. N. Mukherjee, A. Das, *Elements of Bioinorganic Chemistry*,U.N. Dhar & Sons Pvt. Ltd.
28. M. N. Hughes, *Inorganic Chemistry of Biological Process*.
29. Dieter Rehder, Ebbe Nordlander, *Bioinorganic Chemistry*, Oxford University Press; Illustrated edition 2014.

Course Code: CHEM-MAP-11
Course title: Inorganic – 4

Inorganic Preparation:

i. Mohr'ssalt
ii. Potassiumtris(oxalato)chromate(III)trihydrate
iii. Tetraamminecarbonatocobalt(III)nitrate
iv. Potassiumbis(oxalato)cuprate(II)dihydrate
v. Tris(ethylenediamine)nickel(II)chloride

Reference Books

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
3. Das, S. C., Chakraborty, S. B., Practical Chemistry.
4. Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
5. Ghosal, Mahapatra & Nad, An Advanced course in practical Chemistry, New Central Book Agency

Course Code: CHEM-MAT-12
Course title: Physical – 4

1. Physical Chemistry of Biological Molecules Relevant to Life Processes
(15L)

Basic features of primary, secondary, tertiary and quaternary structure of proteins, nucleic acids and lipids, explanation of various interactions, hydrogen bonding in biomolecules.

2. Advanced Chemical Kinetics
(14L)

Brief review of Collision Theory and Activated Complex Theory, ionic reaction, kinetic salt effect, steady-state kinetics, unimolecular reactions, chain reactions, fast reactions, relaxation techniques, flow method, stopped flow method.

3. Group Theory
(13L)

Concepts of Symmetry, symmetry elements, operations,group, sub-group, class, point groups with examples.

4. Basic Molecular Spectroscopy of Diatomic Molecules
(13L)

Rotational spectroscopy, vibrational spectroscopy, rotation-vibration spectroscopy and electronic spectroscopy of diatomic molecules.

5. Basic Concepts of Quantum Mechanics
(20L)

Basic, concepts in Quantum chemistry, Heisenberg Uncertainty Principle. Beginning of Quantum Mechanics: Wave-particle duality, light as particles: photoelectric and Compton effects; electrons as waves and the deBroglie hypothesis; Uncertainty relations (without proof). Wave function: Schrodinger time-independent equation; nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function.

Reference Books

1. Castellan, G.W. Physical Chemistry, Narosa.
2. Atkins, P.W. & Paula, J. de Atkins, Physical Chemistry, Oxford University Press.
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
4. Levine, I. N. Physical Chemistry,Tata McGraw-Hill.
5. Moore,W.J. Physical Chemistry,Orient Longman.
6. Mortimer, R. G. Physical Chemistry, Elsevier.

7. Engel, T. & Reid, P. Physical Chemistry, Pearson.
8. Levine, I. N. Quantum Chemistry, PHI.
9. Atkins, P. W. Molecular Quantum Mechanics, Oxford.
10.Engel,T. & Reid, P. Physical Chemistry, Pearson.
11. F. A Cotton, Chemical Applications of Group Theory.
12. Fundamentals of Molecular Spectroscopy, C. N. Banwell.
13. L. Stryer, J. M. Berg, J. M. Tymoczko, *Biochemistry*, 6th Edn. W.H. Freeman and Co., New York, 1995

Course Code: CHEM-MAP-12
Course title: Physical – 4

1. Determination of Ksp for AgCl by potentiometric titration of $AgNO_3$solution against standard KCl solution.
2. Determination of CMC from surface tension measurements.
3. Determination of molecular weight of a polymer by viscometry

Reference Books

1. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
3. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
4. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.
5. M.P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed., Oxford University Press, 1999.
6. H.R. Allcock, F.W. Lampe & J.E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003).
7. F.W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984) .

Course Code: CHEM-MAT-13
Course title: Organic – 4

1. Cyclic Stereochemistry: (10L)

Conformational analysis and reactivity of six membered, fused and bridged bicyclic compounds: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic syn elimination and fragmentation.

