**Semester Syllabus for M. Sc. in Chemistry**
***(With effect from the session 2019-20)***

## MISSION

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| **M1** | Educate society for generations by providing transformative education with deep disciplinary knowledge and concern for environment |
| **M2** | Develop problem solving, leadership and communication skill in student participants to serve the organisation of today and tomorrow |
| **M3** | Aim for the holistic development of the students by giving them value based ethical education with concern for society |
| **M4** | Foster entrepreneurial skills and mindset in the students by giving life-long learning to make the them responsible citizens |

## PEO: Programme Educational Objectives

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| **PEO1** | Understand the nature and basic concepts of Chemistry Relating to the M.Sc. Degree in Chemistry |
| **PEO2** | Analyse the relationships among different concepts |
| **PEO3** | Perform procedures as laid down in the areas of study |
| **PEO4** | Apply the Basic Concepts learned to execute them |

## PO: Programme Outcome

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| **PO-1** | **Critical Thinking:** Take informed actions after identifying the assumptions that frame our thinking and actions |
| **PO-2** | **Effective Communication:** Will be able to speak, read, write and listen clearly in person and through electronic media in English and in one Indian Language |
| **PO-3** | **Social Interation (Interpersonal Relation):** Elicit views of others, mediate disagreements and prepared to work in team |
| **PO-4** | **Entrepreneurship Capability:** Demonstrate qualities to be prepared to become an enterpreneurship |
| **PO-5** | **Ethics:** Recognize different value systems including your own, understand the moral dimensions and accept responsibility for them |
| **PO-6** | **Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development |
| **PO-7** | **Life-Long Learning:** Acquire the ability to engage in independent and life-long learning in the context of socio-technological changes |

| **FIRST SEMESTER** | | | |
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| **Course No** | **Course Title** | **Credit** | **Mark** |
| CH-401 | GROUP THEORY AND SOLID STATE CHEMISTRY | 03 | 50 |
| CH -402 | TRANSITION METAL CHEMISTRY | 03 | 50 |
| CH -403 | STRUCTURE AND REACTIVITY | 03 | 50 |
| CH -404 | STEREOCHEMISTRY | 03 | 50 |
| CH -405 | THERMODYNAMICS | 03 | 50 |
| CH -406 | DYNAMICS | 03 | 50 |
| CH -407 | INORGANIC PRACTICAL-I | 02 | 50 |
| CH -408 | ORGANIC PRACTICAL-I | 02 | 50 |
| | **Total** | **22** | **400** |
| **SECOND SEMESTER** | | | |
| **Course No** | **Course Title** | **Credit** | **Mark** |
| CH -411 | METAL $\pi$-COMPLEXES AND CLUSTERS | 03 | 50 |
| CH -412 | BIOINORGANIC CHEMISTRY | 03 | 50 |
| CH -413 | ORGANIC REACTION MECHANISM - I | 03 | 50 |
| CH -414 | ORGANIC REACTION MECHANISM - II | 03 | 50 |
| CH -415 | STATISTICAL THERMODYNAMICS & HMO THEORY | 03 | 50 |
| CH -416 | SURFACE CHEMISTRY | 03 | 50 |
| CH -417 | INORGANIC PRACTICAL-II | 02 | 50 |
| CH -418 | ORGANIC PRACTICAL-II | 02 | 50 |
| | **Total** | **22** | **400** |
| **THIRD SEMESTER** | | | |
| **Course No** | **Course Title** | **Credit** | **Mark** |
| CH -501 | INSTRUMENTAL METHODS OF ANALYSIS | 03 | 50 |
| CH -502 | INORGANIC REACTION DYNAMICS & NUCLEAR CHEMISTRY | 03 | 50 |
| CH -503 | ORGANIC REDOX REACTION & SPECTROSCOPY | 03 | 50 |
| CH -504 | PERICYCLIC REACTION, PHOTOCHEMISTRY & RETROSYNTHESIS | 03 | 50 |
| CH -505 | QUANTUM CHEMISTRY | 03 | 50 |
| CH -506 | ATOMIC & MOLECULAR SPECTROSCOPY | 03 | 50 |
| CH -507 | PHYSICAL PRACTICAL | 03 | 50 |
| CH -508 | REVIEW WORK | 02 | 50 |
| | **Total** | **23** | **400** |

| **FOURTH SEMESTER** | | | |
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| **Core Courses** | | | |
| **Course No** | **Course Title** | **Credit** | **Mark** |
| CH -511 | ADVANCED ORGANOMETALLIC CHEMISTRY | 03 | 50 |
| CH -512 | ADVANCED SPECTROSCOPY | 03 | 50 |
| CH -513 | COMPUTER APPLICATION IN CHEMISTRY | 02 | 50 |
| CH -514 | ANALYTICAL PRACTICAL | 02 | 50 |
| CH -515 | PRACTICAL ON COMPUTER IN CHEMISTRY | 02 | 50 |
| CH -516 | SEMINAR | 02 | 50 |
| ***A student is required to choose any three theory elective courses either from Group A or Group B*** | | 09 | 150 |
| | **Total** | **23** | **450** |
| **Elective Courses** | | | |
| **Group A** | | | |
| CH-521 | ADVANCED ORGANIC SYNTHESIS | 03 | 50 |
| CH-522 | PHOTOPHYSICAL PROCESSES & INSTRUMENTATION | 03 | 50 |
| CH-523 | CHEMISTRY OF NANO MATERIALS | 03 | 50 |
| CH-524 | INDUSTRIAL PROCESSES | 03 | 50 |
| **Group B** | | | |
| CH-531 | ADVACED ANALYTICAL CHEMISTRY | 03 | 50 |
| CH-532 | SUPRAMOLECULAR CHEMISTRY | 03 | 50 |
| CH-533 | ADVANCED SURFCE CHEMISTRY & CATALYSIS | 03 | 50 |
| CH-534 | MATERIAL AND ENERGY BALANCE | 03 | 50 |

**FIRST SEMESTER**

| **ACH-401:** | **GROUP THEORY AND SOLID STATE CHEMISTRY** | **3 credits** |
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| **Course Objective** | 1. To provide basic knowledge on symmetry of molecules applied through mathematical group theory.<br>2. Providing idea how the symmetry of the molecule helps to predict the useful information about the eigen functions and eigen values without solving the Schrodinger wave equation. Students will be able to solve many problems associated with structure, bonding, and reactivity of molecules.<br>3. To acquire the basic understanding of the structure of solids that will be helpful for designing and developing new materials with tunable properties. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of group theory and solid state chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Symmetry and Group Theory*** | |
| | Symmetry operation, symmetry element, classification of symmetry elements, definition of group, subgroup, cyclic groups, molecular point groups, platonic solids, group multiplication table, group generators, conjugacy relation and classes, matrix representation of symmetry elements, character of a representation, reducible and irreducible representation, the great orthogonality theorem (without proof) and its explanation, properties of irreducible representation. | |
| ***UNIT-II:*** | ***Symmetry and Spectroscopy*** | |
| | Character table (explanation and significance), construction of character tables for $C_{2v}$, $C_{3v}$, $C_{4v}$ and $D_4$ point groups, direct product, the standard reduction formula, Applications of group theoretical methods for selection rules in Infrared, Raman and electronic spectroscopy. | |
| ***UNIT-III:*** | ***Solid State Chemistry*** | |
| | General idea of crystal lattice, unit cell, classification of crystals, crystal planes, Miller indices, Bragg's law and applications, determination of cubic crystal structure from systematic absences in diffraction pattern, perfect and imperfect crystals, point defects, Schottky defects and Frenkel defects, thermodynamics of Schottky and Frenkel defects, bonding in ionic solids, colour centers, non-stoichiometry defects, general idea of band theory of solids. | |
| ***TEXT BOOKS*:** | ***1.*** *Symmetry and Group Theory in Chemistry by R. Ameta, New Age International Ltd., 1st edn, 2013, New Delhi.*<br>***2.*** *Solid State Chemistry by D. K. Chakravarty, New Age International Limited, 1996, New Delhi.*<br>***3.*** *Solid State Chemistry and its Applications by A.R. West, Wiley, 1989, 2nd edition, Singapore.*<br>***4.*** *Principles of the Solid State by H.V. Keer, Wiley Eastern. Limited, 1993, New Delhi.* | |
| **REFERENCE BOOKS** | ***1.*** *Chemical Applications of Group Theory by F. A. Cotton, Wiley India (P) Ltd., 3rd edition, 2009, New Delhi.*<br>**2.** *Symmetry and Spectroscopy of Molecules by K. V. Ready, New Age International Ltd. 2nd edn, 2009, New Delhi.* | |
| **ACH-402:** | **TRANSTION METAL CHEMISTRY** | **3 credits** |

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| **Course Objective** | 1. Students will be familiar with various theories such as CFT, MOT and LFT, and their successful applications in the field of metal-ligand bonding.<br>2. To endow with idea about different micro-energy levels of metals and to provide knowledge regarding the electronic spectra.<br>3. To offer idea concerning the correlation between the electronic structure and magnetic properties of coordination complexes**.** |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of transition metal complexes<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course |
| ***UNIT-I*** | ***Theories of Metal-Ligand Bonding*** |
| | a. Crystal field theory (CFT): Splitting of d-orbital under the influence of octahedral, tetrahedral, tetragonal, square planar, trigonal bipyramidal and square pyramidal fields, Streochemical and thermodynamic effect of CF splitting, CFSE and Jahn-Teller effect.<br>b. Molecular orbital theory (MOT): Sigma bonding in octahedral complexes: Classification of metal valence orbitals into sigma symmetry, formation of ligand group orbitals (LGOs) of sigma symmetry, Formation of molecular orbitals of sigma symmetry, construction of molecular orbital energy level diagram involving only sigma bond contribution from ligands, pi bonding in octahedral complexes, Classification of metal valence orbital into pi symmetry, Formation of LGOs of pi symmetry. Formation of pi MOs and construction of molecular orbital energy level diagram involving sigma and pi contribution from pi donor ligands, Sigma and pi bonding in tetrahedral complexes.<br>c. Ligand field theory (LFT) and adjusted crystal field theory (ACFT). |
| ***UNIT-II*** | ***Complex Equilibria and Term Diagram*** |
| | a. Complex Equilibria: Types of complex equilibria in solution and types of complex equilibrium constant (stability constant), The complex formation functions, Determination of stability constant by spectrophotometric method and pH titration method, Stabilization of unusual oxidation state.<br>b. Term Diagram: Russell-Saunders or L-S coupling scheme, Term symbols and their derivation by Pigeon-Hole diagram especially for $p^n$ and $d^n$ configuration, Inter-electron repulsion parameters and spin-orbit coupling parameters, The effect of weak crystal field on S, P, D, F, G, H and I terms, Orgel diagram for $d^1$ to $d^9$ configuration, Term interaction and the energies of the levels.<br>c. Correlation diagram: Strong field configuration of $O_h$ symmetry, the method of descending symmetry, correlation diagram for $d^2$ and $d^3$confuguration, Tanabe-Sugano diagram (qualitative explanation and significance). |
| ***Unit-III*** | ***Electronic Spectral and Magnetic Properties of Metal Complexes*** |
| | a. Electronic spectral properties of metal complexes: Introduction, types of experimental recording of the spectra, selection rules (mechanism of electronic transition, orbital selection rule, Laporte rule or purity selection rules, spin selection rule), Relaxation of selection rules (departure from cubic symmetry d-p mixing vibronic coupling), Nature of electronic spectral bands with respect to band intensity and bandwidth, Classification of electronic spectra. Ligand field spectra of octahedral and tetrahedral complexes and evaluation of Dq, B' and beta(β) parameters for the complex with $T_1$ ground state and $A_2$ ground state, |

