VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM & SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE (HONOURS)

MAJOR IN CHEMISTRY

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), 2023 & NEP, 2020

VIDYASAGAR UNIVERSITY
BACHELOR OF SCIENCE (HONOURS) MAJOR IN CHEMISTRY
(under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. (Hons.)	1st	I	**SEMESTER-I**							
			Major-1	**CEMHMJ101**	**T:Organic Chemistry-I** **P: Organic Chemistry Lab- I**	**4**	**3-0-1**	**15**	**60**	**75**
			SEC	**CEMSEC01**	**P: Chemistry of Cosmetics & Perfumes**	**3**	**0-0-3**	**10**	**40**	**50**
			AEC	**AEC01**	Communicative English -1 (***common for all programmes***)	**2**	**2-0-0**	**10**	**40**	**50**
			MDC	**MDC01**	Multidisciplinary Course -1 (***to be chosen from the list***)	**3**	**3-0-0**	**10**	**40**	**50**
			VAC	**VAC01**	ENVS (***common for all programmes***)	**4**	**2-0-2**	**50**	**50**	**100**
			Minor CEM (Disc.-I)	**CEMMI01**	**T:Atomic Structure, Acids And Bases, Redox Reactions, & States of Matter; P: Practical *(To be taken by students of other Disciplines)***	**4**	**3-0-1**	**15**	**60**	**75**
					Semester-I Total	**20**				**400**
		II	**SEMESTER-II**							
			Major-2	**CEMHMJ102**	**T:Inorganic Chemistry-I** **P: Inorganic ChemistryLab-I**	**4**	**3-0-1**	**15**	**60**	**75**
			SEC	**CEMSEC02**	**P: Medicinal & Pharmaceutical Chemistry**	**3**	**0-0-3**	**10**	**40**	**50**
			AEC	**AEC02**	MIL-1 (***common for all programmes***)	**2**	**2-0-0**	**10**	**40**	**50**
			MDC	**MDC02**	Multi Disciplinary Course-02 (***to be chosen from the list***)	**3**	**3-0-0**	**10**	**40**	**50**
			VAC	**VAC02**	Value Added Course-02 (***to be chosen from the list***)	**4**	**4-0-0**	**10**	**40**	**50**
			Minor (Disc.-II)	**CEMMI02**	**T: General Organic Chemistry, Aliphatic Hydrocarbons & Chemical Kinetics; P: Practical** **(*To be taken by students of other Disciplines)***	**4**	**3-0-1**	**15**	**60**	**75**
			Summer Intern.	**CS**	Community Service	**4**	**0-0-4**	**-**	**-**	**50**
					Semester-II Total	**24**				**400**
					TOTAL of YEAR-1	**44**				**800**

MJ = Major, MI = Minor Course, SEC = Skill Enhancement Course, AEC = Ability Enhancement Course, MDC = Multidisciplinary Course, VAC = Value Added Course; CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical, MIL = Modern Indian Language, ENVS = Environmental Studies

MAJOR (MJ)

Major-1: ORGANIC CHEMISTRY-I **Credits 04 (Theory-03, Practicals-01)**

MJ1T: ORGANIC CHEMISTRY-I **Credits 03 (Theory: 45 Lectures)**

Course contents:

A. **Basics of Organic Chemistry**

Bonding and Physical Properties **(20 Lectures)**

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.

B. **General Treatment of Reaction Mechanism I** **(5 Lectures)**

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: generation and stability, structure using orbital picture and electrophilic/nucleophilicbehavior of reactive intermediates (elementary idea).

C. **Stereochemistry I** **(20 Lectures)**

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 ($C_{\alpha v}$, C_{nh}, C_{nv}, C_n, $D_{\alpha h}$, 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. Keeler, J., Wothers, P. *Chemical Structure and Reactivity – An Integrated approach*, Oxford University Press.
3. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003.
4. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
5. Carey, F. A., Guiliano, R. M. *Organic Chemistry*, Eighth edition, McGraw Hill Education, 2012. 6. Eliel, E. L. &Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
6. Nasipuri, D. *Stereochemistry of Organic Compounds*, Wiley Eastern Limited.
7. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education)
9. Fleming, I. *Molecular Orbitals and Organic Chemical Reactions*, Reference/Student Edition, Wiley, 2009.
10. James, J., Peach, J. M. *Stereochemistry at a Glance*, Blackwell Publishing, 2003.
11. Robinson, M. J. T., *Stereochemistry*, Oxford Chemistry Primer, Oxford University Press, 2005.

MJ1P: ORGANIC CHEMISTRY LAB- I **Credits 01 (30 Lectures)**

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 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

Solid compounds: oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, cane sugar, benzoic acid and salicylic acid

Liquid Compounds: formic acid, acetic acid, methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and 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).
5. Dutta, S, *B. Sc. Honours Practical Chemistry*, Bharati Book Stall.

Major-2: INORGANIC CHEMISTRY-I **Credits 04 (Theory-03, Practicals-01)**

MJ2T: INORGANIC CHEMISTRY-I **Credits 03(Theory: 45 Lectures)**

Course contents:

Extra nuclear Structure of atom **(14 Lectures)**

Bohr's theory, its limitations and atomic spectrum of hydrogen atom; Sommerfeld's Theory. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Pauli's Exclusion Principle, Hund's rules and multiplicity, Exchange energy, Aufbau principle and its limitations, Ground state Term symbols of atoms and ions for atomic number up to 30.

Chemical periodicity **(5 Lectures)**

Modern IUPAC Periodic table, Effective nuclear charge, screening effects and penetration, Slater's rules, atomic radii, ionic radii (Pauling's univalent), covalent radii, lanthanide contraction. Ionization potential, electron affinity and electronegativity (Pauling's, Mulliken's and Allred-Rochow's scales) and factors influencing these properties, group electronegativities. Group trends and periodic trends in these properties in respect of s-, p- and d-block elements. Secondary periodicity, Relativistic Effect, Inert pair effect.

Acid-Base reactions **(12 Lectures)**

Acid-Base concept: Arrhenius concept, theory of solvent system (in H_2O, NH_3, $SO_2$and HF), Bronsted-Lowry's concept, relative strength of acids, Pauling's rules. Lux-Flood concept, Lewis concept, group characteristics of Lewis acids, solvent levelling and differentiating effects. Thermodynamic acidity parameters, Drago-Wayland equation. Superacids, Gas phase acidity and proton affinity; HSAB principle. Acid-baseequilibria in aqueous solution (Proton transfer equilibria in water), pH, buffer. Acid-base neutralisation curves; indicator, choice of indicators.

Redox Reactions and precipitation reactions **(14 Lectures)**

Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples)

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

Reference Books

1. Lee, J. D. *Concise Inorganic Chemistry*,5th Ed., Wiley India Pvt. Ltd., 2008.
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).

MJ2PINORGANIC CHEMISTRY LAB-I Credits 01(30 hr. Class)

Acid and Base Titrations:

1. Estimation of carbonate and hydroxide present together in mixture
2. Estimation of carbonate and bicarbonate present together in a mixture.
3. Estimation of free alkali present in different soaps/detergents.

Oxidation-Reduction Titrimetric

1. Estimation of Fe(II) using standardized $KMnO_4$ solution
2. Estimation of oxalic acid and sodium oxalate in a given mixture
3. Estimation of Fe(II) and Fe(III) in a given mixture using $K_2Cr_2O_7$ solution.
4. Estimation of Fe(III) and Mn(II) in a mixture using standardized $KMnO_4$ solution.
5. Estimation of Fe(III) and Cu(II) in a mixture using $K_2Cr_2O_7$.
6. Estimation of Fe(III) and Cr(III) in a mixture using $K_2Cr_2O_7$.

Reference Books

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis* 6th Ed., Pearson, 2009.
2. Ghosal, Mahapatra&Nad, *An Advanced course in practical Chemistry*, New Central Book Agency.

MINOR (MI)

Minor-1:ATOMIC STRUCTURE, ACIDS AND BASES, REDOX REACTIONS, &STATES OF MATTER. (Credits 04)

MI-1T:ATOMIC STRUCTURE, ACIDS AND BASES, REDOX REACTIONS, &STATES OF MATTER. Credits 03(45 Lectures)

Course contents:

Section A: Inorganic Chemistry-I (20 Lectures)

Atomic Structure (7 Lectures)

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.

Acids and bases (7 Lectures)

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.

Redox reactions (6 Lectures)

Balancing of equation of redox reactions: oxidation number and ion-electron methods. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation), formal potential, oxidimetry and reductimetry.

Section

B: Physical Chemistry-I (25 Lectures)

Kinetic Theory of Gases and Real gases (10 Lectures)

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

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

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

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

Liquids **(08 Lectures)**

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)

Solids **(07 Lectures)**

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 (qualitative treatment only); Defects in crystals; Glasses and liquid crystals.

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 India, 2006
5. Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
6. Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
7. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
8. Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
9. Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
10. Chugh, K.L., Agnish, S.L. *A Text Book of Physical Chemistry* Kalyani Publishers
11. Bahl, B.S., Bahl, A., Tuli, G.D., *Essentials of Physical Chemistry* S. Chand &Co.ltd.
12. Palit, S. R., *Elementary Physical Chemistry* Book Syndicate Pvt. Ltd.
13. Mandal, A. K. *Degree Physical and General Chemistry* Sarat Book House
14. Pahari, S., *Physical Chemistry* New Central Book Agency
15. Pahari, S., Pahari, D., *Problems in Physical Chemistry* New Central Book Agency
16. Mukherjee, R.C., *Modern Approach to Physical Chemistry I & II*BharatiBhawan

MI-1P: Practical **Credits 01**

Course Outline:

Section A: Inorganic Chemistry –LAB **(15 Lectures)**

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 $K_2Cr_2O_7$using redox indicator.
5. Estimation of Cu(II) ions iodometrically using $Na_2S_2O_3$.

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.

Section B: Physical Chemistry-LAB **(15 Lectures)**

(I) Surface tension measurement (use of organic solvents excluded)
- a) Determination of the surface tension of a liquid or a dilute solution using a Stalagmometer
- b) Study of the variation of surface tension of a detergent solution with concentration

(II) Viscosity measurement (use of organic solvents excluded)
- a) Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer
- b) Study of the variation of viscosity of an aqueous solution with concentration of solute

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

Minor-2: GENERAL ORGANIC CHEMISTRY, ALIPHATIC HYDROCARBONS & CHEMICAL KINETICS **Credits 04**

MI-2T: GENERAL ORGANIC CHEMISTRY, ALIPHATIC HYDROCARBONS & CHEMICAL KINETICS **Credits 03**

(45 Lectures)

Course contents:

Section A: Organic Chemistry-I **(30 Lectures)**

Fundamentals of Organic Chemistry **(5 Lectures)**

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

Stereochemistry **(8 Lectures)**

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.

Nucleophilic Substitution and Elimination Reactions (5 Lectures)

Nucleophilic substitutions: SN1 and SN2 reactions; eliminations: E1 and E2 reactions (elementary mechanistic aspects); Saytzeff and Hofmann eliminations; elimination vs substitution.

Aliphatic Hydrocarbons (12 Lectures)

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 KMnO4, ozonolysis and oxidation with hot alkaline $KMnO_4$.

Section B: Physical Chemistry (15 Lectures)

Chemical Kinetics

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

Reference Books:

1. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
2. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
3. Madan, R. L. Organic Chemistry, S. Chand & Sons.
4. Wade, L. G., Singh, M. S., Organic Chemistry.
5. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Eliel, E. L. &Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
8. Sen Gupta, Subrata. Basic Stereochemistry of Organic molecules.
9. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
10. Bahl, A. &Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.
11. Chugh, K.L., Agnish, S.L. *A Text Book of Physical Chemistry* Kalyani Publishers

12. Bahl, B.S., Bahl, A., Tuli, G.D., *Essentials of Physical Chemistry* S. Chand &Co.ltd.
13. Palit, S. R., *Elementary Physical Chemistry* Book Syndicate Pvt. Ltd.
14. Mandal, A. K. *Degree Physical and General Chemistry* Sarat Book House
15. Pahari, S., *Physical Chemistry* New Central Book Agency
16. Pahari, S., Pahari, D., *Problems in Physical Chemistry* New Central Book Agency

MI-2P: Practical **Credits 01 (30 Lectures)**

MI2P: Organic Chemistry- LAB

Qualitative Analysis of Single Solid Organic Compound(s) **(20 Lectures)**

Experiment A: Detection of special elements (N, Cl, and S) in organic compounds.
Experiment B: Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH)

Experiment C: Detection of functional groups: Aromatic-NO_2, Aromatic -NH_2, - COOH, carbonyl (no distinction of –CHO and >C=O needed), -OH (phenolic) in solid organic compounds.

Experiments A - C with unknown (at least 6) solid samples containing not more than two of the above type of functional groups should be done.

Physical Chemistry-LAB **(10 Lectures)**

(I) Study the kinetics of the following reactions
a) Initial rate method: Iodide-persulphate reaction
b) Integrated rate method:
(i) Acid hydrolysis of methyl acetate with hydrochloric acid
(ii) Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate
(iii) Decomposition of H_2O_2

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.
8. *University Hand Book of Undergraduate Chemistry Experiments*, edited by Mukherjee, G. N., University of Calcutta, 2003.
9. Palit, S.R., *Practical Physical Chemistry* Science Book Agency
10. Mukherjee, N.G., *Selected Experiments in Physical Chemistry* J. N. Ghose&Sons
11. Dutta, S.K., *Physical Chemistry Experiments* Bharati Book Stall

SKILL ENHANCEMENT COURSE (SEC)

SEC 1: Chemistry of Cosmetics & Perfumes **Credits 03**

SEC1P: Chemistry of Cosmetics & Perfumes **Full Marks: 50**

Course Outline:

Part-A:

i) Preparation of talcum powder.
ii) Preparation of shampoo.
iii) Preparation of enamels.
iv) Preparation of hair remover.
v) Preparation of face cream.
vi) Preparation of nail polish and nail polish remover.
vii) Preparation of Lipstick.