2. The Logic of Organic Synthesis: (20L)

Retrosynthetic analysis: disconnections; synthons, donor and acceptor synthons; natural reactivity and umpolung; linear and convergent synthesis, 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 1,5-dioxygenated compounds), reconnection (1,6-dicarbonyl); protection-deprotection strategy (alcohol, amine, carbonyl, acid).

Strategy of ring synthesis: thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique; Baldwin rules and exceptions, Thorpe-Ingold Effect, Inter-conversion of ring systems (contraction and expansion): general utility in organic synthesis

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: Felkin-Anh and Zimmermann-Traxler models, Rearrangement reactions involving electron rich and electron deficient centres.

3. Pericyclic reactions: (10L)

Pericyclic Reaction: Introduction, classification and stereochemical modes, selection rules of electrocyclic reactions, 2-component cycloadditions (4π- and 6π-electrons) and sigmatropic rearrangements ([1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements). Rationalization based on 'aromatic transition state' and FMO approaches (4π- and 6π-electrons). Fluxional tautomerism.

4. NMR Spectroscopy: (20L)

Introduction; nuclear spin; NMR active molecules; basic principles of Proton Magnetic Resonance; equivalent and non-equivalent protons; chemical shift and factors influencing it; ring current effect; significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant (1st order spectra); relative intensities of first-order multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR ; elementary idea about non-first-order splitting; anisotropic effects in alkene, alkyne, aldehydes and aromatics; NMR peak area, integration; relative peak positions with coupling patterns of common organic compounds (both aliphatic and benzenoid-aromatic); rapid proton exchange; interpretation of NMR spectra of simple compounds.

NMR phenomenon (CW and FT-NMR), ^{1}H NMR: Chemical shift δ, inductive and anisotropic effects on δ, chemical and magnetic equivalent / non-equivalent protons, spin-spin coupling (hydrogen-hydrogen and hydrogen with other spin active nuclei such as ^{13}C, ^{19}F), structural correlation to coupling constant J, First order patterns, Second order effects, Nomenclature of spin system, Examples of A_2, AB, AX, AMX, ABX, ABC systems etc, Techniques for simplification of ^{1}H NMR spectra (Chemical techniques: deuteration, trifluoroacetylation, lanthanide shift reagents, chiral

resolving agents; Instrumental techniques: use of higher magnetic field, spin decoupling, NOE); ^{13}C NMR spectroscopy, Application of NMR and other spectroscopic techniques to solve structures and mechanistic problems.

5. Biomolecules: (15L)

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, Dakin West reaction; resolution of racemic amino acids. 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 (enzymatic) of peptides: use of CNBr. Nucleic acids: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; mechanism for acid catalysed hydrolysis of nucleosides (both pyrimidine and purine types); comparison of alkaline hydrolysis of DNA and RNA; elementary idea of double helical structure of DNA (Watson Crick model); complimentary base–pairing in DNA.

Reference Books:

1. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London.
2. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
3. Sengupta, Subrata. Basic Stereochemistry of Organic molecules.
4. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
5. Eames, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
6. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
7. Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley, 2009.
8. Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.
9. Gilchrist, T. L. & Storr, R. C. Organic Reactions and Orbital symmetry, Cambridge University Press.
10. Warren, S. Organic Synthesis the Disconnection Approach, John Wiley and Sons.
11. Warren, S., Designing Organic Synthesis, Wiley India, 2009.
12. Carruthers, W. Modern methods of Organic Synthesis, Cambridge University Press.
13. Willis, C. A., Wills, M., Organic Synthesis, Oxford Chemistry Primer, Oxford University Press.
14. Kemp, W. Organic Spectroscopy, Palgrave.
15. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015).
16. Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Private Limited.

Course Code: CHEM-MAP-13
Course title: Organic – 4

1. Quantitative Analysis

i. Estimation of glucose by titration using Fehling's solution

ii. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method

2. Chromatographic Separations:

i. TLC separation of a mixture containing 2/3 amino acids

ii. TLC separation of a mixture of dyes (e.g. fluorescein and methylene blue)

Reference Books:

1. University Hand Book of Undergraduate Chemistry Experiments, edited byMukherjee, G. N. University of Calcutta, 2003
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta,2015.
3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson(2012).
4. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education.