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| | Spectrochemical and nephlelauxetic series, charge transfer spectra.<br>b. Magnetic properties of metal complexes: Origin of magnetic behavior, concept of magnetic susceptibility, dia, para, ferro and antiferro magnetism, magnetic moments from multiple width cases, quenching of orbital magnetic moment by crystal field, spin-orbit coupling and anomalies magnetic moments, Spin-crossover in coordination compounds. | |
| ***TEXT BOOKS*** | *1. Advanced Inorganic Chemistry by F. A. Cotton and G. Wilkinson, Wiley India (P) Ltd., New Delhi, 6th edition, 1999.*<br>*2. Inorganic Chemistry (*Principles of Structure and Reactivity*) by James E. Huheey, Ellen A. Keiter, Richard L. Keiter and Okhil K. Medhi Pearson Education, 4th edn, 2006.*<br>*3. Inorganic Chemistry by G. L. Miessler and D. A. Tarr, Pearson Education, 3rd edn, 2004.*<br>*4. Fundamental concepts of Inorganic Chemistry(vol-5, and vol-6) by Asim K. Das and Mahua Das, CBS publishers and distributors, 2nd Edition,2019.* | |
| ***REFERENCE BOOKS*** | *1. Selected topics in Inorganic Chemistry by Wahid U. Malik, G. D. Tuli, R. D. Madan, S. Chand and Company Ltd., New Delhi, Revised Edition, 2010.* | |
| **ACH-403:** | **STRUCTURE AND REACTIVITY** | **3 credits** |
| **Course Objective** | 1. Understanding the basic concepts about nature of bonding in organic molecules, reaction mechanisms of various organic reactions with respect to their the structure and conformational aspects.<br>2. Imparting knowledge in the theory and applications of various organic reactions and their importance in various scientific fields. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of organic structure and reactivity<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Nature of Bonding in Organic Molecules*** | |
| | Delocalized chemical bonding, Conjugation, Cross conjugation, Resonance, Hyperconjugation, Bonding in fullerenes, Tautomerism. Aromaticity in benzenoid and non-benzenoid compounds, Alternant and non-alternant hydrocarbons, Huckel's rule, energy levels of pi-molecular orbitals of simple systems, Annulenes, Anti-aromaticity, Homo-aromaticity, Bonds weaker than covalent-addition compounds. | |
| ***UNIT-II:*** | ***Reaction Mechanism: Structure and Reactivity*** | |
| | Types of mechanisms, Types of reactions, Thermodynamic and kinetic requirements, Kinetic and thermodynamic control, Hammond's postulate, Potential energy diagrams, Transition states and intermediates, Methods of determining mechanisms, Hard and soft acids and bases,<br>Effect of structure on reactivity: Resonance and field effects, Steric effect, Quantitative treatment, The Hammett equation and linear free energy relationship, Substituent and reaction constants, Taft equation. | |
| ***UNIT-III:*** | ***Reagents in Organic Synthesis*** | |
| | Gilman's reagent, Lithium dimethyl cuprate, Lithium diisopropyl amide, DCC, 1,3-Dithiane, Trimethyl sillyl iodide, Tri-n-butyl tin hydride, Osmium tetroxide, Selenium dioxide, Phase transfer catalysis (Crown ether, Merrifield resin, Wilkinson's catalyst), Dichloro dicyano benzoquinone (DDQ). | |
| ***TEXT BOOKS:*** | *1. Mechanism and Theory in Organic Chemistry by Lowry and Richardson (Harper Row Publishers, New York)*<br>*2. Organic Chemistry, Sixth Edition, Morrison and Boyd, Pearson India; 2016*<br>*3. Peter Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Edition,* | |

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| | *Pearson Education Ltd., England, 2013.*<br>4. *Jonathan Clayden, Nick Greeves, and Stuart Warren. "Organic Chemistry," Oxford University Press, 2014.* | |
| ***REFERENCE BOOKS:*** | 1. *Advanced Organic Chemistry: Reaction Mechanism and Structure by Jerry March (Wiley Eastern Limited)*<br>2. *W. Carruthares, Iain coldham, Modern Methods of Organic Synthesis South Asia Edition, Cambridge University Press, Fourth Edition, 2015.*<br>3. *F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry Part B: Reaction and Synthesis, Springer, 5th Edition, 2010.* | |
| **ACH-404:** | **STEREOCHEMISTRY** | **3 credits** |
| **Course Objective** | 1. Understanding the basic concepts about structure and three dimensional conformations of various organic molecules and their role in various reactions<br>2. Imparting knowledge in the theory and applications of various organic reactions with their stereochemical aspects and their importance in various scientific fields. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of stereochemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | Chirality, Fischer projection and R and S notations, Threo and erythro nomenclature, E and Z nomenclature, Optical isomerism in biphenyls and allenes, Concept of Prostereoisomerism and Assymetric synthesis (including enzymatic and catalytic nexus), Conformation of a few acyclic molecules (alkanes, haloalkanes), Conformation of cyclic systems having one and two sp2 carbon atoms. | |
| ***UNIT-II:*** | Dynamic stereochemistry: Conformation and reactivity, Selection of substrates, Quantitative correlation between conformation and reactivity, (Weinstein-Eliel equations and Curtin-Hammett principles), Conformational effects on stability and reactivity in acyclic compounds (ionic elimination, intramolecular rearrangements, NGP) and in cyclic systems, (Nucleophilic substitution reaction at ring carbon, Formation and Cleavage of epoxide rings, Addition reactions to double bonds, Elimination reactions). | |
| ***UNIT-III:*** | Molecular dissymmetry and chiroptical properties, Linearly and circularly polarised lights, Circular birefringence and circular dicroism, ORD, Plane curves, Cotton effect, Rotatory Dispersion of ketones, Axial haloketone rule, the Octane rule. Helicity rule. | |
| ***TEXT BOOKS:*** | 1. *D. Nasipuri, Stereochemistry of Organic Compounds Principles and Applications, New Age International Publishers, 3rd Edition, 2011*<br>2. *Stereochemistry: Conformation and Mechanism by P.S. Kalsi New Age Publishers; Tenth Edition, 2019*<br>3. *Stereochemistry of Organic Compounds by Ernest L. Eliel Wiley; 1st Edition, 2008*<br>4. *Advanced organic chemistry, by Jagdamba Singh, L D S Yadav, Pragati Prakashan, 2019* | |
| ***REFERENCE BOOKS:*** | 1. *I. L. Finar, Organic Chemistry Vol. I & Vol. II, Longman (Cambridge), 2011.*<br>2. *W. Carruthares, Iain coldham, Modern Methods of Organic Synthesis South Asia Edition, Cambridge University Press, Fourth Edition, 2015.*<br>3. *F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry Part B: Reaction and Synthesis, Springer, 5th Edition, 2010.* | |
| **ACH-405:** | **THERMODYNAMICS** | **3 credits** |
| **Course Objective** | 1. Understanding the basic concepts about thermodynamic properties<br>2. Imparting knowledge in the theory and applications of various aspects of | |

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| | thermodynamics and their importance in chemical and biological systems. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of thermodynamics<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Classical Thermodynamics*** | |
| | Brief resume of the concepts of laws of thermodynamics, Free energy, chemical potential and entropy, Third law of thermodynamics and determination of entropy, Entropy and probability, Boltzmann-Planck equation, Partial molar properties (partial free energy, molar volume and molar heat content), Their significance and determination. Concept of fugacity and its determination. | |
| ***UNIT-II*** | ***Thermodynamics of Living Systems*** | |
| | Bioenergetics and thermodynamics, Phosphate group transfer and ATP, Biological oxidation-reduction reactions. | |
| ***UNIT-III*** | ***Non-Equilibrium Thermodynamics*** | |
| | Microscopic reversibility, Entropy productions and irreversible process, Different types of forces and fluxes, Steady states & Cross phenomena, Phenomenological equations, Onsager reciprocity theorem, Chemical Reactions. | |
| ***TEXT BOOKS:*** | *1. Text Book of Physical Chemistry (Vol-1-4) by K.L. Kapoor, McGraw-Hill, 6th ed., 2020*<br>*2. Physical Chemistry by D.N. Bajpai, S. Chand Publishing. 2001*<br>*3. Principles of Physical Chemistry by Puri, Sharma & Pathania, Vishal Publishing Co., 47th ed., 2020*<br>*4. Physical Chemistry by Atkins, Oxford University Press, 11th ed., 2018* | |
| ***REFERENCE BOOKS:*** | *1. Physical Chemistry Through Problems by Dogra & Dogra, New Age International Private Limited, 2015*<br>*2. Chemical Thermodynamics by Rastogi & Mishra, 6th ed., 2018*<br>*3. Thermodynamics for Chemists by S. Glasstone, Krieger Pub Co, 1972*<br>*4. Molecular Thermodynamics by McQuarrie & Simon, University Science Books, 1999*<br>*5. Principle of Biochemistry by A.L. Lehninger. WH Freeman, 7th ed. 2017* | |
| **ACH-406:** | **DYNAMICS** | **3 credits** |
| **Course Objective** | 1. To give an overview of chemical kinetics including fast reaction and electrochemistry<br>2. To elucidate students about the physical significance of catalysis in terms of understanding the mechanism of the process.<br>3. To provide in-depth knowledge on chemical kinetics, fast reactions, catalysis and electrochemistry. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of dynamics<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Chemical Kinetics*** | |
| | Theories of reaction rates, Collision theory, Transition state theory, Arrehenius equation and the activated complex theory, Reaction between ions, Salt effect, Steady-State Kinetics, Kinetic and Thermodynamic concept of Reactions, Treatment of unimolecular | |

