DEPARTMENT OF CHEMISTRY

KOHIMA SCIENCE COLLEGE (AUTONOMOUS),

JOTSOMA, NAGALAND

REVISED M.SC SYLLABUS
2023

CHOICE-BASED CREDIT SYSTEM
(CBCS)

Dated: 11-05-2023

M.Sc. Chemistry Course structure (CBCS Scheme)

1st Semester		**Total 24 credits**
CHECORE- 1	Inorganic Chemistry-I	4
CHE CORE- 2	Organic Chemistry-I	4
CHE CORE- 3	Physical Chemistry-I	4
CHE CORE- 4	Physical Chemistry-II	4
LAB COURSE –I	Organic Chemistry	8
2nd Semester		**Total 24 credits**
CHE CORE- 5	Inorganic Chemistry-II	4
CHE CORE- 6	Organic Chemistry-II	4
CHE CORE- 7	Organic Chemistry-III	4
CHE CORE- 8	Physical Chemistry-III	4
LAB COURSE –II	Inorganic Chemistry	8
3rd Semester		**Total 24 credits**
CHE CORE- 9	Inorganic Chemistry-III	4
CHE CORE- 10	Physical Chemistry-IV	4
LAB COURSE –III	Physical Chemistry	8
DSE-1		4
DSE-2		4
4th Semester		**Total 24 credits**
CHE CORE- 11	Inorganic Chemistry-IV	4
CHE CORE-12	Organic Chemistry-IV	4
LAB COURSE –IV	Project work/Course Work	8
DSE-3		4
DSE-4		4

FIRST SEMESTER **CHEM CORE – 1** **Credit: 4**

INORGANIC CHEMISTRY - I

Unit 1

Symmetry and Structure

Symmetry elements and operations; equivalent symmetry elements and equivalent atoms; symmetry point groups with examples from inorganic compounds; groups of very high symmetry; molecular dissymmetry and optical activity; systematic procedure for symmetry classification of molecules and illustrative examples; molecular symmetry for compounds having co-ordination numbers 2 to 9. Brief review of group theory, Matrix representation;Reducible and irreducible representations.

Unit 2

(a)Stereochemistry and Bonding: LCAO-MO theory for homonuclear and heteronuclear diatomic molecules; orbital symmetry and overlap; Walsh diagrams; electronegativity (Pauling, Mulliken and Allred-Rochow methods); and polarity of bonds; review of VSEPR model and the use of outer d-orbitals.

(b) Metal-Ligand Equilibria in Solution: Stepwise and overall formation constants; trends in stepwise formation constants; determination of binary formation constant by spectrophotometry; factors affecting stability of metal complexes and chelate effect.

Unit 3 ***Magnetic Properties:***

Brief review of different types of magnetic behavior, spin-orbit coupling, quenching of orbital angular momenta, temperature-independent paramagnetism, measurement of magnetic susceptibility using Gouy and Faraday methods, Term symbols for metal ions;

Unit.4. ***Crystal field theory:***

Crystal field theory and its application to explain magnetic properties of coordination compounds, spin crossover; Structural effects: ionic radii and Jahn-Teller effect; octahedral vs. tetrahedral coordination, magnetic properties of Lanthanides and Actinides and splitting of f-orbitals in octahedral field.

Unit 5.*Electronic Structure of Transition Metal Complexes*

Electronic absorption spectra of octahedral and tetrahedral complexes, Orgel diagrams, Tanabe-Sugano diagrams, calculation of Dq, B and ß values, selection rules, band intensities and band widths, spectra of high-spin octahedral and tetrahedral complexes of d^1 to d^9 systems, Spectrochemical series; Adjusted crystal field theory, Nephelauxetic series, molecular orbital theory of complexes (qualitative principles involved in complexes with and without π-bonding), MO diagrams for octahedral and tetrahedral complexes and charge-transfer spectra.

Recommended Books and References

1. J. E. Huheey, E. A. Keiter, R. L. Keiter& O. K. Medhi.*Principles of Structure and Reactivity* (1st
impression), Pearson Education (2006).
2. F. A. Cotton. *Chemical Applications of Group Theory*, (3rd edn.), John Wiley & Sons (1999).
3. F. A. Cotton and G. Wilkinson, *Advanced Inorganic Chemistry* (5th edition), John Wiley (1988).
4. P. Atkins, T. Overton, J. Rourke, M. Weller & F. Armstrong.*Shriver and Atkins Inorganic Chemistry*, Oxford University Press (2006).
5. N. N. Greenwood & A. Earnshaw. *Chemistry of the Elements*, Pergamon Press (1984).
6. F. Basolo& R. G. Pearson, *Mechanism of Inorganic Reactions*, Wiley Eastern (1967).
7. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann.*Advanced Inorganic Chemistry* (6th
edition), John Wiley (1999).
8 S. F. A. Kettle, *Physical Inorganic Chemistry*, Spectrum (1996).
9. B. Douglas, D. McDaniel and J. Alexander. *Concepts and Models of Inorganic Chemistry* (3rd edn.),
John Wiley & Sons (1994).

CHEM CORE-2 Credits: 4

ORGANIC CHEMISTRY – I
(Stereochemistry and Organic reaction)

Unit 1 ***Stereochemistry***

Configuration nomenclature; Axial and planar chirality and helicity; Topicity and prostereo-isomerism; Racemic modification and optical purity; Conformational analysis of acyclic, cyclic, heterocyclic and steroidal systems; Effects of conformation on reactivity.Regioselectivity, stereospecificity and stereoselectivity: Mechanistic and stereochemical aspects of Addition of halogen polar reagents to alkenes.

Unit 2 ***Substitution Reaction***

Applications of acid-base concept, HSAB theory and its application in nucleophilic substitution at saturated carbon; Parameters influencing reaction rates; Hammett and Taft equations, neighboring group participation by π and σ bonds, Anchimeric assistance; Synthetic applications of nucleophilic substitution involving alcohols, thiols and amines ; Aromatic nucleophilic substitutions.

Unit-3*Elimination Reaction*

Mechanism and stereochemistry of different types of eliminationreactions; Effects of substrate structure, attacking base, leaving group and medium; Formation of other double bonds (C=N, C=O) and triple bonds by elimination reactions.

Unit 4 ***Photochemistry***

Photochemistry of alkenes and carbonyl compounds; Photooxygenation;Photochemistry of aromatic compounds; Photochemical isomerisation, addition and substitution;Photo-Fries rearrangement of ethers and anilides; Barton reaction, Hoffmann-Loefller-Freytag reaction, di-π- methane rearrangement; Singlet molecular oxygen reactions; Photo-cleavages.

Unit 5 ***Pericyclic Reaction***

Main features of pericyclic reactions; Woodward-Hoffman rules, correlationdiagram and FMO approaches; Electrocyclic reactions – conrotatory and disrotatory motions for *4n*and *4n+2* systems;. Cycloadditions – antarafacial and suprafacial additions, [2+2] and [4+2]reactions (*hν*and *Δ*), 1,3-dipolar cycloadditions and chelotropic reactions; Sigmatropic*[i,j]* shiftsof C-H and C-C bonds; Sommelet-Hauser, Claisen, thio-Claisen, Cope and aza-Coperearrangements.

Recommended Books and References

1. D. Nasipuri, *Stereochemistry of Organic Compounds*, 2nd Edn, New Age International (1994).
2. J. March. *Advanced Organic Chemistry: Reactions, Mechanisms and Structure* (4th edn.), Wiley Student Edition, John Wiley & Sons Asia Pte. Ltd. (2005).
3. P. S. Kalsi. *Stereochemistry, Conformation and Mechanism* (7th edn.), New Age (2008).
4. C. Depuy& O. L. Chapman. *Molecular Reactions and Photochemistry*, Prentice-Hall of India (1975).
5. Basic Stereochemistry of organic molecules, SubrataSen Gupta Oxford university press
6. F. A. Carey & R. J. Sanburg. *Advanced Organic Chemistry*, Part A and B, 3rd edn. (1990).
7. Wamser& Harris, *Fundamentals of Organic Reaction Mechanisms*, John Wiley (1990).
8. R. B Woodward & R. Hoffman, *Conservation of Orbital Symmetry*; Verlag-Chemie Academic Press (1970).
9. I. Fleming. *Frontier Orbital Theory and Organic Reactions*, John Wiley & Sons (1976).A. P.Marchand& R. E. Lehr, *Pericyclic Reactions*, Academic Press (1977).
10. P.S. Kalsi, Stereochemistry conformation and mechanism (7th Edn), New Age International (2008).

CHEM CORE-3

PHYSICAL CHEMISTRY –ICredits: 4

(Quantum, Surface, Solid state Chemistry & Spectroscopy)

Unit 1 ***General Principles of Quantum Mechanics and Application to Model Systems***

Introduction; operators and related theorems; uncertainty principle; postulates; properties of wave functions; Schrodinger equation; energy eigen value equation; equation of motion and constant of motion.

Exactly solvable problems: Particle in a box, harmonic oscillator, rigid rotator, step potential and tunneling, hydrogen atom.

Unit 2 ***Approximation Methods and Chemical Bonding***

Linear and non-linear variations method; applications (He atom and other simple systems); Hellmann-Feynmann theorem; antisymmetry principle and many-electron wave functions.

Born-Oppenheimer approximation; valence bond (VB) and molecular orbital (MO) theory for diatomic molecules – hydrogen molecule ion, hydrogen molecule; excited states of H_2 – singlet and triplet; non-crossing rule and correlation diagram; hybridization; Huckel MO treatment for simple and conjugated polyenes.