Any other preparation as per the instruction of respective College

Part-B: Field visit and submission of the Report

Suggested Readings:

1. Stocchi, E. Industrial Chemistry, Vol, Ellis Horwood Ltd. UK (1990). Jain,
2. P.C. & Jain, M. Engineering Chemistry DhanpatRai& Sons, Delhi.Sharma,
3. B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

SEC 2: Medicinal & Pharmaceutical Chemistry **Credits 03**

SEC 2P: Medicinal & Pharmaceutical Chemistry **Full Marks: 50**

Part-A: Extraction

i) Extraction of eucalyptus leaf ingredient
ii) Extraction of eugenol from clove
iii) Extraction of nicotine from tobacco.
iv) Curumine from turmeric
v) Extraction of caffeine from tea/coffee

Part-B: A project: Collection and brief introduction of at least 10 herbal plants

Suggested Readings:

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.

VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM & SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE (HONOURS)

MAJOR IN CHEMISTRY

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), 2023 & NEP, 2020

VIDYASAGAR UNIVERSITY
BACHELOR OF SCIENCE (HONOURS) MAJOR IN CHEMISTRY
(under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. (Hons.)	2nd	III	SEMESTER-III							
			Major-3	CEMHMJ03	T: Physical Chemistry-I; P: Practical	4	3-0-1	15	60	75
			Major-4	CEMHMJ04	T: Organic Chemistry-II; P: Practical	4	3-0-1	15	60	75
			SEC	CEMSEC03	P: Preparation of Household Chemicals (Practical)	3	0-0-3	10	40	50
			AEC	AEC03	Communicative English -2 (***common for all programmes***)	2	2-0-0	10	40	50
			MDC	MDC03	Multidisciplinary Course -3 (***to be chosen from the list***)	3	3-0-0	10	40	50
			Minor-3 (Disc.-I)	CEMMIN03	T: Inorganic Chemistry –II & Organic Chemistry-II; P: Practical	4	3-0-1	15	60	75
					Semester-III Total	20				375
		IV	SEMESTER-IV							
			Major-5	CEMHMJ05	T: Inorganic Chemistry-II; P: Practical	4	3-0-1	15	60	75
			Major-6	CEMHMJ06	T: Physical Chemistry-II; P: Practical	4	3-0-1	15	60	75
			Major-7	CEMHMJ07	T: Organic Chemistry-III; P: Practical	4	3-0-1	15	60	75
			AEC	AEC04	MIL-2 (***common for all programmes***)	2	2-0-0	10	40	50
			Minor-4 (Disc.-II)	CEMMIN04	T: Physical Chemistry –III & Inorganic Chemistry-III; P: Practical	4	3-0-1	15	60	75
			Summer Intern.	INT	Internship/ Apprenticeship - activities to be decided by the Colleges following the guidelines to be given later	4	0-0-4	-	-	50
					Semester-IV Total	22				400
					TOTAL of YEAR-2	42				775

MJ = Major, MI = Minor Course, SEC = Skill Enhancement Course, AEC = Ability Enhancement Course, MDC = Multidisciplinary Course, CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical, MIL = Modern Indian Language

SEMESTER-III

MAJOR (MJ)

Major-3: PHYSICAL CHEMISTRY-I **Credits 04 (Theory-03, Practicals-01)**

MJ3T: PHYSICAL CHEMISTRY-I **Credits 03 (Theory: 45 Lectures)**

A. FITNESS TRAINING FOR PHYSICAL CHEMISTRY **(7 LECTURES)**

(I) Units and Dimensions: Physical quantity, Units and unit systems, Symbols, Basic and Derived units, SI units, Dimensions, Principle of homogeneity of dimensions, Atomic Units. (Examples should be taken from various chapters of Physical Chemistry)

(II) Plots of Simple Functions: linear plots; its slopes and intercepts, choice of proper scale, Plots of polynomial, exponential and trigonometric functions and their combinations. Plots of inverse and hyperbolic functions. . (Examples should be taken from various chapters of Physical Chemistry).

B. CHEMICAL KINETICS: PART-1 **(12 LECTURES)**

(I) Introduction, stoichiometric coefficient, Extent or advancement of reaction, Rate of a reaction in terms of advancement of reaction, Law of mass action, Differential rate law, rate constant and its unit, order and molecularity:

(II) Integrated rate laws for simple reactions involving only one reactant: zero. half, one, two, three and n-th order reactions, Half life time, time of completion, average life time. Integrated rate laws involving more than one reactants: 2nd and third order. Pseudo first order reactions.

(III) Determination of order of a reaction: method of differential rate law, n_t and n_c, method of integrated rate law, method of half-life time, method of isolation.

(IV) Complex reactions: Opposing reactions, Equilibrium Constant; Consecutive reactions, slowest step is the rate determining step. Parallel reactions KCP and TCP

(V) Temperature dependence of rate constant; Arrhenius equation, energy of activation.

(VI) Rate-determining step and steady-state approximation – explanation with suitable examples. Arrhenius Complex and van't Hoff complex.

(VII) Homogeneous catalysis: with reference to acid-base catalysis.

C. THERMODYNAMICS: PART-1 (FIRST LAW OF THERMODYNAMICS & THERMOCHEMISTRY) **(16 LECTURES)**

(I) Mathematics for Thermodynamics: Derivatives, Partial derivatives, State functions and Path functions, Exact and Inexact differentials, Cyclic rule, Chain rule, Legendre transformations, Homogeneous functions, Extremization problems.

(II) Introduction, Some basic concepts; System; isolated, closed and open; Thermodynamic system. Surroundings, Universe, Boundaries and its classifications, Properties of a system: Extensive and Intensive; State property and path property, Different types of processes: reversible and irreversible processes, Isothermal and adiabatic processes. Thermodynamic state, Equation of states, Steady state and Equilibrium state. Thermal equilibrium, Zeroth law of Thermodynamics and its applications. Definition of temperature.

(III) Concept of heat and work: Work in various processes (reversible, irreversible, isothermal, adiabatic), indicator diagrams,

(IV) Joule's experiments, Concept of internal energy (U), First law of thermodynamics; its various statements.

(V) Joule-Thomson experiment; concept of enthalpy (H); J-T coefficient, Inversion temperature, Expressions of J-T coefficient and inversion temperature for VDW gas. Cooling and heating due to JT expansion.

(VI) Heat capacity relations. General relations, relations for ideal and VDW gas.

(VII) Adiabatic Changes of states: relations among various state properties of ideal and VDW gas for adiabatic reversible process, Expressions of work, adiabatic cooling, its difference from the JT cooling.

(VIII) Thermochemistry: Basic laws of thermochemistry, Standard states; Temperature dependence of enthalpy of a reaction: Kirchhoff's equation. Enthalpy of reactions for various processes; enthalpy of formation, enthalpy of combustion, lattice enthalpy and the Born-Haber cycle, enthalpy of neutralizations, bond dissociation enthalpy and the average bond enthalpy, resonance enthalpy, enthalpy of solution and dilution, adiabatic flame temperature.

D. QUANTUM MECHANICS: PART-1 (HISTORICAL DEVELOPMENTS AND OLD QUANTUM THEORY) (10-LECTURES)

(I) A brief introduction to Quantum Mechanics

(II) Black body radiation: experimental observations, important features, Stefan Boltzmann law, Wien's distribution formula and the Wien's displacement law, Rayleigh-Jeans formula, Planck's hypothesis and the theoretical explanations BB energy distribution.

(III) Particle aspect of light: Photoelectric effect: Experimental observations and Einstein's explanation; Compton effect; Experimental observations and Compton's explanations.

(IV) Wave aspects of particle: de Broglie's wave particle duality

(V) Heisenberg Uncertainty Principle: Position-Momentum Uncertainty principle, Statements and qualitative explanations from the dual nature of light and particle. Various consequences of HUP. Energy-time uncertainty principle.

(VI) Old quantum theory: Bohr, Wilson and Sommerfeld quantization rule and their applications to PIAB, LSHO, RR and H-atom problems.

SUGGESTED BOOKS

Text Books:

1. Physical Chemistry, G.W. Castellan, Narosa, New Delhi
2. Physical Chemisty, I. N. Levine, McGraw Hill, NewYork
3. Physical Chemistry, P. Atkins, J.D Paula and J. Keeler, Oxford University Press, New York
4. Physical Chemistry: A Molecular Approach, D. A. McQuarrie and J. D. Simon, Viva Book Private Limited, New Delhi.
5. Physical Chemistry, T. Engel and P. Reid, Pearson Education,Inc, India.
6. Text Book of Physical Chemistry, S. Glasstone, Macmillan India Limited, New Delhi

Reference Books:

7. Chemical Kinetics, K. J. Laidler, Pearson Education India.
8. Quantum Mechanics, J. L. Powel and B. Crasemann, Dover Publications Inc., UK.
9. Quantum Chemistry, I. N. Levine, Pearson Education India.
10. Mathematics for Physical Chemistry, D. A. McQuarrie, Univ Science Books.
11. Heat & Thermodynamics, M. W. Zemansky & R. H. Dittman, The McGraw-Hill Companies Inc., New York.

MJ3P: PHYSICAL CHEMISTRY LAB- I Credits 01 (30 Hrs.)

1. Calibration of various apparatus such as burette, pipette, volumetric flux, measuring cylinder etc.
2. Concepts of molecular weight, equivalent weight, various concentration terms, primary and secondary standard solutions and their preparations with proper explanations of types of apparatus to be used to prepare these solutions.

Prepare the following solutions

(i) Primary standard oxalic acid solution by accurate weighing
(ii) Primary standard potassium dichromate solutions by accurate weighing
(iii) Secondary standard sodium hydroxide solutions by approximate weighing
(iv) Secondary standard sodium thiosulphate solutions by approximate weighing
(v) Secondary standard potassium permanganate solution by approximate weighing
(vi) Secondary standard sulphuric acid, hydrochlroric acid and acetic acid solutions of various strength from the supplied concentrated solutions.

3. Study of kinetics of acid-catalyzed hydrolysis of an ester
4. Study of kinetics of decomposition of H_2O_2
5. Determination of specific rotation of cane sugar using polarimeter
6. Study the kinetics of inversion of cane sugar using polarimeter.

SUGGESTED BOOKS

Text Books:

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015
2. Nad A. K, Mahapatra B. and Ghoshal A., "An Advanced Course In Practical Chemistry'', New Central Book Agency (P) Limited, 2014
3. Maity S.K. and Ghosh N.K, " Physical Chemistry Practicals", New Central Book Agency (P) Limited, 2012
4. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

Reference Books:

5. Practical Physical Chemistry – A.M. James, F.F. Prichard
6. Findlay's Practical Physical Chemistry – B.P. Levitt
7. Experimental Physical Chemistry – Shoemaker and Ga
8. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

MJ-4: ORGANIC CHEMISTRY-II **Credits 04(Credits: Theory-03, Practicals-01)**

MJ4T: ORGANIC CHEMISTRY-II **Credits 03**

Course content:

Stereochemistry II, General Treatment of Reaction Mechanism II, Substitution and Elimination Reactions and Chemistry of Alkenes and Alkynes **Theory: 45 Lectures**

Stereochemistry II **(8 Lectures)**

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*).

General Treatment of Reaction Mechanism II **(12 Lectures)**

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 (kH /kD); principle of microscopic reversibility; Hammond's postulate.

Substitution and Elimination Reactions **(10 Lectures)**

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^3centre: mechanisms (with evidence) relative rates and stereochemical features: SN1, SN2, SN2', SN1' (allylic rearrangement) and SN^i; 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].

Elimination reactions: E1, E2, E1cB and Ei (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.

Chemistry of Alkenes and Alkynes **(15 Lectures)**

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; Birch reduction of benzenoid aromatics; interconversion of *E*- and *Z*-alkenes; contra-thermodynamic isomerization of internal alkenes.

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.

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. James, 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.

MJ4P: ORGANIC CHEMISTRY-III (Lab) **Credits 01 LAB (30 Hrs.)**

Experiment: Qualitative Analysis of Single Solid Organic Compounds

a) Detection of special elements (N, S, Cl, Br) by Lassaigne's test
b) Solubility and classification (solvents: H2O, 5% HCl, 5% NaOH and 5% NaHCO3)
c) Detection of the following functional groups by systematic chemical tests: aromatic amino (-NH2), aromatic nitro (-NO2), amido (-CONH2, including imide), phenolic –OH, carboxylic acid (-COOH), carbonyl (-CHO and >C=O).
d) Melting point of the given compound

[Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups of unknown (**at least six)** organic compounds].

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. *PracticalOrganic 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.

MINOR (MI)

Minor 3: (Inorganic Chemistry –II & Organic Chemistry-II) **Credits 04; Full Marks-75**

MI -3T (Theory) **Credits-03**
(45 lectures)

Course Content:

Inorganic Chemistry–II

Chemical Periodicity: **(10 Lectures)**

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. 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.

Chemical Bonding and Molecular Structure: **(20 Lectures)**

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

***Covalent bonding*:** VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds. 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): H_2, B_2, C_2, N_2, O_2, F_2. MO diagram of CO and explanation of its ligating behaviour based on MO approach. Comparison of VB and MO approaches.

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 India.

Organic Chemistry-II

Aromatic Hydrocarbon **(05 Lectures)**

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); side chain oxidation of alkyl benzenes (up to 4 carbons on benzene).

Organometallic Compounds **(05 Lectures)**

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

Aryl Halides **(05 Lectures)**

Preparation: (chloro-, bromo- and iodobenzene): from phenol, Sandmeyer reactions. Reactions (Chlorobenzene): nucleophilic aromatic substitution (replacement by –OH group) and effect of nitro substituent (activated nucleophilic substitution).

