PROGRAMME AND COURSE STRUCTURE WITH CREDIT DISTRIBUTION

FOR

UG Degree Programmes with Single Major

IN

CHEMISTRY

(*w.e.f.* 2023-2024)

BANKURA UNIVERSITY
BANKURA
WEST BENGAL
PIN - 722155

STRUCTURE IN CHEMISTRY

SEMESTER-I

Category of Course	Course Code	Course Title	Credit	Marks			No. of Hours		
				I.A.	ESE	Total	Lec.	Tu.	Lab.
1. Major :: DSC	S/CHEM/101/MJC-1	Fundamentals of Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
2. Minor Stream	S/CHEM/102/MN-1	Fundamentals of Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
3. Multidisciplinary	S/CHEM/103/MD-1	Basic Chemistry	3	10	40	50	45		
4. Skill Enhancement Courses	S/CHEM/104/SEC-1	Basic Analytical Chemistry	3	10	40	50	45		
5. Ability Enhancement Course	ACS/105/AEC-1	Compulsory English: Literature and Communication	2	10	40	50	30		
6. Value Added Courses	ACS/106/VAC-1	Environmental Studies	4	10	40	50	60		
Total credits = 4+4+3+3+2+4 = 20				Total no. of courses = 6					

SEMESTER-II

Category of Course	Course Code	Course Title	Credit	Marks			No. of Hours		
				I.A.	ESE	Total	Lec.	Tu.	Lab.
1. Major :: DSC	S/CHEM/201/MJC-2	Fundamentals of Chemistry II	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
2. Minor Stream	S/CHEM/202/MN-2	Fundamentals of Chemistry II	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
3. Multidisciplinary	S/CHEM/203/MD-2	Chemistry in Daily life	3	10	40	50	45		
4. Skill Enhancement Courses	S/CHEM/204/SEC-2	Pharmaceuticals Chemistry	3	10	40	50	45		
5. Ability Enhancement Course	ACS/205/AEC-2	MIL-I (Santali, Sanskrit and Bengali)	2	10	40	50	30		
6. Value Added Courses	ACS/206/VAC-2	****	4	10	40	50	60		
Total credits = 4+4+3+3+2+4 = 20				Total no. of courses = 6					

**** Health and wellness/Understanding India: Indian Philosophical Traditions and Value Systems/Basics of Indian Constitution/Arts and Crafts of Bengal/Historical Tourism in West Bengal.

SEMESTER-III

Category of Course	Course Code	Course Title	Credit	Marks			No. of Hours		
				I.A.	ESE	Total	Lec.	Tu.	Lab.
1. Major :: DSC	S/CHEM/301/MJC-3	Organic Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
2. Major :: DSC	S/CHEM/302/MJC-4	Physical Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
3. Minor Stream	S/CHEM/303/MN-3	Inorganic Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
4. Multidisciplinary	S/CHEM/304/MD-3	Analytical Clinical Biochemistry	3	10	40	50	45		
5. Skill Enhancement Courses	S/CHEM/305/SEC-3	Analytical Clinical Biochemistry	3	10	40	50	45		
6. Ability Enhancement Course	ACS/306/AEC-3	MIL-II (Santali, Sanskrit and Bengali)	2	10	40	50	30		
Total credits = 4+4+4+3+3+2 = 20				Total no. of courses = 6					

SEMESTER-IV

Category of Course	Course Code	Course Title	Credit	Marks			No. of Hours		
				I.A.	ESE	Total	Lec.	Tu.	Lab.
1. Major :: DSC	S/CHEM/401/MJC-5	Inorganic Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
2. Major :: DSC	S/CHEM/402/MJC-6	Inorganic Chemistry II	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
3. Major :: DSC	S/CHEM/403/MJC-7	Organic Chemistry II	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
4. Major :: DSC	S/CHEM/404/MJC-8	Physical Chemistry II	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
5. Minor Stream	S/CHEM/405/MN-4	Organic Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
6. Ability Enhancement Course	ACS/406/AEC-4	####	2	10	40	50	30		
Total credits = 4+4+4+4+4+2 = 22				Total no. of courses = 6					

Compulsory English: Literature, Language and Communication

SEMESTER-V

Category of Course	Course Code	Course Title	Credit	Marks			No. of Hours		
				I.A.	ESE	Total	Lec.	Tu.	Lab.
1. Major :: DSC	S/CHEM/501/MJC-9	Inorganic Chemistry III	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
2. Major :: DSC	S/CHEM/502/MJC-10	Organic Chemistry III	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
3. Major :: DSC	S/CHEM/503/MJC-11	Physical Chemistry III	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
4. Major :: DSC	S/CHEM/504/MJC-12	Analytical Chemistry	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
5. Minor Stream	S/CHEM/505/MN-5	Physical Chemistry I	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
6. Internship Course	ACS/506/INT-3	Internship III	2			50	60		
Total credits = 4+4+4+4+4+2 = 22				Total no. of courses = 6					

SEMESTER-VI

Category of Course	Course Code	Course Title	Credit	Marks			No. of Hours		
				I.A.	ESE	Total	Lec.	Tu.	Lab.
1. Major :: DSC	S/CHEM/601/MJC-13	Inorganic Chemistry IV	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
2. Major :: DSC	S/CHEM/602/MJC-14	Organic Chemistry IV	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
3. Major :: DSC	S/CHEM/603/MJC-15	Physical Chemistry IV	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
4. Major :: DSC	S/CHEM/604/MJC-16	Polymer Chemistry	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
5. Minor Stream	S/CHEM/605/MN-6	Organic Chemistry II	3 (Th.) + 1 (Lab.) = 4	10	25 (Th.) 15 (Lab.)	50	45		30
Total credits = 4+4+4+4+4 = 20				Total no. of courses = 5					

N.B.: S = Science, CHEM = Chemistry, MJ = Major, MN = Minor, ACS = Arts Commerce Science, C = Core Course, AEC = Ability Enhancement Course, SEC = Skill Enhancement Course, DSC = Discipline Specific Core, DSE = Discipline Specific Elective, VAC = Value Added Course, MD = Multidisciplinary, INT = Internship, I.A. = Internal Assessment, ESE = End-Semester Examination, Lec. = Lecture, Tu.= Tutorial, and Lab. = Laboratory

Summer Internship (INT)

- Students who want to exit after first or second year have to complete one summer internship of 4 credits in addition to the 40 credits of first year and 82 credits after second year.
- Students have to successfully complete a summer internship of 2 credits in semester-V to qualify for the degree in chemistry.

Year	Conditions	Credits	Course Type
First	The students who want to exit after first year for **Certificate Course in Chemistry** have to secure 4 credits in addition to 40 credits after successfully completing summer internship/apprenticeship (in semester-I or II) in an industry or organization or training in labs or any government office/organization as may be decided by the department or college. Those who completed summer internship of 4 credits in first year will be allowed to re-enter the degree programme within three years and complete it within the stipulated maximum of seven years.	4 (Additional for Certificate Course in Chemistry)	Practical
Second	The students who want to exit after second year for **Diploma in Chemistry** have to secure 4 credits in addition to 82 credits after successfully completing summer internship/apprenticeship (in semester-I, II, III or IV) in an industry or organization or training in labs or any government office/organization as may be decided by the department or college. Those who completed summer internship of 4 credits in second year will be allowed to re-enter within three years and complete the degree programme within the maximum period of seven years.	4 (Additional for Diploma in Chemistry)	Practical
Third	The students who want **Degree in Chemistry** have to secure mandatory 2 credits in addition to 124 credits after successfully completing summer internship/apprenticeship (in semester-V) in an industry or organization or training in labs or any government office/organization as may be decided by the department or college.	2 (Mandatory for Degree in Chemistry)	Practical

Important Guidelines

- All graphs for physical chemistry courses must be done using standard spreadsheet software (Excel, Origin etc.)
- Each college should take necessary measures to ensure they should have the following facilities:
  1. UV-VIS Spectrophotometer with printer
  2. Internet facility
  3. Computers (~1 computer for 5 students)
- For proper maintenance of above mentioned facilities, clean & dry AC rooms are mandatory.
- Each lecture is of 1 hr duration for both theory and practical classes.

Bankura University Syllabus for Chemistry 2023-2027

PROGRAMME OUTCOME

The undergraduate (UG) programme of chemistry is composed of major, minor and interdisciplinary subjects. The syllabus is based on the national education policy (NEP) which covers almost all the fields of chemistry. The students will be enriched with plenty of knowledge after the completion of the course. The complete syllabus is compatible with the competitive examination for higher studies and research. In this programme there are various multidisciplinary courses. The students will acquire multidisciplinary skills which will be of tremendous value to them.

SEM-I

Major (MJC - 1)

(Credits - 3 + 1)

Core T-1-Fundamentals of Chemistry I (3 Credits) **(45 Lectures)**

Extra Nuclear Structure of Atom **(8 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.

Chemical Periodicity **(6 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); 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 **(6 Lectures)**

Concepts of acids and bases; thermodynamic acidity parameters, Drago-Wayland equation; superacids, gas phase acidity and proton affinity; HSAB principle; acid-base equilibria in aqueous

solution (proton transfer equilibria in water), pH, buffer; acid-base neutralisation curves; indicator, choice of indicators.

Redox and Precipitation Reactions (10 Lectures)

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.

Bonding and Physical Properties of Organic Compounds (10 Lectures)

Introduction: Nomenclature of organic compound, Lewis structure, calculation of formal charges and double bond equivalent (DBE); molecular formula, idea of framing constitution from molecular formula.

Valence bond theory: Concept of hybridisation, shapes of molecules, resonance (including hyperconjugation); 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; acyclic p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems).

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.

Stereochemistry I (5 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_v, C_{nh}, C_{nv}, C_n, D_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 pseudo asymmetry; chiral centres and number of stereoisomerism: systems involving 1/2/3-chiral centre(s) (AA, AB, ABA and ABC types).

Reference Books

- Lee, J. D. Concise Inorganic Chemistry, ELBS.
- Douglas, B. E., McDaniel, D. H., Alexander, J. Concepts & Models of Inorganic Chemistry, Wiley India.
- Day, M. C., Selbin, J. Theoretical Inorganic Chemistry, ACS Publications.
- Atkins, P. Shriver & Atkins' Inorganic Chemistry, Oxford University Press.
- Cotton, F. A., Wilkinson, G., Gaus, P. L. Basic Inorganic Chemistry, Wiley India.
- Sharpe, A. G. Inorganic Chemistry, Pearson Education.
- Huheey, J. E., Keiter, E. A., Keiter, R. L. Inorganic Chemistry, Principles of Structure and Reactivity, Harpor Collins College.
- Dutta, R. L., De, G. S. Inorganic Chemistry (Volume 1), The New Book Stall.
- Sarkar, R. General and Inorganic Chemistry, Volume 1, New Central Book Agency (P) Limited.
- Morrison, R. N., Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
- Graham Solomons, T. W., Fryhle, C. B. Organic Chemistry, John Wiley & Sons Inc.
- Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Pearson Education.
- James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing.
- Robinson, M. J. T. Stereochemistry, Oxford Chemistry Primer, Oxford University Press.
- Pal, S. C. Principles of Stereochemistry and their Application in Organic Reactions, Techno World.
- Sen Gupta, S. Basic Stereochemistry of Organic molecules, Oxford University Press.

Course Outcomes

1. To learn the concept about extra-nuclear structures of atoms.
2. To acquire detailed knowledge about the periodic table and the trend of various periodic properties.
3. To study about acid base reactions in detail.

4. To gather in-depth knowledge about redox and precipitation reactions.
5. To learn detailed knowledge about bonding and physical properties of organic compounds.
6. To gather preliminary and basic knowledge about stereochemistry.

Core P-1-Chemical Analysis Lab (1 Credit) (30 Lectures)

Acid-Base Titrations

1. Standardization of NaOH using standard oxalic acid solution.
2. Estimation of carbonate and bicarbonate present together in a mixture

Oxidation-Reduction Titrimetry

3. Standardization of $KMnO_4$ using standard oxalic acid solution.
4. Estimation of Fe (II) using standardized $KMnO_4$ solution.
5. Estimation of Fe (III) using standard $K_2Cr_2O_7$ solution.
6. Estimation of Fe (II) and Fe (III) in a given mixture using standard $K_2Cr_2O_7$ solution.

Estimation of Organic Compounds

7. Estimation of glucose by titration using Fehling's solution.
8. Estimation of glycine by Sörensen's formol method.
9. Estimation of formaldehyde (Formalin).
10. Estimation of acetic acid in commercial vinegar.

Reference Books

- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson.
- Mukherjee, G. N. Handbook of Inorganic Analysis, U. N. Dhur Sons Pvt. Ltd.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
- Maji, S. K. Practical Inorganic Chemistry, Books and allied (P) Ltd.
- University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta.
- Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
- Mann, F. G., Saunders, B. C. Practical Organic Chemistry, Pearson Education.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes

1. To become skilled at carrying out acid-base titrations as well as oxidation-reduction analysis after getting hands-on training in laboratory.

2. To become experienced to estimate glucose, glycine, formaldehyde and acetic acid in organic samples.

Minor (MN - 1)

(Credits - 3 + 1)

T-1-Fundamentals of Chemistry I (3 Credits) **(45 Lectures)**

Extra Nuclear Structure of Atom **(8 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, 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.

Chemical Periodicity **(6 Lectures)**

Modern IUPAC Periodic table, effective nuclear charge, screening effects and penetration, Slater's rules, atomic radii, ionic radii (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, inert pair effect.

Acid Base **(6 Lectures)**

Concepts of acids and bases; thermodynamic acidity parameters; Drago-Wayland equation; superacids, gas phase acidity and proton affinity; HSAB principle; acid-base equilibria in aqueous solution (proton transfer equilibria in water), pH, buffer; acid-base neutralisation curves; indicator, choice of indicators.

Redox and Precipitation Reactions **(10 Lectures)**

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.