Unit 3 ***Adsorption and Aggregation***

Surface tension and surface free energy; Pressure across an interface: Laplace equation, Kelvin equation; Wetting: Young-Dupre equation; Adsorption in liquid systems: Gibbs adsorption isotherm; Adsorption on solids: Langmuir isotherm, BET isotherm. Surfactants, classification of surfactants, hydrophobic interaction, aggregation/micellization of surfactants, critical micelle concentration (cmc), factors affecting the cmc, thermodynamics of micellization: phase separation and mass action models.

Unit 4 ***Solid State Chemistry***

Review of the basic concepts: Bragg's law, Miller indices, Elements of symmetry (plane, axis and centre of symmetry). Crystal Defects: Types of defects, thermodynamics of Schottky and Frenkel defect formation, Kroger-Vink notation for crystal defects. Ionic Conductivity & Photoconductivity; Colour Centers, Traps, Phosphors;

Solid Solutions: Substitutional, interstitial and subtractional solid solutions & distortions. Electrical and Magnetic Properties (Hall Effect); BCS-type superconductivity.

Unit 5 ***Microwave, Infrared and Raman Spectroscopy***

Introduction:Interaction of light with matter, mechanism of absorption & emission of radiation. Microwave& Vibrational spectroscopy: rigid rotor model; rotational spectra of diatomics and polyatomics; effect of isotopic substitution, selection rules and intensity distribution.

Vibrational spectra of diatomics; Morse potential; Vibration-rotational spectra of diatomics; P.Q,R branches, normal modes of vibration, overtones, hot bands. Raman spectroscopy: Origin; rotational and vibrational Raman spectra of diatomics.

Recommended Books and References

1. *Quantum Chemistry*, I. N. Levine. Prentice Hall India (2001).
2. *Quantum Chemistry*, D. A. McQuarrie. Viva Books Pvt Ltd (2003)
3. *Introductory Quantum Chemistry*,A. K. Chandra. Tata McGraw Hill (1994).
4. *Micelles: Theoretical and Applied Aspects*, Y. Moroi. Plenum (1992).
5. *Solid State Chemistry and its Applications*, A. R. West. John Wiley (1998).
6. *Fundamentals of Molecular Spectroscopy*, C. N. Banwell and E. M. McCash. 4th edn., Tata McGraw-Hill, New Delhi (1994).
7. *Physical Chemistry*, D. A. McQuarrie and J.D. Simon –VIVA Students Ed. (2003).
8. *Principle of physical chemistry*,B.R.Puri&L.R.Sharma&M.S.Patiana(2013) edition.

9.Molecular Quantum Mechanics, P. W. Atkins. Oxford University Press (1986)

10.Coulson's Valence, R. McWeeny. ELBS (1979).

11. *Molecular Spectroscopy*, J. D. Graybeat. McGraw-Hill International Edition (1988).

CHEM CORE-4 **Credits:4**

PHYSICAL CHEMISTRY -II
(Electrochemistry & Thermodynamics)

Unit 1 ***Electrolyte Solution***

Structure of water, effect of an ion on the structure of water, solvation number,Fugacity and activity, activity coefficients and physical significance of activity coefficient of an electrolyte, determination of mean ionic activity coefficient by Solvent vapour pressure and Cell concentration methods,expression of mean ionic activity coefficients in terms of ionic strength. , ion – ion interactions, Debye-Huckel theory of ion-ion interaction; Linearized Poisson–Boltzmann equation; derivation of Debye – Hückel – Onsager equation, limiting law.

Unit 2 Electrochemistry

Ion-solvent interaction: free energy change due to ion-solvent interactions; Born model;electrical double layer; Helmholtz-Perrin model; Gouy-Chapman diffuse charge model and Stern model.Electrodics: The basic electrodic equation: Butler–Volmer equation and Tafel equation; overpotential; polarizable and nonpolarizable interfaces. Irreversible electrode processes: Overvoltage and polorography
Bioelectrochemistry: Electrochemical mechanisms of the nervous system.

Unit 3 ***Transport Phenomena***

Diffusion coefficients, Fick's first law of steady – state diffusion, Fick's second law of non – steady state diffusion, relation between diffusion coefficient and mean free path, relation between thermal conductivity / viscosity and mean free path of a perfect gas, Einstein's relation between diffusion coefficient and absolute mobility of ions, Stokes – Einstein equation, Nernst – Einstein equation, Nernst – Planck flux equation.

Unit 4 ***Non-Equilibrium Thermodynamics***

Entropy of irreversible processes – Clausius inequality; entropy production (heat flow, chemical reactions, electrochemical reactions) and entropy flow; Entropy production in open systems; Rate of entropy production – generalized forces and fluxes; Phenomenological equations, Onsager reciprocity relation; Electrokinetic phenomena; Stationary non-equilibrium states -states of minimum entropy production.

Unit 5 ***Statistical Thermodynamics***

Concept of distribution, Thermodynamic probability and most probable distribution. Ensemble averaging, postulates of ensemble averaging. Canonical, grand canonical and microcanonical ensembles, corresponding distribution laws (using Lagrange's method of undetermined multipliers).Partition function - Translational, Rotational, Vibrational and Electronic partition functions, calculation of thermodynamic properties in terms of partition function.Applications of partition functions. Heat capacity behaviour of solids - Chemical equilibria and equilibrium constant in terms of partition functions, Fermi-Dirac statistics, distribution law and applications to metal. Bose-Einstein statistics - distribution law and application to helium.

Recommended Books and References

1. *Modern Electrochemistry* J. O. M. Blockris and A. K. N. Reddy: Vol. 1 : Ionics, 2nd Ed., Plenum Press, New York, (1998).
2. *Modern Electrochemistry*, J. O. M. Blockris and A. K. N. Reddy and M. Gamboa – Aldeco : Vol. 2A, Fundamentals of Electrodics, 2nd Ed. Plenum Press, New York, (2000).
3. *Electrochemical Methods: Fundamentals and Applications* A. J. Bard and L. R. Faulkner, 2nd Ed., John Wiley &Sons : New York, (2002).
4. *Non-Equilibrium Thermodynamics – Principlesand Applications* C. Kalidas and M. V. Sanganarayana., Macmillan India (2002).
5. *Statistical Thermodynamics* (Hardback) By (author) M.C. Gupta, Publisher: New Age International.(1998).
6. Thermodynamics, J. Rajaram and J.C. Kuriacose, Educational Publishers.(2013).
7. Thermodynamics, R. C. Srivastava, Subit K. Saha, Abhay K. Jain, Prentice Hall of India, Pvt. Ltd.(2004).

8.Electrochemical Methods : Fundamentals and Applications A. J. Bard and L. R. Faulkner, 2nd Ed., John Wiley & Sons : New York, (2002).

9.Statistical Thermodynamics, B.J. McClelland, Chapman and Hall & Science Paperbacks, London, (1973).

10Physical Chemistry, T. Engel and P. Reid, Pearson Education and Dorling Kindersley (India) (2006).

11. Introduction to Thermodynamics of Irreversible Processes, I. Prigogine Interscience (1960)

First SemesterCHEM Lab Course-I Credits: 8

(ORGANIC CHEMISTRY)

PART A

1. Purification Techniques of organic compounds and their spectroscopic identifications.
   a) Separation/ purification of binary mixtures by Thin Layer Chromatography (TLC) and Column chromatography (CC).
   b) Purification of tertiary mixtures of amino acids by Paper Chromatography.
2. Extraction of Natural Products: Any one of the following – solasodine, caffeine, nicotine, piperine, rosine, carotenoids, curcumin, Citral.
3. Organic Preparations: At least eight preparations (involving two or more than two steps) involving the following representative reactions-
   a. Esterification and saponification
   b. Oxidation (peracid, chromic acid, Mn(Vll)
   c. Hydride reduction or hydrogenation
   d. Nucleophilic substitution
   e. Cycloaddition reaction
   f. Grignard reaction
   g. Condensation reaction
   h. Preparation of dyes
   i. Aromatic electrophilic substitution
   j. Heterocyclic synthesis
4. Qualitative Analysis of Binary Mixtures (only two)

PART B:

Principle, instrumentation, handling, precautionary measures, experiment, data collection and analysis of the following instruments:

1. IR
2. HPLC and GC
3. Microwave

Recommended Books and References

1. R. K. Bansal. *Laboratory Manual of Organic Chemistry* (3^{rd}edn.), Wiley-Eastern (1994).
2. R. G. Brewster & W.E. Mcwedn. *Unitized Experimental Organic Chemistry* (4^{th}edn.), East-West Press (1977).
3. A. I. Vogel. *Practical Organic Chemistry* (3^{rd}edn.), Longman Group Ltd. (1973).

4 A. O. Fitton& R. K. Smallery.*Practical Heterocyclic Chemistry* Academic Press (1968)

5.R.L. Shriner & R. C. Fuson. *Systematic Identification of Organic Compounds* (5^{th}edn.), John Wiley & Sons (1964).

SECOND SEMESTER CHEM CORE-5 Credits: 4

INORGANIC CHEMISTRY – II

Unit 1 ***Transition Metal π-acid Complexes and Supramolecular Chemistry***

Bonding, synthesis and reactivity of transition metal complexes with CO, NO, O_2, N_2 and tertiaryphosphine and arsine ligands; metal carbonyl clusters: LNCC andHNCC, Wade's rule and the capping rule. Supramolecular chemistry: Definition, supramolecular host-guest compounds, macrocyclic effect.