Reference Book:

1. Sethi, A. *Conceptual Organic Chemistry;* New Age International Publisher.
2. Parmar, V. S. *A Text Book of Organic Chemistry*, S. Chand & Sons.
3. Madan, R. L. *Organic Chemistry*, S. Chand & Sons.
4. Wade, L. G., Singh, M. S., *Organic Chemistry.*
5. Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd.
6. (Pearson Education).
7. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

MI-3P Practical **Credit-01**

Inorganic Chemistry Laboratory **(10 Hrs.)**

1. Estimation of Fe(II) and Fe(III) in a given mixture.

2. Estimation of Fe(III) and Cu(II) in a mixture.

Organic Chemistry Lab **(20 Hrs.)**

A. Separation, based upon solubility, by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. NaHCO3, etc., of components of a binary solid mixture; purification of any one of the separated components by crystallization.
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.
B. Identification of a pure organic compound
Solid compounds: oxalic acid, tartaric acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.
Liquid Compounds: methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene

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. Bhattacharyya, R. C, *A Manual of Practical Chemistry.*
6. Vogel, A. I. *Elementary Practical Organic Chemistry*, Part 2: *Qualitative Organic Analysis*, CBS Publishers and Distributors.
7. 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.
8. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman,

SKILL ENHANCEMENT COURSE (SEC)

SEC 3P: Preparation of Household Chemicals (Practical) **Credits 03 Full Marks: 50**

Part A:

(i) Preparation of liquid disinfectant
(ii) Preparation of Liquid Detergent
(iii) Preparation of Dish wash Liquid Soap
(iv) Preparation of Hand Sanitizer
(v) Preparation of simple organophosphates, phosphonates and thiophosphates

Part B: Field visit and submission of the report

Suggested Readings:

1. Vogel's text book of Qualitative Chemical Analysis (Longman ELBS Edition)
2. Vogel's text book of Quantitative Analysis (Longman ELBS Edition)
3. Practical Organic Chemistry by A.I.Vogel
4. Practical Organic Chemistry by O.P. Agarwal
5. Practical Organic Chemistry by F.G. Mann & B.C. Sounders
6. Comprehensive Practical Organic Chemistry Qualitative Analysis by V.K.Ahluwali
7. Text book of Quantitative inorganic Analysis including elementary instrumental Analysis: A.I.Vogel (Third Ed.)
8. S mall scale industries and house hold industries in developing economy by Shetty M.C.
9. Manufacture of perfume cosmetics and detergents by Prasad Giri Raj
10. Industrial chemistry by B.K.Sharma.

SEMESTER-IV

MAJOR (MJ)

Major-5: INORGANIC CHEMISTRY-II **Credits 04 (Theory-03, Practical-01)**

MJ5T: INORGANIC CHEMISTRY-II **Credits 03 (Theory: 45 Lectures)**

A. Chemical Bonding-I: **(15 Lectures)**

(i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Solubility energetics of dissolution process, Defects in solids, line and plane defects, Schottky and Frenkel defects (Elementary idea) non-stoichiometric defect in crystal, Colour centres (F-center) in ionic crystals.

(ii) Covalent bond: Polarizing power and polarizability, ionic potential, Fajan's rules. Lewis structures, formal charge. Valence Bond Theory. The hydrogen molecule (Heitler-London approach), directional character of covalent bonds, hybridizations, equivalent and non-equivalent hybrid orbitals, Bent's rule, Dipole moments, VSEPR theory, shapes of molecules and ions containing lone pairs and bond pairs (examples from main groups chemistry) and multiple bonding (σ and π bond approach).

B. Chemical Bonding-II: **(12 Lectures)**

(i) Molecular Orbital Theory: Molecular orbital concept of bonding (The approximations of the theory, Linear combination of atomic orbitals (LCAO)) (elementary pictorial approach): σ- and π-bonds and δ- interaction, multiple bonding. Orbital designations: gerade, ungerade, HOMO, LUMO. Orbital mixing, MO diagrams of H_2, Li_2, Be_2, B_2, C_2, N_2, O_2, F_2, and their ions wherever possible; Heteronuclear molecular orbitals: CO, NO, NO^+, CN^-, HF, BeH_2, CO_2 and H_2O. Bond properties: bond orders, bond lengths.

(ii) Metallic Bond: Qualitative idea of valence bond and band theories, electrical and thermal conductivity of metals, Semiconductors (intrinsic and extrinsic: p-type and n-type) and insulators, Superconductivity (only basic idea).

(iii) Weak Chemical Forces: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Intermolecular forces: Hydrogen bonding (theories of hydrogen bonding, valence bond treatment), host-guest interactions, Halogen bonds. Effects of chemical force, melting and boiling points.

C. Chemistry of s and p Block Elements: **(18 Lectures)**

Group trends in electronic configuration, Common oxidation states, Allotropy and catenation (with example), Oxides of N, P, S and Cl, Oxo/Peroxo acids of P, S and Cl, Basic properties of halogens. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses: Li_2O, Na_2O_2 and KO_2, BeH_2, $BeCl_2$, boric acid, borates, borax, sodium perborate, boron nitrides, borazines, borohydrides (diborane)**,** carbides (covalent and ionic type), diamond, graphite, silanes, silicones, phosphazenes, sulphur-nitrogen binary compounds, interhalogen compounds, polyhalide ions, pseudohalogens, Chlorofluorocarbons (CFCs).

Noble Gases: Separation of Noble gases, Clathrates; Structure and properties of XeF_2, XeF_4, XeF_6, XeO_2F_2 and XeO_3, XeO_4^{2-} and XeO_6^{4-}.

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry, 5th Ed., Wiley India Pvt. Ltd., 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, John Wiley and Sons (2005).
9. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
10. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.
11. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.
12. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.
13. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

MJ5P: INORGANIC CHEMISTRY LABORATORY- II (Credit 01) (30 Hrs.)

Qualitative semimicro analysis of mixtures containing four radicals. Emphasis should be given to the understanding of the chemistry of different reactions and to assign the most probable composition.

- **Acid Radicals**: Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+},Al^{3+},Cr^{3+}, Mn^{2+}/Mn^{4+}, Fe^{2+}/Fe^{3+}, Co^{2+}/Co^{3+}, Ni^{2+}, Pb^{2+}, Cu^{2+}, Zn^{2+}, Bi^{3+}, NH_4^+, Mg^{2+}.
- **Basic Radicals**: F^-, Cl^-, Br^-, I^-, SCN^- , S^{2-} , SO_3^{2-}, SO_4^{2-} , $S_2O_3^{2-}$, NO_3^- , NO_2^- , PO_4^{3-}, BO_3^{3-}, H_3BO_3.
- **Insoluble Materials**: Al_2O_3, $SrSO_4$, $BaSO_4$, CaF_2.

Suggested Readings:

1. Svehla, G., Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. Ghosal, Mahapatra and Nath; An Advanced course in practical Chemistry

Major-6: PHYSICAL CHEMISTRY-II **Credits 04 (Theory-03, Practicals-01)**

MJ6T: PHYSICAL CHEMISTRY-II Credits 03 **(Theory: 45 Lectures)**

Course contents:

A. STATES OF MATTER: PART-1 (GASEOUS STATE) (LECTURE-15)

(I) Mathematical interlude: Gamma functions, Error and co-error functions, Method of successive approximations, Graphical method of solutions. Concept of probability.

(II) Kinetic Theory of gases: Postulates, Derivation of basic equation of KTG, Concept of pressure and temperature. Derivation of empirical gas laws from the basic equation of KTG.

(III) Maxwell's speed distribution: Maxwell's velocity distribution in 1D, Maxwell's speed distribution in 2D and 3D. Nature of the distributions, graphical representations, calculation of average, RMS, most probable speed and average kinetic energy in each case.

(IV) Maxwell's kinetic energy distribution: Maxwell's kinetic energy distribution in one, two and three dimensions, Nature of the distribution, graphical representations calculations of average kinetic energy in each case. Calculation of probability of finding molecules having energy $\geq$ a threshold value, Importance of the result.

(V) Principle of Equipartition of energy: Statement of the principle, degrees of freedom, Molar heat capacity of gases of different atomicity and structures, Limitations of this principle. .

(VI) Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Wall collision. Rate of effusion and Graham's law of effusion.

(VII) Barometric distribution formula.

(VIII) Deviation of gases from ideal behaviour: Liquifaction of gases and Andrew's curve, critical constants. Law of continuity of states, Compressibility factor; Amagat's plots. Kammerling-Onnes or the virial equation of state.

(IX) van der Waals equation and its features; 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; van der Waals equation expressed in virial form and significance of second virial coefficient; Boyle temperature.

(X) Intermolecular interactions among neutral covalent molecules: Dipole-dipole or Keesom interaction, Dipole-induced dipole or Debye interaction, Induced dipole-induced dipole or London interactions. Hard sphere model, Lennard-Jones potential, Buckingham potential.

B. ELECTROCHEMISTRY: PART-1 (CONDUCTANCE) (LECTURE-7)

(I) Transport Phenomena: General law of transport, Examples of various laws of transport

(II) Conductance in a solution: Strong and weak electrolytes, Conductance, Specific Conductance, cell constant, Equivalent and molar conductance and their interrelations.

(III) Variation of specific and equivalent conductance with dilution for strong and weak electrolytes. Ionic mobility, Determination of equivalent conductance at infinite dilution for strong and weak electrolyte. Kohlrausch's law of independent migration of ions. Ionic conductance and transport number. Relation between ionic mobility and ionic conductance. Factors determining ionic and equivalent conductance: concentration, size of the solvated ions, temperature, viscosity of the solvent and the Walden's rule. Abnormally high ionic conductance of H^+ and OH^-.

(IV) Qualitative idea of Debye –Huckel theory of Ion atmosphere -asymmetric or relaxation effect and electrophoretic effect; Kohlrausch equation, Wien effect, Debye-Falkenhagen effect.

(V) Determination by Moving boundary method, Hittorf rule. Abnormal transport number.

(VI) Application of conductance measurement; Determination of degree of dissociation of weak electrolyte, Determination of ionization constant of weak acid, Determination solubility product of sparingly soluble salts, determination of ionic product of water, determination of rate constant of saponification of ester. Conductometric titrations; principles and various examples.

C. THERMODYNAMICS: PART-2 (SECOND LAW OF THERMODYNAMICS and SYSTEM OF VARIABLE COMPOSITIONS) (LECTURE-12)

(I) Limitations of 1st law of thermodynamics, Spontaneous process and its characteristic features. Need for a Second law.

(II) Engine, its efficiency and the Kelvin Planck statement of 2nd law of thermodynamics. Heat pump and refrigerator, their performance and the Clausius statement of 2nd law of thermodynamics. Equivalence of Kelvin-Planck and Clausius statement of second law of thermodynamics.

(III) Carnot engine: Carnot cycle, Efficiency of Carnot engine taking ideal gas as the working substance, efficiency in terms of P-V diagram. Efficiency of Carnot engine taking VDW gas as the working substance, Carnot's theorem; statements and proofs, Efficiency of Stirling engine. Thermodynamic scale of temperature.

(IV) Introduction to the concept of entropy (S). Properties of entropy. Clausius inequality; Statement of second law of thermodynamics in terms of entropy and the conditions of spontaneity and equilibrium. Limitations of this criteria. Entropy change of systems, surroundings and the universe for various processes and transformations. Carnot's cycle in T-S diagram and expressions of efficiency. Trouton's rule.

(V) Carathedory's statement of 2nd law of thermodynamics (statement only), Two adiabates never intersect, Oneadiabate and one isotherm intersect once, Maxwell's equal area constructions.

(VI) Auxiliary state functions: Legendre transformation. Gibbs free energy (G) and Helmholtz free energy (A) . Their physical significance. Variations of G and A with T, P and V. Thermodynamic criteria for spontaneity and equilibrium in terms of change in G and A. Exergonic and endergonic processes. Coupled reaction.

(VII) Thermodynamic free entropy: Messieu function and Planck's function. Their properties and physical significance.

(VIII) Fundamental equations of thermodynamics, Maxwell's relations; Thermodynamic square, Thermodynamic equations of states, Temperature dependence of free energy functions: Gibbs-Helmholtz equation.

D. QUANTUM MECHANICS: PART-2 (POSTULATES OF QUANTUM MECHANICS AND OPERATOR ALGEBRA) (LECTURE-11)

(I) Postulate-1 of Quantum mechanics: Genesis of Schrodinger equation, Time independent Schrodinger equation and its nature, Wave function, Born's probabilistic interpretation of wave function, acceptability criteria of wave function, Normalized wave functions and normalization procedure, Orthogonal and orthonormal set of wave functions, Degeneracy of wave functions,

(II) Postulate-2 of Quantum Mechanics: Classical observable, concepts of operators, Linear operators, Systematic approach to construct quantum mechanical operator for a classical observable, Various examples.

(III) Postulate-3 of Quantum Mechanics: Eigen value equations, Commutation relations and their physical significance. Important theorems regarding commutations and simultaneous eigen functions. Angular momentum operators and commutation relations associated to them.

(IV) Postulate-4 of Quantum Mechanics: Average values of a classical observable in a quantum state, Representation of quantum mechanics, Bra-ket notations, Hermitian operator; definition

properties and examples, Theorems of Hermitian operators, Gram-Schmidt orthogonalization techniques, Swartz inequality, Generalized Heisenberg uncertainty principle.

(V) Postulate-5 of Quantum Mechanics: Time dependent Schrodinger equation, Concept of stationary states, Probability current density, Ehrenfest equation of states.

SUGGESTED BOOKS

Text Books:

1. Physical Chemistry, G.W. Castellan, Narosa, New Delhi
2. Physical Chemisty, I. N. Levine, McGraw Hill, NewYork
3. Physical Chemistry, P. C. Rakshit, Sarat Book House, India.
4. Physical Chemistry: A Molecular Approach, D. A. McQuarrie and J. D. Simon, Viva Book Private Limited, New Delhi.
5. Physical Chemistry, R. J. Silbey, R. A. Alberty & M. G. Bawendi, John Wiley & Sons, Inc.
6. Text Book of Physical Chemistry, S. Glasstone, Macmillan India Limited, New Delhi

Reference Books:

1. Heat & Thermodynamics, M. W. Zemansky & R. H. Dittman, The McGraw-Hill Companies Inc., New York.
2. Chemical Thermodynamics: Basic concepts & methods, I. M. Klotz & R. M. Rosenberg, Wiley-Interscience, India.
3. Quantum Mechanics: Concepts and Applications, N. Zettili, A John Wiley and Sons, Ltd., Publication.
4. Introduction to Quantum Mechanics, D. J. Griffiths & D. F. Schroeter, Cambridge University Press.
5. Principles of Physical Chemistry, S. H. Maron & C. F. Prutton, CBS Publishers & Distributors Pvt. Ltd.