Bonding and Physical Properties of Organic Compounds (10 Lectures)

Introduction: Nomenclature of organic compound, Lewis structure, calculation of formal charges and double bond equivalent (DBE); molecular formula, idea of framing constitution from molecular formula.

Valence bond theory: Concept of hybridisation, shapes of molecules, resonance (including hyperconjugation); 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.

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.

Stereochemistry I (5 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; molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of epimers; concept of stereogenicity, chirotopicity and pseudo asymmetry; chiral centres and number of stereoisomerism: systems involving 1/2/3-chiral centre(s) (AA, AB, ABA and ABC types).

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- Sharpe, A. G. Inorganic Chemistry, Pearson Education.
- Huheey, J. E., Keiter, E. A., Keiter, R. L. Inorganic Chemistry, Principles of Structure and Reactivity, Harper Collins College.
- Atkins, P. W., Paula, J. Physical Chemistry, Oxford University Press.
- Mingos, D. M. P. Essential Trends in Inorganic Chemistry, Oxford University Press.
- Winter, M. J. The Orbitron, http://winter.group.shef.ac.uk/orbitron/, An illustrated gallery of atomic and molecular orbitals.
- Burgess, J. Ions in Solution: Basic Principles of Chemical Interactions, Ellis Horwood.
- Morrison, R. N. Boyd, R. N., Bhattacharjee, S. K. Organic Chemistry, Pearson Education.
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
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- Sen Gupta, S. Basic Stereochemistry of Organic Molecules, Oxford University Press.
- Mishra, S., Giri, G. C., Roy, S. K., Chanda, J. Snatak Rasayan, Santra Publication Pvt. Ltd.

Course Outcomes

1. To learn the concept about extra-nuclear structures of atoms.
2. To acquire detailed knowledge about the periodic table and the trend of various periodic properties.
3. To study about acid base reactions in detail.
4. To gather in-depth knowledge about redox and precipitation reactions.
5. To learn detail knowledge about bonding and physical properties of organic compounds.
6. To gather preliminary and basic knowledge about stereochemistry.

P-1-Chemical Analysis I (1 Credit) **(30 Lectures)**

Acid-Base Titrations

1. Standardization of NaOH using standard oxalic acid solution.

2. Estimation of carbonate and bicarbonate present together in a mixture.

Oxidation-Reduction Titrimetry

3. Standardization of $KMnO_4$ using standard oxalic acid solution.

4. Estimation of Fe (II) using standardized $KMnO_4$ solution.

5. Estimation of Fe (III) using standard $K_2Cr_2O_7$ solution.

6. Estimation of Fe (II) and Fe (III) in a given mixture using standard $K_2Cr_2O_7$ solution.

Estimation of Organic Compounds

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

8. Estimation of glycine by Sörensen's formol method.

9. Estimation of formaldehyde (Formalin).

10. Estimation of acetic acid in commercial vinegar.

Reference Books

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- Mukherjee, G. N. Handbook of Inorganic Analysis, U. N. Dhur Sons Pvt. Ltd.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
- Maji, S. K. Practical Inorganic Chemistry, Books and Allied (P) Ltd.
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- Mann, F. G., Saunders, B. C. Practical Organic Chemistry, Pearson.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes

1. To become skilled at carrying out acid-base titrations as well as oxidation-reduction analysis after getting hands-on training in laboratory.

2. To become experienced to estimate glucose, glycine, formaldehyde and acetic acid in organic samples.

Multidisciplinary (MD - 1)

(Credits - 3)

Basic Chemistry (3 Credits) **(45 Lectures)**

1. Structure of atom - discovery of sub-atomic particles; atomic models; Bohr's model for hydrogen atom.

2. Classification of element and periodicity in properties - why we need to classify elements? genesis of periodic classification; modern periodic law and the present form of periodic table; periodic trends in properties of elements.

3. Chemistry of carbon compounds: Hybridization of carbon, σ and π bonds, functional group approach for the following (preparations & reactions) to be studied in context to their structures: aliphatic hydrocarbons (alkanes, alkenes, alkynes, alcohols, ethers, carbonyls, carboxylic acids, esters, amines and amide) and aromatic hydrocarbons.

4. Methods of purification of organic compound - filtration, crystallization, sublimation, distillation and chromatography.

5. Acids and bases - different concept of acids and bases - Arrhenius, Lowry-Bronsted, Lewis and salt; ionization of acids and bases, Ostwald dilution law, buffer solution; indicators.

6. Gaseous state, gas laws, ideal gas equation and real gas equation.

7. Thermodynamics - concept of heat and work, state and path function, reversible process, isothermal and adiabatic processes, internal energy, enthalpy, reaction enthalpy.

Reference Books

- Dutta, R. L., De, G. S. Inorganic Chemistry (Volume I), the New Book Stall.
- Palit, S. R. Elementary Physical Chemistry, Book Syndicate Pvt. Ltd.
- Pahari, S. Physical Chemistry New Central Book Agency.
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
- Bahl, A., Bahl, B. S. Advanced Organic Chemistry, S. Chand.
- Sen Gupta, S. Organic Chemistry: General Course, Book Syndicate (P) Ltd.

Course Outcomes

1. To learn the basic chemistry of various types of carbon compounds.

2. To learn different methods for purification of organic compounds.

3. To gather brief knowledge about structure of atoms, elemental periodicity, acids and bases.

4. To acquire basic knowledge about thermodynamics.

Skill Enhancement Course (SEC - 1)

(Credits - 3)

Basic Analytical Chemistry (3 Credits) **(45 Lectures)**

Introduction **(10 Lectures)**

Introduction to analytical chemistry and its interdisciplinary nature; concept of sampling; importance of accuracy, precision and sources of error in analytical measurements; presentation of experimental data and results from the point of view of significant figures.

Analysis of Soil **(6 Lectures)**

Composition of soil, concept of pH and pH measurement, complexometric titrations, chelation, chelating agents, use of indicators

1. Determination of pH of soil samples.

2. Estimation of calcium and magnesium ions as calcium carbonate by complexometric titration.

Analysis of Water **(6 Lectures)**

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

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

2. Determination of dissolved oxygen (DO) of a water sample.

Analysis of Food Products **(6 Lectures)**

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

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

2. Analysis of preservatives and colouring matter.

Analysis of Cosmetics **(6 Lectures)**

Major and minor constituents and their functions

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

2. Determination of constituents of talcum powder: magnesium oxide, calcium oxide, zinc oxide and calcium carbonate by complexometric titration.

Suggested Applications **(6 Lectures)**

1. To study the uses of phenolphthalein in trap cases.

2. To analyse arson accelerants.

3. To carry out analysis of gasoline.

Suggested Instrumental Demonstrations (5 Lectures)

1. Estimation of macro nutrients; potassium, calcium, magnesium in soil samples by flame photometry.

2. Spectrophotometric determination of iron in vitamin/dietary tablets.

3. Spectrophotometric identification and determination of caffeine and benzoic acid in soft drinks.

Reference Books

- Willard, H. H., Merritt, L. L., Dean, J., Settoe, F. A. Instrumental Methods of Analysis, Wadsworth Publishing Company Ltd., Belmont, California, USA.
- Skoog, D. A., Holler, F. J., Crouch, S. Principles of Instrumental Analysis, Cengage Learning India Edition.
- Skoog, D. A., West, D. M., Holler, F. J. Analytical Chemistry: An Introduction, Saunders College Publishing, Fort Worth, Philadelphia.
- Harris, D. C. Quantitative Chemical Analysis, Macmillan Education.
- Dean, J. A. Analytical Chemistry Handbook, McGraw Hill.
- Day, R. A., Underwood, A. L. Quantitative Analysis, Prentice Hall of India.
- Freifelder, D. M. Physical Biochemistry, W. H. Freeman & Co. NY USA.
- Cooper, T. G. The Tools of Biochemistry, John Wiley & Sons, NY USA.
- Vogel, A. I. Vogel's Qualitative Inorganic Analysis, Prentice Hall.
- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson.
- Robinson, J. W. Undergraduate Instrumental Analysis, Marcel Dekker Inc. NY USA.
- Christian, G. D. Analytical Chemistry, John Wiley & Sons, New York.

Course Outcomes:

1. To learn about introduction to analytical chemistry and its interdisciplinary nature.

2. To learn about analysis of soil.

3. To study analysis of water.

4. To gain knowledge of analysis of food products.

5. To come to know about analysis of cosmetics.

SEM II

Major (MJC - 2)

(Credits - 3 + 1)

Core T-2-Fundamentals of Chemistry II (3 Credits) **(45 Lectures)**

Gaseous state I **(12 Lectures)**

1. Kinetic theory of gases: Concept of pressure and temperature; collision of gas molecules; collision diameter; collision number and mean free path; frequency of binary collisions (similar and different molecules); wall collision and rate of effusion.

2. Maxwell's distribution of speed and energy: Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; calculations of average, root mean square and most probable values in each case; kinetic energy distribution in one, two and three dimensions, principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

Liquid State **(6 Lectures)**

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

2. Surface tension: Surface tension, surface energy, excess pressure, capillary rise method, work of cohesion and adhesion, angle of contact; spreading of liquid over other surface; vapour pressure over curved surface; temperature dependence of surface tension.

Thermodynamics I **(12 Lectures)**

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

2. Thermochemistry: Standard states; heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; laws of thermochemistry; bond energy, bond

dissociation energy and resonance energy from thermochemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions; adiabatic flame temperature; explosion temperature.

General treatment of Organic Reaction Mechanism I (10 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.

Reaction thermodynamics: Free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change via BDE, intermolecular & intra-molecular 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 nucleophilicity and basicity; HSAB principle; application of thermodynamic principles in acid base equilibria.

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

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

Stereochemistry II (5 Lectures)

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

- Atkins, P. W., Paula, J. Atkins' Physical Chemistry, Oxford University Press.
- Castellan, G. W. Physical Chemistry, Narosa.
- McQuarrie, D. A., Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
- Engel, T., Reid, P. Physical Chemistry, Pearson.
- Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
- Kapoor, K. L. A Textbook of Physical Chemistry, Tata McGraw-Hill.
- Rakshit, P. C. Physical Chemistry, Sarat Book House.
- Ball, D. W. Physical Chemistry, Thomson Press.
- Mortimer, R. G. Physical Chemistry, Elsevier.
- Laidler, K. J. Chemical Kinetics, Pearson.
- Glasstone, S., Lewis, G. N. Elements of Physical Chemistry.
- Zemansky, M. W., Dittman, R. H. Heat and Thermodynamics, Tata-McGraw-Hill.
- Rastogi, R. P., Misra, R. R. An Introduction to Chemical Thermodynamics, Vikas.
- Morrison, R. N., Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Graham Solomons, T. W., Fryhle, C. B. Organic Chemistry, John Wiley & Sons Inc.
- Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Pearson Education.
- James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing.
- Robinson, M. J. T. Stereochemistry, Oxford Chemistry Primer, Oxford University Press.
- Pal, S. C. Principles of Stereochemistry and their Application in Organic Reactions, Techno World.
- Sen Gupta, S. Basic Stereochemistry of Organic molecules, Oxford University Press.

Course Outcomes

1. To gather detail knowledge about kinetic theory of gases and speed distribution of gas molecules.
2. To acquire in-depth knowledge about viscosity and surface tension of liquid state.
3. To learn detail about thermodynamical parameters and thermochemistry.
4. To learn basic and important points about general organic reaction mechanism.
5. To gather in-depth knowledge about stereochemical configuration and isomerisms.

Core P-2-Physico-Chemical Analysis Laboratory (1 Credit) (30 Lectures)

Physical Chemistry Practicals

1. Determination of relative viscosity of unknown solution (glycerol, sucrose) at various concentrations using Ostwald Viscometer.

2. Determination of surface tension of a liquid at various concentrations using Stalagmometer.

3. Determination of pH of unknown buffer solution by colour matching method.

Identification of Pure Organic Compounds

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

Determination of melting point and boiling point of identified compounds

Reference Books

- Palit, S. R. Practical Physical Chemistry, Science Book Agency.
- Mukherjee, N. G. Selected Experiments in Physical Chemistry, J. N. Ghose & Sons.
- Dutta, S. K. Physical Chemistry Experiments, Bharati Book Stall.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
- Mann, F. G., Saunders, B. C. Practical Organic Chemistry, Pearson Education.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes:

1. To become skilled in order to determine viscosity, surface tension and pH of unknown samples/solutions.

2. To become skilled to identify different kinds of pure organic compounds.

Minor (MN - 2)

(Credits - 3 + 1)

T-2-Fundamental of Chemistry II (3 Credits) (45 Lectures)

Gaseous State I **(12 Lectures)**

1. Kinetic theory of gases: Concept of pressure and temperature; collision of gas molecules; collision diameter; collision number and mean free path; frequency of binary collisions (similar and different molecules); wall collision and rate of effusion.

2. Maxwell's distribution of speed and energy: Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions (derivation not required); expression of average, root mean square and most probable values in each case; kinetic energy distribution in one, two and three dimensions (derivation not required), principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

Liquid State **(6 Lectures)**

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

2. Surface tension and energy: Surface tension, surface energy, excess pressure, capillary rise and surface tension; work of cohesion and adhesion, angle of contact; spreading of liquid over other surface, vapour pressure over curved surface; temperature dependence of surface tension.

Thermodynamics I **(12 Lectures)**

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

2. Thermo-chemistry: Standard states; heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; laws of thermo-chemistry; bond energy, bond dissociation energy and resonance energy from thermo-chemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions; adiabatic flame temperature; explosion temperature.

General treatment of Organic Reaction Mechanism I **(10 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.

Reaction thermodynamics: Free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change via BDE, intermolecular & intra-molecular 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 nucleophilicity and basicity; HSAB principle; application of thermodynamic principles in acid base equilibria.

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

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

Stereochemistry II **(5 Lectures)**

Relative and absolute configuration: D/L and R/S descriptors; erythro/threos 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.