Unit 2 ***Kinetics and Mechanism of Inorganic Reactions***

Labile and inert complexes; mechanisms of ligand-replacement reactions; ligand displacementreactions in square planar and octahedral complexes; the *trans* effectand its application; isomerisation andracemisation of tris-chelate complexes; electron transfer reactions; stereochemical non-rigidity and fluxional molecules.

Unit 3 ***Transition Metal–Carbon Bond***

(a) Transition Metal–Carbon σ-Bond: Brief review of metal alkyl compounds; transition metalcarbene and transition metal-carbyne compounds; transition metal vinylidene and transition metalallenylidene compounds.

(b) Transition Metal-Carbon π-Bond: Cyclopropenylcation (C_3R^{3+}) as a ligand; C_4R_4 as a ligand (R = H, Me, Ph)

Unit 4 ***Syntheses of Cyclopentadienyl and Arene Metal Analogues***

Synthesis and reactions of cyclopentadienyl metal carbonyls, cyclopentadienyl metal hydrides,cyclopentadienyl metal halides, arene metal group complexes, η6-arene-chromium tricarbonyl inorganic synthesis.

Unit 5 ***Applications to Organic Synthesis and Homogeneous Catalysis***

(a) In Organic Synthesis: Hydrozirconation of alkenes and alkynes; Carbonylation of Colman'sreagent; η4-diene iron-tricarbonyls in organic synthesis

(b) In Catalysis: Asymmetric hydrogenation; synthesis of acetic acid (Monsanto acetic acid process); Arylation/vinylation of olefins (Heck reaction); Wacker process (olefin oxidation); Asymmetric epoxidation.

Recommended Books and References

1. M. Bochmann. Organometallics-I Complexes with Transition Metal-Carbon σ-Bonds, Oxford Chemistry Primers (1994).
2. M. Bochmann. Organometallics-2 Complexes with Transition Metal–Carbon π-bonds, Oxford
3. J. E. Huheey, E. A. Keiter, R. L. Keiter& O. K. Medhi, *Principles, Structure and Reactivity* (1st impression), Pearson Education (2006).
4. F. A. Cotton, G. Wilkinson, C.A. Murillo & M. Bochmann, *Advanced Inorganic Chemistry* (6^{th}edn.), John Wiley (1999).
5. J. W. Steed & J. L. Atwood.*Supramolecular Chemistry*, John Wiley (2002
6. B. R. Puri, L. R. Sharma, and K. C. Kalia, *Principles of Inorganic Chemistry*, Milestone.
7. P. Atkins, T. Overton, J. Rourke, M. Weller & F. Armstrong.*Shriver and Atkins Inorganic Chemistry*, Oxford University Press (2006).
8. T. Moeller. *Inorganic Chemistry: A Modern Approach*, John Wiley (1982).
9. J. W. Steed & J. L. Atwood.*Supramolecular Chemistry*, John Wiley (2002)

CHEM CORE-6 Credits: 4

ORGANIC CHEMISTRY – II
(Redox Reaction and Reactive intermediates)

Unit 1 ***Redox Reaction-I***

Catalytic hydrogenation: Scope and mechanisms for heterogeneous catalytic hydrogenation ofalkenes and other functional groups; Homogeneous catalytic hydrogenation with Wilkinson catalyst; Dissolving metal reductions: Scope and basic mechanisms; Liquid ammonia reduction with alkali metals, Birch reduction of arenes.

Unit 2 ***Redox Reaction-II***

(a) Use of hydroboration in reduction, oxidation and carbonylation, regioselectivity, stereo-selectivity and synthetic utility of alkyl boranes; Reduction of carbonyl group with hydrazine

(b) Oxidation of alcohols & aldehydes with Cr &Mn oxidants; Uses of PCC, PDC and Collin's reagent, Oxidation of C=C and C-H bonds; Alkene epoxidation by peracids and metal/alkyl hydroperoxides, DMSO oxidations; Oxidative cleavage of C-C single and double bonds; periodates, LTA and SeO_2.

Unit 3 ***Reactive Intermediates-I***

(a) ***Carbenes:*** Stability, structure and spin states of carbenes; Cyclopropanation – spin dependenceand stereochemistry; Carbene insertion to C-H bonds; Rearrangement to alkenes; Wolff rearrangement of acylcarbenes and its synthetic applications; Carbenoids.

(b) ***Nitrenes*****:** Stability, structure and spin states of nitrenes; C-H bond insertions and aziridineformation; Rearrangement of acylnitrenes (Hoffmann, Curtius and Schmidt reactions with applications in organic synthesis).

Unit 4 ***Reactive Intermediates-II***

(a) ***Free Radicals*****:** Stability and fate of organic free radicals; Radical cyclisation and coupling reactions; Addition to multiple bonds; Aromatic substitution by radicals; Allylicbromination by NBS and decarboxylativebromination.

(b) ***Arynes*****:** Generation, structure and stability of arynes; Benzyne mechanism for aromaticnucleophilic substitution; Direction of aryne bond formation and of nucleophilic addition.

Unit 5***Carbon-Carbon bond formation***

(a) ***Nucleophilic C-C bond formation:***Henry reaction, Wittig reaction and Horner-Wordwoth-Emmons reaction and their selectivities; Chemistry of enolates – *E, Z* geometry of enolates, stereoselectiveenolate reactions, alkylation, aldol condensation(Zimmerman models), Mukaiyama reaction.

(b) ***Electrophilic C-C bond formation:***Prins reaction, Vilsmeier-Hack reaction, Pictet-Sprenglerreaction, Heck reaction, Stille coupling, Suzuki coupling, Neigishii reaction, Acylation of carbonyl carbon; Carbonyl cyclizations and cleavages.

Recommended Books and References

1. H. O. House. *Modern Synthetic Reactions*, W. A. Benjamin (1972).
2. J. March. *Advanced Organic Chemistry: Reactions, Mechanisms and Structure* (4^{th}edn.), Wiley Student Edition, John Wiley & Sons Asia Pte. Ltd. (2005).
3. T. L. Gilchrist & C. W. Rees, *Carbenes, Nitrenes and Arynes*, Nelson, London (1969).
4. V. K. Ahluwalia& R. Aggarwal, *Organic Synthesis: Special Techniques*, Narosa Publishing House, New Delhi (2001).

5. R. M. Silverstein, G. C. Basseler& T. C. Morill.*Spectroscopic Identification of OrganicCompounds*, 7^{th}Edn., John Wiley (2005).
6. W. Kemp. *Organic Spectroscopy* (3rd edn.), McMillan Press Ltd. (1991).

Second Semester CHEM CORE-7 Credits: 4

ORGANIC CHEMISTRY – III

(**Synthesis &Retrosynthesis in Organic Chemistry)**

Unit 1 ***Reagents in organic synthesis*:**

K-selecteride and L-selecteride, sodium cyanoborohydride,superhydrides, Dess-Martin periodinane,manganese dioxide, Fetizon reagent, dioxiranes, ceric ammoniumnitrate, Gilman's reagent, lithium disopropylamide, dicyclohexylcarbodimide, trimethysilyl iodide, tri-n-butyltin hydride, Tebbe reagent, baker's yeast, lipase, Mosher's reagent.

Unit-2

Synthons and synthetic equivalents, disconnection approach, functional group inter-conversions, importance of order of events in organic synthesis, one group and two group C-X disconnections, chemoselectivity, reversal of polarity, cyclisation reactions, amine synthesis.

Unit 3

One group C-C disconnections – alcohols and carbonyl compounds, regioselectiviity, alkene synthesis, use of acetylenes and aliphatic nitro compounds in organic synthesis. Two group C-C disconnections – Diels-Alder reaction, α,β-unsaturated carbonyl compounds, control in carbonyl condensations and Michael addition.

Unit 4

(a) Principle of protection and deprotection of alcohol, amine, carbonyl and carboxyl groups; Common protecting groups.

(b) Retrosynthesis, Synthesis and characterization of the following: Quercetin, Pinene, Camphor, Prostaglandins and Taxol.

Unit 5*Miscellaneous reactions:* Biginelli reaction, Hantzsch reaction, Passerini reaction, Ugireaction, McMurryolefination, Ring closing metathesis (RCM) - Grubb's reaction, Mitsonobu reaction, Nefreaction, Sharpless asymmetric epoxidation and asymmetric dihydroxylation. Carboxylic acids and derivatives, decarboxylation reactions, 1,3-dithiane reactivity.

Recommended Books and References

1. Stuart Warren, *Organic Synthesis The Disconnection Approach*, John Wiley & Sons (1982)
2. Nicolaou and Sorensen; *Classics in Total Synthesis*, Wiely-VCH (2003)
3. F. A. Carey & R. J. Sundberg. *Advanced Organic Chemistry* Part B, Plenum Press (2007).
4. M. B Smith. *Organic Synthesis* (2^{nd} end.), McGraw-Hill, Inc. (2001).
5. J. March. *Advanced Organic Chemistry: Reactions, Mechanism and Structure* (4^{th}edn.), John Wiley & Sons (2005).
6. Fundamentals of Organic synthesis Vol.II NCBA publication Ratan Kumar Kar
7. Organic synthesis Krishna Prakash publication Ltd M.P.Saluja
8. M. Harmata. *Strategies and Tactics in Organic Synthesis* 4 & 5, Academic Press (2004).
9. W. Carruthers. *Some Modern Methods of Organic Synthesis* (4^{th}edn.), Cambridge University Press (2004).
10. B. M Trost& I Fleming. *Comprehensive Organic Synthesis*, Vols 1-9, Pergamon (1991).