MJ6P: PHYSICAL CHEMISTRY LAB- II Credits 01 **(30 Hrs.)**

1. Conductometric titrations
   - (i) Strong acid vs. strong base
   - (ii) Weak monobasic acid vs. Strong base.
   - (iii) Weak dibasic acid vs. Strong base
   - (iv) Mixed acid vs. strong base
   - (v) Silver nitrate vs. potassium chloride
2. Determination of ionization constant and equivalent conductance at infinite dilution of an weak acid.
3. Determination of rate constant of saponification of an ester conductometrically.
4. Determination of solubility product of a sparingly soluble salt.

SUGGESTED BOOKS

Text Books:

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015
2. Nad A. K, Mahapatra B. and Ghoshal A., "An Advanced Course In Practical Chemistry'', New Central Book Agency (P) Limited, 2014
3. Maity S.K. and Ghosh N.K, " Physical Chemistry Practicals", New Central Book Agency (P) Limited, 2012
4. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

Reference Books:

5. Practical Physical Chemistry – A.M. James, F.F. Prichard
6. Findlay's Practical Physical Chemistry – B.P. Levitt
7. Experimental Physical Chemistry – Shoemaker and Ga
8. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

MJ-7: ORGANIC CHEMISTRY-III **Credits 04**

MJ7T: ORGANIC CHEMISTRY-III **Credits 03**

Course content:

Stereochemistry III, Aromatic Substitution, Carbonyl and Related Compounds, Organometallics

Theory: 45 Lectures

Stereochemistry III **(10 Lectures)**

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 (*Ra/Sa* and *P/M*); atropisomerism; racemisation of chiral biphenyls; *buttressing* effect.

Concept of prostereoisomerism: prostereogeniccentre; 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 propseudoasymmetriccentre.

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 stereogeniccentre: Felkin- Anh and Zimmermann-Traxler models.

Aromatic Substitution **(5 Lectures)**

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); *Ipso* substitituion.

Nucleophilic aromatic substitution: addition-elimination mechanism and evidences in favour of it; SN1 mechanism; cine substitution (benzyne mechanism), structure of benzyne.

Carbonyl and Related Compounds **(25 Lectures)**

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, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement, oxidations and reductions: Clemmensen, Wolff-Kishner, LiAlH4, NaBH4, MPV, Oppenauer, Bouveault- Blanc, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

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, SeO2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Tollens', Knoevenagel, Claisen-Schmidt Claisen ester including Dieckmann, Stobbe; Mannich reaction, Perkin reaction, Favorskii rearrangement; alkylation of active methylene compounds. specific enol equivalents (lithium enolates, enamines, 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 annulation.

Substitution at sp^2 carbon (C=O system): mechanism (with evidence): *B*AC2, *A*AC2, *A*AC1, *A*AL1 (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

Organometallics **(5 Lectures)**

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 organometallic reagents.

Suggested Readings:

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., Giuliano, 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. Graham Solomons, T.W., Fryhle, C. B. *Organic Chemistry*, John Wiley & Sons, Inc.
10. March, J. *Advanced Organic Chemistry*, Fourth edition, Wiley.
11. Jenkins, P. R., *Organometallic Reagents in Synthesis*, Oxford Chemistry Primer, Oxford University Press.
12. Ward, R. S., *Bifunctional Compounds*, Oxford Chemistry Primer, Oxford University Press.

MJ7P: ORGANIC CHEMISTRY-III (Lab) **Credits 01**

(30 Lectures)

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 crystallization from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.

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

Suggested Readings:

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 OrganicChemistry*, Pearson Education (2009).
4. Furniss, B.S., Hannaford, A.J., Smith, P.W.G., Tatchell, A.R. *Practical Organic Chemistry*, 5thEd.,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.

MINOR (MI)

MI-4: (Physical Chemistry –III & Inorganic Chemistry-III) Credits 04 (Full Marks: 75)

MI -4T (Theory) **Credits-03**
(45 lectures)

Course Content

Physical Chemistry-III

A. Principles of Thermodynamics (20 Lectures)

(I) Introduction and First Law of Thermodynamics: Introduction, Some basic concepts; System; isolated, closed and open; Surroundings, Universe, Boundaries and its classifications, Properties of a system: Extensive and Intensive; State property and path property, Different types of processes: reversible and irreversible processes, Isothermal and adiabatic processes. Steady state and Equilibrium state. Thermal equilibrium, Zeroth law of Thermodynamics and its applications. Concept of heat and work: p-V type work in various processes, indicator diagrams, Joule's experiments, Concept of internal energy (U), First law of thermodynamics; its various statements. Joule-Thomson experiment; concept of enthalpy (H); J-T coefficient, Inversion temperature, Expressions of J-T coefficient and inversion temperature for VDW gas (without derivation). Cooling and heating due to JT expansion. Heat capacity relations. General relations, relations for ideal gas. Adiabatic changes of states: relations among various state properties of ideal gas for adiabatic reversible process, expressions of work, adiabatic cooling, its difference from the JT cooling.

(II) Thermochemistry: Basic laws of thermochemistry, Standard states; Temperature dependence of enthalpy of a reaction: Kirchhoff's equation. Enthalpy of reactions for various processes; enthalpy of formation, enthalpy of combustion, lattice enthalpy and the Born-Haber cycle, enthalpy of neutralizations, bond dissociation enthalpy and the average bond enthalpy.

(III) 2nd Law of Thermodynamics and Auxiliary State Functions: Limitations of 1st law of thermodynamics, Spontaneous process and its characteristic features. Need for a Second law. Kelvin-Planck statement, Clausius statement of 2nd law of thermodynamics. Carnot engine: Carnot cycle, Efficiency of Carnot engine taking ideal gas as the working substance, efficiency in terms of P-V diagram. Carnot's theorem; statements only. Concept of entropy (S). Properties of entropy. Clausius inequality; Statement of second law of thermodynamics in terms of entropy and the conditions of spontaneity and equilibrium. Entropy change of systems, surroundings and the universe for various processes and transformations.

Gibbs free energy (G) and Helmholtz free energy (A). Their physical significance.. Thermodynamic criteria for spontaneity and equilibrium in terms of change in G and A. Fundamental equations of thermodynamics, Maxwell's relations; Thermodynamic square, Thermodynamic equations of states, Temperature dependence of free energy functions: Gibbs- Helmholtz equation.

B. Chemical and Ionic Equilibrium (10 Lectures)

(I) Chemical Equilibrium: Concept of Chemical Potential, van't Hoff's reaction isotherm, Different kind of true equilibrium constant K_p and K_c. pseudo equilibrium constant K_x. Interrelations among K_p, K_c and K_x. Temperature dependence of equilibrium constant. van't Hoff's equations (isobar and isochore) Shifting of equilibrium due to change in external parameters e.g. concentration, temperature, pressure and addition of inert gas; Le Chatelier's principle and its its applications.

(II) Ionic Equilibrium: Concept of mean ionic activity and mean ionic activity coefficient. Ionic strength, Debye-Huckel limiting law. Solubility, activity solubility product, concentration solubility product of sparingly soluble salt. Their interrelations. Effect of addition of inert electrolyte on the solubility and concentration solubility product. Common ion effect and its applications. pH, calculation

of pH in various solutions, ionic product of water, Dissociation constants of weak acids and weak bases, Buffer and buffer capacity, Henderson equation, salt hydrolysis and expressions of pH, acid-base neutralisation reactions, Acid-base neutralization curves, Indicator and its choice for neutralization reactions.

Inorganic Chemistry-III

Chemistry of s and p block Elements: (15 Lectures)

Group trends in electronic configuration, common oxidation states, inert pair effect, diagonal relationship, Oxo/Peroxo acids of P, S and Cl. Study of the following compounds with emphasis on: preparation, structure & bonding, properties and uses: Li_2O, Na_2O_2 and KO_2, BeH_2, $BeCl_2$, boric acid, borates, borax, sodium perborate, boron nitrides, borazines, borohydrides (diborane), carbides (covalent and ionic type), diamond, graphite, silanes, silicones, phosphazenes, sulphur-nitrogen binary compounds, interhalogen compounds, polyhalide ions, pseudohalogens, Chlorofluorocarbons (CFCs). Noble Gases: Separation of Noble gases, Clathrates; Structure and properties of XeF_2, XeF_4, XeF_6, xenate and perxenate. Use of noble gases.

Reference Books:

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

Rodgers, G.E. *Inorganic & Solid State Chemistry*, Cengage Learning India Ltd., 2008.

MI-4P Practical **Credit: 01**

(30 Lectures)

Section A: Physical Chemistry Lab

- Determination of solubility and concentration solubility product of a sparingly soluble salt (say KHTa) using acid-base titration.
- Preparation of buffer solutions and find the pH of an unknown buffer solution by colour matching method

Section B: Inorganic Chemistry Laboratory

Identification of three radicals from the given mixtures. Emphasis should be given to the understanding of the chemistry of different reactions:

- **Acid Radicals**: NH_4^+, Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, $Mn^{2+/4+}$, $Fe^{2+/3+}$, $Co^{2+/3+}$, Ni^{2+} and Cu^{2+}.
- **Basic Radicals**: Cl^-, Br^-, I^-, SCN^-, S^{2-}, SO_4^{2-}, NO_3^-, NO_2^-, PO_4^{3-}, BO_3^{3-} and H_3BO_3.

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).
7. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM&SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE (HONOURS)

MAJOR IN CHEMISTRY

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes

(CCFUP), 2023& NEP, 2020

VIDYASAGAR UNIVERSITY
BACHELOR OF SCIENCE (HONOURS) MAJOR IN CHEMISTRY
(under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. (Hons.)	3rd	V	SEMESTER-V							
			Major-8	CEMHMJ08	T: Inorganic Chemistry-III; P: Practical	4	3-0-1	15	60	75
			Major-9	CEMHMJ09	T: Physical Chemistry-III; P: Practical	4	3-0-1	15	60	75
			Major-10	CEMHMJ10	T: Organic Chemistry-IV; P: Practical	4	3-0-1	15	60	75
			Major Elective-01	CEMHDSE1	Advanced Physical Chemistry-I OR Advanced Physical Chemistry-II	4	3-1-0/ 3-0-1	15	60	75
			Minor-5 (Disc.-I)	CEMMIN05	T: Organic Chemistry – III & Physical Chemistry - IV; P: Practical *(To be taken from other Discipline)*	4	3-0-1	15	60	75
			Semester-V Total			20				375
		VI	SEMESTER-VI							
			Major-11	CEMHMJ11	T: Inorganic Chemistry-IV; P: Practical	4	3-0-1	15	60	75
			Major-12	CEMHMJ12	T: Physical Chemistry-IV; P: Practical	4	3-0-1	15	60	75
			Major-13	CEMHMJ13	T: Organic Chemistry-V; P: Practical	4	3-0-1	15	60	75
			Major Elective-02	CEMHDSE2	Analytical Methods in Chemistry OR Inorganic Materials Of Industrial Importance	4	3-1-0/ 3-0-1	15	60	75
			Minor-6 (Disc.-II)	CEMMIN06	T: Inorganic Chemistry-IV & Organic Chemistry-IV; P: Practical *(To be taken from other Discipline)*	4	3-0-1	15	60	75
			Semester-VI Total			20				375
			YEAR-3			40				750
			Eligible to be awarded Bachelor of Science in Anthropology *on Exit*			126	Marks (Year: I+II+III)			2325

MJ = Major, MI = Minor Course, DSE = Discipline Specific Elective Course, CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical

SEMESTER-V

MAJOR (MJ)

MAJOR-8: INORGANIC CHEMISTRY-III
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ8T: INORGANIC CHEMISTRY-III **Credits 03 (Theory: 45 Lectures)**

A. **Coordination Chemistry-I**: (**8 Lectures)**

Coordinate bonding: double and complex salts. Werner's theory of coordination complexes, Classification of ligands, Ambidentate ligands, chelates, Coordination numbers, IUPAC nomenclature of coordination complexes (up to two metal centers), Isomerism in coordination compounds constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes

B. **Coordination Chemistry-II**: (**30 Lectures)**

CFT: VB description and its limitations. Elementary Crystal Field Theory: splitting of d^nconfigurations in octahedral, square planar and tetrahedral, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Factors affecting Δ, Spectrochemical series (including Irving-Williams Series), Jahn- Teller distortion (including dynamic and static), octahedral site stabilization energy (OSSE). Applications of CFSE (spinel structure determination, variation of some physical properties across a period: Ionic radii & Lattice, Limitations of CFT.

Metal-ligand bonding (MO concept): Basic differences between CFT & LFT,σ- and π-bonding in octahedral and tetrahedral complexes (qualitative pictorial approach), effects of the π- bonding on the oxidation states of transitional metals. MO approach for explaining spectrochemical series of ligands.

Magnetic properties, Electronic transition and Colour of the Co-ordination compounds: Orbital and spin magnetic moments, spin only and effective (Orbital Contribution) magnetic moments of co-ordination compounds, paramagnetic susceptibility &Curie–Weiss law(without derivation),concept of ferro&ferri-magnetism, quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only). Spin crossover (SCO) phenomenon (Spin state equilibrium)

d-d electronic transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ions,Nephelauxetic effect, Raacah parameter. Selection rules for electronic spectral transitions (Laporte and spin selection rule); spectrochemical series of ligands; Colour of co-ordination compounds, charge transfer spectra.

C. **Chemistry of d- block elements (3d, 4d & 5d): (7 Lectures)**

General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, Structure and bonding of $Cr_2(\mu\text{-}O_2CCH_3)_4(H_2O)_2$,$Re_2Cl_8^{2-}$ and $W_2Cl_9^{3-}$. Study of the following compounds with emphasis on preparation, properties and uses: $KMnO_4$, $K_2Cr_2O_7$, Ruthenium red, Creutz-Taube complex.

Suggested Readings:

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. Figgis, B.N; Introduction to Ligand Fields.
3. Greenwood, N.N. &Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann. 1997.
4. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.