Course Code: CHEM-MIT – 4
Course title: Physical & Inorganic

Physical Chemistry– 3

1. Solutions (5L)

Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions; Vapour pressure-composition and temperature-composition curves of ideal and non-ideal solutions; Distillation of solutions; Leverrule; Azeotropes, Nernst distribution law and its applications.

2. PhaseEquilibria (5L)

Phases, components and degrees of freedom of a system, criteria of phase equilibrium; Gibbs Phase Rule and its thermodynamic derivation; Derivation of Clausius – Clapeyron equation and its importance in phase equilibria; Phase diagrams of one-component systems (water and sulphur).

3. Conductance (6L)

Conductance,cell constant, specificconductanceandmolar conductance;Variationof specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Ostwald's dilution law;

4. Electromotiveforce (6L)

Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry; Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential; Electrochemical series; Thermodynamics of a reversible cell, calculation of thermodynamic properties: G, H and S from EMF data

Inorganic Chemistry – 3

1. TransitionElements(3dseries) (10L)

General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.

Lanthanoids and actinoids: Electronic configurations, oxidation states, colour, magnetic properties, lanthanide contraction, separation of lanthanides (ion exchange method only).

2. Chemistry of s and p-block elements : (13L)

(i) Group trends in electronic configuration, modification of pure elements, common oxidation states, inert pair effect, and their important compounds in respect of the following groups of elements:

a) B-Al-Ga-In-Tl; b) C-Si-Ge-Sn-Pb; c) N-P-As-Sb-Bi

(ii) Allotropy and catenation (examples of C, P and Scompounds). Study of the following Compounds with emphasis on preparation, properties, structure and bonding: diborane; borazine; boron nitride, boric acid, borax, fluorocarbons (with environmental effect); interhalogens, pseudohalogens, fluorides and oxides of xenon. Synthesis, structural aspects and applications of silicones and phosphazines. Structural properties of various silicates.

Reference Books

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
6. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
7. Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.
8. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
9. Pahari, S., Physical Chemistry New Central Book Agency.
10. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.
11. Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
12. Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
13. Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
14. Rodgers, G.E. Inorganic &Solid State Chemistry, Cengage Learning India Ltd., 2008.

Course Code: CHEM-MIP- 4
Course title: Physical - 3 & Inorganic - 3

Physical Chemistry – 3

1. Distribution Law

a. Study of the equilibrium of one of the following reactions by the distribution method: $I_2(aq) + I^-(aq) = I^-(aq)$

3

2. Conductance

a. Determination of dissociation constant of a weak acid (cell constant, equivalent conductance are also determined)

b. Perform the following conductometric titrations:

i. Strong acid vs. strong base

ii. Weak acid vs. strong base

3. Potentiometry

Perform the following potentiometric titrations:

i. Weak acid vs. strong base

ii. Potassium dichromate vs. Mohr's salt

Inorganic Chemistry – 3

1. Complexometric estimation of (i) Mg^{2+} or (ii) Zn^{2+} using EDTA.
2. Preparation of any two of the following complexes:

a. tetraamminecarbonatocobalt(III)nitrate

b. tetraamminecopper(II)sulphate

c. potassiumtrioxalatochromate(III)trihydrate

d. potassiumbisoxalatocuprate(II)trihydrate

Reference Books

1. Mendham, J., A.I.Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
3. Das, S. C., Chakraborty, S. B., Practical Chemistry.
4. Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
5. Ghosal, Mahapatra &Nad, An Advanced course in practical Chemistry, New Central Book Agency

Semester VIII

Course Code: CHEM-MAT-14
Course title: Inorganic – 5

1. Molecular Orbital Treatment for Metal Complexes (10L)

Symmetry designation of LGOs and metal orbitals. Simplified MO energy level diagrams of octahedral and square planar complexes. Symmetries of the metal-ligand σ and π MOs. Effect of Metal – ligand π interaction on ligand field strength. Charge transfer transitions in metal complexes.