CHEM CORE-8 Credits: 4

PHYSICAL CHEMISTRY – III
(Chemical Kinetics & Polymer Chemistry)

Unit 1*Theories of Reaction Rates*

Collision theory, Potential energy surfaces (basic idea), generalized kinetic theory, rate theories based on thermodynamics, conventional transition state theory (CTST) - equilibrium hypothesis, statistical mechanics and chemical equilibrium, derivations of the rate equations, applications of CTST - reaction between atoms, thermodynamic formulation of conventional transition state theory. Factors determining reaction rates in solution, collision in solution, encounter, Franck - Rabinowitch effect, reaction between ions, single-sphere and double-sphere model for activated complex, influence of ionic strength (primary salt effects),

Unit 2*Acid-base and Enzyme Catalysis*

General catalytic mechanisms, fast pre-equilibrium: Arrhenius intermediates, Steady-state conditions: van't Hoff intermediates, activation energies of catalyzed reactions, acid-base catalysis, General and Specific acid-base catalysis, mechanisms of acid-base catalysis - reaction between acetone and iodine, catalytic activity and acid - base strength, salt effects, acidity functions. Enzyme catalysis, Simple enzyme mechanisms, influence of substrate concentration:Michaelis-Menten equation- single and double intermediates, Lineweaver - Burk plot, Eadie-Hofstee plots, Complex enzyme mechanism.

Unit 3Effect of Ions on Reaction Rates

Theory of unimolecular reactions, Lindemann mechanism and Hinshelwood treatment.Rice-Ramsperger-Kassel Treatment, Slater's treatment, Marcus's extension of the RRK Treatment, Influence of foreign gases, Intermolecular energy transfer, Intramolecular energy transfer, Laser induced unimolecular reactions, decomposition of ions, combination and disproportion reactions, Mechanisms of atom and radical combinations, ion-dipole and dipole-dipole reactions, pressure effects and volume of activation - van't Hoff's equation, substitution and correlation effects on reactivity, Linear Free Energy Relationships(LFER) - Hammett equation, uses and limitation.

Unit 4Chain Reactions

Linear chain reactions, Autocatalysis, Reaction between hydrogen and halogen, Calculation of Energy Barriers for Elementary Steps and comparison of the Mechanisms of the Hydrogen– Halogen Reactions, pyrolysis of acetaldehyde and ethane, general considerations of free radical chain mechanism,, Explosive Reactions - Combustion between hydrogen and oxygen, kinetic aspect of polymerization reactions, molecular mechanisms, Kinetic Chain Length, free radical mechanisms, cationic and anionic polymerization.

Unit 5 *Polymer Chemistry*

Definition, Classification of polymers, Chain configuration of macromolecules, Isotactic polymers, Atactic polymers, Syndiotactic polymers, Graft polymers, Electrically conducting polymers, Molecular mass of polymers, Number and Mass average molecular mass, Specialised methods of polymerization: (i)solid state polymersation,(ii) metathesis polymerisation and (iii)group transfer polymerisation Special treatment to Zieglar-Natta co-ordination polymerization.

Recommended Books and References

1. *Chemical Kinetics*,K. J. Laidler, (4th Edn.), Pearson Eductions (2007).
2. *Chemical kinetics and Reaction Mechanism* by James H. Espenson, 2nd Ed., McGraw-Hill, (1995).
3. *Chemical Kinetics and Reaction Dynamics* by Santosh K. Upadhyay, Anamaya Publishers,New Delhi, (2006).
4. *Chemical kinetics and Reaction Mechanism* by James H. Espenson, 2nd Ed., McGraw-Hill,(1995).
5. *Atkin's Physical Chemistry*Atkins, P. W. & Paula, J. de 8th Ed., Oxford University Press (2006).
6. *Chemical Kinetics and Reaction Dynamics* by Santosh K. Upadhyay, Anamaya Publishers,New Delhi, (2006).
7. *Introduction to Polymer Science,* V. R. Gowarikar, N. V. Vishwanathan and J. Sridhar - Wiley Eastern,(2006)
8. *Chemical Kinetic Methods: Principles of Relaxation Techniques and Applications* by C. Kalidas, New Age International (P) limited, Publishers, (1996).
9. *Chemical Kinetics and Dynamics*, J.I. Steinfeld, J.S. Francisco and W.L. Hase, 2nd Edition, Prentice Hall International, Inc., (1999).
10. *Chemical Kinetics: From Molecular Structure to Chemical Reactivity*, by L. Arnaut, SebastiaoFormosinho, Hugh Burrows, Elsevier, (2007).

SECOND SEMESTER

LABORATORY COURSE – IICredits: 8
(INORGANIC CHEMISTRY)

1. Quantitative estimation involving volumetric (redox and complexometry), gravimetric and spectrophotometiric methods of constituents in three component mixtures.

2. Preparation and Characterization of the following compounds (at least 6 preparations are to be completed by turn):

(i) Reinecke's salt
(ii) Tris(oxalate) manganese(III)
(iii) Tetrapyridinesilver(II)peroxidisulphate
(iv) Tris(acetylacetonato) iron(III)
(v) Bis(N,N-diethyldithiocarbamato)nitrosyliron(I)
(vi) Optical isomers of tris(ethylenediamine)cobalt(III)chloride
(vii) Linkage isomers of nitro and nitritopentamminecobalt(III) chloride
(viii) Ferrocene or dibenzene chromium
(ix) Hydridochlorocarbonyltris(triphenylphosphine)ruthenium(II)
(x) Tris(2,2'-bipyridine)ruthenium(II) perchlorate
(xi) $[(p\text{-(cymene)}RuCl_2]_2$
(xii) Tri(acetylacetonato)manganese(III)
(xiii) Prussian Blue
(xiv) Turnbull's Blue

3. Characterization includes microanalysis, conductance measurements and UV-Visible.
4. Less common metal ions: Ti,Mo,W,Tl, V,U,Zr,Th (Qualitative Analysis).

Recommended booksand references

1. J. Mendham, R. C. Danney, J. D. Barnes & M. Thomas. *Vogel's Textbook of Quantitative Chemical Analysis*, Peterson Education (2000).
2. G. Marr & B. W. Rockett. *Practical Inorganic Chemistry*, Van Nostrand (1972).
3. G. Pass & H. Sutcliffe. *Practical Inorganic Chemistry* (2^{nd}edn.), Chapman & Hill (1974)
4 .J. Basset, R. C. Denney, G.H. Jeffery & J. Mendham. *Vogel's Text Book of Quantitative Analysis* (4^{th}edn.), English Language Book Society (1978).
5. H. H. Willard, L. L. Merrit& J. A. Dean. *Instrumental Methods of Analysis* (4^{th}edn.), East-West Press (1974).
6.G. W. Parshall (Ed. in Chief). *Inorganic Synthesis*, Vol. 15, McGraw Hill, p. 48 (1974).

THIRD SEMESTER

CHEM CORE-9 Credits: 4

INORGANIC CHEMISTRY–III

Unit 1

Infrared and Raman Spectroscopy: Structural studies (involving IR and Raman spectro-scopy) of coordination compounds containing the following molecules/ions and ligands - NH_3, H_2O, OH^-,SO_4^{2-}, CN^-, SCN^-, NO. Application of IR and Raman spectroscopy.

Unit 2.

Magnetic Resonance Spectroscopy

Electron spin resonance spectroscopy: ESR of d1 to d9 transition metal ions in cubic and tetragonal ligand fields; evaluation of g values, metal hyperfine coupling constants and super hyperfine coupling constants (nitrogen/nitrogen-oxygen donor ligands).

Nuclear magnetic resonance spectroscopy: Applications of 31P, 19F, 119Sn and 195Pt NMR Spectroscopy in the structural assessment of inorganic compounds.

Unit 3

Mass spectrometry: Basic principles, ionization techniques, isotope abundance, molecular ion,deduction of structure through mass spectral fragmentation. ESI-MS and MALDIMS-applications in biomolecules. Studies of inorganic/ coordination and organometallic representative compounds. Instrumentation.

Unit 4.

Mossbauer Spectroscopy: Principles, Doppler shift and recoil energy, isomer shift and its interpretation, quadrupole interactions, effect of magnetic field on Mossbauer spectra,, applications to metal complexes, metal carbonyls, iron and tin compounds.

Unit 5

X-ray Crystallography: Lattices, planes and indices; X-ray diffraction and Bragg's law; Crystal systems and symmetry, point groups, stereographic projection of 32 point groups and space groups; Crystal growing; Data collection, data reduction, refinement and structure solution of some compounds.

Recommended Books and References

1. K. Nakamoto. *Infrared and Raman Spectra of Inorganic and Coordination Compounds*, (6th edn.), John Wiley (2008).

2. R. V. Parish. *NMR, NQR, EPR and Mossbauer Spectroscopy in Inorganic Chemistry*, Ellis Horwood, New York (1990).

3. B. N. Figgis. *Introduction to ligand fields*, Interscience Publishers, 1966

4. J. A. Iggo, *NMR Spectroscopy in Inorganic Chemistry*, OUP Oxford (2000)

5. G.H.Stout and L.H.Jensen, *X-ray Structure Determination: A Practical Guide*, The McMillan Company, New York (1968)

Reference Books

R. S. Drago. *Physical Methods in Chemistry*, Saunders College Publishers (1977).

Third Semester

CHEM CORE-10 Credits: 4

PHYSICAL CHEMISTRY – IV
(Surface Chemistry & Solid state Chemistry)

Unit 1 ***Introduction***

(a) Characteristic Features of Surfactants: General structural features & behavior of surfactants,classification of surfactants, hydrophobic/solvophobic interaction, Kraft point.
(b) Adsorption of Surfactants: Adsorption at solid/liquid, liquid/gas and liquid/liquid interfaces,Gibbs adsorption equation, adsorption isotherms, effect of added electrolyte on the surface excess of ionic surfactants.