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| | reaction ( Lindemann-Hinshelwood and Rice-Ramspeger-Kassel-Marcus (RRKM) theories), Dynamic chain ( $H_2$ + $Br_2$ reaction, pyrolysis of $CH_3CHO$, Decomposition of ethane). | |
| ***UNIT-II:*** | ***Catalytic & Fast Reaction*** | |
| | Kinetics of Catalytic Reactions: Acid-base Catalysis, Enzyme Catalysis, Homogeneous & Heterogeneous Catalysis.<br>Fast reactions: General feature, Study of Fast reactions by relaxation, Stopped flow and Flash photolysis. | |
| ***UNIT-III:*** | ***Electrochemistry*** | |
| | Interionic attraction theory and Debye-Huckel treatment, Derivation of Onsager limiting law and its verification and modification, Activities, activity coefficients, Debye-Huckel treatment, Debye-Huckel-Bronsted equation, Salt effect, Determination of activity coefficients from solubility method, Ion association, Determination of thermodynamic dissociation constant of weak electrolytes by Shedlovsky method and by EMF method, Nernst equation, redox systems, electrochemical cells. | |
| ***Text Books:*** | 1. *Chemical Kinetics by K.J. Laidler, Pearson; 3rd edition, 1997*<br>2. *Textbook of Physical Chemistry [Vol. 5] by K L Kapoor, McGraw Hill, 2014*<br>3. *Principles of Physical Chemistry by B.R. Puri, L.R. Sharma, M.S. Pathania, Vishal Publishing Co, 47th ed. 2016*<br>4. *An Introduction to Electrochemistry by S. Glasstone, Affiliated East-West Press Pvt. Ltd. 2008* | |
| ***Reference Books*** | 1. *Advanced Physical Chemistry by D.N. Bajpai, S. Chand; 2nd ed. 1992*<br>2. *Atkins' Physical Chemistry by P. W. Atkins and Julio de Paula, , Oxford; 10th ed. 2014*<br>3. *Modern Electrochemistry (Vol-I) by Bockris & Reddy, Springer, 2nd ed. 1998*<br>4. *Reaction Kinetics by Pilling & Seakins, Oxford University Press, 2nd ed. 1996*<br>5. *Physical Chemistry Through Problems by Dogra & Dogra, New Age International Private Limited, 2015* | |
| **ACH-407:** | **INORGANIC PRACTICAL-I** | **2 credits** |
| **Course Objective** | 1. Understanding the basic concepts behind the separation cations and anions.<br>2. To analyze the principles behind the identifications of different radicals.<br>3. Apply the principles of Common ion effect and solubility effect in qualitative analysis<br>4. Demonstrate and use the different reagents for identifications of cations and anions | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of inorganic radical analysis<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the Project or field assignment as per the knowledge gained in the course | |
| | Analysis of an inorganic mixture containing not more than 6 radicals. The mixture will include rare earth like Tungstate, Vanadate, Molybdate and Cerium (IV). Insoluble matters and other interfering radicals will also be included. Organic radicals are excluded. | |
| ***BOOKS:*** | 1. *Vogel's Qualitative Inorganic Analysis, 7th edition; Revised by G. Svehla.*<br>2. *Vogel's Text Book of Quantitative Chemical Analysis, 5th Revised by G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denny.*<br>3. *Advanced Practical Inorganic Chemistry, 22nd edition; By Gurdeep Raj* | |

| **ACH-408:** | **ORGANIC PRACTICAL-I** | **2 credits** |
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| **Course Objective** | 1. Understanding the basic concepts behind the separation unknown organic compounds.<br>2. To analyze the principles behind the identifications of different organic functional groups.<br>3. Apply the principles of analytical methods in identification of organic compounds.<br>4. Demonstrate and use the different reagents for identifications of functional groups. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of separation of unkown organic compounds<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the Project or field assignment as per the knowledge gained in the course | |
| | Isolation and identification of multi-functional compounds in a mixture of two organic compounds. | |
| ***BOOK:*** | *Advanced Practical Organic Chemistry, 3/e by N K Vishnoi* | |

**SECOND SEMESTER**

| **ACH-411:** | **METAL $\pi$-COMPLEXES AND CLUSTERS** | **3 credits** |
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| Course Objectives: | 1. To provide knowledge on the CO ligand as well as its analogs, and to understand the synergism between the ligand to metal forward σ–donation and the metal to ligand backward π–donation observed in a metal-ligand interaction.<br>2. To know the concept of cluster compounds of transition metals and to understand the theoretical models that explain the bonding of cluster compounds.<br>3. To provide knowledge about polyacids and their properties. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of metal complexes and clusters<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I*** | ***Carbon Monooxide Complexes*** | |
| | Metal carbonyls, structure and bonding, vibrational spectra of metal carbonyls for bonding and structural elucidation, important reaction of metal carbonyls, carbonylate anions and carbonylate hydride, carbonyl halides and related compounds. Nature of M-C bond in carbonyls. | |

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| ***UNIT-II*** | ***Complex of Carbon Monoxide Analogs*** | |
| | (a) Preparation, bonding and important reaction of transition metal complexes with isocyanide, cyanide, dinitrogen, carbon disulphide and nitrogen monoxides.<br>(b) Transition metal to carbon multiple bonded: compounds chemistry of carbenes, carbynes. | |
| ***UNIT-III*** | ***Metal Cluster and Polyacids*** | |
| | Metal cluster: Occurrence of metal-metal bonds in metal complexes, Bonding in metal cluster. Metal carbonyl type clusters. Anionic and hydride cluster. Method of synthesis, super large cluster, electron counting in medium size cluster (Wade's rule, Capping rule), Isolable relationship, cluster of Fe, Ru, Os groups. Cluster of Co, Rh, Ir groups. Cluster of Ni, Pd, Pt groups. Catalysis by cluster.<br>Isopoly and heteroply acids and salts. | |
| ***TEXT BOOKS:*** | 1. *Advance Inorganic Chemistry by F.A. Cotton, G. Wilkinson & C. Murillo, Wiley Publication, 6th edition, 1999.*<br>*2. Inorganic Chemistry (*Principles of Structure and Reactivity*) by James E. Huheey, Ellen A. Keiter, Richard L. Keiter and Okhil K. Medhi, Pearson Education, 4th edn, 2006.*<br>*3. Inorganic Chemistry by G. L. Miessler and D. A. Tarr, Pearson Education, 3rd edn, 2008* | |
| ***REFERENCE BOOKS*** | *1. Comprehensive Coordination Chemistry, by Wilkinson, Gillarsand, Pergamon Press, 1989.*<br>*2. Modern Aspect of Inorganic Chemistry by Emelius and Sharpe, Routledge & Kegan Paul PLC, England, 4th revised edition, 1978.* | |
| **ACH-412:** | **BIOINORGANIC CHEMISTRY** | **3 credits** |
| **Course Objective** | 1. To introduce the cross disciplinary aspects of chemistry and biology such as protein structure, conformation, and the importance of transition metal ions in storage and carrier proteins as well as in enzymes.<br>2. To introduce the structure and function of oxygen storage and transport proteins, photosynthetic system, and enzymes.<br>3. To provide knowledge of coordination chemistry in biology. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of bioinorganic chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I*** | ***Biomolecules and their Roles in Metal Ions Storage and Transportation*** | |
| | Amino acids, peptides and proteins, structures of proteins, Ramachandran's plot, lipids, lipid bilayer, biological membranes, chemistry of biologically relevant molecules like ADP, ATP, FAD, NADP, nucleotides. Biologically important metal ions (Na, K, Mg, Ca, Cu, Fe, Zn, Co and Mo) and their functions, mechanism of transport of metal ions through biological fluids and membranes, different types of passive and active transport processes and their mechanism, $Na^+/K^+$ pump, calcium pump, and ionophores. Storage and transport of iron, copper and zinc, siderophores, structure and function of ferritin, transferrin in regard to Fe-storage and transportation, | |
| ***UNIT-II*** | ***Role of Proteins as Oxygen and Electron Carriers*** | |
| | Chemistry of porphyrin, Iron porphyrins (Heme proteins): Hemoglobin (Hb), Myoglobin (Mb) and their behavior as oxygen carrier, $O_2$ affinity, cooperativity and Bohr's effect, Heme protein as electron carrier with particular reference to cytochrome-c and cytochrome-450, and cytochrome oxidase. Catalases and peroxidases. Non-heme oxygen uptake protein (hemerythrin and hemocyanin). | |

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| | Magnesium porphyrins (Chlorophyll): Photosynthesis, the light and dark reaction (Calvin cycle). Non-heme iron-sulphur protein as electron carrier, rubredoxins and ferredoxins. | |
| ***UNIT-III*** | ***Biomolecular Catalysis*** | |
| | Preliminary idea about enzyme, cofactor, co-enzyme, apoenzyme, prosthetic group, metal-activated enzyme and metalloenzyme. Enzyme-substrate binding problem, carboxypeptidase, carbonic anhydrase and their biological significance, Interchangeability of zinc and cobalt enzyme. Blue-oxidases (ascorbate oxidase, cerulloplasmin, laccase) and non-blue Oxidases (amine oxidase, galactose oxidase, lysyl oxidase, cytochrome c oxidase), structure and biological functions of molybdenum nitrogenase, superoxide dismutase. | |
| ***BOOKS:*** | *1. Bio-Inorganic Chemistry by Asim K Das.*<br>*2. Bio-Inorganic Chemistry by E. Ochia.*<br>*3. Bioorganic, BioInorganic and Supramolecular Chemistry by P. S. Kalsi and J. P. Kalsi.*<br>*4. Inorganic Chemistry (4$^{th}$ Edn) by Huheey, Keiter, Keiter and Medhi.*<br>*5. Bioinorganic and Suparmolecular Chemistry by A. Bhagi and G. R. Chatwal.* | |
| **ACH-413:** | **ORGANIC REACTION MECHANISM – I** | **3 credits** |
| **Course Objective:** | 1. Understanding the basic concepts about the way organic reactions are taking place and also to make the students understand the mechanisms of different organic reactions including various stereochemical, mechanistic and conformational aspects<br>2. Imparting knowledge in the theory and applications of various organic reactions and various spectroscopic techniques which are very important characterization techniques for different fields of science | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of organic reaction mechanism<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I*** | The $S_N2$, $S_N1$, mixed $S_N1$ and $S_N2$ and SET mechanisms. The neighbouring group mechanism, Neighboring group participations by sigma and pi bonds, anchimeric assistance. Classical and nonclassical carbocations, phenonium ions, norbornyl system, common carbocation rearrangements, application of NMR spectroscopy in the detection of carbocations. The $S_NI$ mechanism. Nucleophilic substitution at an allylic, aliphatic trigonal and a vinylic carbon. Reactivity effects of substrate structure, attacking nucleophile, leaving group and reaction medium, phase transfer catalysis, ambident nucleophile, regioselectivity. | |
| ***UNIT-II*** | Alipahatic Electrophilic Substitution mechanism: $S_E1$, $S_E2$ and $S_E^I$ mechanisms, Effect of substrate, leaving group and solvent, Reactions (hydrogen exchange, migration of double bonds, keto-enol tautomerism, halogenation, aliphatic diazonium coupling, Stork-enamine reaction).<br>Aromatic electrophilic substitution mechanism: Structure reactivity relationship in mono-substituted benzene, ring isomer proportions, orientation in benzene ring with one or more than one substituent, Orientation in other ring systems, Vilsmeir - Haack reaction, Pechmann reaction. | |
| ***UNIT-III*** | Aromatic Nucleophilic Substitution mechanism: Introduction to different mechanisms, Aromatic nucleophilic substitutions ($S_NAr$, $S_N1$ aryne), Effect of substrates, leaving groups, and nucleophile, Reactions: Nucleophilic displacement in | |