MJ8P: INORGANIC CHEMISTRY LABORATORY- III (Credit 01; 30 hrs.)

A. **Complexometric titration using EDTA**:

1. Estimation of Zn(II).
2. Estimation of Ca(II)
3. Estimation of Ca(II) and Mg(II) in a mixture.
4. Estimation of Total Hardness of water.

B. **Spectrophotometry (determination of 10Dq and λ_{max}):**

1. Measurement of 10Dq by spectrophotometric method.
2. Determination of λ_{max} of $[Mn(acac)_3]$ and $[Fe(acac)_3]$ complexes.

C. **Estimation of metal content in some selective samples:**

1. Estimation of Cr and Mn in Steel.

2. Estimation of available chlorine in bleaching powder.

3. Estimation of Ca^{2+} and Mg^{2+} of dolomite.

Suggested Readings:

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

Ghosal, Mahapatra and Nath; An Advanced course in practical Chemistry.

MAJOR-9: PHYSICAL CHEMISTRY-III
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ9T: PHYSICAL CHEMISTRY-III **Credits 03 (Theory: 45 Lectures)**

Course contents:

A. STATES OF MATTER: PART-2 (LIQUID STATE) **(11 Lectures)**

(I) General properties of liquid state. Short range order and long range disorder, Internal pressure,

(II) Viscosity: Definition and units. Viscosity as a transport phenomenon, Streamlined motion and turbulent motion. Critical velocity and Reynold's number, Newton's law of viscosity, viscosity coefficient; Newtonian and non-Newtonian fluids. Poiseuille's equation, Determination of viscosity coefficient of a liquid using Ostwald viscometer. Terminal velocity and Stoke's law. Determination of viscosity coefficient of liquids by falling sphere method. Viscosity of gas, relation between viscosity coefficient and mean free path. Temperature dependence of viscosity coefficient of gas and liquid and their comparison. Determination of viscosity activation energy. Determination of viscosity average molar mass of a macromolecule.

(III) Surface tension: Definition and units. Surface energy, Molecular theory of surface tension, Interfacial tension, Contact angle and condition of wetting a solid by a liquid. Young equation, Work of cohesion and work of adhesion, Dupre equation, spreading coefficient, condition of spreading of one liquid on another liquid, Excess pressure and the Laplace equation, capillary rise and capillary depression. Tate's equation. Jurin's law. Determination of surface tension by capillary rise method, Determination of surface tension by drop weight and drop count method. Vapour pressure over curved surface and the Kelvin equation. Temperature dependence of surface tension, Eotvos-Ramsay and Shield equation,

B. ELECTROCHEMISTRY: PART-2 (ELECTROCHEMICAL CELL)

(11 Lectures)

(I) Redox reaction, half cell reactions. Balancing of redox rection by ion electron method. Electrolysis and Faraday's laws of electrolysis. Different types of electrochemical cell. Different types of electrodes.

(II) Thermodynamics of reversible Galvanic cell. Electromotive Force (EMF) and the standard EMF their temperature dependence.

(III) Nernst equation. Oxidation and reduction potential and their relation. Spontaneity and equilibrium of a redox reaction in terms of reduction potential, Equilibrium constant and the standard reduction potential. Electrochemical series. Construction and representations of cell from the redox reaction. Redox reaction from the representation of the cell.

(IV) Chemical cell with and without transference. Expressions of EMF, various examples.

(V). Concentration cells with and without transference, Expressions of EMF, various examples. Liquid junction potential and its elimination, Salt bridge. Role of electrolyte and the agar powder.

(VI) Reference electrodes and their importance. Standard hydrogen electrode, saturated calomel electrode

(VII) Applications of EMF measurement: Principle determination of pH using standard hydrogen electrode, glass electrode and Quinhydrone electrode and their comparison. Potentiometric titrations of Mohr salt solution by potassium dichromate solution and the silver nitrate solution by potassium chloride solution. Significance of various plots.

C. THERMODYNAMICS: PART-3 (CHEMICAL EQUILIBRIUM, IONIC EQUILIBRIUM)

(15 Lectures)

(I) System of variable compositions: Molar and Partial molar quantities. Chemical potential, its various definitions, Chemical potential as a measure of escaping tendency. Additivity rule, Gibbs-Duhem equation, Chemical potential for various systems. Chemical potential for pure ideal gas, Chemical potential for ideal gas mixture, Change in thermodynamic quantities for ideal gas mixing. Chemical potential for real gas. Fugacity and fugacity coefficient. Chemical potential for non-electrolytic solution, activity and activity coefficient.

(II) Chemical Equilibrium: Thermodynamic criteria for equilibrium, van't Hoff's reaction isotherm, True Equilibrium constant (K_a) and standard Gibbs free energy of a reaction. Different kind of true equilibrium constant K_p and K_c. pseudo equilibrium constant K_x. Definitions and interrelations among K_p, K_c and K_x. Temperature dependence of equilibrium constant. van't Hoff's equations (isobar and isochore) Shifting of equilibrium due to change in external parameters e.g.

concentration, temperature, pressure and addition of inert gas; Le Chatelier's principle and its its applications. Gibbs free energy as a function of advancement of reaction, graphical interpretations.

(III) Chemical potential of electrolytic solution, Concept of mean ionic activity and mean ionic activity coefficient. Ionic strength, Relation between mean ionic activity coefficient and the ionic strength of the solution:, Debye-Huckel limiting law, It's importance and limitations.

(IV) Solubility, activity solubility product, concentration solubility product of sparingly soluble salt. Their interrelations. Effect of addition of inert electrolyte on the solubility and concentration solubility product. Common ion effect and its applications. Determination of mean ionic activity coefficient from solubility measurement.

(V) pH: definition, calculation of pH in various solutions, ionic product of water, Dissociation constants of weak acids and weak bases, Buffer and buffer capacity, Henderson equation, salt hydrolysis and expressions of pH, acid-base neutralisation reactions, Acid-base neutralization curves, Indicator and its choice for neutralization reactions, Principle of determination of pH by color matching method.

D. QUANTUM MECHANICS: PART-3 (APPLICATIONS TO EXACTLY SOLVABLE PROBLEMS; PIAB, LSHO, RR and H-ATOM) (8 Lectures)

(I) Particle in a box problem (PIAB): Construction of time independent Schrodinger equation and solution of free particle problem in 1D. Calculations of average values of x, x^2, p_x and p_x^2. Validity of Heisenberg uncertainty principle. Applications of PIAB model; Free Electron Molecular Orbital Theory and its limitations.Extension of the problem to 2D and 3D. Concept of degeneracy,

(II) Simple Harmonic Oscillator (SHO): Classical linear SHO, Hooke's law and the nature of potential energy. Setting up of the Time Independent Schrodinger equation, Solutions. Expression of wave function, Normalizations. Orthonormal set of wave functions. Graphical representations. Calculations of average values of x, x^2, p_x and p_x^2.

(III) Rigid Rotor (RR): Setting up of Time Independent Schrodinger equation for rigid rotor (Solution is not required), Nature of wave functions, spherical harmonics, values of L^2 and L_z. Quantized energy expressions and discussions with energy, degeneracy.

(IV) H-atom problem. Spherically symmetric potential for H-atom and H-like one electron ions. Setting up of electronic Schrödinger equation in spherical polar coordinates. Separation of

variables. Solutions of only φ-part of Schrodinger equation. Radial and angular part of wave functions and the overall wave function. Construction of real orbitals. Various plots such as ψ vs r, | ψ |2 vs r. Radial distribution function or the radial probability density, Angular plots for s, p and d orbitals. Expressions of energy and its significance, Quantum numbers, degeneracy. Nodes.

Suggested Books:

Text Books:

1. Physical Chemistry, G.W. Castellan, Narosa, New Delhi
2. Physical Chemisty, I. N. Levine, McGraw Hill, NewYork
3. Physical Chemistry, T. Engel and P. Reid, Pearson Education,Inc, India.
4. Principles of Physical Chemistry, S. H. Maron& C. F. Prutton, CBS Publishers & Distributors Pvt. Ltd.
5. Physical Chemistry, R. S. Berry, S. A. Rice & J. Ross, Oxford University Press, New York.
6. Physical Chemistry, S Pahari, New Central Book Agency.

Reference Books:

1. The Principles of Chemical Equilibrium, K. Denbigh, Cambridge University Press.
2. Quantum Mechanics, D. A. McQuarrie, Viva, India.
3. Quantum Chemistry, I. N. Levine, Pearson Education India.
4. An introduction to Electrochemistry, S. Glasstone, East-West Press (Pvt.) Ltd.
5. Heat & Thermodynamics, M. W. Zemansky& R. H. Dittman, The McGraw-Hill Companies Inc., New York.

MJ9P: PHYSICAL CHEMISTRY LAB- III **Credits 01(30 hrs.)**

1. Determination of relative viscosity coefficient of an unknown solution using Ostwald viscometer

2. Determination of relative surface tension of an unknown solution using Stalagmometer.

3. Determination of pH of unknown solution (buffer), by color matching method

4. Determination of concentration of an unknown solution of a weak acid (monobasic or dibasic) and pK_a value(s) by pH-metric titrations using a glass electrode.

5. Determination of concentrations of unknown solution of $K_2Cr_2O_7$ and the standard reduction potential of Fe^{3+}/Fe^{2+} couple by potentiometric titration.

6. Determination of concentrations of unknown solution of KCl and the solubility product of AgCl by potentiometric titration.

Suggested Books

Text Books:

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015
2. Nad A. K, Mahapatra B. and Ghoshal A., "An Advanced Course In Practical Chemistry'', New Central Book Agency (P) Limited, 2014
3. Maity S.K. and Ghosh N.K, " Physical Chemistry Practicals", New Central Book Agency (P) Limited, 2012
4. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

Reference Books:

5. Practical Physical Chemistry – A.M. James, F.F. Prichard
6. Findlay's Practical Physical Chemistry – B.P. Levitt
7. Experimental Physical Chemistry – Shoemaker and Ga
8. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

MAJOR-10: ORGANIC CHEMISTRY-IV
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ-10T: ORGANIC CHEMISTRY-IV **Credits 03 (Theory: 45 Lectures)**

Course Content:

Nitrogen compounds, Rearrangements, Carbohydrates, and Organic Spectroscopy

Nitrogen compounds **(8 Lectures)**

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.

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 reaction (with mechanism): Thorpe nitrile condensation, von Richter reaction.

Diazonium salts and their related compounds: reactions (with mechanism) involving replacement of diazo group; reactions: Gomberg, Meerwein, Japp-Klingermann.

Rearrangements **(12 Lectures)**

Mechanism with evidence and stereochemical features for the following

Rearrangement to electron-deficient carbon: Wagner-Meerwein rearrangement, pinacol rearrangement, dienone-phenol; Wolff rearrangement in Arndt-Eistert synthesis, benzil-benzilic acid rearrangement, Demjanov rearrangement, Tiffeneau–Demjanov rearrangement.

Rearrangement to electron-deficient nitrogen: rearrangements: Hofmann, Curtius, Lossen, Schmidt and Beckmann.

Rearrangement to electron-deficient oxygen: Baeyer-Villiger oxidation, cumenehydroperoxide-phenol rearrangement and Dakin reaction.

Aromatic rearrangements: Migration from oxygen to ring carbon: Fries rearrangement and Claisen rearrangement.

Migration from nitrogen to ring carbon: Hofmann-Martius rearrangement**,** Fischer-Hepp rearrangement, *N*-azo to *C*-azo rearrangement, Bamberger rearrangement, Orton rearrangement and benzidine rearrangement.

Carbohydrates **(10 Lectures)**

Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine- water oxidation, HNO_3 oxidation, selective oxidation of terminal $–CH_2OH$ of aldoses, reduction to alditols, Lobry de Bruyn-van Ekenstein rearrangement; stepping-up (Kiliani-Fischer method) and stepping–down (Ruff's &Wohl's methods) of aldoses,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).

Organic Spectroscopy **(15 Lectures)**

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); applicationof Woodward's Rules for calculation of λmax 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 λmax 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 vibrationsare 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.

NMR Spectroscopy (Basic concept):introduction;nuclearspin;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; interpretation of NMR spectra of simple compounds.

Suggested Readings:

1. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry* (*Volume 2: Stereochemistry and the Chemistry of Natural Products*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Norman, R.O. C., Coxon, J. M. *Principles of Organic Synthesis*, Third Edition, Nelson Thornes, 2003.
4. Clayden, J., Greeves, N., Warren,S., *Organic Chemistry*, Second edition, Oxford University Press 2012.
5. March, J. *Advanced Organic Chemistry*, Fourth edition, Wiley.
6. Harwood, L. M., *Polar Rearrangements*, Oxford Chemistry Primer, Oxford University Press.
7. Bailey, Morgan, Organonitrogen Chemistry, Oxford Chemistry Primer, Oxford University Press.
8. Warren, S. *Organic Synthesis the Disconnection Approach*, John Wiley and Sons.
9. Warren, S., *Designing Organic Synthesis*, Wiley India, 2009.
10. Carruthers, W. *Modern methods of Organic Synthesis*, Cambridge University Press.
11. Willis, C. A., Wills, M., *Organic Synthesis*, Oxford Chemistry Primer, Oxford University Press.
12. Silverstein, R. M., Bassler, G. C., Morrill, T. C. *Spectrometric Identification of Organic Compounds*, John Wiley and Sons, INC, Fifth edition.
13. Kemp, W. *Organic Spectroscopy*, Palgrave.
14. Pavia, D. L. *et al. Introduction to Spectroscopy,* 5th Ed. Cengage Learning India Ed. (2015).
15. Dyer, J. *Application of Absorption Spectroscopy of Organic Compounds*, PHI

MJ10P: ORGANIC CHEMISTRY-IV (LAB) **(Credits 01; 30 hrs.)**

Spectroscopic Analysis of Organic Compounds

1. Assignment of labelled peaks in the ^{1}H NMR spectra of the known organic compounds explaining the relative δ-values and splitting pattern.

2. Assignment of labelled peaks in the IR spectrum of the same compound explaining the relative frequencies of the absorptions (C-H, O-H, N-H, C-O, C-N, C-X, C=C, C=O, N=O, C≡C, C≡N stretching frequencies; characteristic bending vibrations are included).