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- Barrow, G. M. Physical Chemistry, Tata McGraw-Hill.
- Castellan, G. W. Physical Chemistry, Narosa.
- Kotz, J. C., Treichel, P. M., Townsend, J. R. General Chemistry, Cengage Learning India Pvt. Ltd. New Delhi.
- Mahan, B. H. University Chemistry, Narosa.

- Petrucci, R. H. General Chemistry, Macmillan Publishing Co. New York.
- Chugh, K. L., Agnish, S. L. A Text Book of Physical Chemistry, Kalyani Publishers.
- Bahl, B. S., Bahl, A., Tuli, G. D. Essentials of Physical Chemistry, S. Chand.
- Palit, S. R. Elementary Physical Chemistry, Book Syndicate Pvt. Ltd.
- Mandal, A. K. Degree Physical and General Chemistry, Sarat Book House.
- Pahari, S. Physical Chemistry, New Central Book Agency.
- Pahari, S., Pahari, D. Problems in Physical Chemistry, New Central Book Agency.
- Shriver, D. F., Atkins, P. W. Inorganic Chemistry, Oxford University Press.
- Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
- Rodgers, G. E. Inorganic Solid State Chemistry, Cengage Learning India Ltd.
- Morrison, R. N., Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Graham Solomons, T. W., Fryhle, C. B. Organic Chemistry, John Wiley & Sons Inc.
- Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Pearson Education.
- James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing.
- Robinson, M. J. T. Stereochemistry, Oxford Chemistry Primer, Oxford University Press.
- Pal, S. C. Principles of Stereochemistry and their Application in Organic Reactions, Techno World.
- Sen Gupta, S. Basic Stereochemistry of Organic molecules, Oxford University Press.
- Mishra, S., Giri, G. C., Roy, S. K., Chanda, J. Snatak Rasayan, Santra Publication Pvt. Ltd.

Course Outcomes

1. To gather detail knowledge about kinetic theory of gases and speed distribution of gas molecules.
2. To acquire in-depth knowledge about viscosity and surface tension of liquid state.
3. To learn detail about thermodynamical parameters and thermochemistry.
4. To learn basic and important points about general organic reaction mechanism.
5. To gather in-depth knowledge about stereochemical configuration and isomerisms.

P-2-Physico-Chemical Analysis Laboratory (1 Credit) (30 Lectures)

Physical Chemistry Practicals

1. Determination of relative viscosity of unknown solution (glycerol, sucrose) using Ostwald Viscometer.

2. Determination of surface tension of a liquid using Stalagmometer.

3. Determination of pH of unknown buffer solution by colour matching method.

Identification of Pure Organic Compounds

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

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- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
- Mann, F.G., Saunders, B. C. Practical Organic Chemistry, Pearson Education.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes

1. To become skilled in order to determine viscosity, surface tension and pH of unknown samples/solutions.

2. To become skilled to identify different kinds of pure organic compounds.

Multidisciplinary (MD - 2)

(Credits - 3)

Chemistry in Daily Life (3 Credits) **(45 Lectures)**

1. Hydrocarbons in daily use: Coal based chemicals, petro-chemicals-kerosene, Liquefied petroleum gas (LPG).

2. Agrochemicals: Manufacture of ammonia and ammonium salts, sulphur-phosphate, fungicides, herbicides, pesticides.

3. Glass and ceramics: Manufactures of glasses, optical glass and colour glass, porcelain, enamel and cement.

4. Food chemistry: Classification of foods - carbohydrates, proteins and fats; nutritional and medicinal values, food additives-food flavour, food colour, food preservatives, artificial sweeteners, food adulteration in some common foods like turmeric, coriander, peppers etc.

5. Drugs and pharmaceuticals: Aspirin, paracetamol, ibuprofen, vitamin C, vitamin B12 etc.

6. Surface chemistry: Surface tension of liquids and related phenomenon, colloids and surface active agents (detergents), micelles and applications.

Reference Books

- Mandal, S. K., Ghanta, R. Pharmaceutical Chemistry and Production: An Introductory Textbook. Bentham Science Publishers.
- Sengupta, S. Application Oriented Chemistry. Books Syndicate Pvt. Ltd.
- Gangopadhyay, P. K. Application Oriented Chemistry, Books Syndicate Pvt. Ltd.

Course Outcomes

1. To learn about daily usable hydrocarbons, agrochemicals, glass and ceramics.
2. To gather basic knowledge about food chemistry, drugs and pharmaceuticals and surface chemistry.

Skill Enhancement Course (SEC - 2)

(Credits - 3)

Pharmaceuticals Chemistry (3 Credits) **(45 Lectures)**

Drugs & Pharmaceuticals

Drug discovery, design and development; basic retro-synthetic approach, synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (aspirin, paracetamol, lbuprofen); antibiotics (Chloramphenicol); antibacterial and antifungal agents (Sulphonamides; Sulphanethoxazol, Sulphacetamide, Trimethoprim); antiviral agents (Acyclovir), central nervous system agents (Phenobarbital, Diazepam), cardiovascular (Glyceryl trinitrate), antilaprosy (Dapsone), HIV-AIDS related drugs (AZT- Zidovudine).

Fermentation

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

Hands on Practical

1. Preparation of Aspirin and its analysis.
2. Preparation of magnesium bi-silicate (antacid).

Reference Books

- Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press.
- Singh, H., Kapoor, V. K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi.
- Foye, W. O., Lemke, T. L., William, D. A. Principles of Medicinal Chemistry, B. I. Waverly Pvt. Ltd. New Delhi.
- Mandal, S. K., Ghanta, R. Pharmaceutical Chemistry and Production: An Introductory Textbook. Bentham Science Publishers.

Course Outcomes

1. To learn about drugs and pharmaceuticals in detail.
2. To gather basic knowledge about fermentation process.
3. To know the hands on preparation procedure of Aspirin and magnesium bi-silicate.

SEM-III

Major (MJC - 3)

(Credits - 3 + 1)

Core T-3-Organic Chemistry I (3 Credits) **(45 Lectures)**

MO Theory **(5 Lectures)**

Cyclic p-orbital system (neutral systems):[4], [6]-annulenes; charged systems: 3-,4-,5-membered ring systems); Hückel's rules for aromaticity upto [10]-annulene (including mono nuclear heterocyclic compounds upto 6-membered ring); concept of anti-aromaticity and homo-aromaticity; 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.

General Treatment of Reaction Mechanism I **(25 Lectures)**

Reactive intermediates: carbocations (carbenium and carbonium ions), carbanions, carbon radicals, and carbenes: generation and stability, structure using orbital picture and electrophilic/nucleophilic behaviour of reactive intermediates (elementary idea).

Substitution and elimination reactions: free-radical substitution reactions: halogenation of alkanes, mechanism (with evidence) and stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate.

Nucleophilic substitution reactions: substitution at sp^3 centre: mechanisms (with evidence), relative rates and stereochemical features: S_N1, S_N2, S_N2', $SN^{1'}$ (allylic rearrangement) and S_N^i, effects of solvent, substrate structure, leaving group and nucleophiles (including ambient nucleophiles, cyanide and nitrite); substitutions involving NGP; role of crown ethers and phase transfer catalysts.

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.

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*-substitution.

Nucleophilic aromatic substitution: addition-elimination mechanism and evidences in favour of it; aromatic S_N^1 mechanism; *cine* substitution (benzyne mechanism), structure of benzyne.

Stereochemistry III **(15 Lectures)**

Chirality arising out of stereo-axis: chiral axis in allenes, stereoisomerism of substituted cumulenes with even and odd number of double bonds; spiro compounds, alkylidene cycloalkanes and biphenyls; related configurational descriptors (Ra/Sa and P/M); atropisomerism; racemisation of chiral biphenyls; buttressing effect.

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

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

Reference Books

- Finar, I. L. Organic Chemistry (Volume 1), Pearson Education.
- Morrison, R. T., Boyd, R. N., Bhattacharjee, S. K. Organic Chemistry, Pearson Education.
- Solomons, G. T. W., Fryhle, C. B., Snyder, S. A. Organic Chemistry, John Wiley & Sons Inc.
- Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Pearson Education.
- March, J. Advanced Organic Chemistry, Wiley.
- Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Oxford University Press.
- Eliel, E. L., Wilen, S. H. Stereochemistry of Organic Compounds, Wiley London.
- Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
- Pal, S. C. Principles of Stereochemistry and their Application in Organic Reactions, Techno World.
- Sen Gupta, S. Basic Stereochemistry of Organic Molecules, Oxford University Press.

Course Outcomes

1. To impart understanding of the MO theory on cyclic p orbital system and the concept about aromaticity.
2. To develop detailed understanding of organic reaction mechanism, types of organic reactions.

3. To acquire the essence of stereochemistry of organic molecules, which include chirality arising out of stereo-axis, concept of prostereoisomerism and conformation.

Core P-3-Organic Chemistry I Laboratory (1 Credit) (30 Lectures)

PART A

1. Organic preparations: The following reactions are to be performed, noting the yield of the crude product:

i. Nitration of aromatic compounds
ii. Condensation reactions
iii. Hydrolysis of amides/imides/esters
iv. Acetylation of phenols/aromatic amines
v. Benzoylation of phenols/aromatic amines

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

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

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

PART B

1. Separation of binary mixture: 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 and *p*-toluidine; *p*-nitrobenzoic acid and *p*-aminobenzoic acid; *p*-nitrotoluene and *p*-anisidine; benzoic acid and benzophenone, urea and benzophenone etc.

2. Determination of boiling point: determination of boiling point of common organic liquid compounds e.g., ethanol, cyclohexane, chloroform, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide etc. [Boiling point of the chosen organic compounds should preferably be less than 160°C and higher than 60 °C].

Reference Books

- Vogel, A. I. Elementary Practical Organic Chemistry, Part 1: Small Scale Preparations, CBS Publishers and Distributors.

- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes

1. To gather knowledge and skills to understand the laboratory methods related to organic preparation.
2. To develop practical knowledge about separation of the binary organic mixture.
3. To determine the boiling points of different organic liquid compounds.

Major (MJC - 4)

(Credits - 3 + 1)

Core T-4-Physical Chemistry I (3 Credits) **(45 Lectures)**

Gaseous State II **(9 Lectures)**

Real Gas and Intermolecular forces: 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 behavior; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; virial equation of state; van der Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions); Lennard-Jones potential - elementary idea.

Thermodynamics II **(15 Lectures)**

1. Second Law: need for a second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine and refrigerator; Kelvin-Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; Values of dQ/T and Clausius inequality; Entropy change of systems and surroundings for various processes and transformations; Entropy and unavailable work; Auxiliary state functions (G and A) and their variation with T, P and V, criteria for spontaneity and equilibrium.

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

Chemical Equilibrium **(6 Lectures)**

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

Chemical Kinetics I **(15 Lectures)**

Rate law, order and molecularity: introduction of rate law, extent of reaction; rate constants, order; rate equation for first, second and nth order reactions; pseudo first order reactions; determination of order of a reaction by half-life and differential method; opposing reactions, consecutive reactions and parallel reactions (all steps first order); kinetic and thermodynamic control of products.

Role of temperature and theories of reaction rate: temperature dependence of rate constant; Arrhenius equation, energy of activation; rate-determining step and steady-state approximation - explanation with suitable examples.

Reference Books

- Atkins, P. W., Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
- Castellan, G. W. Physical Chemistry, Narosa.
- McQuarrie, D. A., Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
- Engel, T., Reid, P. Physical Chemistry, Pearson.
- Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
- Glasstone, S., Lewis, G. N. Elements of Physical Chemistry.
- Zemansky, M. W., Dittman, R. H. Heat and Thermodynamics, Tata-McGraw-Hill.
- Rastogi, R. P., Misra, R. R. An Introduction to Chemical Thermodynamics, Vikas.
- Ball, D. W. Physical Chemistry, Thomson Press.
- Mortimer, R. G. Physical Chemistry, Elsevier.
- Laidler, K. J. Chemical Kinetics, Pearson.
- Kapoor, K. L. A Textbook of Physical Chemistry, Tata McGraw-Hill.
- Rakshit, P. C. Physical Chemistry, Sarat Book House.

Course Outcomes

1. To learn about the basic properties of real gases and weak intermolecular forces.

2. To acquire knowledge about 2nd law of thermodynamics and important thermodynamic relations.
3. To gather in-depth knowledge about chemical equilibrium.
4. To gather preliminary and basic knowledge about reaction kinetics.

Core P-3-Physical Chemistry I Laboratory (1 Credit) (30 Lectures)

1. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate.
2. Study of kinetics of decomposition of H_2O_2.
3. Study of kinetics of $K_2S_2O_8$ + KI reaction.

Reference Books

- Viswanathan, B., Raghavan, P. S. Practical Physical Chemistry, Viva Books.
- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson.
- Harris, D. C. Quantitative Chemical Analysis, W. H. Freeman & Company, New York.
- Palit, S. R., De, S. K. Practical Physical Chemistry, Science Book Agency.
- University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
- Levitt, B. P. edited Findlay's Practical Physical Chemistry, Longman Group Ltd.
- Gurtu, J. N., Kapoor, R. Advanced Experimental Chemistry, S. Chand.

Course Outcomes

1. To become skilled at carrying out acid catalyzed hydrolysis of ester.
2. To become experienced to monitor the kinetics of any chemical reaction.

Minor (MN - 3)

(Credits - 3 + 1)

T-3-Inorganic Chemistry I (3 Credits) (45 Lectures)

Chemical Bonding and Molecular Structure (30 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) and heteronuclear diatomic molecules such as CO, NO and NO^+. Comparison of VB and MO approaches.