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| | areno-diazonium salts by different nucleophiles, Chichibabin reaction.<br>Free radical Substitution: Intermediates, Reaction at $sp^2$ carbon, Reactivity in aliphatic substrates, Reactivity at bridge head position, Reactivity in aromatic substrates. | |
| ***TEXT BOOKS:*** | *1. Organic Reactions and Their Mechanisms by P S Kalsi, New Age International Private Limited; Fifth edition, 2020*<br>*2. Organic Reaction Mechanisms by Raj K. Bansal, New Age International Private Limited, 2012*<br>*3. Mechanism and Theory in Organic Chemistry by Lowry and Richardson (Harper Row Publishers, New York)*<br>*4. Jonathan Clayden, Nick Greeves, and Stuart Warren. "Organic Chemistry," Oxford University Press, 2014.* | |
| ***REFERENCE BOOKS:*** | *1. Advanced Organic Chemistry: Reaction Mechanism and Structure by Jerry March (Wiley Eastern Limited)*<br>*2. W. Carruthares, Iain coldham, Modern Methods of Organic Synthesis South Asia Edition, Cambridge University Press, Fourth Edition, 2015.*<br>*3. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry Part B: Reaction and Synthesis, Springer, 5th Edition, 2010.* | |
| **ACH-414:** | **ORGANIC REACTION MECHANISM – II** | **3 credits** |
| **Course Objective:** | 1. Understanding the basic concepts about the way organic reactions are taking place and also to make the students understand the mechanisms of different organic reactions including various stereochemical, mechanistic and conformational aspects<br>2. Imparting knowledge in the theory and applications of various organic reactions and various spectroscopic techniques which are very important characterization techniques for different fields of science | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of organic reaction mechanism<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I*** | Addition to carbon-carbon multiple bonds, Electrophilic, Nucleophilic and Free radical addition, Orientation and Reactivity, Addition to cyclopropanes, Reactions: Hydroboration, Michael reaction, Sharpless Asymmetric epoxidation.<br>Addition to carbon-heteroatom multiple bonds: Mechanism and reactivity, Reactions: Mannich reaction, $LiAlH_4$ reduction of carbonyl compounds, acids, esters, nitriles, addition of Grignard reagents - Reformatsky reaction, Aldol condensation, Knoevenagel condensation, Perkin reaction, Tollens reaction, Wittig reaction, Prins reaction, Benzoin condensation. | |
| ***UNIT-II*** | Elimination mechanism: $E_1$, $E_2$, $E_1CB$ and $E_2CB$ mechanisms, Orientation, Effect of substrate, base, leaving group and medium, Orientation of double bond, Sayetzeff and Hoffman rules, Pyrolytic elimination reaction, Oxidative elimination (oxidaton of alcohol by chromium, Moffatt oxidation). Reactions: Cleavage of quaternary ammonium hydroxides, Chugaev reaction, Shapiro reaction. | |
| ***UNIT-III*** | General mechanistic considerations – nature of migration, migratory aptitude, memory effects.<br>A detailed study of the following rearrangements, Wagner-Meerwein, Favorskii, Carbene intermediate, Arndt-Eistert synthesis, Neber, Nitrene intermediates (Beckmann, Hofmann, Schmidt, Lossen, Curtius), Baeyer-Villiger, Shapiro reaction, | |

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| | Von-Richter, Sommelet-Hauser rearrangement. | |
| ***TEXT BOOKS:*** | *1. Organic Reactions and Their Mechanisms by P S Kalsi, New Age International Private Limited; Fifth edition, 2020*<br>*2. Organic Reaction Mechanisms by Raj K. Bansal, New Age International Private Limited, 2012*<br>*3. Mechanism and Theory in Organic Chemistry by Lowry and Richardson (Harper Row Publishers, New York)*<br>*4. Jonathan Clayden, Nick Greeves, and Stuart Warren. "Organic Chemistry," Oxford University Press, 2014.* | |
| ***REFERENCE BOOKS:*** | *1. Advanced Organic Chemistry: Reaction Mechanism and Structure by Jerry March (Wiley Eastern Limited)*<br>*2. W. Carruthares, Iain coldham, Modern Methods of Organic Synthesis South Asia Edition, Cambridge University Press, Fourth Edition, 2015.*<br>*3. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry Part B: Reaction and Synthesis, Springer, 5th Edition, 2010.* | |
| **ACH-415:** | **STATISTICAL THERMODYNAMICS & HMO THEORY** | **3 credits** |
| **Course Objective** | 1. Understanding the basic concepts about Statistical Thermodynamics and HMO Theory.<br>2. To elucidate students about the physical significance of Classical and Quantum Statistical Mechanics, Partition Functions and Huckel Molecular Orbital Theory<br>3. To provide in-depth knowledge on the application of Classical and Quantum Statistical Mechanics, Partition Functions and Huckel Molecular Orbital Theory. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of statistical thermo-dynamics and HMO theory<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I*** | ***Classical and Quantum Statistical Mechanics*** | |
| | Concept of probability, Starling approximations, Most probable distribution, System, Phase Space, μ-Space, ϒ-Space, Liouville's Theorem, Statistical Equilibrium, Brief Concepts on Ensembles, Canonical, Grand Canonical and Micro-canonical ensembles.<br>Bose-Einstien statistics, Fermi-Dirac statistics and Maxwell-Boltzmann statistics | |
| ***UNIT-II*** | ***Partition Functions & Statistical Thermodynamic Properties of Solids*** | |
| | Significance of partition function, Calculation of thermodynamic properties and equilibrium constant in terms of partition functions, Evaluation of transnational, vibrational and rotational partition function for monoatomic and polyatomic ideal gases, electronic partition function.<br>Some thermal characteristics of crystalline solids, Classical treatment of solids, Einstein Model, Debye Modification, Limitation and modification of Debye theory. | |
| ***UNIT-III*** | ***Huckels Molecular Orbital Theory*** | |
| | Huckel theory of conjugated systems (Ethylene, Allyl systems, butadiene, cyclopropenyl, cyclobutadiene, bicyclobutadiene, $H_3^+$, $H_3$ and $H_3^-$), Calculation of bond order, charge density, free valence index, Application of group theory for the simplification of MO determinants of 1,4- butadiene and naphthalene. | |
| ***BOOKS*** | *1. Physical Chemistry by D.N. Bajpai*<br>*2. Statistical Thermodynamics by M. C. Gupta* | |

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| | *3. Introduction to Quantum Chemistry by A.K. Chandra*<br>*4. Notes on Molecular Orbital Calculations by J.D. Roberts* | |
| ***REFERENCE BOOKS:*** | *1. McQuarrie, Donald A. (1975). Statistical mechanics. New York: Harper & Row. ISBN 0-06-044366-9.*<br>*2. Chandler, David (1987). Introduction to Modern Statistical Mechanics. Oxford University Press. ISBN 0-19-504277-8.*<br>*3. Peliti, Luca (2011). Statistical Mechanics in a Nutshell. Princeton University Press. p. 417. ISBN 978-0-691-14529-7.* | |
| **ACH-416:** | **SURFACE CHEMISTRY** | **3 credits** |
| **Course Objective** | 1. Demonstrate physical chemistry aspects of surface chemistry related to phase rule, polymer chemistry and theories of adsorption.<br>2. To elucidate students about the physical significance of phase rule, polymer chemistry, kinetics of polymerization, and theories of adsorption<br>3. To provide in-depth knowledge on the application of phase rule, polymer chemistry and theories of adsorption. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of surface chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I*** | ***Phase Rule*** | |
| | Concept of Equilibrium between phases, Derivation of phase rule, Ideal Solution, Liver Rule, Brief concept on one and two component system, Application of phase rule to three component systems of both solids and liquids. | |
| ***UNIT-II*** | ***Adsorption*** | |
| | Surface tension, Capillary action, Adsorption, types of adsorption, Gibbs adsorption isotherm, Freundlich's adsorption isotherm, Langmuir's adsorption isotherm and its limitations, BET adsorption isotherm and its applications, Heat of adsorption, estimation of surface areas of solids from solution adsorption studies. | |
| ***UNIT-III*** | ***Macromolecules*** | |
| | Polymer-definition, Classification of polymer, Polymer structure, Number average and molecular weight average, Step growth & chain growth polymerization, Kinetics of polymerization, Stereochemistry of polymerization. | |
| ***BOOKS:*** | *1. Text Book of Physical Chemistry Vol-1-4 by K.L. Kapoor*<br>*2. Physical Chemistry by D.N. Bajpai*<br>*3. Physical Chemistry by A.W. Atkins*<br>*4. Introductory Quantum Chemistry by A.K. Chandra*<br>*5. Polymer Science by Gowariker, Viswanathan & Sreedhar*<br>*6. Polymer Science & Technology by J. R. Fried* | |
| **ACH-417:** | **INORGANIC PRACTICAL-II** | **2 credits** |
| **Course Objective** | 1. Understanding the basic concepts and principle of estimations.<br>2. To analyze the principles behind the identifications of different elements.<br>3. Demonstrate and use the different reagents for identifications and analysis of inorganic complexes. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of inorganic radical analysis<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the Project or field assignment as per the knowledge gained in | |

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| | the course |
| | 1. Principle of estimation of the main constituents of Brass and Portland Cement.<br>(a) Estimation of Ca and Mg in a given solution prepared from a sample of cement by EDTA method.<br>(b) Estimation of Cu and Zn in a given solution prepared from a sample of Brass.<br>2. Determination of $MnO_2$ in pyrolusite.<br>3. Preparation and cheracterisation of the following inorganic compounds:<br>(i) Tetramminecupric sulphate $[Cu(NH_3)_4]SO_4 .H_2O$<br>(ii) Sodium cobaltinitrite , $Na_3[Co(NO_2)_6]$<br>(iii) Potassium chromioxalate , $K_3[Cr(C_2O_4)_3]$. |
| ***BOOKS:*** | *1. Vogel's Qualitative Inorganic Analysis, 7th edition; Revised by G. Svehla.*<br>*2. Vogel's Text Book of Quantitative Chemical Analysis, 5th Revised by G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denny.*<br>*3. Advanced Practical Inorganic Chemistry, 22nd edition; By Gurdeep Raj* |
| **ACH-418:** | **ORGANIC PRACTICAL-II** **2 credits** |
| **Course Objective** | 1. Understanding the basic concepts in preparation of organic compounds.<br>2. To analyse and apply the basic idea to the preparation of organic compounds by different methods.<br>3. Apply the principles of analytical methods in evaluation of organic compounds.<br>4. Deduce structure of synthesized organic molecules. |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of organic compounds.<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the Project or field assignment as per the knowledge gained in the course |
| | 1. Preparation of benzoin, benzil and benzillic acid from benzaldehyde.<br>2. Preparation from p-idotoluene from p-toluidene.<br>3. Preparation of ethyl acetoacetate from ethyl acetate.<br>4. Estimation of nitrogen by Kjeldahl method.<br>5. Estimation of keto group by gravimetric method.<br>6. Dibenzalacetone from benzaldehyde.<br>7. Cannizaro reaction – 4-chloro benzaldehyde as substrate.<br>Grignard reaction – synthesis of triphenyl methanol from benzoic acid. |
| ***BOOK:*** | *Advanced Practical Organic Chemistry, 3/e by N K Vishnoi* |

**THIRD SEMESTER**

| **CH-501:** | **INSTRUMENTAL METHOD OF ANALYSIS** | **3 credits** |
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| **Course Objectives:** | 1. To understand the fundamental principles that drive FES and AAS.<br>2. To provide idea about the electrochemical methods and to realize their significances in the diverse fields.<br>3. To understand the basic concepts related to TGA, DTA and DSC and their modern applications in the various fields. | |
| **Course** | CO-1. Remember and understand the basic concepts/principles of instrumental method of analysis | |