3. The students must record full spectral analysis of **at least 10 (ten)**compound from the following list:

(i) 4-Bromoacetanilide (ii) 2-Bromo-4-methylacetophenone (iii) Vanillin (iv) 2-Methoxyacetophenone (v) 4-Aminobenzoic acid (vi) Salicylamide (vii) 2-Hydroxyacetophenone (viii) 1,3-Dinitrobenzene (ix) *trans*-Cinnamic acid (x) Diethyl fumarate (xi) 4-Nitrobenzaldehyde (xii) 4- Methylacetanilide (xiii) Mesityl oxide (xiv) 2-Hydroxybenzaldehyde (xv) 4-Nitroaniline (xvi) 3-Nitrobenzaldehyde (xvii) 2-Methoxybenzaldehyde (xviii) Methyl 4-hydroxybenzoate (xxix) Methyl 3- hydroxybenzoate (xx) 3-Aminobenzoic acid (xxi) 3-Nitroanisole.

Suggested Readings:

1. *Practical Workbook Chemistry (Honours), UGBS, Chemistry*, University of Calcutta, 2015
2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education

MAJOR ELECTIVE (DSE)

MAJOR ELECTIVE-1 (OPTION-A):
ADAVNCED PHYSICAL CHEMISTRY-I
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ DSE-1(A)T:ADAVNCED PHYSICAL CHEMISTRY-I Credits 03 (45 Lectures)

Course contents:

A. ADSORPTION AND COLLOIDAL SYSTEMS (12Lectures)

(I) Adsorption: definition, difference between adsorption and absorption, Different types of adsorption; Physical and chemical adsorption and their distinctive features, Extent of adsorption, Adsorption isotherms for adsorption of gases on solid surface: Freundlich and Langmuir adsorption isotherm (with derivation), BET adsorption isotherm (without derivation), determination of surface area of adsorbent, Isosteric heat of adsorption.

Adsorption isotherms for adsorption of solid on liquid surface: Gibbs adsorption isotherm, variation of surface tension with concentration, Surface active agent, Micelle and Critical Micelle Concentration.

(II) Colloidal system: definition and general properties, Classifications of colloids. Lyophobic and lyophilic colloids and their distinctive features, Preparation of lyophobic colloids, peptization and dialysis, Electrical properties of lyophobic colloids, Origin of charge, Flocculation and Schultz-Hardy rule, Electro-kinetic phenomena (qualitative idea only). Double layer potential and Zeta potential, Stability of colloids in terms of zeta potential, Optical properties of colloids, Tyndall effect, Kinetic property of colloid, Brownian motion and determination of Avogadro number by Perrin's method. Protective action of lyophilic colloid and Gold number.

B. CHEMICAL KINETICS: PART-2 (10 Lectures)

(I) Collision theory of reaction rate, Unimolecular gas phase reaction, Lindemann mechanism.

(II)Transition State theory: Classical treatment and Eyring equation.

(III) Primary and secondary kinetic salt effect

(IV)Enzyme catalysis; Characteristic features, Effect of pH and temperature. Turn over number, Michaelis-Menten equation, Michaelis-Menten plot, Lineweaver-Burk plot, Eadie's plot, Eadie-hofstee plot, Woolf-Hanes plot.

(V) Heterogeneous catalysis,

C. ELECTRICAL PRPERTIES OF MOLECULES **(6 Lectures)**

Fundamentals of electrostatics, Coulomb's law, electric field, electric potential, dielectric constant or relative permittivity, Dipole moment, induced dipole moment, Polarization and polarizability: Polarizability of atoms and molecules, dielectric constant and polarisation, molar polarisation for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation (both without derivation) ,their applications and limitations; Determination of dipole moments and polarizabilty, Molar refraction, Lorentz-Lorenz equation, Molar polarization as a function of frequency.

D. ELECTRONIC SPECTROSCOPY AND PHOTOCHEMISTRY **(10Lectures)**

(I) Basic laws of photochemistry, Grotthus-Drapper law and Stark-Einstein law of photochemical equivalence. Primary and secondary process of a photochemical reaction. Quantum yield, Chemical actinometry, Reasons for low and high quantum yields, Examples. Lambert-Beer's law: Lambert-Beer's law and its limitations, Absorbance, transmittance and molar extinction coefficient, calibration curve.

(II) Photochemical processes: Differential rate laws of various photochemical reaction HI decomposition, $H_2+Br_2 \rightarrow 2HBr$ reaction, dimerisation of anthracene, photostationary state or photochemical equilibrium, Fluorescence quenching (qualitative idea only) and the Stern-Volmerequation, Photosensitized reaction. Chemiluminescence.

E. POLYMER CHEMISTRY **(7 Lectures)**

Polymers: Classification of polymers, nomenclature, Monodisprese and polydisperse polymeric sample, Different kind of average molar masses, number average, mass average, viscosity average and sedimentation average molar masses. Determination of average molar masses by end group analysis, viscosity measurement and osmotic pressure measurement. Kinetics of polymerization.

SUGGESTED BOOKS

Text Books:

1. Physical Chemistry, P. C. Rakshit, Sarat Book House, India.
2. Text Book of Physical Chemistry, S. Glasstone, Macmillan India Limited, New Delhi.
3. Physical Chemistry: Volume I, A. Nag, McGraw Hill Education.
4. Physical Chemistry, G.W. Castellan, Narosa, New Delhi.
5. Physical Chemistry, T. Engel and P. Reid, Pearson Education,Inc, India.
6. Physical Chemistry, S Pahari, New Central Book Agency.

Reference Books:

7. Chemical Kinetics, K. J. Laidler, Pearson Education India.
8. Fundamentals of Molecular Spectroscopy, C. N. Banwell, McGraw-Hill Inc.
9. Modern Spectroscopy, J. M. Hollas, John Wiley & Sons, Ltd.
10. Polymer Science & Technology, P. Ghosh, McGraw Hill Education.
11. Fundamentals of Photochemistry, K. K. Rohatgi-Mukherjee, New Age International Publishers.

MJ DSE-1(A)P: ADVANCED PHYSICAL CHEMISTRY LAB- I (Credits 01; 30 hrs)

1. Verification of Beers law and determination of molar extinction coefficient and concentration of a color absorbing species ($K_2Cr_2O_7$ and $KMnO_4$ solutions) using a colorimeter or spectrophotometer.
2. Determination of pK_{In} of Bromocresol green indicator and the determination of pH of an unknown buffer spectrophotometrically.
3. Study of of $K_2S_2O_8$ – KI kinetics and determination of rate constant spectrophotometrically.
4. Study of $K_2S_2O_8$ – KI kinetics spectrophotometrically and the effect of ionic strength.
5. Verification of Freundlich adsorption isotherm using adsorption of acetic acid from its aqueous solution by activated charcoal.
6. Determination of Critical Micelle Concentration of a surfactant by surface tension measurement.

SUGGESTED BOOKS

Text Books:

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015
2. Nad A. K, Mahapatra B. and Ghoshal A., "An Advanced Course In Practical Chemistry'', New Central Book Agency (P) Limited, 2014
3. Maity S.K. and Ghosh N.K, " Physical Chemistry Practicals", New Central Book Agency (P) Limited, 2012
4. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

Reference Books:

5. Practical Physical Chemistry – A.M. James, F.F. Prichard
6. Findlay's Practical Physical Chemistry – B.P. Levitt
7. Experimental Physical Chemistry – Shoemaker and Ga
8. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

OR

MAJOR ELECTIVE-1 (OPTION-B):
ADAVNCED PHYSICAL CHEMISTRY-II
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ DSE-1(B)T:ADAVNCED PHYSICAL CHEMISTRY-II Credits 03 (45 Lectures)

CourseContent:

A. STATISTICAL ANALYSIS OF DATA (7 Lectures)

Measurement of central tendency- mean, median, mode; error and accuracy, standard deviations and precisions, Difference between accuracy and precision, Normal distribution, skewness and Kurtosis, Covariance and correlation coefficient, Regression and Least square fitting. Rounding of numbers, significant figures.

B. NUMERICAL METHODS (10 Lectures)

(I) Interpolation and extrapolation.

(II) Numerical derivatives

(III) Numerical integration: Trapezoidal rule and Simpson's rule.

(IV) One dimensional root finding methods: Bisection method, Newton-Raphson method, fixed point iteration method

(V) Solutions of ordinary differential equation: Runge-Kutta method.

C. SYMMETRY AND GROUP THEORY (10 Lectures)

(I) Definition of abstract group, theorems of group, Group multiplication table and rearangement theorem, cyclic group, subgroup, coset, Lagrange's theorem, Similarity transformation and conjugate elements, Class.

(II) Symmetry elements and symmetry operations, Point group.

(III) Matrix representation of symmetry operations and the point group. Character of matrix representation, Reducible and irreducible representations.

(IV) Great Orthogonality Theorem (without proof) and its consequences, Constructions of character table.

(V) Applications of group theory in IR and vibrational Raman spectroscopy. Mutual exclusion principle.

D. APPROXIMATE METHODS IN QUANTUM MECHANICS (8 Lectures)

(I) Need of approximate methods in quantum mechanics.

(II) Variation principle: Statement and proof on Rayleigh-Ritz variation principle, Example, Linear variation principle.

(III) Perturbation Theory: Rayleigh-Schrodinger perturbation theory for nondegenerate and time independent case. Expression of first order correction of energy and wave function, second order correction of energy. Examples.

E. POLYELECTRON ATOMS/IONS AND COVALENT BONDING (10 Lectures)

(I) Construction of Time Independent Schrodinger equation for polyelectron atoms or ios, Aufbau principle and electronic configuration, System of quantum identical particles, antisymmetry principle, Pauli's exclusion principle, Hund's rules, L-S and J-J coupling, Atomic term symbols.

(II) Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+; Bonding and antibonding orbitals; Qualitative extension to H_2; Comparison of LCAO-MO and VB treatments of H_2 and their limitations.

SUGGESTED BOOKS

Text Books:

1. Physical Chemistry, R. J. Silbey, R. A. Alberty& M. G. Bawendi, John Wiley & Sons, Inc.
2. Physical Chemisty, I. N. Levine, McGraw Hill, NewYork
3. Physical Chemistry, P. Atkins, J.D Paula and J. Keeler, Oxford University Press, New York.
4. Physical Chemistry: A Molecular Approach, D. A. McQuarrie and J. D. Simon, Viva Book Private Limited, New Delhi.
5. Physical Chemistry, T. Engel and P. Reid, Pearson Education,Inc, India.
6. Physical Chemistry, H. Chatterjee, Platinum Publishers.

Reference Books:

7. Chemical Applications of Group Theory, F. A. Cotton, Wiley; Third edition.
8. Quantum Mechanics, B. H. Bransden and C. J. Joachain, Pearson.
9. Quantum Chemistry, I. N. Levine, Pearson Education India.
10. Mathematics for Physical Chemistry, D. A. McQuarrie, Univ Science Books.
11. Basic Training in Mathematics: A fitness program for science students, R. Shankar, Springer.

MJ DSE-1(B)P: ADVANCED PHYSICAL CHEMISTRY LAB- II (Credits 01; 30 Hrs.)

(I) Basics of Fortran language: Column position rules, Fortran constants, Fortran variables and its declaration, Library functions, Some basic commands (read, write, pause, stop, end), Control statements, DO loops, Array and subscripted variables, Function and Subroutines.

(II) Computer Programming based on numerical methods:

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

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

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

4. Numerical solutions of Differential equation: Solution of Schrodinger equation for one dimensional problems such as PIAB, LSHO.

SUGGESTED BOOKS

Text Books:

1. Computer Programming in Fortran 90 and 95, VRajaraman, Prentice Hall India Learning Private Limited.
2. Fortran 77 and Numerical Methods, C. Xavier, New Age International Pvt Ltd Publishers.
3. Numerical Recipes in Fortran, The Art of Scientific Computing – W.H. Press, S.A. Teukolsky, W.T.Vellerling, B.P. Flannery.
4. Modern Fortran: Building efficient parallel applications, M. Curcic, Manning Publishers.

MINOR-5: (Organic Chemistry – III & Physical Chemistry - IV)
Credits 04; FM- 75
(Theory-03, Practical-01)

Minor (MI)-5T:Organic Chemistry – III & Physical Chemistry – IV **Credits 03; 45 lectures**

Course contents:

Organic Chemistry-III **(15 Lectures)**

Alcohols, Phenols and Ethers

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 KMnO4, acidic dichromate, concentrated HNO3); Oppenauer oxidation;

Diols: Preparation (with OsO4); pinacol- pinacolone rearrangement (with mechanism) (with symmetrical diols only).

Phenols: Preparation: cumenehydroperoxide method, from diazonium salts; acidic nature of phenols; Reactions: electrophilic substitution: nitration and halogenations;

Fries rearrangement and Claisen rearrangement.

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

Carbonyl Compounds

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; Reactions: with HCN, ROH, $NaHSO_3$, NH_2-G derivatives and with Tollens' and Fehling's reagents; iodoform test; aldol condensation (with mechanism); Cannizzaro reaction (with mechanism),Wittig reaction, benzoin condensation; Clemmensen reduction, Wolff- Kishner reduction and Meerwein-Pondorff- Verley (MPV) reduction.

Preparation and synthetic applications of Grignard reagent, Diethyl Malonate (DEM) and Ethyl acetoacetate (EAA)

Reference Books:

1. Sethi, A. *Conceptual Organic Chemistry*; New Age International Publisher.
2. Parmar, V. S. *A Text Book of Organic Chemistry*, S. Chand & Sons.
3. Madan, R. L. *Organic Chemistry*, S. Chand & Sons.

4. Wade, L. G., Singh, M. S., *Organic Chemistry*, Pearson.
5. Finar, I. L. *Organic Chemistry* (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Bahl, A. &Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.