2. Metal Complexes of π acid Ligands and Organometallic Chemistry: (22L)

Characteristic Features of π-acid ligands. Preparation, properties, structures and reactivities of metal carbonyls, nitrosyls, dinitrogen and dioxygen complexes. Tertiary phosphines as ligands. Definition and classification of organometallic compounds, hapticity of ligands, General method of preparation of metal-carbon sigma-bonded complexes, Zeise's salt, Preparation, structure, properties and reactions of ferrocene, elementary idea about oxidative addition, reductive elimination and insertion reaction. Stduy of the following catalytic process: alkene hydrogenation (Wilkinson's catalyst), Hydroformylation, Wacker process and olefin polymerization reaction (Ziegler-Natta catalyst).

3. **Ring, Cage and Cluster Compounds (20L)**

Isotopes of boron and their uses, diborane—synthesis and structure, nomenclature and the chemistry of boranes. Polyhedral skeletal electron pair theory (PSEPT)—Wade's rule, skeletal electron counting for higher boranes, carboranes and B-N clusters, vertices and cage structures, 'styx' rule—equation of balance, structures of higher boranes (neutral, cationic and anionic), metalloboranes and metallocarboranes. Structures of low nuclearity and high nuclearity carbonyl clusters—valence electron counting and metal–metal bonds.

4. **Separation Technique: Liquid & Solid Phase Extraction**

(8L)

Principle and protocol of separation, fundamental concept of liquid phase and solid phase extraction. Single, multiple and counter current liquid phase extraction, salting out agent, kinetics of solvent extraction, metal ion extraction. Examples & applications of solid phase extraction.

Recommended Books

1. F. Albert Cotton, *Chemical Applications of Group Theory*, 1990, Willey
2. Vincent, Alan, *Molecular symmetry and Group theory: A programmed Introduction to Chemical Applications*, 2001, Wiley.
3. K. Veera Reddy, *Symmetry and Spectroscopy of Molecules*, 2020, New Age International Publications.
4. Todd B. Marder, Zhenyang Lin, *Contemporary Metal Boron Chemistry I: Borylenes, Boryls, Borane Sigma-Complexes, and Borohydrides*, Springer; 2008 Edn.
5. Russell N. Grimes, *Metal Interactions with Boron Clusters*, Springer; 2013
6. William N Lipscomb, *Boron Hydrides*, Dover Publications Inc.; Illustrated edition, 2012.
7. W Siebert, *Advances In Boron Chemistry*, Royal Society of Chemistry, 1997.
8. R. L. Dutta & G.S. De, *Inorganic Chemistry* - Vol I, the New Book Stall Publisher.
9. R. P. Sarkar, *General and Inorganic Chemistry*: Volume I, New Central Book Agency.
   Ch. Elschenbroich, A. Salzer - Organometallics, VCH, Weinheim, 4thed., 2006.
10. R.H. Crabtree - The Organometallic Chemistry of the Transition Metals, Wiley, NewYork, 3rd ed., 2005.
11. J.K. Kochi - Organometallic Mechanisms and Catalysis, Academic Press, NewYork, 1978.

12. S. KomiyaEd. - Synthesis of Organometallic Compounds, Wiley, New York, 1997.
13. J.D. Atwood - Inorganic and Organometallic Reaction Mechanisms, Brooks/Cole, Belmont, CA, 1985.
14. A. Yamamoto - Organotransition Metal Chemistry, Wiley, New York, 1990.
15. C.M. Lukehart - Fundamental Organometallic Chemistry, Brooks, Cole, Monterey, 1985.
16. M. Bochmann - Organometallics 1 and 2, Oxford Science Publications, Oxford, 1994.
17. I. Haiduc, J.J. Zuckerman - Basic Organometallic Chemistry, Walter de Gruyter, Berlin, 1985.
18. W. Parkins, R.C. Poller, - An Introduction to Organometallic Chemistry, Palgrave Macmillan, Oxford, 1987.
19. J.S. Thayer - Organometallic Chemistry, An Overview, VCH, New York, 1988.
20. A. Dean, *Chemical Separation Methods*, Van Nostrand Reinhold, London, 1970.
21. D. G. Peters, J. M. Hayes and G. M. Hieftje, *Chemical Separations and Measurements: Theory and Practice of Analytical Chemistry*, Saunders, Wiley Interscience, New York, 1974.
22. G. H Morrison, H. Freiser, *Solvents Extraction of Chelates*, Wiley, 1959
23. G. H Morrison, H. Freiser, *Solvent Extraction in Analytical Chemistry*, Wiley. 1957