Comparative Study of p-block Elements (15 Lectures)

Group trends in electronic configuration, modification of pure elements, common oxidation states, inertpair effect, and their important compounds in respect of the following groups of elements:

i. B-Al-Ga-In-Tl
ii. C-Si-Ge-Sn-Pb
iii. N-P-As-Sb-Bi
iv. O-S-Se-Te
v. F-Cl-Br-I

Reference Books

- Huheey, J. E., Keiter, E. A., Keiter, R. L. Inorganic Chemistry, Principles of Structure and Reactivity, Harper Collins College.
- Greenwood, N. N., Earnshaw, A. Chemistry of the Elements, Butterworth-Heinemann.
- Cotton, F. A., Wilkinson, G., Murrillo, C. A., Bochmann, M. Advanced Inorganic Chemistry, Wiley.
- Miessler, G. L., Donald, A. Tarr. Inorganic Chemistry, Pearson.
- Purecell, K. F., Kotz, J. C. An Introduction to Inorganic Chemistry, Saunders:Philadelphia.
- Mingos, D. M. P. Essential Trends in Inorganic Chemistry, Oxford University Press.
- Mishra, S., Giri, G. C., Roy, S. K., Chanda, J. Snatak Rasayan, Santra Publication Pvt. Ltd.

Course Outcomes

1. To acquire detailed knowledge about ionic and covalent bonding among atoms.
2. To learn the basic concept of chemical bonding with the help of MO theory.
3. To learn the comparative study of p-block elements.

P-3-Inorganic Chemistry I Laboratory (1 Credit) (30 Lectures)

Qualitative semi-micro analysis of mixtures containing three radicals; emphasis should be given to theunderstanding of the chemistry of different reactions.

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

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

Reference Books

- Svehla & Sivasankar, Vogel's Qualitative Inorganic Analysis, Pearson.
- Maji, S. K. Practical Inorganic Chemistry, Books & Allied (P) Ltd.

Course Outcomes

1. To become skilled at carrying out qualitative semi-micro analysis of mixtures of three radicals.

Multidisciplinary (MD - 3)

(Credits - 3)

Analytical Clinical Biochemistry (3 Credits) **(45 Lectures)**

Review of Concepts **(15 Lectures)**

1. Carbohydrates: biological importance of carbohydrates.
2. Proteins: classification, biological importance; primary and secondary and tertiary structures of proteins, denaturation of proteins.
3. Enzymes: classification; active site, coenzymes and cofactors, biocatalysis, effect of pH and temperature on enzyme activity.
4. Lipids: biological importance of triglycerides and phosphoglycerides and cholesterol.
5. Structure of DNA (Watson-Crick Model) and RNA, genetic code, biological roles of DNA and RNA.

Biochemistry of Disease **(10 Lectures)**

A diagnostic approach of blood/ urine analysis:

1. Blood: composition and functions of blood, blood coagulation; blood collection and preservation of samples; anaemia, regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.
2. Urine: collection and preservation of samples; formation of urine; composition and estimation of constituents of normal and pathological urine.

Hands on Practical **(20 Lectures)**

PART A:

Identification and estimation of the following:

1. Carbohydrates - qualitative and quantitative.
2. Lipids - qualitative.

3. Determination of the iodine number of oil.
4. Determination of the saponification number of oil.
5. Proteins - qualitative.

Reference Books

- Cooper, T. G. Tool of Biochemistry. Wiley-Blackwell.
- Wilson, K., Walker, J. Practical Biochemistry, Cambridge University Press.
- Varley, H., Gowenlock, A. H., Bell, M. Practical Clinical Biochemistry, Heinemann, London.
- Devlin, T. M. Textbook of Biochemistry with Clinical Correlations, John Wiley & Sons.
- Berg, J. M., Tymoczko, J. L., Stryer, L. Biochemistry, W. H. Freeman & Company, New York.
- Talwar, G. P., Srivastava, M. Textbook of Biochemistry and Human Biology, PHI Learning.
- Nelson, D. L., Cox, M. M. Lehninger Principles of Biochemistry, W. H. Freeman & Company, New York.
- Mikes, O., Chalmers, R. A. Laboratory Handbook of Chromatographic Methods, D. Van Nostrand & Co.
- Basu, K., Saha, C., Chakraborty, B., Chakraborty, S. Lectures on Analytical Clinical Biochemistry, Techno World.

Course Outcomes

1. To learn the basic concept of carbohydrates, protein, enzymes, lipids etc.
2. To acquire knowledge about the diagnostic approach of blood and urine analysis.
3. To gather hands on laboratory experience about estimation of carbohydrates, lipids and proteins.

Skill Enhancement Course (SEC - 3)

(Credits - 3)

Analytical Clinical Biochemistry (3 Credits) **(45 Lectures)**

Review of Concepts **(15 Lectures)**

1. Carbohydrates: biological importance of carbohydrates, metabolism, cellular currency of energy (ATP), glycolysis, alcoholic and lactic acid fermentations, Krebs cycle; isolation and characterization of polysachharides.

2. Proteins: classification, biological importance; primary and secondary and tertiary structures of proteins: α-helix and β-pleated sheets, isolation, characterization, denaturation of proteins.

3. Enzymes: nomenclature, characteristics (mention of ribozymes), and classification; active site, mechanism of enzyme action, stereospecificity of enzymes, coenzymes and cofactors, enzyme inhibitors, introduction to biocatalysis: importance in "green chemistry" and chemical industry.

4. Lipids: classification. biological importance of triglycerides and phosphoglycerides and cholesterol; lipid membrane, liposomes and their biological functions and underlying applications; lipoproteins; properties, functions and biochemical functions of steroid hormones; biochemistry of peptide hormones.

5. Structure of DNA (Watson-Crick Model) and RNA, genetic code, biological roles of DNA and RNA: replication, transcription and translation, introduction to gene therapy.

6. Enzymes: nomenclature, classification, effect of pH, temperature on enzyme activity, enzyme inhibition.

Biochemistry of Disease **(10 Lectures)**

A diagnostic approach of blood/ urine analysis:

1. Blood: composition and functions of blood, blood coagulation; blood collection and preservation of samples; anaemia, regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

2. Urine: collection and preservation of samples; formation of urine; composition and estimation of constituents of normal and pathological urine.

Hands on Practical **(20 Lectures)**

PART A:

Identification and estimation of the following:

1. Carbohydrates - qualitative and quantitative.
2. Lipids - qualitative.
3. Determination of the iodine number of oil.
4. Determination of the saponification number of oil.
5. Determination of cholesterol using Liebermann-Burchard reaction.
6. Proteins - qualitative.
7. Isolation of protein.
8. Determination of protein by the Biuret reaction.
9. Determination of nucleic acids.

PART B:

Data Handling

1. Introductory report writing activities: creating word document file and incorporation of text (MS-word); incorporation of chemical structures, chemical equations (use of ChemSketch and ChemDraw software).

2. Handling numeric data: creating a spreadsheet (MS-Excel), entering and formatting information, basic functions and formulae, creating charts, tables and graphs; incorporating tables and graphs into word processing documents; simple calculations, plotting graphs using a spreadsheet; presentation: presentation of information in powerpoint document (MS-powerpoint).

Reference Books

- Cooper, T. G. Tool of Biochemistry. Wiley-Blackwell.
- Wilson, K., Walker, J. Practical Biochemistry, Cambridge University Press.
- Varley, H., Gowenlock, A. H., Bell, M. Practical Clinical Biochemistry, Heinemann, London.
- Devlin, T. M. Textbook of Biochemistry with Clinical Correlations, John Wiley & Sons.
- Berg, J. M., Tymoczko, J. L., Stryer, L. Biochemistry, W. H. Freeman & Company, New York.
- Talwar, G. P., Srivastava, M. Textbook of Biochemistry and Human Biology, PHI Learning.
- Nelson, D. L., Cox, M. M. Lehninger Principles of Biochemistry, W. H. Freeman & Company, New York.
- Mikes, O., Chalmers, R. A. Laboratory Handbook of Chromatographic Methods, D. Van Nostrand & Co.
- Basu, K., Saha, C., Chakraborty, B., Chakraborty, S. Lectures on Analytical Clinical Biochemistry, Techno World.

Course Outcomes

1. To learn the basic concept of carbohydrates, protein, enzymes, lipids etc.
2. To acquire knowledge about the diagnostic approach of blood and urine analysis.
3. To gather hands on laboratory experience about estimation of carbohydrates, lipids and proteins.
4. To acquire hands on experience on isolation of protein, determination of cholesterol and nucleic acids etc.
5. To develop basic knowledge about data handling using MS Word, MS Excel and MS PowerPoint.

SEM IV

Major (MJC - 5)

(Credits - 3 + 1)

Core T-5-Inorganic Chemistry I (3 Credits) **(45 Lectures)**

Chemical Bonding **(25 Lectures)**

Ionic bond: general characteristics, types of ions, size effects, radius ratio rule, 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; defects in solids (elemementary idea); solubility energetics of dissolution process.

Covalent bond: polarizing power and polarizability, ionic potential, Fazan'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 group chemistry) and multiple bonding (σ and π bond approach).

Molecular orbital concept of bonding: (the approximations of the theory, linear combination of atomic orbitals (LCAO)) (elementary pictorial approach) sigma, pi-bonds, delta 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.

Metallic bond: qualitative idea of valence bond and band theories; semiconductors and insulators, defects in solids.

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), receptor-guest interactions, halogen bonds; effects of chemical force, melting and boiling points.

Theoretical Principles of Inorganic Qualitative Analysis **(10 Lectures)**

Basic principles involved in analysis of cations and anions and solubility products, common ion effect, principle involved in separation of cations into groups and choice of group reagents, interfering anions (fluoride, borate, oxalate and phosphate) and need to remove them after Group II.

Radioactivity **(10 Lectures)**

Nuclear stability and nuclear binding energy, nuclear forces: meson exchange theory, nuclear models (elementary idea): concept of nuclear quantum number, magic numbers.

Nuclear reactions: artificial radioactivity, transmutation of elements, fission, fusion and spallation; nuclear energy and power generation; separation and uses of isotopes.

Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

Reference Books

- Lee, J. D. Concise Inorganic Chemistry, John Wiley and Sons.
- Huheey, J. E.; Keiter, E.A., Keiter, R. L. Inorganic Chemistry, Principles of Structure and Reactivity, Harper Collins College.
- Douglas, B. E., McDaniel, D. H. Concepts & Models of Inorganic Chemistry, Oxford.
- Porterfield, H. W. Inorganic Chemistry, Academic Press.
- Purecell, K. F., Kotz, J. C. An Introduction to Inorganic Chemistry, Saunders:Philadelphia.
- Cotton, F. A., Wilkinson, G., Gaus, P. L. Basic Inorganic Chemistry, Wiley India.
- Gillespie, R. J., Hargittai, I. The VSEPR Model of Molecular Geometry, Prentice Hall.
- Albright, T. Orbital Interactions in Chemistry, John Wiley & Sons.
- Mingos, D. M. P. Essential Trends in Inorganic Chemistry, Oxford University Press.
- Miessler, G. L., Fischer, P. J., Tarr, D. A. Inorganic Chemistry, Pearson.

Course Outcomes

1. To acquire detailed knowledge about ionic and covalent bonding among atoms.
2. To learn the detail of molecular orbital concept of chemical bonding.
3. To learn about properties of metallic bond and weak chemical forces.
4. To gather knowledge about theoretical principles of inorganic qualitative analysis.

Core P-5-Inorganic Chemistry I Lab (1 Credit) **(30 Lectures)**

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

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

Anion Radicals: F^{-}, Cl^{-}, Br^{-}, BrO_3^{-}, I^{-}, IO_3^{-}, SCN^{-}, S^{2-}, SO_4^{2-}, NO_3^{-}, NO_2^{-}, PO_4^{3-}, H_3BO_3, BO_3^{3-}, $CrO_4^{2-}/Cr_2O_7^{2-}$, $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$.

Insoluble Materials: Al_2O_3 (ig), Fe_2O_3 (ig), Cr_2O_3 (ig), SnO_2, $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$.

Reference Books:

- Svehla & Sivasankar, Vogel's Qualitative Inorganic Analysis, Pearson.
- Maji, S. K. Practical Inorganic Chemistry, Books & Allied (P) Ltd.

Course Outcomes

1. To become skilled at carrying out qualitative semi-micro analysis of mixtures of three radicals.

Major (MJC - 6)

(Credits - 3 + 1)

Core T-6-Inorganic Chemistry II (3 Credits) **(45 Lectures)**

General Principles of Metallurgy **(8 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.

Chemistry of s and p Block Elements **(14 Lectures)**

Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group, allotropy and catenation; study of the following compounds with emphasis on structure, bonding, preparation, properties and uses: beryllium hydrides and halides, boric acid and borates, boron nitrides, borohydrides (diborane) and graphitic compounds, silanes, oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine, peroxo acids of sulphur, sulphur-nitrogen compounds, interhalogen compounds, polyhalide ions, pseudohalogens, fluorocarbons and basic properties of halogens.

Noble Gases **(8 Lectures)**

Occurrence and uses, rationalization of inertness of noble gases, clathrates: preparation and properties of XeF_2, XeF_4 and XeF_6; nature of bonding in noble gas compounds (valence bond treatment and MO treatment for XeF_2 and XeF_4); xenon-oxygen compounds, molecular shapes of noble gas compounds (VSEPR theory).

Inorganic Polymers **(5 Lectures)**

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

Coordination Chemistry-I **(10 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 centres), Isomerism in coordination compounds, constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes.

Reference Books

- Reddy, L. K. Principles of Engineering Metallurgy, New Age International Publishers.
- Huheey, J. E., Keiter, E. A., Keiter, R. L. Inorganic Chemistry, Principles of Structure and Reactivity, Harper Collins College.
- Greenwood, N. N., Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann.
- Cotton, F. A., Wilkinson, G., Murrillo, C. A., Bochmann, M. Advanced Inorganic Chemistry, Wiley.
- Miessler, G. L., Donald, A. Tarr. Inorganic Chemistry, Pearson.
- Purecell, K. F., Kotz, J. C. An Introduction to Inorganic Chemistry, Saunders:Philadelphia.
- Mingos, D. M. P. Essential Trends in Inorganic Chemistry, Oxford University Press.