Physical Chemistry-IV

(A) Electrochemistry (15 Lectures)

(I) Conductance

Conductance, Specific Conductance, Equivalent and molar conductance and their interrelations. Variation of specific and equivalent conductance with dilution for strong and weak electrolytes. Ionic mobility, Kohlrausch's law of independent migration of ions. Ionic conductance and transport number. Relation between ionic mobility and ionic conductance. Factors determining ionic and equivalent conductance: concentration, size of the solvated ions, temperature, viscosity of the solvent and the Walden's rule. Abnormally high ionic conductance of H^+ and OH^-.Conductometric titrations; principles and various examples

(II) Electromotive Force

Thermodynamics of reversible Galvanic cell. Electromotive Force (EMF) and the standard EMF their temperature dependence. Nernst equation. Spontaneity and equilibrium of a redox reaction in terms of reduction potential, Equilibrium constant and the standard reduction potential. Electrochemical series. Principle determination of pH using glass electrode. Potentiometric titrations of Mohr salt solution by potassium dichromate solution and the silver nitrate solution by potassium chloride solution. Significance of various plots.

(B) Quantum Mechanics (15 Lectures)

de Broglie's wave particle duality. Heisenberg Uncertainty Principle, Basic postulates of quantum mechanics, Time independent Schrodinger equation, Wave function, Born's probabilistic interpretation of wave function, acceptability criteria of wave function, Normalized wave functions and normalization procedure, Orthogonal and orthonormal set of wave functions, Degeneracy of wave functions, Operators, liner and Hermitian operators, Eigen value equations, Commutation relations: Average values of a classical observable in a quantum state, Time dependent Schrodinger equation, Concept of stationary states

Applications of Quantum mechanics to simple problems, Particle in a box problem (PIAB, Simple Harmonic Oscillator (SHO), Rigid Rotor (RR) and H-atom problem

Reference Books:

1. Barrow, G.M. *Physical Chemistry* Tata McGraw- Hill (2007).
2. Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
3. McQuirre and Simon, Physical Chemsitry
4. P.C. Rakshit, *Physical Chemistry*
5. H. Chatterjee, *Physical Chemistry*
6. A Nag, *Physical Chemistry*
7. S Pahari *Physical Chemistry*
8. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
9. Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
10. Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
11. Chugh, K.L., Agnish, S.L. *A Text Book of Physical Chemistry*Kalyani Publishers
12. Bahl, B.S., Bahl, A., Tuli, G.D., *Essentials of Physical Chemistry* S. Chand & Co. Ltd.
13. Palit, S. R., *Elementary Physical Chemistry* Book Syndicate Pvt. Ltd.

Minor (MI)-5P:PRACTICAL **Credits 01; 30hrs.**

Section A: Organic Chemistry Lab

Organic Preparations

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

1. Condensation reactions
2. Acetylation of phenols/aromatic amines
3. Benzoylation of phenols/aromatic amines
4. Diazo coupling reactions of aromatic amines
5. Bromination of anilides using green approach (Bromate-Bromide method)

Section B: Physical Chemistry Lab

- Conductometric titrations
  - (i) Weak dibasic acid vs. Strong base
  - (ii) Mixed acid vs. strong base
- Determination of ionization constant and equivalent conductance at infinite
- Determination of concentrations of unknown solution of $K_2Cr_2O_7$ and the standard reduction potential of Fe^{3+}/Fe^{2+} couple by potentiometric titration.
- Determination of concentrations of unknown solution of KCl and the solubility product of AgCl by potentiometric titration.
- Determination of concentration of an unknown solution of a weak acid (monobasic or dibasic) and pK_a value(s) by pH-metric titrations using a glass electrode.

Reference Books:

1. U*niversity 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. 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., *Textbook of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
7. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
8. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

SEMESTER-VI

MAJOR (MJ)

MAJOR-11: INORGANIC CHEMISTRY-IV
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ-11T: INORGANIC CHEMISTRY-IV **Credits 03 (Theory: 45 Lectures)**

A. Bioinorganic Chemistry: **(15 Lectures)**

Bioinorganic Chemistry Elements of life: essential and beneficial elements, major, trace and ultratrace elements. Basic chemical reactions in the biological systems and the role of metal ions (specially Na^+, K^+ , Mg^{2+}, Ca^{2+} , $Fe^{3+/2+}$, $Cu^{2+/+}$, and Zn^{2+}). Metal ion transport across biological membrane Na^+ / K^+-ion pump (with mechanism) Dioxygen molecule in life. Bioenergetic principle and role of ATP, Dioxygen management proteins: Haemoglobin, Myoglobin, Hemocyanine and Hemerythrin. Electron transfer proteins: Cytochromes and Fe-S proteins (Ferredoxins, Rubredoxins etc).Biological nitrogen fixation (Nitrogenase), Metal ions transport and storage proteins: ferritin, transferrin, ceruloplasmin (only function) Photosynthesis: Photosystem-I and Photosystem-II (with appropriate Z-scheme) Toxic metal ions and their effects, chelation therapy (examples only), Pt and Au complexes as drugs (examples only), chemistry of cis-platin as anticancer agent, metal dependent diseases (examples only).

B. Organometallic Chemistry and Catalysis: **(19 Lectures)**

Defination and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. 18-electron and 16-electron rules (pictorial MO approach). Applications of 18-electron rule to metal carbonyls, nitrosyls, cyanides. General methods of preparation of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls. π-acceptor behaviour of CO, synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation, structure, evidences of synergic effect. Metallocene: Ferrocene, cobaltocene and nickelocene, Preparation and reactions of ferocene (acetylation, alkylation, metallation, Mannich Condensation). Reactions of organometallic complexes: substitution, oxidative addition, reductive elimination and insertion reactions.

Catalysis: Alkene hydrogenation (Wilkinson's Catalyst), Hydroformylation, Wacker Process, Synthetic gasoline (Fischer Tropsch reaction), Ziegler-Natta catalysis for olefin polymerization, Monsanto Acetic Acid Process.

C. Reaction Kinetics and Mechanism: (7 Lectures)

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Cis/Trans- effect and their application in complex synthesis, Nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes, outer sphere and inner sphere electron transfer mechanism (with examples).

D. Chemistry of block Elements: (4 Lectures)

Electronic configuration, Separation of lanthanides (ion-exchange method only), lanthanide contraction, oxidation states, colour, spectral and magnetic properties, Uses of lanthanide compounds as shift reagent, comparison of electronic spectra among 3d, 4f and 5f.

Reference Books

1. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.

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. Greenwood, N.N. &Earnshaw A. Chemistry of the Elements, ButterworthHeinemann, 1997.

4. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.

5. Bertini, I., Gray, H. B., Lippard, S.J., Valentine, J. S., Viva, 2007.

6. Basolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.

7. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.

8. Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988.

9. Collman, J. P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987.

10. Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. New York, NY: John Wiley, 2000.

MJ-11P: INORGANIC CHEMISTRY LABORATORY- III (Credit 01; 30 Hrs.)

A. Gravimetric Estimation:

1. Estimation of Ba(II) as $BaSO_4$.
2. Estimation of phosphate (PO_4^{3-}) as Lead Phosphate [$Pb_3(PO_4)_2$].
3. Estimation of Al(III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminiumoxinate).
4. Estimation of chloride

B. Inorganic Preparations:

1. $[Cu(CH_3CN)_4]PF_6$ and $[Cu(CH_3CN)_4]ClO_4$
2. Tris-(ethylenediamine) nickel(II) chloride.
3. $[Mn(acac)_3]$ and $Fe(acac)_3]$ (acac= acetylacetonate)
4. Preparation of Mohr's Salt

Suggested Readings:

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

MAJOR-12: PHYSICAL CHEMISTRY-IV
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ-12T: PHYSICAL CHEMISTRY-IV **Credits 03 (Theory: 45 Lectures)**

Course contents:

A. STATES OF MATTER: PART-3 (SOLID STATE) (7 LECTURES)

(I) General properties of solid state. Classification of solid based on bonding. Classifications of solid in terms of geometry; Crystalline and amorphous solid. True crystal and the polycrystalline solid.

(II) Crystalline solid: Fourteen Bravais Lattice. Some basic concepts of crystalline solid; lattice, basis, crystal structure, unit cell, face, edge, vertices, interfacial angle etc. crystal planes and their graphical representations. Primitive unit cell. Different types of cubic crystals; SC, BCC and FCC. Calculation of packing efficiency, closed packed and loose packed structure, Density of a crystal.

(III) Laws of Crystallography: Law of constancy of interfacial angle, Law of rational indices, Weiss and Miller indices, Interplanar spacing between two identical parallel planes, Angle between two non-parallel planes. Law of symmetry.

(IV) X-ray diffraction: Bragg's law, Alternative form of Bragg's law, Determination of crystal structure from the systematic absence of certain planes in x-ray diffraction. Techniques of X-ray diffraction, Powder diffraction method; Structure of NaCl and KCl crystals.

(V) Lattice heat capacity: Experimental observations, Classical theory and the Dulong – Petit's law; Einstein's theory- Derivation and explanation of temperature dependence of lattice heat capacity, limitations; Debye modification and the Debye- T^3 law.

B. STATISTICAL THERMODYNAMICS (8 LECTURES)

(I) Introduction to statistical thermodynamics, Difference from classical thermodynamics, Some basic concepts; Thermodynamic system, Instanteneous configuration, Macrostates, microstates, Thermodynamic weight, Postulate of equal a priori probabilities, Most dominating configurations. Elementary idea of ensemble. Different types of identical particles (qualitative idea).

(II) Connection between microscopic and macroscopic description; Boltzmann definition of entropy.

(III) Preliminary idea of Thermodynamic Partition function, Thermodynamic quantities in terms of partition function.

(IV) 3rd law of Thermodynamics: Absolute entropy, Planck's law, Calculation of absolute entropy, Nernst heat theorem

C. THERMODYNAMICS: PART-4 (PHASE EQUILIBRIUM) (18 LECTURES)

(I) Definitions of phase, component and degrees of freedom with various examples; Gibb's phase rule and its derivations. Order of phase transitions; 1^{st} order, 2^{nd} order and lamda-order phase transitions with characteristics features.

(II) Phase diagrams for pure substance. μ vs. T phase diagram, effect of pressure on transition temperature. Triple point. Clapeyron equation; Clausius-Clapeyron equation. P vs T phase diagram. Phase diagram for water, CO_2 and Sulphur

(III) Colligative properties: Vapour pressure, effect of addition of nonvolatile solute, Raoult's law, relative lowering of vapour pressure as a colligative property, Chemical potential of the components in of solution, Origin of colligative properties, Raoult's law; Thermodynamic derivation of various colligative properties such as (i) Elevation of boiling point, (ii) Depression of freezing point and (iii) Osmotic pressure and vant' Hoff equation, .Reverse osmosis, Solubility as a colligative property. Inter-relations among various colligative properties, Abnormal colligative properties of electrolytic solution, van't Hoff factor, van'f Hoff factor and degree of dissociation of weak electrolyte. Determination of molecular weight using various colligative properties.

(IV) Liquid-Vapor Phase Equilibrium: Binary solutions: Variation of total vapour pressure with the mole fraction in the liquid phase, Variation of total vapour pressure with the mole fraction in the vapor phase, Relative amount in the liquid phase and vapour phase, Lever rule, Principle of isothermal fractional distillation of an ideal binary liquid mixture. Principle of isobaric fractional distillation; Temperature vs. composition phase diagram, Change in various thermodynamic quantities when liquids are mixed to form an ideal solution, Non-ideal binary liquid mixture, positive and negative deviations from ideality

Duhem-Margules equation and its consequences, Konowaloff's rule; relative compositions in liquid phase and vapour phase. Azeotropic solution; Solubility of gas in liquid, Henry's law.

(V) Liquid-liquid phase equilibrium, partially miscible liquids, Conjugate solutions, Temperture-Composition phase diagram for partially miscible liquids with special reference to Phenol-water system. Critical solution temperature and effect of pressure and impurity.

Immiscible liquid pairs.

Nernst's distribution law; It's derivation, Partition coefficient, Principle of determination of partition coefficient. Distribution of solute when it is associated in one of the phases, Principle of solvent extraction.

(VI) Solid-liquid phase equilibrium, Eutectic mixture. Thermal analysis, Construction of temperature-composition phase diagram for simple eutectic system, formation of compounds with congruent melting point and incongruent melting point. Ice mixture, Fusion mixture, Elevation of freezing point.

(VII) Three component phase diagram. Water, benzene and acetic acid system. Triangular plots.

D. MOLECULAR SPECTROSCOPY:PART-1 (ROTATIONAL, VIBRTIONAL, ELECTRONIC & RAMAN SPECTROSCOPY) (12 LECTURES)

(I) Introduction: Nature of light with special reference of electromagnetic radiation. Various types of motion in a molecule. Separation of these motions and the Born-Oppenheimer approximation. Mechanism of interaction of molecule and the electromagnetic radiation; classical and semiclassical treatments. Fermi-Golden rule and the selection rules for transition (without derivation), relative intensities of spectral lines or bands, Broadening of a spectra and the line shape.

(II) Rotation spectroscopy or Microwave spectroscopy: Moment of inertia. Classifications of molecules based on relative values of components of moment of inertia. Linear top, symmetric top (prolate and oblate), spherical top, asymmetric top. Heteronuclear diatomic molecule as a Rigid Rotor model. Energy expression and degeneracy. Selection rules, relative intensities of spectral lines, determination of bond lengths, isotopic substitution. Limitations of RR model. Effect of nonrigidity.

(III) Vibrational spectroscopy or IR spectroscopy: Diatomic molecule as a linear Simple Harmonic Oscillator, Energy expressions, selection rules, fundamental band, Determination of

force constant of the bond. Limitations of SHO model. Effect of anharmonicity, Morse oscillator model, Determination of bond dissociation energies, Explanations of existence of overtones, and hot bands, Applications of IR spectroscopy.

SUGGESTED BOOKS

Text Books:

1. Physical Chemistry, G.W. Castellan, Narosa, New Delhi.
2. Physical Chemisty, W. J. Moore, Orient Longman, New Delhi.
3. Physical Chemistry, P. Atkins, J.D Paula and J. Keeler, Oxford University Press, New York.
4. Physical Chemistry: A Molecular Approach, D. A. McQuarrie and J. D. Simon, Viva Book Private Limited, New Delhi.
5. Physical Chemistry, T. Engel and P. Reid, Pearson Education,Inc, India.
6. Text Book of Physical Chemistry, S. Glasstone, Macmillan India Limited, New Delhi.