Course Code: CHEM-MAT-15
Course title: Physical – 5

1. Macromolecules **(13L)**

Polymers – definition, types of polymers – electrically conducting, fire resistant, , liquid crystal polymers, condensation polymerization, copolymerization, kinetics of polymerization, molecular mass of polymers, number average and mass average molecular weights, Determination of these molecular weights.

2. Basic Statistical Thermodynamics **(15L)**

Configuration: Macrostates, microstates and configuration; variation of W withE; equilibrium configuration. Boltzmann distribution: Thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation); Applications to barometric distribution; Partition function, concept of ensemble -canonical ensemble and grand canonical ensembles.
Partition function: molecular partition function and thermodynamic properties.

3. Group Theory
(12L)

Group multiplication tables for cyclic and non-cyclic groups, matrix representations of symmetry operations and their characters, reducible representations, irreducible representations, great orthogonality thereom (no derivation), construction of character tables, applications of group theory.

4. Advanced Quantum Mechanics **(12L)**

Rotation and angular momentum, spherical harmonics, H-atom solution, many electron systems, variation and perturbation theory, Born Oppenheimer approximation.

5. Working principles of Instrumental techniques (8L)

Uv-visible spectrophotometer, conductometer, potentiometer, pH-meter, FT-IR spectrometer, tensiometer

Reference Books

1. Castellan, G.W. Physical Chemistry, Narosa.
2. Atkins, P.W. & Paula, J. de Atkins, Physical Chemistry, Oxford University Press.
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
4. Levine, I. N. Physical Chemistry,Tata McGraw-Hill.
5. Moore,W.J. Physical Chemistry,Orient Longman.
6. Mortimer, R. G. Physical Chemistry, Elsevier.
7. Engel, T. & Reid, P. Physical Chemistry, Pearson.
8. Levine, I. N. Quantum Chemistry, PHI.
9. Atkins, P. W. Molecular Quantum Mechanics, Oxford.
10. Engel,T. & Reid, P. Physical Chemistry, Pearson.
11. F. A Cotton, Chemical Applications of Group Theory.
12. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.
13. M.P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed., Oxford University Press, 1999.
14. H.R. Allcock, F.W. Lampe & J.E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003).
15. F.W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984) .

Course Code: CHEM-MAT-16
Course title: Organic – 5

1. Photochemistry (10L)

Basic principles, Jablonski diagram, photochemistry of olefinic compounds, *cis-trans* isomerization, Paterno-Buchi reaction, Norrish Type-I and Type-II reactions, photoreduction of ketons, di-π methane rearrangement, photochemistry of arenes, photoreactions in solid state, photochemistry of nitro, azo and diazo compounds, photo-fragmentation reactions (Barton, Hofmann-Loffler-Freytag).

2. Oxidising and reducing agents in organic synthesis (10L)

(a) Oxidation: metal-based oxidants; non metal-based oxidation: Swern oxidation, Moffatt oxidation, hypervalent iodine-based oxidants.

(b) Reduction: metal hydrides; hydrogenation; dissolving metal reductions; samarium iodide.

3. Chemistry of Organoboron, Organosulfur, Organophosphorous and Organosilicon Reagents (20L)

Organoboron chemistry: Hydroboration, region-, chemo- and stereoselectivity. Conversion of C-B bond to C-hetero and C-C bonds. Use of allylboration and crotylboration.

Organosulfur chemistry: application of sulphoxides, sulfones and sulphur ylides in organic synthesis.

Organophosphorous chemistry: phosphorus ylides, Wittig reaction and its modifications. Phosphines and phosphites. Arbutsov reaction.

Organosilicon: Generalisations in silicon chemistry, Use of arylsilanes, vinylsilanes, epoxysilanes, allylsilanes.

