

KASHI NARESH UNIVERSITY BHADOHI

(National Education Policy-2020)

**Syllabus
of
Chemistry
(w.e.f. Academic Session 2026-2027)**

For

M.Sc. Chemistry

Approved by
Board of Studies
Department of chemistry,
Kashi Naresh University Bhadohi


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SEMESTER-WISE STRUCTURE

SYLLABUS OF M.Sc.Chemistry Ist YEAR ovt.

FIRST SEMESTER

PAPER	DESCRIPTION	MARKS	Credit
PAPER I (CHE-101T)	Inorganic Chemistry-I	100 (75+25)	4
PAPER II (CHE-102T)	Organic Chemistry-I	100(75+25)	4
PAPER III (CHE-103T)	Physical Chemistry-I	100(75+25)	4
PAPER IV (CHE-104T)	[CHE-104A] - Sec-A Computer for Chemist (Compulsory for all student)	100(75+25)	(2+2)4
	[CHE-104B]- Sec-B Mathematics for Chemist (For students without mathematics in B.Sc) OR [CHE-104C]- Sec-C Biology for Chemist (For students without Biology in B.Sc)		
PAPER V (CHE-105P)	Inorganic, Organic, Physical Chemistry based, Viva-voce and Records	100(75+25)	4

SECOND SEMESTER

PAPER	DESCRIPTION	MARKS	Credit
PAPER I (CHE-201T)	Inorganic Chemistry-II	100 (75+25)	4
PAPER II (CHE-202T)	Organic Chemistry-II	100(75+25)	4
PAPER III (CHE-203T)	Physical Chemistry-II	100(75+25)	4
PAPER IV (CHE-204T)	Research methodology and Spectroscopic Techniques	100(75+25)	4
PAPER V (CHE-105P)	Inorganic, Organic, Physical Chemistry based, Viva-voce and Records	100(75+25)	4

M.Sc. Chemistry IInd YEAR

THIRD SEMESTER

PAPER	DESCRIPTION	MARKS	Credit
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PAPER II (CHE-302T)	Bio-inorganic and Bio-organic Chemistry	100(75+25)	4
PAPER III (CHE-303T)	Photochemistry and Environmental Chemistry	100(75+25)	4
PAPER IV (CHE-304P)	Inorganic, Organic, Physical Chemistry based, Viva-voce and Records	100(75+25)	4
RESEARCH (CHE-305R)	Dissertation/Research Project	100	4

FOURTH SEMESTER

PAPER	DESCRIPTION	MARKS	Credit
PAPER I (CHE400 A-J)	Elective Paper-I	100(75+25)	4
PAPER II (CHE 400A-J)	Elective Paper-II	100(75+25)	4
PAPER III (CHE 400A-J)	Elective Paper-III	100(75+25)	4
PAPER IV (CHE404P)	Inorganic, Organic, Physical Chemistry based Viva-voce and Records	100(75+25)	4
RESEARCH (CHE405R)	Dissertation/Research Project	100	4

Elective papers

A. Organo-transition Metal chemistry	F. Organic Synthesis-I
B. Bioinorganic and Supra molecular Chemistry,	G. Organic Synthesis-II
C. Photo Inorganic chemistry	H. Heterocyclic Chemistry
D. Analytical Chemistry and Techniques	I. Chemistry of Natural products
E. Polymers	J. Medicinal Chemistry

Note¹- Out of given Ten Elective Papers, students have to select any three papers.

Note²:- External Assessment- Written Examination (75 Marks), Internal Assessment- (25 Marks) : for every Theory & Practical Papers.

*Research Projects include industrial training/internship/survey work etc. (100 Marks) for both IIIrd and IVth Semester.



UNIT-I

Symmetry and Group Theory in Chemistry

Symmetry elements and symmetry operation, definitions of groups, subgroups, relation between orders of a finite group and its subgroup. Conjugacy relation and classes. Point symmetry group. Schonflies symbols, representation of groups by matrices (representation of the C_n , C_{nv} , C_{nh} , D_{nh} etc groups to be worked out explicitly). Character of a representation. Character tables and their use in spectroscopy.