Unit 2 ***Micelles & Mixed Surfactants***

Micelle formation by surfactants: Critical micelle concentration, cmcmeaurement, conductance behaviour of ionic micellar solution, micellar structure and shape, factors affecting cmc, temperature dependence of cmc, thermodynamics of micellization, counterion binding constant.Different types of mixed micelle, cmc of mixed micelle, Rubingh's treatment, Rodenas treatment, conterion binding in mixed surfactants.

Unit 3 ***Solubilisation and Emulsification***

Solubilization and Emulsification by Surfactants: Factors determining extent of solubilization, formation of emulsions, factors determining emulsion stability, microemulsions, conductance behaviour of microemulsions, reactions in micellar and microemulsion media.

Unit 4***Packing in Crystals Structures***

Cubic close packing, hexagonal close packing, packing of ions,alloys and molecular structures atomic coordinates and nomenclature , structural relationships,polyhedral representation of crystal systems,packing of structures in terms of the distribution of tetrahedral sites,octahedral sites and packing ions .Structural elucidation and distribution of interstitial sites in hcp structures: AX type - wurtzite (ZnS);AX_2 type-rutile (TiO_2) ,Structural elucidation and distribution of interstitial sites in ccp structures : AX type - rock salt (NaCl), AX_2type - cadmium chloride ($CdCl_2$)

Unit 5 ***Properties of Solids***

(a) Magnetic Properties: Classification of materials, Line of forces, Effect of temperature, Magnetic moment calculations, Ferro- and antiferromagnetic ordering, Dependence of magnetic properties on size, Magnetic domains and Hysteresis.
(b) Electrical Properties: Dielectric materials, Dielectric properties: dielectric constant and related quantities, Polarizability, Concepts of ferroelectricity, Pyroelectricity and Piezoelectricity.
c) Electronic Properties: Metals, Insulators, Semiconductors and Superconductors, Density of states, Origin of bands, Band theory, Intrinsic and extrinsic semiconductors p-n junction, Bonding in solids.

Recommended Books and References

1. *Surfactants and Interfacial Phenomena,*M. J. Rosen. (3rd edn.), John Wiley (2004).
2. *Micelles,*Y. Moroi. Plenum (1992).
3. *Solid State Chemistry and its applications,*Anthony R. West, John Wiley & Sons.(2014)
4. *Principals of Nanoscience and Nanotechnology,* M. A. Shah and Tokeer Ahmad, Narosa Publications, (2010).
5. *Solid State Chemistry,* Lesley Smart and Elaine Moore, Chapman & Hall.(1995)
6. *New Directions in Solid State Chemistry* C. N. R. Rao and J. Gopalakrishnan, , Cambridge University Press.(2010)

*7. Surfactants,*K. R. Lange. Hanser Pub. (1999).

8. Dynamics of Surfactant Self-Assemblies, R. Zana (ed.). CRC Press (2005).

9. Mixed Surfactant Systems, M. Abe & J. F. Scamehorn. CRC Press (2004).

`10.*Principles of the Solid State,* H. V. Keer, New Age International Publishers.(2017)

11.*Solid State Chemistry,* D. K. Chakrabarty, New Age International Publishers.(2006)

12.*Solid State Chemistry Techniques,* A. K. Cheetham and Peter Day, Oxford Science Publications.(1987).

Third Semester Credits: 8

LABORATORY COURSE – III

(PHYSICAL CHEMISTRY)

PART A:

Students are to perform seven/eight experiments from the following list:

1. Determination of order of reaction, rate constant and energy of activation for saponification of an ester by NaOH, conductometrically.
2. Determination of critical micellar concentration (CMC) of sodium lauryl sulphate from the measurement of conductivities at different concentrations.
3. Determination of strengths of halides in a mixture, potentiometrically.
4. Determination of pH of buffer solutions and hence to calculate the E_0 of quinhydrone electrode.
5. Verification of Beer-Lambert's law and determination of pKa of an indicator, spectrophotometrically.
6. Spectrophotometric determination of pKa of an indicator in micellar and microemulsion media.
7. Determination of partial molar volume of a solute in solution.
8. Determination of the stability constant of the complex formed between Cu(II) ions and 5-sulphosalicylic acid between pH 3-5 by colorimetric method and hence to calculate thefree energy of formation of the complex.
9. Determination of specific rotation of sucrose and rate constant of its hydrolysis using a polarimeter.
10. Determination of coordination number of Cu^{2+} in copper-ammonia complex by partition method.
11. To study the kinetics of iodination of acetone.
12. Determination of the acidic and basic dissociation constants of an amino acid and hence its isoelectric point.

PART B:

Principle, instrumentation, handling, precautionary measures, experiment, data collection and analysis of the following instruments:

1. Fluorescence spectroscopy
2. UV- spectroscopy/Dynamic Light Scattering
3. TGA-DSC

Textbooks

1. *Experiments in Physical Chemistry* D. P. Shoemaker, C. W. Garland & J. W. Nibler. (5th edn.), McGraw Hill (1989)
2. *Experimental Physical Chemistry*, V. D. Athawala& P. Mathur. New Age International. Publishers (2001).
3. *Experiments in Physical Chemistry*, R.C. Das and B. Behra – Tata McGraw Hill.(1983).
4. *Advanced Practical Physical Chemistry*, J.B. Yadav - Goel Publishing House.(1981).
5. *Advanced Experimental Chemistry*, Vol. I - Physical, J.N. Gurtu and R. Kapoor ,S. Chand & Co. (2016)
6. *Selected Experiments in Physical Chemistry*, N.G. Mukherjee – J.N. Ghose& Sons.
7. *Experiments in Physical Chemistry*, J.C. Ghosh - BhartiBhavan.(2007)
8. *Senior Practical Physical Chemistry*, B.D.Khosla; V.C.Garg, AdarshKhosla R. Chand & Co.(2007).

FOURTH SEMESTERCHEM CORE-11 Credits: 4
INORGANIC CHEMISTRY - IV

Unit 1 ***Bioinorganic Chemistry***
Essential and trace elements in biological systems, structure and functions of biological membranes; mechanism of ion transport across membranes;sodium pump; ionophores: valinomycin and crownether complexes of Na+ and K+; ATP and ADP;photosynthesis: chlorophyll, PS I and PS II.Rubredoxin and ferredoxins.

Unit 2.
Metalloporphyrins
Introduction to hemeproteins,Structure and optical spectra; heme proteins: magnetic susceptibility, epr and electronic spectra;
hemoglobin and myoglobin: molecular structures, thermodynamics and kinetics of oxygenation, electronic and spatial structures, synthetic oxygen carriers, model systems; iron enzymes, peroxidase, catalase and cytochrome P-450

Unit 3
Metalloenzymes
Copper enzymes, superoxide dismutase, cytochrome oxidase and ceruloplasmin; Coenzymes; Molybdenum enzyme: xanthine oxidase; Zinc enzymes: carbonic anhydrase, carboxy peptidase and interchangeability of zinc and cobalt in enzymes; Vitamin B12 and B12 coenzymes; Iron storage, transport, biomineralization and siderophores.

Unit 4 ***Metals in Medicine***
Metal deficiency and disease; toxicity of mercury, cadmium, lead, beryllium, selenium and arsenic; biological defence mechanisms; chelation therapy; metals used for diagnosis and chemo-therapy, platinum complexes as anticancer drugs, Pt-DNA binding, complexes of gold, copper, zinc,mercury, arsenic and antimony as drugs.

.**Unit 5.*****Photochemistry of Metal Complexes and Metal–Metal Multiple Bonds***
Excited states, ligand field states, charge-transfer states and Thexistates;Phosphoresence and fluorescence; Photochemical reactions: substitution and redox reactions of Cr(III), Ru(II) and Ru(III) complexes;Applications: synthesis and catalysis, chemical actinometry and photochromism; Metal-metal multiple bonds, major structural types, quadrupole bonds and one dimensional solids.

Recommended Books and References1.S. J. Lippard& J. M. Berg.*Principles of Bio-Inorganic Chemistry*, Panima Publ. Corpn. (2005).
2. E.-I. Ochiai.*Bioinorganic Chemistry – An Introduction*, Allyn and Bacon Inc. (1977).
3 M. N. Hughes. *The Inorganic Chemistry of Biological Processes*, Wiley (1981).
4. R.P. Hanzlik. *Inorganic Aspects of Biological and Organic Chemistry*, Academic Press (1976)
5. F.A. Cotton &G.Wilkinson.*Advanced Inorganic Chemistry* (5thedn.), JohnWiley (1988)
6. D.M.Roundhill.*Photochemistry and Photophysics of Metal Complexes*, Plenum Press(1990).
7. A.W. Adamson &P.D. Fleischauer.*Concepts of Inorganic Photochemistry*, John Wiley & Sons (1975).

8. H. Kraatz& N. Metzler-Nolte (Eds.).*Concepts and Models in Bioinorganic Chemistry*, Wiley
9. S. J. Lippard& J. M. Berg.*Principles of Bio-Inorganic Chemistry*, Panima Publ. Corpn. (2005).
10. A.W. Adamson &P.D. Fleischauer.*Concepts of Inorganic Photochemistry*, John Wiley & Sons (1975).