4. Heterocyclic compounds: (**10L)**

5- and 6-membered rings with one heteroatom; nomenclature, reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine; synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis, Paal-Knorr synthesis, Hantzsch; furan: Paal-Knorr synthesis, Feist-Benary synthesis and its variation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis; benzo-fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and important reactions (with mechanistic details) of indole, quinoline, isoquinoline, isoindoles and isobenzofurans; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Doebner- Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis

5. Natural Products (Terpenoids, Alkaloids and Steroids) (10L)

(a) Terpenoids: Introduction, isoprene rule, general methods of isolation, structure elucidation and synthesis of some representative members of mono and sesquiterpenes.

(b) Alkaloids: Definition and classification, general methods of isolation and structure elucidation, structure and synthesis of some alkaloids: ephedrine, nicotine and papaverine.

(c) Steroids: Introduction, classification, nomenclature and general properties. Chemistry of Vitamin-D.

(d) Basic knowledge on biogenesis and biosynthesis of terpenoids, alkaloids and steroids.

Reference Books:

1. J. M. Coxon and B. Holton, *Organic Photochemistry*, Cambridge University Press, London, 1974.
2. K. K. Rohatgi-Mukherjee, *Fundamentals of Photochemistry*, New Age International (P) Limited, Publishers, India, 2007.
3. C. H. J. Wells, *Introduction to M.L. Photochemistry*, Chapman and Hall, London, 1974.
4. W. A. Noyes, G.S. Hammond and J. N. Pitts, *Advances in Photochemistry*, Vol I, Interscience Publisher, New York, 1964.
5. O. L. Chapman, *Some Aspects of Organic Photochemistry*, Dekker, 1967.
6. N. J. Turro, V. Ramamurthy, J. C. Scaiano, *Modern Molecular Photochemistry of Organic Molecules*, University Science, Books, CA, 2010.
7. W. Carruthers and I. Coldham, *Modern methods of Organic Synthesis*, First South Asian Edition 2005, Cambridge University Press.
8. F. A. Carey and R. J. Sundberg, *Advanced Organic Chemistry Part A and Part B*, 4th Edn, Plenum Press, New York, 2001.
9. H. O. House, *Modern Synthetic Reactions*, 2nd Edn, W. A. Benjamin, Inc.
10. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic Chemistry*, Oxford University Press, Oxford, 2001.
11. J. H. Fuhrhop and G. Li, *Organic Synthesis*, Concepts and Methods, Wiley-VCH, New York, 2003.
12. K. Nakanishi, T. Goto, S. Ito, S. Natori and S. Nozoe, *Natural Products Chemistry*, Vol I, Academic Press, New York, 1974.

13. J. Mann, R.S. Davidson, J.B. Hobbs, D.V. Banthorpe, J.B. Harborne *Natural products: their chemistry and biological significance*, Harlow, Essex, England: Longman Scientific Technical; New York : Wiley, 1994.
14. John ApSimon, *The Total Synthesis of Natural Products*: Volume-3 Wiley-Interscience Publication.
15. I. L. Finar, *Organic Chemistry*, Volume 2: *Stereochemistry And The Chemistry Natural Products*, 5th Edn., Pearson Education India, 1956.
16. S.V. Bhat, B. A. Nagasampagi, S. Meenakshi, *Natural Products Chemistry & Applications*, Narosa Publishing House, 2009.
17. Susan E. Thomas, *Organic* Synthesis: The *role of Boron and silicon*, Oxford Science Publications,
18. J. A. Joule, K. Mills, *Heterocyclic Chemistry*, 5th Edn, John Wiley & Sons Ltd, UK, 2010.
19. R. Kartritzky, *Handbook of Heterocyclic Chemistry*, Pergamon Press, London, 1986.
20. R. R. Gupta, M. Kumar, V. Gupta, *Heterocyclic Chemistry II*, Springer Pvt Ltd, India, 2005.
21. R. K. Bansal, *Heterocyclic Chemistry*, 4th Edn, New Age International (P) Ltd, India, 2005.
22. T. L. Gilchrist, *Heterocyclic Chemistry*, Prentice Hall, 1997.