Course Outcomes

1. To acquire detailed knowledge about the chemistry of s and p block elements.
2. To study about the basic characteristics of noble gas.
3. To gather knowledge about inorganic polymers.
4. To learn preliminary knowledge about co-ordination chemistry.

Core P-6-Inorganic Chemistry II Laboratory (1 Credit) **(30 Lectures)**

Iodo/Iodimetric Titrations

- Estimation of Cu(II)
- Estimation of Vitamin C.
- Estimation of (i) arsenite and (ii) antimony in tartar-emetic iodimetrically.
- Estimation of available chlorine in bleaching powder.

Estimation of metal content in some selective samples

- Estimation of Cu in brass.
- Estimation of Fe in cement.

Reference Books

- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson.

Course Outcomes

1. To become experienced to estimate vitamin C, chlorine, copper etc. in a given sample.
2. To become skilled to evaluate the metal content in brass and cement.

Major (MJC - 7)

(Credits - 3 + 1)

Core T-7-Organic Chemistry II (3 Credits) **(45 Lectures)**

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 nonterminal alkynes.

Carbonyl and related Compounds **(30 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 arrangement, oxidations and reductions: Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, Bouveault-Blanc, acyloin condensation; Oppenauer 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, SeO_2 (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; preparation and synthetic applications of diethyl malonate and ethyl acetoacetate; specific enol equivalents (lithium enolates, enamines, aza-enolates and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction.

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

Substitution at Sp^2 carbon (C=O system): mechanism (with evidence): BAC2, AAC2, AAC1, AAL1 (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

Reference Books

- Finar, I. L. Organic Chemistry (Volume 1), Pearson Education.
- Morrison, R. T., Boyd, R. N., Bhattacharjee, S. K. Organic Chemistry, Pearson Education.
- Solomons, T. W. G., Fryhle, C. B., Snyder, S. A. Organic Chemistry, John Wiley & Sons Inc.
- Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Pearson Education.
- March, J. Advanced Organic Chemistry, Wiley.
- Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Oxford University Press.
- Loudon, G. M. Organic Chemistry, Oxford University Press.
- Carey, F. A., Guiliano, R. M. Organic Chemistry, McGraw Hill Education.

Course Outcomes

1. To understand the chemistry of alkenes and alkynes: reactions, mechanisms and structure.
2. To understand the chemistry of carbonyl and related Compounds; reactions, mechanisms and structure.

Core P-7-Organic Chemistry II Laboratory (1 Credit) (30 Lectures)

Qualitative Analysis of Single Solid Organic Compounds

1. Detection of special elements (N, S, Cl, Br) by Lassaigne's test.
2. Solubility and classification (solvents: H_2O, 5 % HCl, 5 % NaOH and 5 % $NaHCO_3$).

3. Detection of the following functional groups by systematic chemical tests: aromatic amino ($-NH_2$), aromatic nitro ($-NO_2$), amido ($-CONH_2$, including imide), phenolic-OH, carboxylic acid (-COOH), carbonyl (-CHO and >C=O); only one test for each functional group is to be reported.

4. Melting point of the given compound.

5. Preparation, purification and melting point determination of a crystalline derivative of the given compound.

6. Identification of the compound through literature survey. Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups with relevant derivatization in known and unknown (at least six) organic compounds.

Reference Books

- Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes

1. To gather knowledge and skills to understand the laboratory methods and tests related to detection of elements and functional groups in different organic samples.

2. To gather knowledge and skills to understand the laboratory methods for further functionalization of exiting functional groups in different organic samples.

Major (MJC - 8)

(Credits - 3 + 1)

Core T-8-Physical Chemistry II (3 Credits) **(45 Lectures)**

Application of Thermodynamics **(25 Lectures)**

Partial properties and chemical potential: chemical potential and activity, partial molar quantities; variation of chemical potential (μ) with temperature and pressure; Gibbs-Duhem equation; fugacity and fugacity coefficient; variation of thermodynamic functions for systems with variable composition; change in G, S H and V during mixing for binary solutions; first order phase transition and Clapeyron equation; Clausius-Clapeyron equation-derivation and use.

Chemical potential and other properties of ideal substances: pure and mixtures: a) pure ideal gas-its chemical potential; thermodynamic parameters of mixing; chemical potential of an ideal gas in an

ideal gas mixture; concept of standard states and choice of standard states of ideal gases b) condensed phase - chemical potential of pure solid and pure liquids, ideal solution - definition, Raoult's law and Henry's law; mixing properties of ideal solutions, chemical potential of a component in an ideal solution; choice of standard states of solids and liquids.

Nernst's distribution law: application - finding out K_{eq} using Nernst distribution law for $KI + I_2 = KI_3$, dimerization of benzene and solvent extraction.

Colligative properties: vapour pressure of solution; ideal solutions, ideally diluted solutions and colligative properties; thermodynamic derivation using chemical potential to derive relations between the four colligative properties - relative lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure and amount of solute; applications in calculating molar masses of normal, dissociated and associated solutes in solution; abnormal colligative properties.

Phase rule: definitions of phases, components and degrees of freedom; phase rule and its derivation; definition of phase diagram; phase diagram for water, CO_2, sulphur; phenol-water system; binary solutions: ideal solution at fixed temperature and pressure; liquid vapour equilibrium for two component systems; principle of fractional distillation; Duhem-Margules equation; Konowaloff's rule; positive and negative deviations from ideal behavior; azeotropic solution; solid-liquid phase diagram; eutectic mixture.

Conductance (12 Lectures)

Ion conductance; conductance and measurement of conductance, cell constant, specific conductance and molar conductance; variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye-Huckel theory of ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Ostwald's dilution law; ionic mobility; application of conductance measurement (determination of solubility product and ionic product of water); conductometric titrations; transport number, principles of Hittorf's and Moving-boundary method; Wien effect, Debye Falkenhagen effect, Walden's rule.

Ionic Equilibria (8 Lectures)

Strong and weak electrolytes, degree of ionization, ionization constant and ionic product of water; ionization of weak acids and bases, pH scale, common ion effect; buffer solutions; derivation of Henderson equation and its applications; buffer capacity, solubility and solubility product of sparingly

soluble salts; activity and activity coefficients of ions; qualitative treatment of acid-base titration curves (calculation of pH at various stages); theory of acid-base indicators; selection of indicators and their limitations.

Reference Books

- Atkins, P. W., Paula, J. de Atkins', Physical Chemistry, Oxford University Press.
- Castellan, G. W. Physical Chemistry, Narosa.
- McQuarrie, D. A., Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
- Levine, I. N. Physical Chemistry, Tata McGraw-Hill
- Kapoor, K. L. A Textbook of Physical Chemistry, Tata McGraw-Hill.
- Rakshit, P. C. Physical Chemistry, Sarat Book House.
- Moore, W. J. Physical Chemistry, Orient Longman.
- Mortimer, R. G. Physical Chemistry, Elsevier.
- Denbigh, K. The Principles of Chemical Equilibrium, Cambridge University Press.
- Engel, T., Reid, P. Physical Chemistry, Pearson.
- Zemansky, M. W., Dittman, R. H. Heat and Thermodynamics, Tata-McGraw-Hill.
- Rastogi, R. P., Misra, R. R. An Introduction to Chemical Thermodynamics, Vikas.
- Klotz, I. M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Methods, Wiley.
- Glasstone, S. An Introduction to Electrochemistry, East-West Press.

Course Outcomes

1. To learn the concept about chemical potential, partial properties etc.
2. To acquire detailed knowledge about the Henry's law and the Nernst's distribution law.
3. To study about four colligative properties and phase equilibrium.
4. To gather in-depth knowledge about conductance properties of ions.
5. To learn detailed knowledge about reaction equilibrium of ions.

Core P-8-Physical Chemistry II Laboratory (1 Credit) (30 Lectures)

1. Determination of partition coefficient for the distribution of I_2 between water and organic solvent.

2. Determination of K_{eq} for $KI + I_2 = KI_3$, using partition coefficient between water and organic solvent

3. Conductometric titration of an acid (strong, weak/ monobasic, dibasic) against strong base.

Reference Books

- Viswanathan, B., Raghavan, P. S. Practical Physical Chemistry Viva Books.

- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson Education.
- Harris, D. C. Quantitative Chemical Analysis, W. H. Freeman & Company, New York.
- Palit, S. R., De, S. K. Practical Physical Chemistry, Science Book Agency.
- University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
- Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
- Gurtu, J. N., Kapoor, R. Advanced Experimental Chemistry, S. Chand & Co. Ltd.

Course Outcomes

1. To become skilled at carrying out acid-base titrations monitoring conductance of ions.

2. To become experienced to evaluate the partition coefficient and equilibrium constant of any chemical reaction.

Minor (MN - 4)

(Credits - 3 + 1)

T-4-Organic Chemistry I (3 Credits) **(45 Lectures)**

Stereochemistry III **(5 Lectures)**

Conformation: conformational nomenclature: eclipsed, staggered, gauche, *syn* and *anti*; dihedral angle, torsion angle; energy barrier of rotation, butane gauche interaction; conformational analysis of ethane.

General Treatment of Reaction Mechanism II **(10 Lectures)**

Reactive intermediates: carbocations, carbanions and free radicals; nucleophiles and electrophiles.

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

Functional Group Chemistry I **(30 Lectures)**

Aliphatic hydrocarbons: (a) alkanes (up to 5 carbons): preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent; reactions: mechanism for free radical substitution: halogenation; (b) 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; (c) alkynes (up to 5 carbons): preparation: acetylene from CaC_2 and conversion into higher

alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides; reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$.

Aromatic hydrocarbons: aromaticity, Huckel's rule; 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: introduction; Grignard reagents: preparations (from alkyl and aryl halide); Reformatsky reaction.

Alcohols and ethers: (a) alcohols (up to 5 carbons): preparation: 1°-, 2°- and 3°- alcohols: using Grignard reagent, reduction of aldehydes, ketones, carboxylic acid and esters; reactions: with sodium, HX (Lucas test), oxidation (alkaline $KMnO_4$, acidic dichromate, concentrated HNO_3); Oppenauer oxidation; (b) diols: preparation (with OsO_4); pinacol-pinacolone rearrangement (with mechanism) (with symmetrical diols only); (d) ethers: preparation: Williamson's ether synthesis; reaction: cleavage of ethers with HI.

Reference Books

- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley India Pvt. Ltd.
- Morrison, R. T., Boyd, R. N., Bhattacharjee, S. K. Organic Chemistry, Pearson Education.
- Singh, M. S. Advanced Organic Chemistry: Reactions and Mechanisms, Pearson Education.
- Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Pearson Education.
- Bahl, A., Bahl, B. S. Advanced Organic Chemistry, S. Chand.
- Mehta, B., Mehta, M. Organic Chemistry, Prentice-Hall of India Pvt. Ltd.
- Sen Gupta, S. Basic Stereochemistry of Organic Molecules, Oxford University Press.
- Kalsi, P. S. Stereochemistry Conformation and Mechanism, New Age International.
- Mishra, S., Giri, G. C., Roy, S. K., Chanda, J. Snatak Rasayan, Santra Publication Pvt. Ltd.

Course Outcomes

1. To build an understanding about stereochemistry of organic compounds.
2. To comprehend and compare various types of organic reactions, mechanisms and intermediates.
3. To impart in-depth knowledge about the functional group chemistry, which include aliphatic and aromatic hydrocarbons, organometallic compounds, alcohols and ethers.

P-4-Organic Chemistry I Laboratory (1 Credit) (30 Lectures)

Qualitative analysis of single solid organic compound(s)

1. Detection of special elements (N, S, and Cl) in organic compounds by Lassaigne's test.
2. Solubility and classification (solvents: H_2O, dil. HCl, dil. NaOH).
3. 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 1 to 3 with unknown (at least 6) solid samples containing not more than two of the above type of functional groups should be done.

Reference Books

- Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Poddar, S. N., Ghosh, S. P. Practical Chemistry, Book Syndicate Pvt. Ltd.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes

1. To gather knowledge and skills to understand the laboratory methods and tests related to detection of special elements and functional groups in different organic samples.

SEM V

Major (MJC - 9)

(Credits - 3 + 1)

Core T-9-Inorganic Chemistry III (3 Credits) **(45 Lectures)**

Coordination Chemistry-II **(25 Lectures)**

VB description and its limitations; elementary crystal field theory: splitting of d^n configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy; spectrochemical series; Jahn-Teller distortion; octahedral site stabilization energy (OSSE); metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples).

Magnetism and colour: orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions; Racah parameter; selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

Chemistry of d- and f-block Elements **(20 Lectures)**

General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry; Lanthanoids and Actinoids: general comparison on electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (ion-exchange method only).

Reference Books

- Huheey, J. E., Keiter, E. A., Keiter, R. L. Inorganic Chemistry, Principles of Structure and Reactivity, Harper Collins College.
- Greenwood, N. N., Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann.
- Cotton, F. A., Wilkinson, G., Murrillo, C. A., Bochmann, M. Advanced Inorganic Chemistry, Wiley.
- Atkins, P. Shriver & Atkins' Inorganic Chemistry, Oxford University Press.
- Purecell, K. F., Kotz, J. C. An Introduction to Inorganic Chemistry, Saunders: Philadelphia.

- Sinha, S. P. Lanthanide and Actinide Research Journal (Volume 1).
- Wulfsberg, G. Principles of Descriptive Inorganic Chemistry, Brooks/Cole: Monterey, CA.

Course Outcomes

1. To gather in-depth knowledge about crystal field theory, magnetism and electronic spectra of coordination complexes.
2. To understand the bonding in metal-ligand complexes using molecular orbital theory and its effect on the properties of transition metals.
3. To develop a comparative understanding of the electronic configuration, oxidation states, and redox properties of 3d, 4d and 5d transition elements.
4. To explore the properties of lanthanides and actinides, including lanthanide contraction, magnetic behavior and separation techniques.