CHEM CORE-12Credits: 4

ORGANIC CHEMISTRY – IV
(Organic Spectroscopy)

Unit 1

(a) Infrared(IR) Spectroscopy:

Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromaticcompounds, alcohols, ethers, phenols, amines; Detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acid anydrides); Effects of H-bonding and solvent effect on vibrational frequency, extension to various organic molecules for structural assignment.

Unit 2*Electronic Spectroscopy:*

UV & Visible Electronic spectra: Frank-Condon principle,Fluorescence, Phosphorescence, electronic spectra of diatomic molecules, chromophores ,auxochromes, absorption and intensity shifts, solvent effects, Woodward Fieser rules.Calculation of λmax of various compounds.

Unit 3

Nuclear Magnetic Resonance (NMR) Spectroscopy-I:

Nuclear Magnetic Resonance Spectroscopy: Basic principles, origin of chemical shifts, factors affecting the chemical shifts and their interpretation, spin-spin coupling, relaxation processes, coupling constants.Approximate chemical shift values of various chemically non-equivalent protons and correlation toprotons bonded to carbon (aliphatic, olefinic, aldehydic and aromatic); Protons bonded to other nuclei(alcohols, phenols, enols, carboxylic acids, amines, amides, SH).

Unit 4

Nuclear Magnetic Resonance (NMR) Spectroscopy-II:

C-13 NMR Spectroscopy: Chemical shift (aliphatic, olefinic, alkynes, aromatic, hetero-aromatic, carbonyl carbon); Coupling constants, two-dimensional NMR spectroscopy, NOESY, DEPT and INEPT terminologies.

Applicationsof IR, NMR and Mass spectroscopy for structure elucidation of organic compounds

Unit-5

Mass Spectroscopy:

Mass spectral fragmentation of organic compounds, common functional groups;molecular peak, McLafferty rearrangements, examples of mass spectral fragmentation of organic compounds with respect to their structure determination

Recommended Books and References

1. W. Kemp. *Organic Spectroscopy* (3rd edn.), McMillan Press Ltd. (1991).

2 .D Williams & I. Fleming.*Spectroscopic Methods in Organic Chemistry*, McGraw Hill (1989).

3. C. N. Banwell& E. M. McCash.*Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill, New Delhi (2006).

4 .R. M. Silverstein, G. C. Basseler& T. C. Morill.*Spectroscopic Identification of OrganicCompounds*, 7^{th}Edn., John Wiley (2005).

5. Elementary Organic spectroscopy (Principle & chemical application)Y.R.Sharma

THIRTH SEMESTER

DISCIPLINE SPECIFIC ELECTIVE (DSE) Credits-4

A : ANALYTICAL CHEMISTRY & CATALYSIS

Unit 1. Analytical instrumentation and methods (A)
Electrochemical and Spectral methods: Polarography: Principle, instrumentation and applications, Cyclic voltammetry, Anodic stripping voltammetry, Amperometry, Coulometry and Conductance methods; Potentiometry: Ion selective electrodes; Atomic absorption spectrometry; Atomic fluorescence spectrometry; Turbidimetry and Nephelometry.

Unit 2. Analytical instrumentation and methods (B)
Experimental Techniques of Purification and Separation: Solvent extraction: principles of extraction, percentage extraction, action of ion exchange resin, ion exchange equilibria, applications.Liquid chromatography: adsorption and partition chromatography, exclusion chromatography,
HPLC (principles, equipment, choice of mobile phase and detector, column efficiency, applications.
Gas chromatography: Principles, instrumentation, choice of column and detector, applications

Unit 3.*Homogeneous Catalysis*
Coordinative unsaturation, oxidative addition reactions, insertion reactions; Reactions of coordinated ligand and activation of small molecules by complexation; Catalytic reactions of alkenes: isomerization, hydrogenation, hydroformylation, hydrosilylation and polymerization

Unit 4. Non-aqueous Solvents
Classification of solvents; general properties of ionizing solvents; chemical reactions; liquid sulfur dioxide as solvent; liquid dinitrogen tetra-oxide; liquid hydrogen fluoride; liquid hydrogen sulfide; liquid hydrogen cyanide; acetic acid; liquid bromine trifluoride; oxyhalides.

Unit 5.Study of some selected topics
Synthesis, properties and structures of boranes, carboranes, silicones, phosphazenes and S,N compounds; non-stoichiometric oxides: zeolites and clay; polymorphism of carbon, phosphorus and sulphur.

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Recommended Books and References

1. R.C. Mehrotra& A. Singh.*Organometallic Chemistry: A Unified Approach* (2nd edn.), New Age International (2000
2. F.A. Cotton &G.Wilkinson.*Advanced Inorganic Chemistry* (5thedn.), JohnWiley (1988)
4. A. K. De. *Environmental Chemistry* (4th edn.), New Age International Limited (2006).
5. P. M. S. Monk. *Fundamentals of Electroanalytical Chemistry*, John Wiley & Sons (2001).
6. H. H. Willard, L.L. Merritt, J.A. Dean & F. A. Settle. *Instrumental Methods of Analysis* (7th edn.),Wadsworth Publishing Company, California (1988).
7. J. Mendham, R. C. Denney, J. D. Barnes and M. Thomas.*Vogel's Textbook of Quantitative Chemical Analysis*, Peterson Education (2000).

8. C. Cutal& A.W. Adamson,.*Comprehensive Coordination Chemistry*, Vol. 1, Editor-in-Chief G. Wilkinson (1985).
9. M. Ratner & D. Ratner.*Nanotechnology: A Gentle Introduction to the Next Big Idea*, Pearson Education (2003).
10. P. Atkins, T. Overton, J. Rourke, M. Weller & F. Armstrong.*Shriver and Atkins Inorganic Chemistry*, Oxford University Press (2006).
11. J. W. Moore & E. A. Moore. *Environmental Chemistry*, Academic Press, London (1976).
12. I. Pulford& H. Flowers. *Environmental Chemistry at a Glance*, Blackwell Publishing (2006).
13. S. E. Manahan. *Environmental Chemistry* (6th edn.), Lewis Publishers, London (1994).

B: NATURAL PRODUCTS & BIO ORGANIC CHEMISTRY

Unit 1 ***Natural Products and their Biosynthetic Pathways***

General classification of natural products, their isolation and characterisation and biosynthesis of common plant products; Biosynthesis pathways for natural products using co-enzymes and enzymes; Synthesis of selected natural products based on genetic classification – fatty acid derivatives and related compounds, general biogenesis and synthesis of cis-jasmone, methyl jasmonate, prostaglandins, exaltone and muscone.

Unit 2*Enzymes*

Mechanism of enzyme action and models, kinds of reactions catalyzed by enzymes, nomenclature, stereochemical aspects, cofactors, co-enzyme chemistry. Structure and function of NADH,FAD, ADP and ATP.

Unit 3*: Alkaloids*

Structure, synthesis and biosynthesis of common alkaloids: Strychnine, lysergic acid, reserpine, nicotine, morphine, emitine.

Unit 4 ***Heterocyclic compound***

(a)Small Ring Heterocycles: Synthesis of aziranes, oxiranes&thiiranes; Ring openings andheteroatom extrusion; Synthesis & reactions of azetidines, oxetanes.

(b)Bicyclic Heterocycles: Synthesis of indole, quinolines, isoquinolines, benzofused diazines,phenothiazines and carbazoles; electrophilic substitution reactions

Unit 5*Terpenoids*

General biosyntheses of mono- and sesquiterpenesditerpenes, and higher terpenes, *trans*-chrysanthemic acid, cyclo-pentatomonoterpene lactones, Synthesis of α-vetinone ,β-eudesmol, hirsutene, *cis* juvenile hormone; *trans* annular cyclisation of caryophyllene, synthesis of caryophyllene and isocaryophyllene; Rearrangements of santonic acid and thujospene.

Recommended Books and References

1. K. Nakanashi. *Natural Products Chemistry*, Vols. I and II, Academic Press, New York and London (1974).

2.S.V. Bhat, B.A. Nagasampagi, S MinakshiNatualaproducyts; Chemistry & Applications, Alpha Science International Ltd. (2011).

3.M. Harmata. *Strategies and Tactics in Organic Synthesis* 4 & 5, Academic Press (2004)

4.Modern Organic chemistry Vishal publishing co. M.K Jain & S.C Sharma

5. Natural Product vol -I& II O.P. Agarwal

6. A. L. Lehninger. *Biochemistry*, Kalyani Publishers (1983).

7. T. L. Gilchrist. *Heterocyclic Chemistry* (2nd edn.), Longman Scientific & Technical Publicns. (1992).

8.R. K. Bansal. *Heterocyclic Chemistry: Synthesis*, *Reactions and Mechanisms*, Wiley Eastern (1991)

C: NUCLEAR CHEMISTRY

Unit I Introduction

Natural radioactivity, half life, mean life. Units of radioactivity, the natural radioactive series, secular and transient equilibrium. The nuclear atom, neutron-proton model of the atom, isotopes and their separation, neutron decay, β-spectrum, the neutrino, electron capture and internal conversion; nuclear stability, stability lines, exotic nuclei.Standardα, β, γ and neutron laboratory sources. Nuclear sizes, binding energy per nucleon, nuclear saturation, liquid drop model leading to Weizsacker formula. Regions of fission and fusion.Magic numbers, shell model, ground state nuclear spins. Qualitative idea of collective models.