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| **Outcome** | CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I*** | ***Spectroscopical Method*** | |
| | Flame Emission Spectroscopy (FES): Basic Principle, instrumentation-Atomizers, Burners, optical system, Detectors, interference in FES and ways to overcome it, Application of FES – Qualitative and Quantitative Analysis, standard addition method and Internal standard method, Error in FES, Limitation of FES.<br>Atomic Absorption Spectroscopy (AAS): Basic Principle, difference between FES and AAS, Standard instruments used, Experimental Procedure, Application of AAS, interferences and remedial measures, comparative study between AAS and FES, sensitivity of Instruments. | |
| ***UNIT-II*** | ***Electroanalyctical Method*** | |
| | Polarography: Basic principle, instrumentation, theory of current-voltage curve, Theory of diffusion current, Ilkovic equation, polarography wave and half wave potential. Application of polarography. Principle, Application, advantage and disadvantage of Cyclic voltammetry anodic stripping voltammetry, amperometry, conductrometry and ion selective electrodes. | |
| ***UNIT-III*** | ***Thermo Analytical Methods*** | |
| | Thermogravimetric analysis (TGA): Principle, instrumentation, factors affecting TGA curve, derivative thermogravimetric analysis (DTGA) and application of thermogravimetric analysis, Differential thermal Analysis (DTA), instrumentation of DTA and application of DTA, Simultaneous study of TGA, DTA with examples. Differential scanning calorimetry (DSC) and thermometric titration. | |
| ***TEXT BOOKS:*** | *1. Analytical Chemistry (Theory and Practice) by U.N. Dash, Sultan Chand & Sons Pvt. Ltd., New Delhi, 2013.*<br>*2. Basic concept of Analytical Chemistry by S. M. Khopkar, New Age International (P) Ltd. Publishers, 3rd Edition, 2008.*<br>*3. Instrumental Methods of Chemical Analysis by Gurdeep R. Chatwal, Sham K. Anand, Himalaya Publishing House, 5th Edition,2014.*<br>*4. Quantitative Analysis by Vogel, Pearson Education Ltd., New Delhi, 6th edition, 2009.* | |
| ***REFERENCE BOOKS*** | *1. Instrumental Method of Analysis by H. Willard, L. Merritt, J. Dean & F. Settle, CBS publisher and distributors Pvt. Ltd., 7th edition, 2004.* | |
| **CHI-502:** | **INORGANIC REACTION DYNAMICS AND NUCLEAR CHEMISTRY** | **3 credits** |
| **Course Objective** | 1. To introduce the concepts of kinetic behavior of inorganic complexes.<br>2. To introduce the role of central metal ion and ligands in the kinetic stability of coordination complexes.<br>3. To provide knowledge of atomic nucleus and its disintegration phenomena.<br>4. To provide knowledge on different types of nuclear reactions and their applications. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of inorganic reaction dynamics and nuclear chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Substitution Reactions of Octahedral Co(III) Compounds*** | |

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| | The nature of substitution reactions, Kinetic Application of Crystal Field Theory, Acid hydrolysis of octahedral Co(III) complexes with reference to effect of charge, chelation, steric crowding & effects of leaving group, Base hydrolysis of octahedral Co(III) complexes: Conjugate base mechanism, Test of conjugate base mechanism, Anation reaction, Substitution reaction without cleavage of metal-ligand bond. |
| ***UNIT-II*** | ***Substitution Reactions of Square Planar Pt (II) Complex and Redox Reactions*** |
| | Thermodynamic and kinetic stability, Trans effect and its synthetic applications, theories of trans effect (polarization & $\pi$ -bonding theories), Factors affecting the rate law and reaction profile (leaving group, steric group, charge, electrophillic catalysis, nucleophile and temperature).<br>Redox reactions: electron tunneling hypothesis, concept of Marcus-Hush theory, atom transfer reactions, one and two electron transfer, complementary and non-complementary reactions, inner sphere and outer sphere reactions, electron transfer through extended bridges, concept of hydrated electron. |
| ***UNIT-III*** | ***Nuclear Chemistry*** |
| | Atomic nucleus, nuclear stability, magic numbers, Radioactivity, General characteristics of radioactive decay, nature of α- and β-particles, and γ-rays, decay kinetics, nuclear reaction, Bethe's notation, types of nuclear reaction, conservations in nuclear reactions, nuclear cross section, compound nuclear theory, the Brett-Wigner Formula, nuclear fission, Process of nuclear fission, liquid drop model, shell model, hard core preformation theory, Fission fragments and their mass distribution, charge distribution, Ionic charge of fission fragments, fission energy, fission cross-sections, Fission neutrons, concept of nuclear reactor and working principle, concept of nuclear fusion. |
| ***BOOKS:*** | *1. Mechanisms of Inorganic Reactions byF. Basolo and R. G. Pearson*<br>*2. Inorganic Chemistry by Asim K Das*<br>*3. Inorganic Chemistry by Cotton and Wilkinson ($4^{th}$ Edn)*<br>*4. Essentials of Nuclear Chemistry by H. J. Arniker* |
| **CH-503:** | **ORGANIC REDOX REACTION AND SPECTROSCOPY** **3 credits** |
| **Course Objective:** | 1. Understanding basic concepts related to synthesis, mechanisms and the functions of various oxidation and reduction reagents and theory and instrumentation of NMR spectroscopy and Mass spectrometry.<br>2. To impart knowledge in the theory and applications of various spectroscopic techniques which are very important characterization techniques for different fields of science |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of organic redox reaction and spectroscopy<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course |
| ***UNIT-I*** | Oxidation: Oxidation of hydrocarbons, oxidation of alcohols by various reagents, and methods, oxidation of carbon-carbon double bonds to diols and epoxides, Chromium (VI), Manganese (VII) oxidants, Oxidation with peracids, oxidation with hydrogen peroxide, with singlet oxygen. Oxidation with ruthenium tetroxide, iodobenzene diacetate, and thallium (III) nitrate, DMSO.<br>Reduction: Catalytic hydrogenation, selectivity of reduction, Reduction by hydride transfer reagents: Aluminium alkoxid, Lithium aluminium hydride (LAH) and Sodium borohydride ($NaBH_4$), di-isobutylaluminium hydride, Sodium cyanoborodydride, Lithium trialkylborohydride, reduction with hydrazine and diimide, reduction with |

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| | trialkyltinhydride, the Birch reduction, the Wolff-Kischner reduction, the Cannizarro reduction, the Resenmund reduction. |
| ***UNIT-II*** | NMR: Magnetic properties of nuclei, Theory of magnetic nuclear resonance with special reference to proton, Instrumentation, Chemical shift, Simple spin-spin interaction, Shielding effects, Diamagnetic anisotropy, NOE, $^{13}C$, $^{15}N$, $^{19}F$, $^{31}P$ NMR (preliminary idea). |
| ***UNIT-III*** | (a) Mass spectrometry: Introduction, Mass spectrum, Determination of molecular formulae, Parent peak, Base peak, Use of molecular fragmentation, Mass spectra of some classes of compounds (hydrocarbons, alcohols, phenols, ketones, aldehydes, acids and esters)<br>(b) Problems involving UV, IR, NMR and Mass spectroscopy. |
| ***TEXT BOOKS:*** | 1. *Reactions, Rearrangements and Reagents by S.N. Sanyal, Bharati Bhawan Publishers & Distributors; Fourth edition, 2019*<br>2. *Organic Reaction Mechanisms by Raj K. Bansal, New Age International Private Limited, 2012*<br>3. *Synthetic Approaches in Organic Chemistry, R.K. Bansal, Narosa Publishing House,India, 1996*<br>4. *Jonathan Clayden, Nick Greeves, and Stuart Warren. "Organic Chemistry," Oxford University Press, 2014.*<br>5. *Introduction to Spectroscopy by Donald L. Pavia, Gary M. Lampman, George S. Kriz, and James R. Vyvyan, Cengage Learning India Private Limited; 2015*<br>6. *R.M. Silverstein, G. C. Bassler, T. C. Morril, Spectrometric identification of Organic Compounds, John Wiley & Sons, Inc, 2010* |
| ***REFERENCE BOOKS:*** | 1. *W. Carruthares, Iain coldham, Modern Methods of Organic Synthesis South Asia Edition, Cambridge University Press, Fourth Edition, 2015.*<br>2. *F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry Part B: Reaction and Synthesis, Springer, 5th Edition, 2010.*<br>3. *J. March and M. B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 6th Edition, Wiley, 2013.*<br>4. *I. L. Finar, Organic Chemistry Vol. I & Vol. II, Longman (Cambridge), 2011.*<br>5. *Spectroscopy of Organic Compounds, by P S Kalsi, New Age International, 2007*<br>6. *Basic $^{1}H$- and $^{13}C$ NMR spectroscopy, by M. Balci, Elsevier, 2005* |
| **CH-504:** | **PERICYCLIC REACTION, PHOTOCHEMISTRY AND RETROSYNTHESIS** **3 credits** |
| **Course Objective:** | 1. Understanding the synthesis and mechanisms of various reactions carried by thermal and photochemical pathways<br>2. Imparting knowledge in the theory and applications of various aspects of photochemistry and pericyclic reactions.<br>3. Providing various methodologies used in organic synthesis, which enable the students to think different possible ways to synthesize an organic compound including retrosynthetic analysis and understanding about the disconnection approach for the organic synthesis and asymmetric synthesis. |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of pericyclic reaction, photochemistry and retrosynthesis<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course |
| ***UNIT-I*** | Pericyclic reactions: Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl system. Classification of pericyclic reactions. Woodward-Hoffmann rules, Correlation diagrams and FMO approaches. Electrocyclic reactions - Conrotatory and disrotatory motions, 4n, 4n+2 and allyl systems. |

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| | Cycloaddition reactions - suprafacial and antarafacial additions, 4n and 4n+2 systems, [2+2] and [4+2] reactions (thermal and photochemical), 1,3 dipolar cycloadditions and cheletropic reactions. Sigmatropic rearrangements - [*i,j*] shifts of C-H and C-C bonds; Sommelet-Hauser, Claisen, thio-Claisen, Cope and aza-Cope rearrangements. Ene reaction. |
| ***UNIT-II*** | First order Photochemical processes Light absorption, Fluorescence and Phosphorescence.<br>Introduction to photochemical reactions: *Cis-Trans* Isomerization, Dissociation, Reduction of ketones, Paterno-Buchi reaction, Norrish type I and II reactions, Di-pi-methane rearrangement, Photochemistry of arenes, Barton reaction. |
| ***UNIT-III*** | Synthetic design: Introduction, Retrosynthetic approach, Terminology in Retro synthetic analysis, One group disconnection, (alcohol, carbonyl compound, olefins and acids), Two group disconnections (β-hydroxy compounds,α, β-unsubstituted carbonyl compounds, 1,3-dicarbonyl compounds, 1,5 dicarbonyl compounds), Synthesis of some organic molecules by disconnection approach. |
| ***TEXT BOOKS:*** | 1. *Conversion of Orbital Symmetry by Woodward & Hoffman*<br>2. *Organic Reactions and Orbital Symmetry by Gilchrist and Storr, Cambridge University Press; 2nd Edition 1979*<br>3. *Mechanism and Theory in Organic Chemistry by Lowry and Richardson (Harper Row Publishers, New York)*<br>4. *Photochemistry and Pericyclic Reactions by Jagdamba Singh and Jaya Singh, NEW AGE; 3rd Edition, 2012*<br>5. *Stuart Warren and Paul Wyatt, Organic synthesis, the disconnection approach, 2nd edition, Wiley, 2012.* |
| ***REFERENCE BOOKS:*** | 1. *I. L. Finar, Organic Chemistry Vol. I & Vol. II, Longman (Cambridge), 2011.*<br>2. *W. Carruthares, Iain coldham, Modern Methods of Organic Synthesis South Asia Edition, Cambridge University Press, Fourth Edition, 2015.*<br>3. *Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure.7th Edition, 2017. Wiley publications.*<br>4. *L. S. Starkey, Introduction to Strategies for Organic synthesis. Wiley & Sons, Inc., Hoboken, New Jersey and Canada. 2012* |
| **CH-505:** | **QUANTUM CHEMISTRY** **3 credits** |
| **Course Objective** | 1. Understanding the basic concepts about Quantum Chemistry.<br>2. To elucidate students about the physical significance of Quantum Chemistry<br>3. To provide in-depth knowledge on the application of Quantum Chemistry. |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of quantum chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course |
| ***UNIT-I*** | ***Exact Quantum Mechanical Results*** |
| | The Schrodinger equation and the postulates of quantum mechanics, Elementary application of the Schrodinger equation, Particle in a box, Harmonic oscillators, Rigid rotator and hydrogen atom. |
| ***UNIT-II*** | ***Approximate Methods & Angular Momentum*** |
| | The variation theorem, Time independent perturbation of non-degenerate systems, Application of Variation Method and Perturbation Theory to the He atom. |