Course Code: CHEM-MAT-17
Course title: Inorganic – 6 & Physical – 6

INORGANIC – 6

1. Qualitative and quantitative aspects of analysis: (8L)

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of theirexpression, normal law of distribution if indeterminate errors, statistical test of data; F, Q andt test, rejection of data, and confidence intervals.

2. Optical methods of analysis: (30L)

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopyand selection rules, validity of Beer-Lambert's law.

i) UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument.

ii) Basic principles of quantitative analysis: estimation of metal ions from aqueoussolution,geometrical isomers, keto-enol tautomers. Determination of composition of metalcomplexes using Job's method of continuous variation and mole ratio method.

iii) Infrared Spectrometry: Basic principles of instrumentation (choice of source,monochromator & detector) for single and double beam instrument; sampling techniques.Structural illustration through interpretation of data, Effect and importance of isotope substitution.

iv) Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, detector, choice of flame and Burner designs. Techniquesof atomization and sample introduction; Method of background correction, sources ofchemicalinterferences and their method of removal. Techniques for the quantitativeestimation of trace level of metal ions from water.

3. Chromatography: (7L)

Classification, principle and efficiency of the technique. Mechanismof separation: adsorption, partition & ion exchange. Development of chromatograms: frontal,elution and displacement methods. Qualitative and quantitative aspects.

Reference Books:

1. Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery andothers) 5th Ed. The English Language Book Society of Longman .
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, Gary D; Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.
7. Ditts, R.V. Analytical Chemistry – Methods of separation.

PHYSICAL – 6

1. Raman Spectroscopy

(12L)

Raman spectroscopy, Classical and Quantum Theories of Raman Scattering, Pure rotational Raman, pure vibrational Raman, concept of polarizability ellipsoid, Raman activity of vibrations of symmetric molecules like H_2O and CO_2, vibration – rotation Raman, mutual exclusion principle,

2. Advanced Statistical Mechanics

(14L)

Phase space, introduction to the ensemble concept, different types of ensembles**,** partition function, fluctuations.

3. Analytical Techniques

(6L)

Thermogravimetry, cyclic voltammetry – principles, instrumentation, interpretation of data.

4. Photoelectron Spectroscopy (13L)

Electron and photoelectron spectroscopy, photoexcitation, photoionization, low energy electron diffraction (LEED), X-ray and UV photoelectron spectroscopy (XPS and UPS), Auger electron spectroscopy (AES), experimental setup, chemical shift, analysis, electron energy loss spectroscopy (EELS), Zero kinetic energy (ZEKE) spectroscopy.

Reference Books

1. Statistical thermodynamics, T.L. Hill, Adison Wiley Publishers.
2. J. Michael Hollas , Modern Spectroscopy, 4th Edition
3. Fundamentals of Molecular Spectroscopy, C. N. Banwell.
4. Paul van der Heide, X-ray Photoelectron Spectroscopy: An introduction to Principles and Practices.
5. Vogel's Textbook of Quantitative Chemical Analysis 5th Ed., Jeffery, G.H.
6. H. Kaur, *Instrumental Methods of Chemical Analysis*, 7th edition, Pragati Prakashan Education Publisher, Meerut.

Course Code: CHEM-MAT-18
Course title: Organic – 7

1. Reactive intermediates: (9L)

Formation, stability and reactivity of carbanions, carbocations (classical and non-classical), carbenes, nitrenes, free radicals and arynes with reference to the basic types of organic reactions.

(a) Determination of reaction mechanism: Hammett equation, Taft equation.

(b) C-C and C-heteroatom bond forming reactions.

2. Structure Activity Relationships (9L)

Linear free energy relationship, Hammett equation and its modifications, electronic factors, steric factors, Taft equation. Quantative structure activity relationship, hydrophobic factors, other factors, Hansch equation, Craig plots, Topliss schemes.

3. Chemistry of non covalent compounds (9L)

Host-Guest interactions: Basic concepts, different types of non-covalent forces leading to bonding of guest molecules to the hosts, cation, anion and neutral molecules binding, Molecular wire, Molecular switches.