UNIT-II

Stereochemistry and Bonding in Main Group Compounds

VSEPR, Walsh diagrams (tri and penta-atomic Molecules), $d\pi-p\pi$ bonds, bent rule and energetics of hybridization, some simple reactions of covalently bonded molecules.

UNIT-III

Metal-Ligand Equilibria in Solution

Stepwise and overall formation constants and their interaction, trends in stepwise constants, factors affecting the stability of metal complexes with reference to the nature of metal ion and ligand, chelate effect and its thermodynamic origin, determination of binary formation constants by pH metry and spectrophotometry.

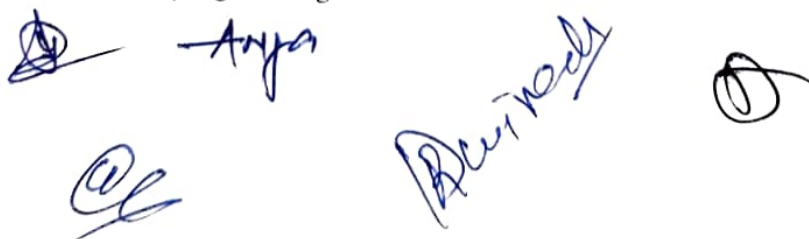
UNIT-IV

Metal-Ligand Bonding

Limitation of crystal field theory, molecular orbital theory. Octahedral, tetrahedral and square Planar complexes, π -bonding and molecular orbital theory.

Books Recommended

1. F.A.Cotton and G. Wilkinson Advanced Inorganic Chemistry, 6th Edn. (1999), John Wiley & Sons, New York.
2. James E.Huheey, Inorganic Chemistry, 4th Edn. (1993), Addison-Wesley Pub. Co., New York.
3. Chemistry of the elements, N.N.Greenwood and A. Earnshaw, Pergammon.
4. Inorganic Electronic Spectroscopy, A.B.P.Lever, Elsevier.
5. Comprehensive Coordination Chemistry, G. Wilkinson, R.D. Gillars and J.A.Mc Cleverty. Pergammon.
6. Magneto Chemistry, R.L.Carlin, Springer Verlag.



Paper II-Organic Chemistry-I

[CHE-102]

Credit-4

UNIT-I

Nature of bonding in Organic Molecules

Delocalized chemical bonding-conjugation, cross conjugation, resonance, hyperconjugation, bonding in fullerenes. Aromaticity in benzenoid and non-benzenoid Compounds, Huckel's rule, energy level of pi-molecular orbitals, annulenes, antiaromaticity,

UNIT-II

A-Stereochemistry: Conformational analysis of cycloalkanes, decalines, effect of conformation of reactivity. Elements of symmetry, chirality, molecule with more than one chiral center, threo and erythro isomers, stereospecific and stereoselective synthesis. Asymmetric synthesis. Optical activity in the absence of chiral carbon biphenyls, allenes and spiranes

B-Reaction mechanism, Structure and reactivity: Methods of determining mechanism, isotope effect. Generation structure, stability and reactivity of benzyne, carbenes and nitrenes. Effect of structure on reactivity resonance and field effect, steric effect, quantitative treatment.

UNIT-III

Aliphatic nucleophilic substitution

The S_N2 , S_N1 , mixed S_N1 , and S_N2 , the neighboring group mechanism, neighboring group participation by Pi and Sigma bonds, anchimeric assistance. Classical and non classical carbocations. The S_N1 , mechanism, nucleophilic substitution at an allylic, aliphatic trigonal and a vinylic carbon. Reactivity effects of substrate structure, attacking nucleophile. Leaving group and reaction medium, ambident nucleophile, regioselectivity.