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| | Ordinary angular momentum, generalized angular momentum, Eigen functions for angular momentum, Addition of angular momentum. | |
| ***UNIT-III*** | ***Chemical Bonding in Diatomics*** | |
| | Born-Oppenheimer Approximation, Molecular Orbital Theory and its Applications, Valence Bond Theory and its Applications, LCAO-MO Theory. | |
| ***TEXT BOOKS*** | *1. Introductory Quantum Chemistry, A.K. Chandra*<br>*2. Fundamentals of Quantum Chemistry, R.K. Prasad* | |
| ***REFERENCE BOOKS:*** | *1. Quantum Chemistry By Ira N. Levine, Seventh edition ISBN-13: 978-0-321-80345-0 Pearson Education Inc. Department 1G, Upper Saddle River, NJ 07458*<br>*2. Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory Revised Edition by* Attila Szabo, Neil S. Ostlund *ISBN-13: 978-0070627390 McGraw-Hill; Revised edition (March 1, 1989)*<br>3. *Quantum Chemistry (Physical Chemistry Series) by Donald A. McQuarrie ISBN-13: 978-0935702132 Univ Science Books (April 1, 1983)* | |
| **CH-506:** | **ATOMIC & MOLECULAR SPECTROSCOPY** | **3 credits** |
| **Course Objective** | 1. Understanding the basic concepts about atomic and molecular specrtoscopy.<br>2. To elucidate students about the physical significance of molecular spectroscopy.<br>3. To provide in-depth knowledge on the application of molecular spectroscopy. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of atomic & molecular spectroscopy<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Atomic Spectroscopy*** | |
| | The electromagnetic spectrum, A general discussion on various molecular excitation processes, Spectra of hydrogen and hydrogen like atoms, alkali metals spectra, L-S coupling, Term symbols, Space quantisation, Zeeman effect, Stark effect, Paschen-Back effect. | |
| ***UNIT-II*** | ***Vibrational and Rotational Spectroscopy*** | |
| | Molecular Spectra of Diatomic Gases, Classification of molecules, Rotational Spectra, Vibrational Spectra, Vibrational-Rotational Spectra, P, Q and R Branches. | |
| ***UNIT-III*** | ***Raman Spectroscopy*** | |
| | Theory of Raman spectra, Rotational Raman spectra, Vibrational Raman spectra, Rotational-Vibrational Raman spectra, comparison with IR spectra. | |
| ***TEXT BOOKS*** | *1. Physical Chemistry by D.N. Bajpai, S. Chand Publishing, 2001, ISBN: 9788121904087*<br>*2. Physical Chemistry Through Problems by Dogra & Dogra, New Age International Private Limited, 2015, ISBN: 8122438059*<br>*3. Fundamentals of Molecular Spectroscopy by G.M. Barrow, McGraw-Hill Book Company, 2017, 4th Ed., ISBN: 9352601734* | |
| ***REFERENCE BOOKS:*** | *1. Physical Chemistry by A.W. Atkins, Oxford University Press, 2018, 11th Ed., ISBN: 9780198814740*<br>*2. Spectroscopy Vol. I & II by Walker & Straw; Chapman and Hall, 1976.*<br>*3. Fundamentals of Molecular Spectroscopy by C.N. Banwell, McGraw-Hill, 2017, 4$^{th}$ Ed.* | |

| **CH-507:** | **PHYSICAL PRACTICAL** | **3 credits** |
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| | 1. Determination of ionization constants of weak acids and verification of Oswald's Dilution law.<br>2. Verification of Onsager's limiting law.<br>3. Conductometric titration of a mixture of $HCl+CH_3COOH$ with NaOH<br>4. Determination of solubility product of $BaSO_4$.<br>5. Potentiometric titration of strong acid with strong base.<br>6. Verification of Beer's Lambert Law and unknown concentration determination.<br>7. Verification of additivity rule spectrophotometrically.<br>8. Determination of temperature coefficient and energy of activation of hydrolysis of ethyl acetate.<br>9. To determine the rate constant of base hydrolysis of ester titrometrically.<br>10. To study the complex formation between ammonia and $Cu^{+2}$.<br>11. To study of an equilibrium $KI + I_2 = KI_3$.<br>12. To study the simultaneous equilibria in benzoic acid - benzene water system.<br>13. Determination of unknown dextrose solution by polarimetry<br>14. Study of inversion of cane sugar in acid medium by polarimetry. | |
| ***BOOK:*** | *1. Experimental Physical Chemistry by Das and Behera*<br>*2. Practical Physical Chemistry by B. Vishwanathan & P.S. Raghavan*<br>*3. Experimental Physical Chemistry by V.D. Athawale* | |
| **CH-507:** | **REVIEW** | **2 credits** |

**FOURTH SEMESTER**

**(Core Courses)**

| **CH-511:** | **ADVANCED ORGANOMETALLIC CHEMISTRY** | **3 credits** |
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| **Course Objective** | 1. To provide basic knowledge and cutting-edge developments in the field of organometallic chemistry<br>2. Students will learn a variety of catalytic and stoichiometric organometallic reactions that demonstrate key synthetic transformations.<br>3. Students will learn the significance of organometallic compounds in the industrial processes. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of advanced organometallic chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***σ- and π-Bonded Organometallic Compounds*** | |
| | History and perspective, definition of organometallic compound, classifications, nature of metal-carbon bond, nomenclature, the 18-electron rule, Preparation and properties of σ-bonded alkyl compounds, Chemistry of σ-bonded aryl compounds, and complexes of allylic, acyclic- and cyclic butadiene ligands. Davis-Green-Mingos (DGM) rules, transition metal π-complexes of olefinic, acetylenic, $\eta^5$- | |

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| | cyclopentadienyl, acyclic pentadienyl, $\eta^5$-cyclohexadienyl and $\eta^5$-cycloheptadienyl ligands: synthesis and reactions. | |
| ***UNIT-II:*** | ***Organometallic Compounds and Unique Reactions*** | |
| | Preliminary idea about the synthesis and reactions of transition metal π-complexes of $\eta^6$-arene, $\eta^6$-cycloheptatriene and $\eta^6$-cyclooctatriene ligands. Coordinative unsaturation, oxidative addition reaction, reductive elimination reaction, Insertion reaction, deinsertion reaction, mechanism of insertion of CO into $CH_3Mn(CO)_5$, intramolecular hydrogen transfer reaction, Agostic interaction, fluxionality and hapticity change in organometallic compounds, transition metal compounds with bonds to hydrogen. | |
| ***UNIT-III:*** | ***Organometallic Compounds in Catalysis*** | |
| | General idea of catalysis, turnover number(TON), turnover frequency (TOF), hydrogenation of alkenes, Tolman catalytic loop, hydroformylation of alkenes (using cobalt and rhodium catalyst), enantioselective hydrofomylation, Zeigler-Natta polymerization of olefins, reduction of carbon monoxide by hydrogen (Fischer-Tropsch reaction), wacker process, mosanto acetic acid synthesis, Cativa process, hydrosilylation reactions, activation of C-H bond, alkene metathesis reactions, Metathesis catalysts, classification of metathesis reactions, importance of metathesis reactions. Preliminary idea about the cross-coupling reactions such as Suzuki, Heck, Sonogashira, Stille, Negishi, Hiyama, and Buchwald-Hartwig. | |
| ***REFERENCE BOOKS:*** | *4. Basic organometallic Chemistry by B. D. Gupta, A. J. Elias, University Press (India) Pvt. Ltd., 2nd edn, Hyderabad, 2013*<br>5. *Organometallic Chemistry by R. C. Mehrotra, A. Singh, New Age International Ltd., 1st edn, 2011, New Delhi* | |
| ***TEXT BOOKS:*** | *1. Organometallic Compounds by Indrajeet Kumar, 4th edn, 2013, Pragati Prakashan, Meerut.*<br>*2. Inorganic Chemistry by G. L. Miessler, D. A. Tarr, 3rd edn., 2004, Pearson Education, Inc.*<br>***3.*** *Inorganic Chemistry by J.E. Huheey, E.A. Keiter, R. L. Keiter, O. K. Medhi, 4th edn, Pearson Education, Inc.* | |
| **CH-512:** | **ADVANCED SPECTROSCOPY** | **3 credits** |
| **Course Objective** | 1. Understanding the basic concepts about specrtoscopy.<br>2. To elucidate students about the physical significance of spectroscopy<br>3. To provide in-depth knowledge on the application of spectroscopy. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of advanced spectroscopy<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the Project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Electron Spin Resonance Spectroscopy*** | |
| | Theory, instrumentation, g-values, hyperfine splitting, ESR spectra of systems with more than one unpaired electrons, double resonance, ENDOR and ELDOR techniques. | |
| ***UNIT-II:*** | ***Photoelectron Spectroscopy*** | |
| | Basic principle, Instrumentation: the basic design of photoelectron spectrophotometer, X-ray photoelectron spectrophotometer, ultraviolet photoelectron spectrophotometer, chemical information from photoelectron spectroscopy, ultraviolet photoelectron spectra and their interpretation, application of X-ray photoelectron spectroscopy, auger lines. | |
| ***UNIT-III:*** | ***Mossbauer Spectroscopy*** | |

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| | Principles of Mossbauer spectroscopy, Experimental methods, Theoretical aspects, Quadrupole splitting, Magnetic hyperfine interaction. | |
| ***BOOKS:*** | *1. Spectroscopy Vol. I & II, Walker & Straw*<br>*2. Fundamentals of Molecular Spectroscopy, C.N. Banwell*<br>*3. Spectroscopy Volume III, Straughan and Walker*<br>*4. Molecular Spectroscopy, P.S. Sindhu*<br>*5. Fundamentals of Molecular Spectroscopy, G.M. Barrow*<br>*6. Physical Chemistry through problems, Dogra & Dogra* | |
| **CH-513:** | **COMPUTER APPLICATION IN CHEMISTRY** | **2 credits** |
| **Course Objective** | 1. Understanding the basic concepts about Computer Application in Chemistry.<br>2. To elucidate students about the physical significance of Computer Application in Chemistry<br>3. To provide in-depth knowledge on the application of Computer Application in Chemistry. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of computer application in chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the Project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Introduction to Computers*** | |
| | Basic structure of a computer: The CPU, the I/O devices, the internal memory, commonly used secondary storage media. Data representation: Overview of binary, octal and hexadecimal number system. The software: Concept of low level and high level languages, Compiler interpreter, editor, operating system concepts, salient features of MS-DOS. Windows operating systems. | |
| ***UNIT-II:*** | ***Programme Development Process*** | |
| | Algorithm, Flowchart, Decision-table, elements of high level programming languages. Input-output statements, conditional statements, control structure, concept of data file, file operations like searching, storing, with reference to C Programming. | |
| ***TEXT BOOKS:*** | *1. Computational Chemistry by A.C. Norris*<br>*2. C Programming Language by Brian W. Kernighan and Dennis M. Ritchie*<br>*3. An Introduction to Digital Computer Design by V. Rajaraman & T. Radhakrishnan* | |
| ***REFERENCE BOOKS:*** | *1. Cramer, Christopher J. Essentials of Computational Chemistry. 2nd ed. West Sussex: Wiley, 2004*<br>*2. The C++ Programming Language (4th Edition) Bjarne Stroustrup Addison-Wesley ISBN 978-0321563842* | |
| **CH-514** | **ANALYTICAL PRACTICAL** | **2 credits** |