4. Green Chemistry (8L)

Introduction, principles, green synthetic methods, catalytic methods, organic synthesis in aqueous media, ionic liquid, supercritical fluids, MCR reactions, microwave-induced organic reactions, real-world cases of green chemistry, Phase transfer catalysis.

5. Pharmaceutical Chemistry and Analysis (10L)

Fundamentals of pharmaceutical drugs, definition and classification. Pharmacokinetics and pharmacogenomics, dose-response relationship. General pathways of drug metabolism. General principles and instrumental methods for the analysis of various pharmaceutical drugs.

Reference Books

1. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, 6th Edn, Pearson Education Ltd, New Delhi, 2011.
2. March, J. *Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 5th Edn, John Wiley, New York, 1999.
3. McManus, S. P. *Organic Reactive Intermediates*, Academic Press Inc. New York.
4. T. H. Lowry, K. S. Richardson, *Mechanism And Theory In Organic Chemistry*, 3rd Edn. AWL.
5. George S. Zweifel and Michael H. Nantz, *Modern Organic Synthesis: An Introduction*, W. H. Freeman Publisher, 2007.
6. Finar, I. L. Organic Chemistry, Volume 2: Stereochemistry And The Chemistry Natural Products, 5th Edn., Pearson Education India, 1956.
7. Lehn, J-M. Supramolecular Chemistry - Concepts and Perspectives, Wiley-VCH Verlag GmbH (1995).
8. Steed, J. W and Atwood, J. L. *Supramolecular Chemistry*, Wiley, 2000.
9. Beer, P. D.; Gale, P. A and Smith, D. K. *Supramolecular Chemistry*, Oxford University Press, 1999.
10. Das, A. K and Das, M. *Environmental Chemistry with Green Chemistry*, 4th edition, Books and Allied (P) Ltd., 2019.

11. Lancaster, M. Green Chemistry: An introductory, RSC publishing, 2nd Edn, 2010.
12. Anastas, Paul T. and Warner, John C. Green Chemistry: Theory and Practice, Oxford University Press, Oxford, 1998.
13. Ahulwalia, V. K. Strategies for Green Organic Synthesis, Ane Books Pvt. Ltd.,1st Edn, 2012.
14. Kar, Ashutosh. *Medicinal Chemistry*, 6th edition, New Age International Publishers.
15. Varley, Gowenlock, H. A. H.; McMurray, J. R.; McLauchlan, D. M. *Varley's Clinical Biochemistry*, 6th edition, Heinemann Medical Books, New Delhi (India): CBS, 2006.
16. Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press (2013).
17. Singh, H. & Kapoor, V. K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan (2012).
18. Foye, W. O.; Lemke, T. L. & William, D. A. Principles of Medicinal Chemistry, 6 th Ed., Lippincott Williams & Wilkins, Philadelphia (2008).

Course Code: CHEM-MAP-18
Course title: Inorganic - 6, Physical - 6 & Organic – 6

Inorganic – 6

I. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

II. Analysis of water and Soil:

(i) Determination of pH of water.

(ii) Total soluble salt

III. Separation Techniques

(i) Chromatography: Separation of mixtures

(ii) Paper chromatographic separation of Fe^{3+}, Al^{3+}, and Cr^{3+}

(iii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f value.

Reference Books:

1. Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G. H. Jeffery and others) 5th Ed. The English Language Book Society of Longman.
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, Gary D; Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004

Physical – 6

Computer Programming based on numerical methods for:

i) Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).

ii) Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

iii) Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values.

iv) Simple exercises using molecular visualization software.

Reference Books

1. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).
2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).
3.Yates, P. Chemical Calculations.2nd Ed. CRC Press (2007).
4.Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.
5. Noggle, J. H. Physical Chemistry on a Microcomputer. Little Brown & Co. (1985).

Organic – 6

Chromatographic Separations:

i. Column chromatographic separation of leaf pigments from spinach leaves
ii. Column chromatographic separation of mixture of dyes
iii Paper chromatographic separation of a mixture containing 2/3 amino acids
iv. Paper chromatographic separation of a mixture containing 2/3 sugars

Reference Books:

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta,2015.
3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson(2012).
4. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education.