Reference Books:

7. A Textbook of Physical Chemistry, K. L. Kapoor, McGraw Hill Education, India.
8. Fundamentals of Molecular Spectroscopy, C. N. Banwell, McGraw-Hill Inc.
9. Modern Spectroscopy, J. M. Hollas, John Wiley & Sons, Ltd.
10. Statistical Mechanics, D. A. McQuarrie, Univ Science Books.
11. Introduction to Solid State Physics, C. Kittel, Wiley; Wiley India Edition.

MJ12P: PHYSICAL CHEMISTRY LAB- IV Credits 01(30 Hrs.)

1. Determination of solubility and concentration solubility product of a sparingly soluble salt (say KHTa) using acid-base titration.

2. Determination of partition coefficient of iodine in between organic solvents (CCl_4 or $CHCl_3$) and water.

3. Determination of equilibrium constant for the reaction for reaction $KI(aq) + I_2 = KI_3$ by partition method.

4. Determination of coordination number of Cu^{2+} ion in cuprammonium complex in aqueous medium by partition method.

5. Determination of upper critical solution temperature (UCST) and the corresponding composition for Phenol-water system.

6. Study of phase diagram of a three component system (water, benzene and acetic acid)

SUGGESTED BOOKS

Text Books:

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015
2. Nad A. K, Mahapatra B. and Ghoshal A., "An Advanced Course In Practical Chemistry'', New Central Book Agency (P) Limited, 2014
3. Maity S.K. and Ghosh N.K, " Physical Chemistry Practicals", New Central Book Agency (P) Limited, 2012
4. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

Reference Books:

5. Practical Physical Chemistry – A.M. James, F.F. Prichard
6. Findlay's Practical Physical Chemistry – B.P. Levitt
7. Experimental Physical Chemistry – Shoemaker and Ga
8. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Book (2009)

MAJOR-13: ORGANIC CHEMISTRY-V
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ-13T: ORGANIC CHEMISTRY-V **Credits 03 (Theory: 45 Lectures)**

Course contents:

Carbocycles, Logic of Organic Synthesis and Heterocycles, Cyclic Stereochemistry, and Bio-molecules

Carbocycles (5 Lectures)

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

The Logic of Organic Synthesis (10 Lectures)

Retrosynthetic analysis: disconnections; synthons, donor and acceptor synthons; latent polarity in bifunctional compounds: consonant and dissonant polarity; illogical electrophiles and nucleophiles; synthetic equivalents; 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).

Synthetic applications of diethyl malonate (DEM) and ethyl acetoacetate (EAA).

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

Heterocycles (10 lectures)

Heterocyclic compounds: 5- and 6-membered rings with one heteroatom; 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; thiophenes: Paal-Knorr 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 and isoquinoline; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Friedlander; isoquinoline: Bischler-Napieralski synthesis.

Cyclic Stereochemistry **(10 Lectures)**

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 & reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (SN1, SN2, SNi, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic *syn* elimination and fragmentation reactions.

Bio-molecules **(10 Lectures)**

Amino acids: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Büchererhydantoin 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 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.

SUGGESTED READINGS:

1. Clayden, J., Greeves, N., Warren, S. *Organic Chemistry*, Second edition, Oxford University Press 2012.
2. Eliel, E. L. &Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London.
3. Nasipuri, D. *Stereochemistry of Organic Compounds,* Wiley Eastern Limited.
4. Fleming, I. *Molecular Orbitals and Organic Chemical reactions*, Reference/Studen Edition, Wiley, 2009.
5. Fleming, I. *Pericyclic Reactions*, Oxford Chemistry Primer, Oxford University Press.

6. Gilchrist, T. L. &Storr, R. C. *Organic Reactions and Orbital symmetry*, Cambridge University Press.

7. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

8. Finar, I. L. *Organic Chemistry* (*Volume 2: Stereochemistry and the Chemistry of Natural Products*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

9. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

10. Loudon, G. M. *Organic Chemistry*, Fourth edition, Oxford University Press

11. James, 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. Davis, B. G., Fairbanks, A. J., *Carbohydrate Chemistry*, Oxford Chemistry Primer, Oxford University Press.

14. Joule, J. A. Mills, K. *Heterocyclic Chemistry*, Blackwell Science.

15. Acheson, R.M. *Introduction to the Chemistry of Heterocyclic compounds*, John Wiely& Sons (1976).

16. Gilchrist, T. L. *Heterocyclic Chemistry*, 3rd edition, Pearson.

17. Davies, D. T., *Heterocyclic Chemistry*, Oxford Chemistry Primer, Oxford University Press.

18. Organic Chemistry, Paula Bruice

MJ-13P: ORGANIC CHEMISTRY-V (LAB) **Credit 01(30 Hrs.)**

A. Chromatographic Separations

1. TLC separation of a mixture of two dyes
2. Column chromatographic separation of leaf pigments from spinach leaves
3. Paper chromatographic separation of a mixture containing 2 amino acids

B. Quantitative Estimations:

Each student is required to perform all the experiments.

1. Estimation of glucose by titration using Fehling's solution
2. Estimation of sucrose by titration using Fehling's solution

3. Estimation of Vitamin-C (reduced)

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

5. Estimation of phenol by bromination (Bromate-Bromide) method

6. Estimation of acetic acid in commercial vinegar

SUGGESTED READINGS:

1. Arthur, I. V. *Quantitative Organic Analysis*, Pearson

2. *University Hand Book of Undergraduate Chemistry Experiments*, edited by Mukherjee, G. N., University of Calcutta

3. *University Hand Book of Undergraduate Chemistry Experiments*, edited by Mukherjee, G. N. University of Calcutta, 2003.

4. Furniss, B.S.;Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012).

MAJOR ELECTIVE (DSE)

MAJOR ELECTIVE-2 (OPTION-A): ANALYTICAL METHODS IN CHEMISTRY
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ DSE-2(A) T: ANALYTICAL METHODS IN CHEMISTRY Credits 03 (45 Lectures)

Course contents:

A. Qualitative and quantitative aspects of analysis: (10 Lectures)

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

B. Optical methods of analysis: (15 Lectures)

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

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument; Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enoltautomers. Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.

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.

Flame Atomic Adsorption and Emission Spectroscopy: Basic principle and instrumentation

C. Separation techniques (Chromatography & Ion-Exchange): (12 **Lectures)**

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media. Chromatography: Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods. Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

D. Thermal methods of analysis: Theory of thermogravimetry (TG), basic principle of instrumentation, Thermogram of $CuSO_4 \cdot 5H_2O$, $Ca_2C_2O_4 \cdot 2H_2O$ and $CaCO_3$.

E. Analysis of soil and water: (8 **Lectures)**

Analysis of soil: Composition of soil, Concept of pH of soil.

Analysis of water: Definition of pure water, sources responsible for contaminating water, COD, BOD, water purification methods.

Suggested Readings:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Willard, H.H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, D.C.: Exploring Chemical Analysis, 9th Ed. New York, W.H. Freeman, 2016.
5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age International Publisher, 2009.
6. Skoog, D.A. Holler F.J. & Nieman, T.A. Principles of Instrumental Analysis, Cengage Learning India Ed.
7. Mikes, O. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.
8. Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.
9. Day, R. A. & Underwood, A. L. Quantitative Analysis, Prentice Hall of India.

MJ DSE-2P: Analytical Methods in Chemistry (Laboratory) Credits 01 (30 Hrs.)

1) Separation of a mixture containing Ni^{2+}& Fe^{2+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry.

2) Paper chromatographic separation of (i) Ni(II) and Co(II) (ii) Fe(III) and Al(III)

3) Analysis of soil: (i) Determination of pH of soil. (ii) Estimation of Calcium, Magnesium and Phosphate.

4) Determination of Dissolved Oxygen (DO) of a water sample.

5) Determination of pKa values of indicator using spectrophotometry.

6) Determination of exchange capacity of cation exchange resin and anion exchange resin.

Suggested Readings:

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

2. Willard, H.H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.

3. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.

4. Harris, D.C. Exploring Chemical Analysis, 9th Ed. New York, W.H. Freeman, 2016.

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, Cengage Learning India Edition.

7. Mikes, O. &Chalmes, R.A. Laboratory Handbook of Chromatographic & Allied Methods, Elles Harwood Ltd. London.

8. Ditts, R.V. Analytical Chemistry: Methods of separation. Van Nostrand, New York, 1974.

OR

MAJOR ELECTIVE-2 (OPTION-B):
INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE
Credits 04; FM- 75
(Theory-03, Practical-01)

MJ DSE-2(A) T: ANALYTICAL METHODS IN CHEMISTRY Credits 03 (45 Lectures)

A. General Principles of Metallurgy: (12 Lectures)

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining.

B. Inorganic Polymers: (6 Lectures)

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines and phosphazenes.

C. Silicate Glass industry: (9 Lectures)

Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

D. Fertilizers: (7 Lectures)

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound.

E. Cement: **(6 Lectures)**

.Different types of cement, Chemical composition and properties, Manufacturing of cement, Setting and hardening, Environmental effects.

F. Alloys: **(5 Lectures)**

Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (Ar and heat treatment, nitriding, carburizing). Composition and properties of different types of steels.

Suggested Readings:

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. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

3. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

4. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.

5. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

6. P. C. Jain, M. Jain: Engineering Chemistry, DhanpatRai& Sons, Delhi.

7. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas Publications, New Delhi.

8. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

MJ DSE-2P: Inorganic Materials of Industrial Importance (Laboratory) **Credits 01 (30 Hrs.)**

1. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
2. Estimation of phosphoric acid in superphosphate fertilizer.
3. Analysis of (Cu, Zn) in brass.
4. Determination of composition of dolomite (by complexometric titration).
5. Estimation of available chlorine in bleaching powder.
6. Estimation of Fe in cement.

Suggested Readings:

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

2. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.

4. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

5. P. C. Jain, M. Jain: Engineering Chemistry, DhanpatRai& Sons, Delhi.

6. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas Publications, New Delhi.

8. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

MINOR (MI)

Minor (MI)-6: Inorganic Chemistry-IV & Organic Chemistry-IV Credits 04(FM: 75)

Minor (MI)-6T: Inorganic Chemistry-IV & Organic Chemistry-IV (Theory) Credits 03

Course Content

Inorganic Chemistry-IV

Qualitative and quantitative aspects of analysis (01 Lecture)

Sampling, errors, accuracy and precision, methods of their expression**.**

Chromatography (04 Lectures)

Principle of chromatographic methods, column chromatography and thin layer chromatography.

Coordination Chemistry (10 Lectures)

Concept of double salt, complex salt, Werner's theory, Classification of ligands: chelating ligands and chelate complexes, Valence Bond Theory (VBT): Inner and outer orbital complexes of Fe, Cr, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6. Limitation of VBT. IUPAC system of nomenclature (mononuclear complexes only).

Bio-inorganic Chemistry: (10 Lectures)

A brief introduction to bio-inorganic chemistry: Essential and beneficial elements, major and trace elements, elements. Basic chemical reactions in the biological systems and the role of metal ions (specially Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Fe $^{2+/\ 3+}$,Ca^{+2} , Cu $^{+/\ 2+,}$ and Zn^{2+}). Di-oxygen (O_2) management protein: Hemoglobin (Hb) (only structure and bio-functions). Toxicity of heavier metal (toxicity of Hg, Cd, Pb, As) and their effects.

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. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. *Inorganic Chemistry, Principles of Structure and Reactivity* 4th Ed., Harper Collins 1993, Pearson,2006.

5. Greenwood, N.N. & Earnshaw A. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.
6. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., *Advanced Inorganic Chemistry* 6th Ed. 1999., Wiley.
7. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.

Organic Chemistry-IV **(20 Lectures)**

Carboxylic acids and their derivatives

Preparation of Carboxylic acids (aliphatic and aromatic); Reactions: Hell–Vohlard–Zelinsky reaction, Reformatsky reaction, Perkin condensation

Preparation of Carboxylic acid's derivatives: Acid chlorides, Anhydrides, Esters and Amides from acids and their inter-conversion.

Acidic and Alkaline hydrolysis of esters (B_{AC}^2, A_{AC}^2, A_{AC}^1 and A_{AL}^1).

Nitrogen compounds

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.

Molecular Rearrangements

Rearrangement to electron-deficient nitrogen: Hofmann, Curtius, Lossen, Schmidt and Beckmann.

Rearrangement to electron-deficient carbon: Pinacol-Pinacolone rearrangement, Wolff rearrangement in Arndt-Eistert synthesis, Benzil-Benzilic acid rearrangement

Rearrangement to electron-deficient oxygen: Baeyer-Villiger oxidation, and Dakin reaction.

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. 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. Graham Solomons, T.W., Fryhle, C. B. *Organic Chemistry*, John Wiley & Sons, Inc.
10. March, J. *Advanced Organic Chemistry*, Fourth edition, Wiley.

Minor (MI) - 6P: Practical **(30 Lectures)**

Section A: Inorganic Chemistry Laboratory

1. Paper chromatographic separation of (a) Ni(II) and Co(II) (b) Fe(III) and Al(III)
2. Estimation of Ni(II) using dimethylglyoxime (DMG).
3. Estimation of total hardness of water by using EDTA
4. Estimation of Ca(II) by complexometric titrations using EDTA
5. Estimation of Mg(II) by complexometric titrations using EDTA
6. Preparation of (a) Mohr's salt (b) Tetraamminecarbonatocobalt (III) ion

Section B: Organic Chemistry Lab

Quantitative Estimations

1. Estimation of glucose by titration using Fehling's solution
2. Estimation of vitamin-C (reduced)
3. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method
4. Estimation of phenol by bromination (Bromate-Bromide) method

Reference Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Ghosal, Mahapatra & Nad, *An Advanced Course in Practical Chemistry*, New Central Book Agency.
3. *University Hand Book of Undergraduate Chemistry Experiments*, edited by Mukherjee, G. N. University of Calcutta, 2003.
4. Das, S. C., Chakraborty, S. B., *Practical Chemistry.*