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| | 1. Determine the pK value of an acid-base indicator.<br>2. To estimate metal ions by spectrophotometric titration.<br>3. To determine the pH of a given solution by spectrphotometrically.<br>4. Adsorption of $CH_3COOH$ on activated charcoal and verification of Freundlich's & Langumir's adsorption isotherm.<br>5. Simultaneous estimation of Mn and Cr in a solution of $KMnO_4$ and $K_2Cr_2O_7$.<br>6. Determination of hydrolysis constant of aniline hydrochloride.<br>7. Determination of ionisation constants of multibasic acid potentiometrically.<br>8. Determination of association constants of $CH_3COOH$ by distribution method between water and toluene.<br>9. To study the rate of acid catalysed iodination of acetone in presence of excess acid and acetone.<br>10. To study the stability constant of a metal complex.<br>11. Estimation of Fe ion in a solution of Mhor's salt. |
| ***BOOK:*** | *1. Experimental Physical Chemistry by Das and Behera*<br>*2. Practical Physical Chemistry by B. Vishwanathan & P.S. Raghavan*<br>*3. Experimental Physical Chemistry by V.D. Athawale* |
| **CH-515:** | **PRACTICAL ON COMPUTER IN CHEMISTRY** **2 credits** |
| **Course Objective** | 1. Understanding the basic concepts of computer application in Chemistry.<br>2. To learn various software to solve technical problems. |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of computer softwares.<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the Project or field assignment as per the knowledge gained in the course |
| | 1. Use of computer programmes like EXCEL, Chemdraw.<br>2. Execution of the Software to solve problems.<br>Development of small programmes for solving chemical problems. |

**(Elective Courses)**

**GROUP-A**

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| **CH-521** | **ADVANCED ORGANIC SYNTHESIS** **3 credits** |
| **Course Objective:** | 1. Learning and understanding the principles behind physical and chemical nature of heterocyclic compounds and their reaction mechanisms<br>2. Imparting knowledge in the theory and applications of various heterocyclic compounds and their physical and chemical behaviour in order to synthesize them for further use in medicinal and material science applications.<br>3. Knowing the synthetic utility of various metallic reagents in chemical transformations in the preparation of various natural and synthetic drugs, materials. |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of advanced organic synthesis<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course |
| ***UNIT-I*** | Chemistry of some natural products, A study of the following compounds involving their |

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| | isolation, structure elucidation, synthesis and biogenesis – Alkaloid - morphine, flavonoids - quercetin, cyanidin and genestein, α-terpeneol, α-pinene. coumarins | |
| ***UNIT-II:*** | Systematic nomenclature (Hantzch-Widman system) for monocycle and fused heterocycles. General approach to heterocyclic synthesis-cyclisation and cycloaddition route, Synthesis and reactivity of common heterocyclic compounds containing one or two heteroatoms (O, N, S): furan, pyrrole, thiophene, indole, thiazole, oxazole, imidazole, pyrazole, pyrimidine, seven membered heterocycles (azepine). | |
| ***UNIT-III:*** | Organometallics Chemistry of Transitional Element and applications in organic synthesis: Preparative structural and characteristic aspects: oxidative insertion, reductive elimination, ligand migration from metal to carbon. Organo lithium, organo copper compounds, organo boranes, organometallic compounds of Zinc, Cadmium, nickel, palladium, mercury and their utilization in chemical reactions. Reactions involving triple bond (Sonogashira reaction), C-C (Kumada, Negishi, Heck, Suzuki and Stille reactions) and C-N (Buchwald-Hartwig reaction) cross-coupling reaction. | |
| ***TEXT BOOKS:*** | *1. Organic Chemistry II by I. L. Finar*<br>*2. Principles of Organic Synthesis by R. O. C. Norman*<br>*3. Creativity in Organic Synthesis by J. S. Bindra and R. Bindra*<br>*4. Heterocyclic Chemistry by A R Katrizsky*<br>*5. Recent Literatures and Review Articles* | |
| ***REFERENCE BOOKS:*** | *1. Jonathan Clayden, Nick Greeves, and Stuart Warren. "Organic Chemistry," Oxford University Press, 2014.*<br>*2. The Essence Of Heterocyclic Chemistry, Parikh, Arun, New Age International, 1st Edition, 2013*<br>*3. Heterocyclic Chemistry, V. K. Ahluwalia, Alpha Science International, 2012*<br>*4. Advanced Organic Chemistry: Structure and Mechanisms (Part A &B). Frances A Carey and Richard J Sundberg, Springer, 2015*<br>*5. Heterocyclic chemistry, R. K. Bansal, New Age International Private Limited; Fifth edition, 2017.* | |
| **CH-522:** | **PHOTOPHYSICAL PROCESSES & INSTRUMENTATION** | **3 credits** |
| **Course Objective** | 1. To provide in-depth knowledge on different photophysical processes, and determination of their rate constants.<br>2. To elucidate students about the physical significance of photophysical processes and their application in chemical and biological sciences.<br>3. To provide knowledge of instruments to monitor different photophysical processes. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of photophysical processes & instrumentation<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | Importance of photochemistry, Laws of photochemistry, photochemistry and spectroscopy, Interaction between light and matter, electronic energy states of atoms, spectroscopic terms for electronic states, orbital symmetry and molecular symmetry, and notation for excited states of organic molecules, Electric dipole transition, Einstein's treatment absorption and emission phenomena, time-dependent Schrödinger equation, the rules governing the transitions between two energy states, Nature of changes on electronic excitation, Electronic, vibrational and rotational energies, potential energy diagram, shapes of absorption band and Frank-Condon principle, emission spectra, environmental effect on absorption and emission spectra, excited state dipole moment, excited state acidity constants-$pk^*$ values, and Wigner spin conservation rule. | |
| ***UNIT-II:*** | Types of photophysical pathways, radiationless transitions-internal conversion and | |

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| | intersystem crossing, fluorescence emission, fluorescence and structure, delayed fluorescence, Quenching of Fluorescence, Theory of Collisional Quenching, Derivation of the Stern-Volmer Equation, Theory of Static Quenching, Combined Dynamic and Static Quenching, Examples of Static and Dynamic Quenching, Deviations from the Stern-Volmer Equation, Quenching Sphere of Action, Derivation of the Quenching Sphere of Action, Effects of Steric Shielding and Charge on Quenching, Fractional Accessibility to Quenchers, Applications of Quenching to Proteins and Membranes, Characteristics of Resonance Energy Transfer, Theory of Energy Transfer for a Donor–Acceptor Pair, Distance Measurements Using FRET. |
| ***UNIT-III:*** | Principles & techniques of Steady State Spectrofluorometers & TCSPC Spectrofluorometers and its Applications, brief concept and applications of Fluorescence Anisotropy & Fluorescence lifetime. |
| ***TEXT BOOKS:*** | 1. *Fundamentals of Photochemistry by K. K. Rohatagi-Mukherjee, New Age International, 3rd edition (2014)*<br>2. *Principles of Fluorescence Spectroscopy by J. R. Lakowicz* |
| ***REFERENCE BOOKS:*** | 1. *Molecular Photochemistry by N. J. Turro,*<br>2. *Principles of Photochemistry by J.A. Baltrop & J.D. Coyle* |
| **CH-523:** | **CHEMISTRY OF NANOMATERIALS** **3 credits** |
| **Course Objective:** | 1. Learning and understanding the principles of nanomaterials, syntheses and their characterizations.<br>2. Introduce students to the modern areas of nanotechnology and train them in the current topics to enable them to take up positions in industry and education research.<br>3. Apply and communicate the knowledge of nanomaterials in science and technology.<br>4. Enable students to apply the concepts of advanced polymers to various industrial applications. |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of chemistry of nanomaterials<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course |
| ***UNIT-I:*** | ***Semiconductors and Devices*** |
| | (a) Conducting and semiconducting organic materials. Synthesis and characterizations of organic semiconductors, band gap engineering. Doping of semiconductors. Core-shell structures and applications.<br>(b) Nanostructured Carbon based materials: Fullerene, Carbon nanotube, graphene. Artificial photosynthetic devices, storage-memory and sensors. Electronic devices and coating. High temperature resistant organic/inorganic polymers. |
| ***UNIT-II:*** | ***Nanomaterials for Energy Conversion and Storage Materials*** |
| | (a) Nanomaterials for Solar Energy Conversion Systems. Principles of photovoltaic energy conversion (PV), Structural characteristics and concepts. Types of photovoltics Cells, Physical concept of photovoltaic cells, Organic solar cells, Dye-Sensitized Solar Cells, Organic-Inorganic Hybrid solar cells.<br>(b) Conducting and ferroelectric materials, structure and features of ferroelectric materials, ceramic materials, organic/inorganic hybrid materials and their fabrications and applications. |
| ***UNIT-III:*** | ***Structure Properties of Polymers and Applications*** |
| | (a) Structure-property relationship, stress-strain behavior, crystalline melting point, effect of chain flexibility and other steric factors, entropy and heat of fusion, glass transition temperature, relationship between Tm and Tg. Effect of |

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| | molecular weight, property requirements and its utilization.<br>(b) Synthetic procedure commercial polymers (polycarbonate, polyurethane, polymethylmethacrylate, polyethyethyleneterpthalate, Nylon, polystyrene), Fire retarding and biomedical polymers |
| ***TEXT BOOKS:*** | *1. Semiconductor for Solar Cells by H J Moller, Artech House Inc, MA, USA, 1993.*<br>*2. Solis State Electronic Device by Ben G Streetman, Prentice Hall of India Pvt Ltd., New Delhi.*<br>*3. Text Book of Polymer Science by F.W. Billmeyer Jr, Wiley.* |
| ***REFERENCE BOOKS:*** | *1. Organic Photovoltaics – Materials, Device Physics and Manufacturing Technologies, Eds. By C. Brabec, V. Dyakonov, U. Scherf), 2nd Ed., Wiley-VCH, Germany, 2014.*<br>*2. Polymer Science by V.R. Gowariker, N.V. Viswanathan and J. Sreedhar, Wiley-Eastern.* |
| **CH-524:** | **INDUSTRIAL PROCESSES** **3 credits** |
| **Course Objective:** | 1. Learning and understanding the principles of different industrial processes.<br>2. Introduce various concepts related to industrial process and applications to students.<br>3. Applying and communicate the knowledge of advanced technologies.<br>4. Enable students to apply the concepts to various industrial applications. |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of industrial processes<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course |
| ***UNIT-I:*** | Petroleum and coal based chemicals: Composition of petroleum, cracking processes, Commercial production of ethylene, acetylene, polymerization mechanisms, Addition, condensation, step growth, chain growth, method of polymerization, Distillation of coal. |
| ***UNIT-II:*** | (a) Oil based industries: Oils and fats: Solvent extraction of oils, hydrogenation of oil, use of oil in the manufacturing of soap, paints and varnishes.<br>(b) Surface active agents: classification and manufacturing of detergents used for cleansing purpose.<br>(c) Fermentation industries. A general discussion on fermentation conditions, manufacturing of penicillin. |
| ***UNIT-III:*** | Pesticides and Pharmaceutical industries: DDT manufacture, BHC manufacture, 2,4-D manufacture, parathion manufacture, Pharmaceutical industry |
| ***BOOKS:*** | 1. *Outlines of Chemical Technology by M. Gopala Rao and Marshall Sittig, Affiliated East-West Press Pvt. Ltd.*<br>2. *Industrial Chemistry by B. K. Sharma, Krishan Prakashan, 2014* |