Unit II Nuclear Reactions I

Nuclear scattering and reactions, cross-sections, units, phase shifts, Resonance, Breit-Wigner formula.Qualitative idea of Bohr's picture of a nuclear reaction.Qualitative idea of the nucleon-nucleon and the complex nucleon-nucleon potential (the optical model).Different types of reactions, notation. Nuclear reaction cycles in stars, thep-p chain and the C-N cycle. Artificial radioactivity, radioactive isotopes of the elements.The Szilard-Chalmers process.Preparation of suitable compounds containing ^{35}S and ^{131}I.Slow neutron absorption in nuclei.Discovery of induced fission its important features.Discovery of spontaneous fission.

Unit III Nuclear Reactions II

Broad ideas of research reactors, power reactors.Recovery of unused fuel and waste disposal.Broad idea of Breeder reactors.Broad sketch of a fusion reactor.Metallurgy of U and Th. Enrichment of Uranium, separation of heavy water from ordinary water.Production of the Trans-Uranic elements.A somewhat detailed study of Pu.Energy loss suffered by charged particles in traversing matter-excitation, ionisation, Bremsshtrahlung and Cerenkov radiation. Attenuation of γ-rays in traversing matter-photoelectric effect, Compton effect and pair production.

Unit IV Instrumentation in Nuclear Chemistry

Instruments for detection and measurement of charged particles and neutrons-G.M. counter, solid state detectors and neutron counters. Cloud chamber.Instruments for γ-rays-scintillation counters.A broad idea of counting and scaling circuits.Shielding of charged particles, γ-rays and neutrons.Van de Graaff and heavy ion beam accelerators.Cyclotron.Very broad idea of Synchrotron principle leading to the era of super-energy machines.Electron Synchrotron and Synchrotron radiation. Radio-dating of wood and Pb-containing minerals

Unit V Application to Chemistry

Finding the elements in a mixture by activation analysis, extraction of radionuclides and transuranic elements by use of carriers.Study of reaction mechanisms like esterification, hydrolysis, oxidation of CO in the presence of MnO, study of PCl_5 with respect to the presence of the last two chlorine atoms and structure of the thiosulphateion.Radiometric titration including radiometric indicators.Brief introduction to radio-chromatography. Direct isotope dilution analysis and inverse isotope dilution analysis. Selection rules for γ-emission (or absorption), Nuclear isomerism, PIXE, Pair production chemistry, Muon chemistry, Mössbauer effect, Cow and Milk system.Applications of nuclear chemistry to biology, medicine, agriculture, industry etc.

Recommended Books & References

1. *Nuclear and Radiochemistry* G. Friedlander, J. W. Kennedy and J. M. Miller, , John Wiley (1981).
2. *Radiochemistry and nuclear chemistry* G. Choppin, J. O. Liljenzin and J. Rydberg, , Butterworth (1996).
3. *Essentials of Nuclear Chemistry*,H. J. Arnikar, Wiley Eastern Ltd. (1995).
4. Indian Association of Nuclear Chemistry & Allied Scientists (2004
5. Nuclear and radiation Chemistry B.K.Sharma , Krishna Publication (2011)

FOURTH SEMESTER

DISCIPLINE SPECIFIC ELECTIVE(DSE)Credits: 4

A. NANO CHEMISTRY & POLYMER SCIENCE

Unit I Fundamentals of Nanoscience and Nanotechnology

Solid materials and their strength, Perspective of length, Nanomaterials, Nanoscience and Nanotechnology, Nanostructures in nature, Prime materials, Carbon nanostructures viz. Carbon-nanotube (Single-walled and multi-walled), Fullerenes, Surface effects of Nanomaterials, Surface plasmon resonance, Quantum size effects, Quantum structures, Quantum confinement, Bright future of nanotechnology. Nanomaterial metal oxides:Zincoxide,Magnesium oxide, Aluminum oxide.

Unit II.Synthesis of Nanomaterials

Introduction, Nanomaterials synthesis, Top-Down and Bottom-Up Approaches, Solvothermal synthesis, Hydrothermal synthesis, Micelle formation, Size of the reverse micelle, Micellarsolubilization,Reverse micellar/Micro-emulsion method, Reverse micelles works as nano reactor, Mechanism for nanoparticle synthesis inside the reverse micelles,Co-precipitation, Sol-Gel Method, Polymeric Precursor Method and Sono-chemical Methods.

Unit III Introduction to Polymers

Polymer Molecules, Conformation and Molecular Dimensions of Polymer Molecules, Properties of Isolated Polymer Molecules, Elasticity and Swelling of Polymer Gels, Molecular Motion of Polymers in Dilute Solutions, Amorphous Polymers, Structure of Amorphous Phase in Bulk Polymers, Mobility in Polymers, Glass Transition- Measurement of T_g , Effect of Various Parameters on T_g, Theoretical Interpretations, Crystallinity in Polymers.

Unit IV Polymer Characterization

Thermodynamics of Polymer Solutions, Flory-Huggins and Lattice Theory of Polymer Solution, Entropy and Enthalpy of Mixing, Theta Temperature, Molecular Weight and Molecular Dimensions by End group Analysis,Ultracentrifugation, Fractionation and Gel Permeation Chromatography, Thermal Analysis of Polymers: Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA) and Differential Thermal Analysis (DTA), Polymer Degradation and Stabilization.

Unit V Polymer Rheology

Definition of Rheology, Geometry of Deformation, Newtonian and Non-Newtonian Behaviors, Measurement of Rheological Properties, Power Law, Free Volume Theory of Polymer Fluidity, Dynamic Flow Behavior, Time-Dependent Fluid Responses, Viscoelastic Properties, Mechanical Models of a Viscoelastic Material, Stress Relaxation, Creep and Relaxation behavior of Plastics.

Recommended Books & References

1. *Principals of Nanoscience and Nanotechnology*, M. A. Shah and Tokeer Ahmad, Narosa Publications, (2010).
2. *Nano Materials*, B. Viswanathan, Narosa Publications, (2009).
3. *Nano: The Essentials*, T. Pradeep, Tata Mcgraw Hill, (2009).
4. *Chemistry of Nanomaterials: Synthesis, Properties and Applications* by C.N.R. Rao, A. Muller and A. K. Cheetham (eds.), Wiley-VCH, Weinheim, (2004).
5. *Text Book of Polymer Science* By F. W. Billmeyer, Wiley-Blackwell; 3rd edition (1984)
6. *Introduction to Polymers* by R. J. Young and P. A. Lovell,Springer-science,BuisnessMedia,B.V(1991)
7. *Polymer Chemistry* by G. Challa, Ellis HorwoodLtd ,(1993)
8. *"Nanomaterials Chemistry: Recent Developments and New Directions"*, ed. by C.N.R. Rao, A. Muller & A.K. Cheetham (Eds.), Wiley-VCH, (2007).
9. *Solid State Chemistry and its applications*, Anthony R. West, John Wiley & Sons.(2017).
10. *Polymers: Chemistry and Physics of Modern Materials* by JMG Cowie,CRC press Taylor & Francis group,(2007)
11. *Principles of Polymerization* by George Odian, Wiley-Interscience; 4 edition (February 9, 2004)

B.APPLIED INORGANIC CHEMISTRY Credits: 4

Unit 1

Inorganic Polymers: Introduction, importance of Inorganic Polymers, Types of Inorganic Polymers. Characterization of Inorganic Polymers: Molecular Weights, Molecular Weight Distributions, Other Structural Features, Chain Statistics, Solubility Considerations, Crystallinity, Transitions, Spectroscopy, Mechanical Properties.

Unit 2.Paints and Varnishes and Portland cement.

(a) Paints and Varnishes: Paints as protective coatings, paints and enamels, materials for paint manufacture, oils used-unmodified oils and their pretreatment, modified drying oils, thinners, pigments and miscellaneous ingredients, composition and uses, defects in varnish films.

(b) Portland cement:

Introduction–raw materials–Different types of Kilns and uses–Manufacture and uses : Slag cement, Acid resisting cement, White cement–additives to cement–setting of cement–properties of cement. Concrete–preparation of concrete, curing of cement. Decay of cement–corrosion of concrete.

Unit 3 Nanomaterials

General introduction to nanomaterials and emergence of nanotechnology; Moore's law; synthesis of nanoparticles of gold, rhodium, palladium, platinum, and silver; Synthesis of nanoparticle semiconductors, nanowires and nanorods; Techniques of synthesis: electroplating and electrophoretic deposition, conversion through chemical reactions and lithography; Thin films: Chemical vapor deposition and Atomic layer deposition techniques; Carbon fullerenes and nanotubes.Applications of nanoparticles.

Unit 4.

Nuclear Chemistry

Basic concepts, models of nuclear structure and stability.Half – life period, Rate of radioactive decay, Synthetic elements, Uranium series,Nuclear reactions: nuclear fission, nuclear fusion.Principle of nuclear reactor,Uses of radioactive isotope,Detection and measurement of radioactivity.Radio-Chemical principle in the use of Tracers .Nuclear Binding energy,isotope dilution techniques and radiometric titrations.Radiopharmaceutical, radioimmunoassay and radiation sterilization. Hot atom chemistry.

Unit 5.