Core P-9-Inorganic Chemistry III Laboratory (1 Credit) (30 Lectures)

Complexometric Titrations

1. Standardization of EDTA using $ZnSO_4$ solution.
2. Estimation of Zn(II) in a Zn(II) and Cu(II) mixture.
3. Estimation of Ca(II) and Mg(II) in a mixture.
4. Estimation of Hardness of water.

Inorganic Preparations

1. $[Cu(CH_3CN)_4]PF_6/ClO_4$
2. Cis and trans $K[Cr(C_2O_4)_2 (H_2O)_2]$
3. Potassium dioxalatodiaquachromate (III)
4. Tetraamminecarbonatocobalt (III) ion
5. Potassium tris(oxalate)ferrate(III)
6. Tris-(ethylenediamine) nickel (II) chloride.
7. $[Mn(acac)_3]$ and $Fe(acac)_3]$ (acac-acetylacetonate)

Reference Books

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis, Pearson.
- Maji, S. K. Practical Inorganic Chemistry Books & Allied (P) Ltd.

Course Outcomes

1. To understand the principles and applications of complexometric titration, including the standardization of EDTA and the estimation of metal ions (Zn^{2+}, Cu^{2+}, Ca^{2+}, Mg^{2+}) and water hardness.
2. To develop skills in handling metal-ligand complexes and applying them for quantitative analysis of metal ions in mixtures.

Major (MJC - 10)

(Credits - 3 + 1)

Core T-10-Organic Chemistry III (3 Credits) **(45 Lectures)**

Nitrogen compounds **(9 Lectures)**

1. **Amines**: Aliphatic & aromatic: general preparation, separation (Hinsberg's method) and identification of primary, secondary and tertiary amines; reaction (with mechanism): Eschweiler-Clarke methylation, diazo coupling reaction, Ritter reaction, Staudinger Reduction, Mannich reaction, hydroamination, reductive amination; Strecker Synthesis, formation and reactions of phenylene diamines, diazomethane and diazoacetic ester.

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

3. **Alkyl Nitrile and Isonitrile**: preparation and reaction (with mechanism): Thorpe nitrile condensation, von Richter reaction.

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

Rearrangement Reactions **(9 Lectures)**

Mechanism with evidence and stereochemical features for the following:

1. 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.

2. Rearrangement to electron-rich carbon: Stevens rearrangement, Sommelet-Hauser rearrangement, Wittig rearrangement, Favorskii rearrangement.

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

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

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

6. 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.

Organometallics **(7 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 behaviour of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organo copper reagents; Reformatsky reaction; concept of umpolung and base-nucleophile dichotomy in case of organometallic reagents.

Organic Spectroscopy I **(20 Lectures)**

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

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

3. **NMR spectroscopy:** Introduction; nuclear spin; NMR active molecules; basic principles of proton magnetic resonance; equivalent and non-equivalent protons; chemical shift and factors influencing it;

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

Reference Books

- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley India Pvt. Ltd.
- Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Oxford University Press.
- Silverstein, R. M., Bassler, G. C., Morrill, T. C. Spectrometric Identification of Organic Compounds, John Wiley & Sons Inc.
- Kemp, W. Organic Spectroscopy, Palgrave.
- D. L. Pavia, G. M. Lampman, G. S. Kriz, Vyvyan, J. Introduction to Spectroscopy, Brooks/Cole.
- Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Pvt. Ltd.
- P. S. Kalsi. Spectroscopy of Organic Compounds, New Age International.
- March, J. Advanced Organic Chemistry, Wiley.
- Harwood, L. M. Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press.
- Bailey, Morgan. Organonitrogen Chemistry, Oxford Chemistry Primer, Oxford University Press.
- Willis, C. A., Wills, M. Organic Synthesis, Oxford Chemistry Primer, Oxford University Press.

Course Outcomes

1. To acquire the thorough knowledge on nitrogen containing organic compounds, organometallics and rearrangement reactions.
2. To grasp the principles and theories of underlying organic spectroscopic techniques - such as UV, IR and NMR - and develop an understanding of how to determine the structure of organic molecules using these methods.

Core P-10-Organic Chemistry III Laboratory (1 Credit) (30 Lectures)

Chromatographic Separations (20 Lectures)

1. Thin Layer Chromatographic (TLC) separation of a mixture containing 2/3 amino acids.
2. Thin Layer Chromatographic (TLC) separation of a mixture of dyes (fluorescein and methylene blue).
3. Column chromatographic separation of leaf pigments from spinach leaves.

4. Column chromatographic separation of mixture of dyes.
5. Paper chromatographic separation of a mixture containing 2/3 amino acids.
6. Paper chromatographic separation of a mixture containing 2/3 sugars.

Spectroscopic Analysis of Organic Compounds (10 Lectures)

1. Assignment of labelled peaks in the 1H 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 15 (fifteen) compounds 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) Benzyl acetate
x) Trans-4-nitrocinnamaldehyde
xi) Diethyl fumarate
xii) 4-Nitrobenzaldehyde
xiii) 4-Methylacetanilide
xiv) Mesityl oxide
xv) 2-Hydroxybenzaldehyde
xvi) 4-Nitroaniline
xvii) 2-Hydroxy-3-nitrobenzaldehyde
xviii) 2,3-Dimethylbenzonitrile
xix) Pent-1-yn-3-ol
xx) 3-Nitrobenzaldehyde
xxi) 3-Ethoxy-4-hydroxybenzaldehyde

xxii) 2-Methoxybenzaldehyde

xxiii) Methyl 4-hydroxybenzoate

xxiv) Methyl 3-hydroxybenzoate

xxv) 3-Aminobenzoic acid

xxvi) Ethyl 3-aminobenzoate

xxvii) Ethyl 4-aminobenzoate

xxviii) 3-nitroanisole

xxix) 5-Methyl-2-nitroanisole

xxx) 3-Methylacetanilide

Reference Books

- Mann, F. G., Saunders, B. C. Practical Organic Chemistry, Pearson Education.
- Mukherjee, G. N. University Hand Book of Undergraduate Chemistry Experiments, University of Calcutta.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.
- Silverstein, R. M., Webstar, F. X., Kiemle, D. J. Spectroscopic Identification of Organic Compounds, John Wiley & Sons Inc.

Course Outcomes

1. To acquire the knowledge and skills necessary to understand the separation of organic compounds using chromatographic methods.
2. To gain an understanding of spectroscopic exercise theoretically to interpret spectra/spectral data (IR and NMR) of organic molecules.

Major (MJC - 11)

(Credits - 3 + 1)

Core T-11-Physical Chemistry III (3 Credits) **(45 Lectures)**

Electrical Properties of Molecules I **(12 Lectures)**

1. Electromotive Force: Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry; Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to

different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb_2O_3 electrodes.

2. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers; Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

Chemical Kinetics II **(5 Lectures)**

1. Kinetics: Collision theory; Lindemann theory of unimolecular reaction; outline of transition state theory (classical treatment); Primary kinetic salt effect, Chain reaction [$H_2(g) + Br_2(g) = 2HBr(g)$].

2. Catalysis: Homogeneous catalysis: Homogeneous catalysis with reference to acid-base catalysis; Enzyme catalysis; Michaelis-Menten equation, Lineweaver-Burk plot, turn-over number, autocatalysis.

Quantum Chemistry I **(14 Lectures)**

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

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

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

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

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

Molecular Spectroscopy I **(14 Lectures)**

1. Interaction of electromagnetic radiation with molecules, different kinds of spectra, Born-Oppenheimer approximation.

2. Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear tri-atomic molecules, isotopic substitution.

3. Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies; diatomic vibrating rotator, P, Q, R branches.

4. Raman spectroscopy: Qualitative treatment of rotational Raman effect; effect of nuclear spin, vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Reference Books

- Glasstone, S. An Introduction to Electrochemistry, East-West Press
- Engel, T., Reid, P. Physical Chemistry, Pearson Education.
- Laidler, K. J. Chemical Kinetics, Pearson Education.
- Kapoor, K. L. A Textbook of Physical Chemistry, Tata McGraw-Hill.
- Levine, I. N. Quantum Chemistry, PHI Pvt. Ltd.
- Atkins, P. W. Molecular Quantum Mechanics, Oxford University Press.
- Maron, S. H., Prutton, C. F. Principles of Physical Chemistry, McMillan
- Klotz, I. M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Methods, Wiley.
- Rastogi, R. P., Misra, R. R. An Introduction to Chemical Thermodynamics, Vikas.
- Banwell, C. N. Fundamentals of Molecular Spectroscopy, Tata-McGraw-Hill.
- Barrow, G. M. Molecular Spectroscopy, Tata-McGraw-Hill.
- Hollas, J. M. Modern Spectroscopy, Wiley India

Course Outcomes

1. To gather detailed knowledge about the electromotive force, concentration cells etc.
2. To acquire the concept of catalysis and transition state theory of kinetics.
3. To learn the basic concept of quantum chemistry and simple quantum models.
4. To collect basic knowledge about rotational, Raman and vibrational spectroscopy.
5. To learn about wavefunction, operator algebra etc. in quantum chemistry.

Core P-11-Physical Chemistry III Laboratory (1 Credit) (30 Lectures)

1. Determination of solubility of sparingly soluble salt in water, in electrolyte with common ions and in neutral electrolyte (using common indicator).

2. Determination of pH of unknown buffer, spectrophotometrically

3. Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ solution.

Reference Books

- Viswanathan, B., Raghavan, P. S. Practical Physical Chemistry Viva Books.
- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson Education.
- Harris, D. C. Quantitative Chemical Analysis, W. H. Freeman & Company, New York.
- Palit, S. R., De, S. K. Practical Physical Chemistry, Science Book Agency.
- University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
- Levitt, B. P. edited Findlay's Practical Physical Chemistry, Longman Group Ltd.
- Gurtu, J. N., Kapoor, R. Advanced Experimental Chemistry, S. Chand & Co. Ltd.

Course Outcomes

1. To become skilled at carrying out potentiometric titrations.
2. To become experienced to evaluate the pH of an unknown sample spectrophotometrically.
3. To become experienced to determine the solubility (and solubility product) of a sparingly soluble salt.

Major (MJC - 12)

(Credits - 3 + 1)

Core T-12-Analytical Chemistry (3 Credits) **(45 Lectures)**

Qualitative and Quantitative Aspects of Analysis **(4 Lectures)**

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

Optical Methods of Analysis **(15 Lectures)**

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

2. UV-Visible spectrometry: basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument.

3. Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers; determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.

4. 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.

5. Flame atomic absorption and emission spectrometry: basic principles of instrumentation (choice of source, monochromator, and detector, choice of flame and burner designs); techniques of atomization and sample introduction; method of background correction, sources of chemical interferences and their method of removal; techniques for the quantitative estimation of trace level of metal ions from water samples.

Methods of Analysis **(6 Lectures)**

Thermal methods: theory of thermogravimetry (TG); basic principle of instrumentation; techniques for quantitative estimation of Ca and Mg from their mixture; Electroanalytical methods: classification of electroanalytical methods; basic principle of pH metric, potentiometric and conductometric titrations; techniques used for the determination of equivalence points; techniques used for the determination of pK_a values**.**

Separation Techniques **(20 Lectures)**

1. Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation.

2. Technique of extraction: batch, continuous and counter current extractions.

3. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and non-aqueous media.

4. Chromatography: definition, classification, principle and efficiency of the technique, especially paper, column chromatography, TLC etc.

(a) Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).

(b) To compare paint samples by TLC method.

Mechanism of separation: adsorption, partition & ion exchange.

(a) Column, ion-exchange chromatography etc.

(b) Determination of ion exchange capacity of anion/cation exchange resin.

5. Development of chromatograms: frontal, elution and displacement methods.

6. Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

7. Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of enantiomeric excess (ee)/diastereomeric excess (de) ratios and determination of enantiomeric

composition using NMR, chiral solvents and chiral shift reagents; chiral chromatographic techniques using chiral columns (GC and HPLC).

8. Role of computers in instrumental methods of analysis.

Reference Books

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis, Pearson Education.
- Willard, H. H., Instrumental Methods of Analysis, Wordsworth Publishing Company, Belmont, California, USA.
- Christian, G. D. Analytical Chemistry, John Wiley & Sons, New York.
- Harris, D. C. Exploring Chemical Analysis, W. H. Freeman & Company, New York.
- Khopkar, S. M. Basic Concepts of Analytical Chemistry, New Age International.
- Skoog, D. A., Holler F. J., Nieman, T. A. Principles of Instrumental Analysis, Cengage Learning India Ed.
- Mikes, O. Laboratory Hand Book of Chromatographic & Allied Methods, John Wiley & Sons.
- Ditts, R. V. Analytical Chemistry; Methods of separation, van Nostrand.

Course Outcomes

1. To develop a clear understanding of sampling, data evaluation, error analysis, and statistical validation (F, Q, t-tests) in analytical chemistry.
2. To understand the principles and applications of UV-Visible, IR, atomic absorption/emission spectrometry, and thermal analysis for qualitative and quantitative estimation of metal ions and organic compounds.
3. To gain knowledge of electroanalytical methods (pH metric, potentiometric, and conductometric titrations) and their application in determining equivalence points and pK_a values.
4. To apply separation techniques like solvent extraction and chromatography (TLC, paper, column, ion-exchange) for the separation and analysis of complex mixtures, including stereoisomeric separation.

Core P-12-Analytical Chemistry Laboratory (1 Credit) (30 Lectures)

Separation Techniques - Chromatography

1. Separation of mixtures: separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.

2. Chromatographic separation of the active ingredients of plants, flowers and juices by TLC solvent.

Extractions

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

2. To separate a mixture of Cu^{2+}& Fe^{3+} by complexation with diethyl ether and HCl and determine the concentration of Cu^{2+} by spectrophotometry.