## GROUP-B

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| **CH-531:** | **ADVANCED ANALYTICAL CHEMISTRY** | **3 credits** |
| **Course Objectives:** | 1. To provide the students an in-depth knowledge of various modern analytical techniques.<br>2. To inculcate basic knowledge of statistical treatment of data among the students.<br>3. To understand the applications of chromatographic techniques and spectrophotometry in a variety of fields. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of advanced analytical chemistry<br>CO-2. Analyse the various concepts to understand them through case studies | |

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| | CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Reliability of Analytical Data*** | |
| | Errors in chemical analysis, classification of errors, significant figures, precision and accuracy, methods of expressing accuracy, absolute error and relative error, methods of expressing precision, average deviation, standard deviation, confidence limits, median value, range, coefficient of variation.<br>Sampling in analysis definition: Theory of sampling, technique of sampling, statistical criteria of good sampling and required size, stratified sampling, transition and storage samples. | |
| ***UNIT-II:*** | ***Solvent Extraction and Ion Exchange*** | |
| | Solvent extraction: basic principles, classification of extraction, mechanism of extraction, extraction equilibria, technique of extraction, applications in analytical chemistry.<br>Ion exchange: synthesis and characteristics of ion exchange, ion exchange equilibrIa, technique of ion exchange, application of ion exchange for separation. | |
| ***UNIT-III:*** | ***Ultraviolet and Visible Spectrophotometry*** | |
| | Introduction, nature of absorbing species, visual colorimetry, photo-electric cell and filters, Photoelectric filter photometry, errors in photoelectric photometry, Spectrophotometry, working of spectrophotometer, simultaneous spectrophotometry, differential spectrophotometry, reflectance spectrophotometry, photometric titrations, composition of coloured complex Sandell's sensitivity, relative concentration and Ringbon's plot, principle of Nephelometry and Turbidimetry, application and factors affecting Nephelometric and Turbidimetric measurement. | |
| ***TEXT BOOKS:*** | 1. *Instrumental Methods of Chemical Analysis by Gurdeep R. Chatwal, Sham K. Anand, Himalaya Publishing House, 5th Edition,2014.*<br>2. *Basic Concept of Analytical Chemistry by S.M. Khopkar,* New Age International (P) Ltd., 2008.<br>3. *A Text Book of Quantitative Inorganic Analysis by A.I. Vogel,* P*earson Education Ltd., 7th edition, 2012.* | |
| ***REFERENCE BOOKS*** | 1. *Instrumental Method of Analysis by H. Willard, L. Merritt, J. Dean & F. Settle, CBS publisher and distributors Pvt. Ltd., 7th edition, 2004.*<br>2. *Analytical Chemistry (Theory and Practice) by U.N. Dash, Sultan Chand & Sons Pvt. Ltd., Mew Delhi, 2013.* | |
| **CH-532:** | **SUPRAMOLECULAR CHEMISTRY** | **3 credits** |
| **Course Objective:** | 1. Understanding basic concepts related to chemical and physical properties of supramolecules.<br>2. To impart knowledge in the theory and applications of various supramolecular concepts and their utilization in different fields of science | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of supramolecular chemistry<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Fundamentals of Supramolecular Chemistry*** | |
| | Terminology and definitions in supramolecular chemistry. Intermolecular forces: Ion | |

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| | pairing, ion-dipole and dipole-dipole interactions; hydrogen bonding; cation-pi, anion-pi, pi-pi interactions and Van der Waal forces. Solvent and solution properties, solvation and hydrophobic effect. Binding constants; definition and use, determination of binding constant by physical methods. | |
| ***UNIT-II:*** | ***Molecular Recognition*** | |
| | Principle of molecular recognition, host-guest complementarity, preorganisation, chelate effect, cooperativity. Synthesis and applications of supramolecular host (crown ethers, lariat ethers, podands, cryptands, spherands, calix[n]arenes, cyclodextrine) as cation and anion binding receptors and receptors for ion-pair recognition. | |
| ***UNIT-III:*** | ***Supramolecular Reactivity and Catalysis*** | |
| | Organocatalysis mediated through hydrogen bonding, preconcentration, self-assembly of catalysts and preorganisation of catalyst-substrate systems. Influence of organisation (effective molarity) on catalysis, Catalytic acyl transfer, acid-base catalysis, catalysis hydrolysis as ATPase mimic | |
| ***TEXT BOOKS:*** | *1. Supramolecular Chemistry: from Molecules to Nanomaterials Eds. by P.A. Gale and J.W. Steed (2012).*<br>*2. Modern Supramolecular Chemistry by F. Diederich, P. J. Stang, R. T. Tykwinski (2008). .*<br>*3. Core Concepts in Supramolecular Chemistry and Nanochemistry by J. W. Steed, D. R. Turner, K. J. Wallace (2007).*<br>*4. Supramolecular Chemistry by J.W. Steed and J.L. Atwood (2011).*<br>*5. Supramolecular Chemistry: Concepts and Perspectives by J.-M. Lehn, Wiley VCH, Weinheim (1995).* | |
| ***REFRENCE BOOKS:*** | *1. Supramolecular Chemistry by V. Balzani (Editor), L. De Cola, Kluwer, Dordrecht (1992).*<br>*2. Introduction to Supramolecular Chemistry by H. Dodziuk, Kluwer Academic Publishers, The Netherlands (2002).*<br>*3. Supramolecular Assemblies Y. Murakami (Editor), Mita Press, Tokyo, (1990).*<br>*4. Advances in Supramolecular Chemistry, Vol 1 (1990), Vol 2 (1992), Vol 3 (1993) by G. W. Gokel (Editor), JAI Press, Greenwich.*<br>*5. Supramolecular Chemistry – Fundamentals and Applications. Advanced Textbook by T. Kunitake, K Ariga, Berlin: Springer-Verlag Heidelberg, 2006. 208 p. ISBN 978-3-540-01298-6.* | |
| **CH-533:** | **SURFACE CHEMISTRY & CATALYSIS** | **3 credits** |
| **Course Objectives:** | 1. To understand the structures of the various organised molecular assemblies.<br>2. To provide knowledge about the analytical applications of the organised assemblies.<br>3. To impart knowledge about the characterisation and applications of the solid catalysts. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of surface chemistry & catalysis<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Structural Aspects of Organized Molecular Assemblies*** | |
| | Surfactants, classification of surfactants, micelles, critical micellar concentration, different methods for determination of critical micellar concentration, thermodynamics of micellization, aggregation number, shape & size and their | |

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| | determination, shape transition, reverse micelles, emulsion, microemulsion (oil in water and water in oil), effect of cosurfactants, thermodynamics of microemulsion formation. | |
| ***UNIT-II:*** | ***Analytical Applications of Organized Assemblies*** | |
| | Application of micellar systems for UV-Visible/fluorescence spectroscopic detection of ions, micellar enhanced phosphorescence and fluorescence, micellar systems in liquid-liquid extraction, surfactant aggregates in flame and plasma atomic spectrometry, micellar systems in chromatography, recent developments in micellar chromatography, application of surfactants in gel electrophoresis. | |
| ***UNIT-III:*** | ***Characterization of Industrial and Model Solid Catalysts*** | |
| | Historical development of catalysis, dividing of catalysis to homogeneous and heterogeneous, enzymatic, phase transfer catalysis. Preparation and characterization of catalysts, influence of heat and mass transport on the rate of catalytic process. Evaluation of activity and selectivity of catalysts. Catalysts acido-basic, hydrogenation-dehydrogenation, oxidation-reduction, zeolite. Mechanisms of catalyzed reactions. Examples of catalysts applications– cracking, alkylation, hydrogenation, hydration and dehydration processes. Modern sorption and spectral methods of characterization of catalysts. | |
| ***TEXT BOOKS*** | 1. *"Catalysis (An integrated Approach to Homogeneous, Heterogeneous and Industrial Catalysis)" by Jacob A. Moulin P. W. N. M. van Leeuwen, and R. A. Van Santen, Elsevier(Studies in Surface Science and Catalysis, vol 79).*<br>2. *Physical Chemistry of Macromolecules by C. Tanford, John Wiley & Sons,1st edition, 1961.* | |
| ***REFERENCE BOOKS*** | 4. *Introduction to Surface Chemistry and Catalysis by Gábor A. Somorjai,* Wiley-Blackwell, *1994.* | |
| **CH-534:** | **MATERIAL AND ENERGY BALANCE** | **3 credits** |
| **Course Objectives:** | 1. To understand the materials concept and chemical processes.<br>2. To provide knowledge about the analytical applications.<br>3. To impart knowledge about the characterisation and applications. | |
| **Course Outcome** | CO-1. Remember and understand the basic concepts/principles of material and energy balance<br>CO-2. Analyse the various concepts to understand them through case studies<br>CO-3. Apply the knowledge in understanding practical problems<br>CO-4. Execute/Create the project or field assignment as per the knowledge gained in the course | |
| ***UNIT-I:*** | ***Material Balance*** | |
| | (a) Material Balances Without Chemical Reactions: Process Flow-Sheet, Material Balances, Recycling Operations, Material Balances of Unsteady State Operations.<br>(b) Material Balances Involving Chemical Reactions, Definition of Terms, Electrochemical Reactions, Recycling, Parallel and Bypassing Operations, Metallurgical Applications. | |
| ***UNIT-II:*** | ***Energy Balance*** | |
| | Energy and Thermo-Chemistry, Energy Balances, Heat Capacity, Heat Capacity of Gases at Constant Pressure, Sensible Heat Changes in Liquids, Heat Capacity of Gaseous Mixtures, Latent Heats, Enthalpy Changes During Phase Transfers Accompanied by Sensible Heat Changes, Enthalpy Changes Accompanying | |

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| | Chemical Reactions, Effect of Temperature on Heat of Formation, Heat of Reaction, Adiabatic Reactions, Effect of Pressure on Heat of Reaction, Thermochemistry of Mixing Process, Dissolution of Solids, Liquid-Liquid Mixtures, Heat of Solution by Partial Molal Quantities. |
| ***UNIT III:*** | ***Stoichiometry and Unit Operations*** |
| | Distillation, Absorption and Stripping, Extraction and Leaching, Crystallisation, Psychrometry, Drying, Evaporation, Less Conventional Operation |
| ***BOOK:*** | *Stoichiometry by B I Bhatt and S. M. Vora, Tata McGraw Hill, New Delhi 2007* |