Agricultural Chemistry

Introduction and classification of soil and survey; Properties of soil; soil texture; soil water, soil temperature, soil colloids, soil minerals, soil pH; acidity and alkalinity, buffering soil, soil fertility , soil formation. Methods of pest controls. Methods of using pest control, insecticides, fungicides. Rodenticides and herbicides, ill effects of pesticides. Fertilizers – Classification and its ill effects. Framyard manure, compost, green manure crops, saw dust

***Recommeded Books and Referenc*es**

1. James E. Mark, Harry R. Allcock, Robert West, Inorganic Polymers, Second Edition, Oxford University Press (2005)
2. P.B. Saxena, Inorganic Polymers, Discovery Publishing House, 2007
3. Roger De Jaeger, Mario Gleria , Inorganic Polymers, Nova Science Publishers, 2007
4. Ronald D. Archer, Inorganic And Organometallic Polymers, John Wiley & Sons, 2001
5. F.A.Cotton& G. Wilkinson, Advanced Inorganic Chemistry, 5th Edition 1988.
6. J.E. Hukeey, E.A.KeiterAndR.L.Keiter, Inorganic Chemistry, Principles Of Structure And Reactivity, 4th 7. G.ZhongCao.*Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, Imperial College Press (2004).
8. M. Ratner & D. Ratner.*Nanotechnology: A Gentle Introduction to the Next Big Idea*, Pearson Education (2003).
9. G. Friedlander, J. W. Kenendy& J. M. Miller.*Nuclear and Radiochemistry*, Wiley Int.
10. H. J. Arnikar. *Essentials of Nuclear Chemistry*, Wiley Eastern.
11. Haissionsky, *Nuclear Chemistry and its applications*, Addison Wesley.
12. Fundamental concepts of applied chemistry - JayashreeGhosh (2006)
13.B.K. Sharma, Industrial Chemistry, 15th edition, Goel Publishing House, 2006.
14.P.C. Jain & Monica Jain, Engineering Chemistry, Dhanpat, Rai Publications, 2009.
15.B.R. Puri, L.R. Sharma, M.S. Pathania, Principles of Inorganic Chemistry, Vishal Publishing Co., 2017.

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C.APPLIED ORGANIC CHEMISTRY

Unit 1 ***Environmental Chemistry***

Chemistry and environmental pollution: Chemical hazards, chemical disasters, environmental biochemistry, toxicological chemistry

Environmental analysis: Analysis of water and wastewater, solid-wastes. toxicbiochemicals effect ofarsenic, lead and mercury.

Environmental protection: pollution prevention, green chemistry, biodegradation, water and wastewater purification – removal of arsenic, iron, fluoride, etc waste minimization, industrial and municipal waste treatment and soil remediation

Unit 2 ***Green Chemistry***

Green chemistry principles: Principles of green chemistry, atom economy, less hazardous chemical syntheses, designing safer chemicals, safer solvents and auxiliaries, design for energy efficiency, renewable feedstock, catalysis, design for degradation, real time analysis for pollution prevention, and inherently safer chemistry for accident prevention.

Design of green synthesis: Ideal synthesis, clean routes, supercritical solvents, ionic liquids, green catalyst, auto-exhaust catalyst and clean technology

Unit 3 ***Polymer chemistry***

Introduction, importance of polymers as a class of material, polymer raw materials

Polymerization techniques: Special features of polymerization, step polymerization, radical chain polymerization, living and non-living chain polymerization, co-ordination polymerization, co-olymerization, ionic polymerization, ring opening polymerization, characterization of polymers, Structure-property relationship: Stereochemistry of polymers, modification of polymers, cross-linking, polymer architecture, polymer processing and fabrication, polymer composites

Applications, degradation and future trends

Unit 4 ***Medicinal chemistry***

History of medicinal chemistry, interaction between drug molecule and receptor sites, drug action mechanism, drug metabolism, approaches to drug design Concept of drug, lead compound and lead modification, prodrugs and soft drugs; Structure-activity relationship (SAR), quantitative structure-activity relationship (QSAR);

Concept of drug receptors – elementary treatment of drug-receptor interactions; Factors affecting modes of drug administration, absorption, metabolism and elimination

Unit 5 ***Biochemistry***

Nucleic acid**:**Structure of purines and pyrimidine bases and their biosynthesis, nucleosides and nucleotides and their nomenclature Primary, secondary and tertiary structure of DNA; DNA replication and heredity;Structure and function of mRNA, tRNA and rRNA., structure of RNA and DNA, replication of DNA and mutagenesis, codon, anticodon, t-RNA, structure and genetic code, transcription and translation

Recommended Books and References

1.Medicinal Chemistry Pearson, D.Sriram, P.Yogeeswari
2.Introduction to Drug Design,New Age International , S.S. Pandeya&J.R.Dimmock
3.Introduction to Medicinal Chemistry Graham & Patrick
4. Medicinal chemistry and Drug discovery M.E .Wolff,John Wiley
5. Environmental Chemistry New Age International limited A.KDe.
6.Environmental Pollution Monitoring and Control New Age International Publisher, Khopkar S.M
7.Environmental Chemistry Lewis Publishers, London E.E.Manahan
8.Environmental Chemistry Academic Press,London J.W .Moore & E.A . Moore
9. A Texbook of Polymer Chemistry S.Chand Publication. M.S.Bhatnagar
10.Polymer Science Wiley Easten limited V.R.Gowariker,N.VViswanathan,JyadevSreedhar
11.Green Chemistry Environmentally Benign Reaction V.K Ahluwalia
12.New trends in Green chemistry,Anamalaya Publishers Ahluwalia V.K. &Kidwai M.R
13.Green Chemistry: An Introductory Text RSC Publishing M.Lancaster
14.Green Chemistry-Theory and Practical Oxford University Press Anastas, P.T & Warner ,J.K
15. Bio-Organic Chemistry PragatiPublising,MeerutVinayPrabha Sharma

D. NANOTECHNOLOGY AND POLYMER TECHNOLOGY Credits: 4

Unit I Characterization of Nanomaterials I

X-Ray DiffractionTechnique: Structure of nanomaterials, X-ray diffraction (XRD), The Laue method, The Rotating crystal method, The Powder method, Determination of grain size/crystallite size using X-ray line broadening studies (Scherrer's formula), Determination of crystallite size distribution using X-ray line shape analysis. Dynamic Light Scattering (DLS) Studies: Principle, Theory and methodology. X-ray diffraction pattern and analysis of some commercial important oxides(ZnO, CuO, $BaTiO_3$), Small angle X-ray scattering (SAXS).

Unit II.Characterization of Nanomaterials II

Electron Microscopic Techniques: Principles of electron microscopy, Scanning Electron Microscopy (SEM), Strengths and limitations of Scanning electron microscopy, Energydispersive X-ray analysis (EDX), Transmission Electron Microscopy (TEM), Atomic ForceMicroscopy (AFM) and Scanning Tunneling microscopy (STM). Method of sample preparation: Chemical fixation technique, Cryo fixation technique, Dehydration, Sectioning, Staining and Mechanical milling.

Unit III Applications of Nanomaterials

Importance of Nanomaterials (Gold, Silver,Dielectric and Magnetic Oxide Nanoparticles), Some selected applications like, Nanomaterials in medicine, Nanomaterials for energy sector, Kinetic energy (KE) penetrators with enhanced lethality, High energy density batteries, Nanomaterials in Next-Generation Computer, Nanomaterials in catalysis and sensors, Nanomaterials for water purification, Nanomaterials in communication sector, Nanomaterials in food, Nanomaterials for the environment, Nanomaterials in automobiles, Nanomaterials in ceramics industry.

Unit IV Polymer Technology

Polymers of Commercial Importance, Mass Polymerization: Solution, Emulsion and Suspension Polymerizations, Ziegler Natta Coordination Polymerization, MethathesisPolymerization.Additives for Plastics: Fillers, Plasticizers, Stabilizers, Lubricants, Flame Retardants, Foaming Agents, Crosslinking Agents,Manufacture, Properties and Applications of Major Thermoplastics and Thermosetting Polymers: PE, PP, PVC, PS, Polyamides, Polyesters, Phenolic Resins, Amino Resins and Epoxy Resins,Polymeric Coatings.

Unit VBiopolymers&Special Polymers

Structure, Functions and Properties of Naturally Occurring Polymers such as Proteins, Polysaccharides and DNA, Polymer Chemistry of Biological Processes, Synthetic Biopolymers, their Fabrication and Applications Conductive Polymers: Theory of Conduction, Synthesis and Applications of Conductive Polymers, Biodegradable Polymers, Biomaterials, Polymers in Medicine, Drug Delivery Systems, Recycling of Polymers.

Recommended Books and References

1. *Principals of Nanoscience and Nanotechnology*, M. A. Shah and Tokeer Ahmad, Narosa Publications, (2010).
2. *Nano Materials*, B. Viswanathan, Narosa Publications, (2009).
3. *Nano: The Essentials*, T. Pradeep, Tata Mcgraw Hill, (2009).
4. *Introduction to Atomic Force Microscopy*, Paul E. West, Pacific Nanotechnology, USA.(2010)
5. *Scanning Probe Microscopy and Spectroscopy*, Ronald Weisendanger, Cambridge University Press. (1994).
6. *Text Book of Polymer Science* By F. W. Billmeyer, Wiley-Blackwell; 3rd edition (1984)
7. *Introduction to Polymers* by R. J. Young and P. A. Lovell,Springer-science,BuisnessMedia,B.V(1991)
8. *"Nanomaterials Chemistry: Recent Developments and New Directions"*, ed. by C.N.R. Rao, A. Muller & A.K. Cheetham (Eds.), Wiley-VCH, (2007).
9. *Physical Principles of Electron Microscopy: An introduction to TEM, SEM and AFM* by R.F. Eqerton, Springer, (2008).
10. *Principles of Polymerization* by George Odian, Wiley-Interscience; 4 edition (February 9, 2004).

FOURTH SEMESTER

CREDITS: .8

LAB COURSE-IV

PROJECT WORK/COURSE WORK