Analysis of Soil

1. Determination of pH of soil.
2. Total soluble salt.
3. Estimation of calcium, magnesium, phosphate, nitrate.

Ion Exchange

Determination of exchange capacity of cation exchange resins and anion exchange resins

Spectrophotometry

1. Determination of pKa values of indicator using spectrophotometry
2. Determination of chemical oxygen demand (COD)
3. Determination of Biological oxygen demand (BOD)

Analysis of Water

Determination of DO, BOD and COD

Reference Books

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis, Pearson Education.
- Willard, H. H. Instrumental Methods of Analysis, Wardsworth Publishing Company, USA.
- Christian, G. D. Analytical Chemistry, John Wiley & Sons, New York.
- Harris, D. C. Exploring Chemical Analysis, W. H. Freeman & Company, New York.
- Khopkar, S. M. Basic Concepts of Analytical Chemistry, New Age International Publisher.
- Skoog, D. A., Holler F. J., Nieman, T. A. Principles of Instrumental Analysis, Cengage Learning India Edition.
- Mikes, O., Chalmes, R. A. Laboratory Handbook of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
- Ditts, R. V. Analytical Chemistry: Methods of Separation. Van Nostrand, New York.

Course Outcomes

1. To develop hands-on experience in separation techniques like paper chromatography, TLC, and solvent extraction for the identification and quantification of metal ions and organic compounds.

2. To apply ion-exchange techniques for determining the exchange capacity of cation and anion exchange resins.
3. To gain practical knowledge in spectrophotometric analysis for determining pK_a values, chemical oxygen demand (COD), and biological oxygen demand (BOD).
4. To perform soil and water analysis, including pH, soluble salts and nutrient content, and assess environmental parameters like dissolved oxygen (DO), BOD, and COD.

Minor (MN - 5)

(Credits - 3 + 1)

T-5-Physical Chemistry I (3 Credits) **(45 Lectures)**

Chemical Kinetics **(8 Lectures)**

a. 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

b. Temperature dependence of rate constant; Arrhenius equation, energy of activation.

Thermodynamics II **(15 Lectures)**

1. Second law: need for a second law; statement of the second law of thermodynamics; concept of heat reservoirs and heat engines; Carnot cycle; physical concept of entropy; Carnot engine and refrigerator; Kelvin-Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; values of dQ/T and Clausius inequality; entropy change of systems and surroundings for various processes and transformations; entropy and unavailable work; auxiliary state functions (G and A) and their variation with T, P and V; criteria for spontaneity and equilibrium.

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

Ionic Equilibria **(10 Lectures)**

Strong and weak electrolytes; degree of ionization; ionization constant and ionic product of water; ionization of weak acids and bases; pH scale; common ion effect; buffer solutions; derivation of Henderson equation and its applications; buffer capacity; solubility and solubility product of sparingly soluble salts; activity and activity coefficients of ions; qualitative treatment of acid-base titration

curves (calculation of pH at various stages); theory of acid-base indicators; selection of indicators and their limitations.

Conductance (12 Lectures)

Ion conductance; conductance and measurement of conductance, cell constant, specific conductance and molar conductance; variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye Huckel theory of ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Ostwald's dilution law; ionic mobility; application of conductance measurement (determination of solubility product and ionic product of water); conductometric titrations; transport number, principles of Hittorf's and Moving-boundary method; Wien effect, Debye Falkenhagen effect, Walden's rule.

Reference Books

- Atkins, P. W., Paula, J. Atkins' Physical Chemistry, Oxford University Press.
- Castellan, G. W. Physical Chemistry, Narosa.
- McQuarrie, D. A., Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
- Engel, T., Reid, P. Physical Chemistry, Pearson.
- Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
- Kapoor, K. L. A Textbook of Physical Chemistry, Tata McGraw-Hill.
- Rakshit, P. C. Physical Chemistry, Sarat Book House.
- Maron, S. H., Prutton, C. F. Principles of Physical Chemistry, McMillan
- Klotz, I. M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Methods Wiley
- Rastogi, R. P., Misra, R. R. An Introduction to Chemical Thermodynamics, Vikas

Course Outcomes

1. To gather basic knowledge about the kinetics of chemical reaction.
2. To acquire basic concept of about 2nd law of thermodynamics and thermodynamic relations.
3. To have the basic ideas on pH scale, buffer solution, indicators and about ionic equilibrium.
4. To collect primary knowledge about ionic conductance, mobility, conductometric titrations etc.

P-5-Physical Chemistry I Lab (1 Credit) (30 Lectures)

1. Determination of solubility product of sparingly soluble salt in water.
2. Determination of partition coefficient for the distribution of I_2 between water and organic solvent.

3. Conductometric titration of an acid (strong, weak/ monobasic) against strong base.

Reference Books

- Viswanathan, B., Raghavan, P. S. Practical Physical Chemistry Viva Books.
- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson Education.
- Harris, D. C. Quantitative Chemical Analysis, W. H. Freeman & Company, New York.
- Palit, S. R., De, S. K. Practical Physical Chemistry, Science Book Agency.
- University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
- Levitt, B. P. edited Findlay's Practical Physical Chemistry, Longman Group Ltd.
- Gurtu, J. N., Kapoor, R. Advanced Experimental Chemistry, S. Chand & Co. Ltd.

Course Outcomes

1. To become skilled at determining solubility (and solubility product) of any salt.
2. To become experienced to evaluate the partition coefficient of any sample between two immiscible solvents.
3. To become experienced in conductometric titrations between acid and bases.

SEM VI

Major (MJC - 13)

(Credits - 3 + 1)

Core T-13-Inorganic Chemistry IV (3 Credits) **(45 Lectures)**

Bioinorganic Chemistry **(15 Lectures)**

Elements of life: Essential and beneficial elements, major, trace and ultra-trace 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; di-oxygen molecule in life; di-oxygen management proteins: haemoglobin, myoglobin, hemocyanine and hemerythrin; electron transfer proteins: cytochromes and ferredoxins; hydrolytic enzymes: carbonate bicarbonate buffering system and carbonic anhydrase and carboxy anhydrase A; biological nitrogen fixation; photosynthesis: photosystem-I and photosystem-II; toxic metal ions and their effects, chelation therapy (examples only), Pt and Au complexes as drugs (examples only), metal dependent diseases (examples only).

Organometallic Chemistry **(15 Lectures)**

Definition 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; pi-acceptor behavior of CO, synergic effect and use of IR data to explain extent of back bonding; Zeise's salt: preparation, structure, evidences of synergic effect; Ferrocene: preparation and reactions (acetylation, alkylation, metalation, Mannich condensation); reactions of organometallic complexes: substitution, oxidative addition, reductive elimination and insertion reactions; catalysis by organometallic compounds.

Study of the Following Industrial Processes **(5 Lectures)**

1. Alkene hydrogenation (Wilkinson's catalyst)
2. Hydroformylation
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Ziegler-Natta catalysis for olefin polymerization.

Reaction Kinetics and Mechanism (10 Lectures)

Introduction to inorganic reaction mechanisms; substitution reactions in square planar complexes; trans-effect and its application in complex synthesis; theories of trans-effect; mechanism of 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.

Reference Books

- Lippard, S. J., Berg, J. M. Principles of Bioinorganic Chemistry, Panima Publishing Company.
- Huheey, J. E., Keiter, E. A., Keiter, R. L. Inorganic Chemistry, Principles of Structure and Reactivity, Harper Collins College.
- Greenwood, N. N., Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann.
- Cotton, F. A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry, Wiley.
- Bertini, I., Gray, H. B., Lippard, S. J., Valentine, J. S. Bioinorganic Chemistry, University Science Books.
- Basolo, F., Pearson, R. C. Mechanisms of Inorganic Chemistry, John Wiley & Sons.
- Purecell, K. F., Kotz, J. C. An Introduction to Inorganic Chemistry, Saunders: Philadelphia.
- Powell, P. Principles of Organometallic Chemistry, Chapman and Hall.
- Collman, J. P. Principles and Applications of Organo-transition Metal Chemistry, University Science Books.
- Crabtree, R. H. The Organometallic Chemistry of the Transition Metals, John Wiley & Sons.

Course Outcomes

1. To understand the role of essential and trace elements in biological systems, metal ion transport, dioxygen management, electron transfer proteins, and enzyme function in biological processes.
2. To develop knowledge of organometallic compounds, including bonding, hapticity, the 18-electron rule, back bonding, and the structure and reactivity of metal carbonyls and ferrocene.
3. To learn the mechanisms and industrial applications of organometallic catalysis, including alkene hydrogenation, hydroformylation, Wacker process, Fischer-Tropsch reaction, and Ziegler-Natta polymerization.

4. To understand reaction kinetics and mechanisms in inorganic complexes, including substitution reactions in square planar and octahedral complexes, trans-effect, and ligand field effects on reaction rates.

Core P-13-Inorganic Chemistry IV Lab (1 Credit) (30 Lectures)

Chromatography of Metal Ions (10 Lectures)

Principals involved in chromatographic separations. Paper chromatographic separation of following metal ions:

1. Ni (II) and Co (II)
2. Fe (III) and Al (III)
3. Mn (II) and Zn (II)

Gravimetry (10 Lectures)

1. Estimation of nickel (II) using dimethylglyoxime (DMG).
2. Estimation of copper as CuSCN.
3. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminium oxinate).
4. Estimation of chloride.

Spectrophotometry (10 Lectures)

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

Reference Books

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis, Pearson Education.

Course Outcomes

1. To understand the principles and techniques of chromatographic separation and apply them for the identification and separation of metal ions like Ni(II), Co(II), Fe(III), Al(III), Mn(II) and Zn(II).
2. To develop skills in gravimetric analysis for the quantitative estimation of metal ions such as Ni(II), Cu(II), Al(III), and chloride using appropriate precipitation and weighing methods.
3. To gain knowledge of spectrophotometric methods for measuring crystal field splitting energy (10 D_q) and determining λ_{max} of metal complexes.
4. To apply spectrophotometry for the quantitative estimation of Mn(III) and Fe(III) in metal-acetyl acetonate complexes.

Major (MJC - 14)

(Credits - 3 + 1)

Core T-14-Organic Chemistry IV (3 Credits) **(45 Lectures)**

Carbocycles **(5 Lectures)**

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

Heterocycles I **(10 Lectures)**

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

Cyclic Stereochemistry **(5 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 and 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.

Pericyclic Reactions **(5 Lectures)**

Mechanism, stereochemistry, regioselectivity in case of,

1. Electrocyclic reactions: FMO approach involving 4π- and 6π- electrons (thermal and photochemical) and corresponding cyclo reversion reactions.
2. Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.

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

Carbohydrates **(10 Lectures)**

1. Monosaccharides: Aldoses upto six carbons; structure of D-glucose and D-fructose (configuration and 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 and 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.
2. Disaccharides: Glycosidic linkages, concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose, inversion of cane sugar.
3. Polysaccharides: starch (structure and its use as an indicator in titrimetric analysis).

Biomolecules I **(10 Lectures)**

1. Amino acids: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketo piperazine; isoelectric point, zwitterions; electrophoresis, reactions (with mechanism): ninhydrin reaction, Dakin-West reaction; resolution of racemic amino acids.
2. Peptides: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection and C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger and 'dansyl' methods); partial hydrolysis; specific cleavage of peptides: use of CNBr.
3. Nucleic acids: pyrimidine and purine bases (only structure and nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; mechanism for acid catalysed hydrolysis of nucleosides (both pyrimidine and purine types); comparison of alkaline hydrolysis of DNA and RNA; elementary idea of double helical structure of DNA (Watson - Crick Model); complimentary base-pairing in DNA.

Reference Books

- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley India Pvt. Ltd.

- Finar, I. L. Organic Chemistry (Volume 2), Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley India Pvt. Ltd.
- Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Oxford University Press.
- Eliel, E. L., Wilen, S. H. Stereochemistry of Organic Compounds, Wiley London.
- Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
- Pal, S. C. Principles of Stereochemistry and their Application in Organic Reactions, Techno World.
- Sen Gupta, S. Basic Stereochemistry of Organic Molecules, Oxford University Press.
- Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley.
- Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.
- Hazra, N., Dey, S. Pericyclic Reactions & Organic Photochemistry, Techno World.
- Gilchrist, T. L., Storr, R. C. Organic Reactions and Orbital Symmetry, Cambridge University Press.
- Morrison, R. N. Boyd, R. N., Bhattacharjee, S. K. Organic Chemistry, Pearson Education.
- Carey, F. A., Guiliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education.
- Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press.
- James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing.
- Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.
- Joule, J. A., Mills, K. Heterocyclic Chemistry, Blackwell Science.
- Gilchrist, T. L. Heterocyclic Chemistry, Pearson Education.

Course Outcomes

1. To acquire the thorough knowledge on polynuclear hydrocarbons and heterocyclic compounds.
2. To develop a clear picture on the stereochemistry of alicyclic compounds.
3. To provide a detailed understanding of pericyclic reactions.
4. To acquire the essence of chemistry of carbohydrates.
5. To comprehend the chemistry of biomolecules, which play crucial roles in the functioning of living organisms

Core P-14-Organic Chemistry IV Lab (1 Credit) **(30 Lectures)**

PART A **(20 Lectures)**

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

1. Side chain oxidation of aromatic compounds.
2. Diazo coupling reactions of aromatic amines.
3. Redox reaction including solid-phase method.
4. Green 'multi-component-coupling' reaction.
5. Selective reduction of m-dinitrobenzene to m-nitroaniline.

- Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.
- Purification of the crude product is to be made by crystallization from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.
- Melting point of the purified product is to be noted.

PART B **(10 Lectures)**

1. Estimation of sucrose 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.
5. Estimation of urea (hypo bromite method).
6. Estimation of saponification value of oil/fat/ester.

Reference Books

- Vogel, A. I. Elementary Practical Organic Chemistry, Part 1: Small scale Preparations, CBS Publishers and Distributors.
- University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G.N. University of Calcutta.
- Mann, F. G., Saunders, B. C. Practical Organic Chemistry, Pearson Education.
- Furniss, B. S., Hannaford, A. J., Smith, P. W. G., Tatchell, A. R. Practical Organic Chemistry, Pearson Education.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.
- Ahluwalia, V. K., Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press.

Course Outcomes

1. To gather knowledge and skills for performing organic reactions.
2. To introduce the basic experimental understanding of estimation of organic compounds.

Major (MJC - 15)

(Credits - 3 + 1)

Core T-15-Physical Chemistry IV (3 Credits) **(45 Lectures)**

Photochemistry **(12 Lectures)**

1. Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields.

2. Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonskii diagram;

3. Rate of Photochemical processes: Photochemical equilibrium and the differential rate of photochemical reactions, Photostationary state; HI decomposition, H2-Br2 reaction, dimerisation of anthracene; photosensitized reactions, quenching; Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence.

Crystal Structure **(10 Lectures)**

1. Bravais Lattice and Laws of Crystallography: Types of solid, Bragg's law of diffraction; laws of crystallography (Haüy's law and Steno's law); permissible symmetry axes in crystals; lattice, space lattice, unit cell, crystal planes, Bravais lattice; packing of uniform hard sphere, close packed arrangements (fcc and hcp); tetrahedral and octahedral voids; void space in ptype, F-type and I-type cubic systems.

2. Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of dhkl; relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation)

3. Determination of crystal structure: powder method; structure of NaCl and KCl crystals

3rd Law of Thermodynamics and Specific Heat **(7 Lectures)**

1. Specific heat of solid: Coefficient of thermal expansion, thermal compressibility of solids; Dulong-Petit's law; Perfect Crystal model, Einstein's theory - derivation from partition function, limitations; Debye's T3 law - analysis at the two extremes

2. 3rd law: Absolute entropy, Plank's law, Calculation of entropy, Nernst heat theorem

3. Adiabatic demagnetization: Approach to zero Kelvin, adiabatic cooling, demagnetization, adiabatic demagnetization - involved curves

Statistical Thermodynamics (8 Lectures)

1. Configuration: Macrostates, microstates and configuration; calculation with harmonic oscillator; variation of W with E; equilibrium configuration.

2. Boltzmann distribution: Thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation); applications to barometric distribution; Partition function, concept of ensemble - canonical ensemble and grand canonical ensembles.

3. Partition function: Molecular partition function and thermodynamic properties, Maxwell's speed distribution; Gibbs' paradox.

Dipole Moment and Polarizability (4 Lectures)

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

Adsorption (4 Lectures)

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

Reference Books

- Atkins, P. W., Paula, J. Atkins' Physical Chemistry, Oxford University Press.
- Castellan, G. W. Physical Chemistry, Narosa.
- McQuarrie, D. A., Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
- Engel, T., Reid, P. Physical Chemistry, Pearson.
- Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
- Kapoor, K. L. A Textbook of Physical Chemistry, Tata McGraw-Hill.
- Rakshit, P. C. Physical Chemistry, Sarat Book House.
- Maron, S. H., Prutton, C. F. Principles of Physical Chemistry, McMillan

- Klotz, I. M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Methods Wiley
- Rastogi, R. P., Misra, R. R. An Introduction to Chemical Thermodynamics, Vikas

Course Outcomes

1. To gather detailed knowledge about the photochemical processes and Lambert-Beer's law.
2. To acquire in depth idea about crystal structure, planes and laws of crystallography.
3. To have detail ideas on specific heat, 3rd law of TD, Nernst heat theorem etc.
4. To collect introductory knowledge about statistical thermodynamics.
5. To accumulate conception about dipole moment, polarizability and adsorption etc.

Core P-15-Physical Chemistry IV Practical (1 Credit) **(30 Lectures)**

1. Verification of Beer's Law for $KMnO_4$ and $K_2Cr_2O_7$ solution
2. Determination of the indicator constant of an acid base indicator colorimetrically
3. Study of phenol-water phase diagram

Reference Books

- Viswanathan, B., Raghavan, P. S. Practical Physical Chemistry, Viva Books.
- Mendham, J. A. I. Vogel's Quantitative Chemical Analysis, Pearson Education.
- Harris, D. C. Quantitative Chemical Analysis, W. H. Freeman & Company, New York.
- Palit, S. R., De, S. K. Practical Physical Chemistry, Science Book Agency.
- University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
- Levitt, B. P. edited Findlay's Practical Physical Chemistry, Longman Group Ltd.
- Gurtu, J. N., Kapoor, R. Advanced Experimental Chemistry, S. Chand & Co. Ltd.

Course Outcomes

1. To become skilled at verifying the Lambert-Beer law for light absorption process.
2. To become experienced to evaluate the indicator constant of an acid base indicator colorimetrically.
3. To become experienced in studying the phase diagram of a two-component system.

Major (MJC - 16)

(Credits - 3 + 1)

Core T-16-Polymer Chemistry IV (3 Credits) **(45 Lectures)**

Introduction **(4 Lectures)**

Different schemes of classification of polymers; polymer nomenclature; molecular forces and chemical bonding in polymers; texture of polymers

Polymer Functionality (5 Lectures)

Criteria for synthetic polymer formation; classification of polymerization processes; relationships between functionality; extent of reaction and degree of polymerization; bi-functional systems; poly-functional systems

Kinetics of Polymerization (6 Lectures)

Mechanism and kinetics of step growth; radical chain growth; ionic chain (both cationic and anionic) and coordination polymerizations; mechanism and kinetics of copolymerization; polymerization techniques

Crystallization and Structure (5 Lectures)

Determination of crystalline melting point and degree of crystallinity, morphology of crystalline polymers, factors affecting crystalline melting point, nature and structure of polymers, structure property relationships.

Polymer Solution (5 Lectures)

Criteria for polymer solubility, solubility parameter, thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory-Huggins theory, lower and upper critical solution temperatures.

Properties of Polymer (20 Lectures)

Molecular weights of polymers (M_n, M_w etc.) by end group analysis, viscometry, light scattering and osmotic pressure methods, molecular weight distribution and its significance; polydispersity index, glass transition temperature (T_g) and determination of T_g, free volume theory, WLF equation, factors affecting glass transition temperature (T_g); physical, thermal, flow and mechanical properties of polymers, brief introduction to preparation, structure, properties and application of the following polymers: polyolefin's, polystyrene and styrene copolymers, poly-(vinyl chloride) and related polymers; poly(vinyl acetate) and related polymers; acrylic polymers; fluoro polymers, polyamides and related polymers; phenol formaldehyde resins (bakelite, novalac), polyurethanes, silicone polymers, polydienes, polycarbonates, conducting polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphide, polypyrrole, polythiophene].

Reference Books

- Seymour R. B., Carraher. C.E. Polymer Chemistry: An Introduction, Marcel Dekker.

- Odian, G. Principles of Polymerization, Wiley.
- Billmeyer, F. W. Textbook of Polymer Science, Wiley Interscience.
- Ghosh, P. Polymer Science and Technology, Tata McGraw-Hill Education.
- Lenz, R. W. Organic Chemistry of Synthetic High Polymers, Interscience Publishers.
- Mandal, K. K., Basu K., Dutta, P. Basic Concepts of Polymer Chemistry, Techno World Publication.
- Manna, A. K. Fundamentals of Polymer Science and Technology, Books & Allied Pvt. Ltd.

Course Outcomes

1. To acquire a knowledge about the fundamentals and importance of polymer chemistry.
2. To study the molecular forces and chemical bonding in polymers.
3. To outline the mechanism and kinetics of polymerizations, polymerization methods and techniques, basic concepts of glass transition temperature, crystallinity and polymer morphology, peculiarities of polymer molecular weight and techniques available for testing and characterization of polymers.
4. To correlate the structure, property relationship in polymeric materials for different applications.

Core P-16-Polymer Chemistry Laboratory (1 Credit) (30 Lectures)

Polymer Synthesis (15 Lectures)

1. Free radical solution polymerization of styrene (St)/methyl methacrylate (MMA)/methyl acrylate (MA)/acrylic acid (AA).
2. Purification of monomer.
3. Polymerization using benzoyl peroxide (BPO)/2,2'-azo-bis-isobutylonitrile (AIBN).
4. Preparation of nylon 66.
5. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein.
6. Redox polymerization of acrylamide.
7. Preparation of urea-formaldehyde resin
8. Preparations of novalac resin/resole resin.

Polymer Characterization (10 Lectures)

1. Determination of molecular weight by viscometry:
   i) Poly acrylamide-aq. $NaNO_2$ solution
   ii) Poly vinyl proplylidine (PVP) in water

2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).
4. Testing of mechanical properties of polymers.
5. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer Analysis **(5 Lectures)**

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method.
2. Instrumental techniques.
3. IR studies of polymers.
4. DSC analysis of polymers.

Reference Books

- Stevens, M. P. Polymer Chemistry: An Introduction, Oxford University Press.
- Allcock, H. R., Lampe, F. W., Mark, J. E. Contemporary Polymer Chemistry, Prentice Hall.
- Billmeyer F. W. Textbook of Polymer Science, Wiley Interscience.
- Fried, J. R. Polymer Science and Technology, Prentice-Hall.
- Munk, P., Aminabhavi, T. M. Introduction to Macromolecular Science, John Wiley & Sons.
- Sperling, L. H. Introduction to Physical Polymer Science, John Wiley & Sons.
- Stevens, M. P. Polymer Chemistry: An Introduction, Oxford University Press.
- Carraher, C. E. Jr. Seymour/Carraher's Polymer Chemistry, CRC Press, Taylor & Francis.

Course Outcomes

1. To acquire the knowledge and skills required for preparing various types of polymers using different methods.
2. To gain an understanding of how to characterize polymers using chemical and instrumental methods.

Minor (MN - 6)

(Credits - 3 + 1)

T-6-Organic Chemistry II (3 Credits) **(45 Lectures)**

Functional Group Chemistry II **(15 Lectures)**

Aryl halides: 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).

Phenols: preparation: cumene hydroperoxide method, from diazonium salts; acidic nature of phenols; reactions: electrophilic substitution: nitration and halogenations; Reimer-Tiemann reaction, Houben-Hoesch condensation, Schotten-Baumann reaction, Fries rearrangement and Claisen rearrangement.

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.

Carboxylic Acids and their Derivatives (10 Lectures)

a) Carboxylic acids (aliphatic and aromatic): strength of organic acids: comparative study with emphasis on factors affecting pK_a values; preparation: acidic and alkaline hydrolysis of esters ($B_{AC}2$ and $A_{AC}2$ mechanisms only) and from Grignard reagents; reactions: Hell-Vohlard-Zelinsky reaction and Claisen condensation; Perkin reaction.

b) Carboxylic acid derivatives (aliphatic): (up to 5 carbons): preparation: acid chlorides, anhydrides, asters and amides from acids; reactions: comparative study of nucleophilicity of acyl derivatives; interconversion among acid derivatives.

Amines and Diazonium Salts (10 Lectures)

a) Amines (aliphatic and aromatic): strength of organic bases; preparation: from alkyl halides, Gabriel's phthalimide synthesis, Hofmann degradation, by reduction of nitro compounds; reactions: with HNO_2 (distinction of primary, secondary and tertiary amines), Schotten-Baumann reaction, Diazo coupling reaction (with mechanism).

b) Diazonium salts: preparation: from aromatic amines; reactions: conversion to benzene, phenol, benzoic acid and nitrobenzene.

c) Nitro compounds (aromatic): reduction under different conditions (acidic, neutral and alkaline).

Amino Acids and Carbohydrates (10 Lectures)

a) Amino acids: preparations (glycine and alanine only): Strecker synthesis, Gabriel's phthalimide synthesis; general properties; zwitterion, isoelectric point; ninhydrin reaction.

b) Carbohydrates: classification and general properties; glucose and fructose: constitution; osazone formation; oxidation-reduction reactions; epimers of glucose (definition and example only); cyclic structures of glucose (determination of ring size excluded); ascending (Kiliani-Fischer method) and descending (Ruff's and Wohl's methods) in monosaccharides (aldoses only); mutarotation.

Reference Books

- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley India Pvt. Ltd.
- Morrison, R. T., Boyd, R. N., Bhattacharjee, S. K. Organic Chemistry, Pearson Education.
- Singh, M. S. Advanced Organic Chemistry: Reactions and Mechanisms, Pearson.
- Bahl, A., Bahl, B. S. Advanced Organic Chemistry, S. Chand & Co. Ltd.
- Mehta, B., Mehta, M. Organic Chemistry, Prentice-Hall of India Pvt. Ltd.
- Madan, R. L. Organic Chemistry, S. Chand & Co. Ltd.
- Sen Gupta, S. Snatak Jaiba Rasayan, M/S Subrata Sen Gupta.

Course Outcomes

1. To provide a comprehensive understanding of functional group chemistry, focusing on both aliphatic and aromatic compounds.
2. To build an understanding about amino acids and carbohydrates.

P-6-Organic Chemistry II Laboratory (1 Credit) (30 Lectures)

1. The following reactions are to be performed, noting the yield of the crude product:
   a) Nitration of aromatic compounds
   b) Condensation reactions
   c) Hydrolysis of amides/imides
   d) Acetylation of aromatic amines
   e) Benzoylation of aromatic amines
2. Purification of the crude product is to be made by crystallisation from water/alcohol.

Reference Books

- Vogel, A. I. Elementary Practical Organic Chemistry, Part 1: Small Scale Preparations, CBS Publishers and Distributors.
- Nad, A. K., Mahapatra, B., Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency.
- Poddar, S. N., Ghosh, S. P. Practical Chemistry, Book Syndicate Pvt. Ltd.
- Manna, A. K. Practical Organic Chemistry, Books and Allied (P) Ltd.

Course Outcomes

1. To develop a comprehensive understanding of laboratory practices for organic preparation.
2. To develop practical knowledge about purification of the crude product.