UNIT-IV

A- Aromatic electrophilic substitution

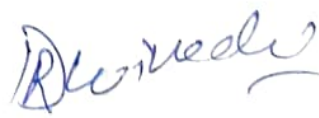
The arenium ion mechanism, orientation and reactivity, energy profile diagrams. The Ortho/Para ratio, ipso attack, orientation in other ring systems. Vilsmeier reaction, Gattermann-Koch reaction.

B- Aromatic nucleophilic substitution

The S_NAr , S_N1 , benzyne and $SRN1$ mechanism. Reactivity effect of substrate structure, leaving group and attacking nucleophile. The Von Richter, Sommelet Hauser, and Smiles rearrangements.

BOOKS SUGGESTED

1. Advanced Organic Chemistry- Reactions, Mechanism and Structure, Jerry March, John Wiley.
2. Advanced Organic Chemistry, F.A.Carey and R.J.Sundberg, Plenum.
3. A Guide Book to Mechanism in Organic Chemistry, Peter Sykes, Longman.
4. Structure and Mechanism in Organic Chemistry, C.K.Ingold, Cornell University press.
5. Organic Chemistry, R.T. Morrison and R.N. Boyd, Prentice Hall.
6. Modern Organic Reactions H.O.House, Benjamin
7. Principles of Organic Synthesis, R.O.C.Normon and J.M.Coxon, Blackie Academic and professional.



8. Pericyclic Reactions. S.M.Mukherji, Macmillan, India.
9. Reaction Mechanism in Organic Chemistry: S.M.Mukherji and S.P.Singh, Macmillan.
10. Stereochemistry of Organic Compounds D.Nasipuri, New Age International.
11. Stereochemistry of Organic Compounds, P.SKalsi, New Age, International.

Paper-III (Physical Chemistry-I)

[CHE-103]

Credit-4

UNIT-I

A-Unifying Principles

Electromagnetic radiation, interaction of electromagnetic radiation with matter-absorption, emission transmission, reflection, refraction, dispersion, polarization and scattering. Uncertainty relation and natural line width and natural line broadening, selection rules, intensity of spectral lines. Born Oppenheimer approximation, rotational, vibrational and electronic energy levels.

B- Microwave Spectroscopy

Classification of molecules, rigid rotor model, Effect of isotopic substitution on the transition frequencies intensities, non-rigid rotor. Stark effect. Applications.

UNIT-II

Vibrational Spectroscopy

A. Infrared Spectroscopy

Review of linear harmonic oscillator, vibrational energies of diatomic molecules, zero point energy, force constant and bond strength; anharmonicity, P.Q.R. branches, vibrations of polyatomic molecules, Selection rules, normal modes of vibration, factors affecting, the band positions and intensities.

B. Raman Spectroscopy

Classical and quantum theories of Raman effect Pure rotational, vibrational and vibrational-rotational Raman spectra, selection rules, mutual exclusion principle. Applications of Raman spectroscopy.

UNIT-III

Quantum Chemistry

A. Fundamental Background: Operators, Postulates of Quantum Mechanics, Hamiltonian for different systems, Angular momentum.

B. Introduction to Exact quantum Mechanical Results: The Schrodinger equation, discussion of solutions of the Schrodinger equation to some model system viz particle in a box, the harmonic oscillator, the rigid rotor, the hydrogen atom.

C. Approximate Methods: The Variation theorem, linear variation principle. Perturbation theory (First order and non-degenerate) Application of variation method and perturbation theory to the Helium atom.

D. Electronic structures of Atoms: Russell-Saunders terms and coupling schemes, term symbols for the pⁿ and dⁿ configurations Spin orbit coupling and Zeeman splitting, introduction to the methods of self-consistent field, Slater type orbitals.

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E. Molecular orbital theory: Huckel theory of conjugated systems, bond order and charged density calculations. Application to ethylene, butadiene, cyclo-butadiene and Benzene molecules.

UNIT-IV

Chemical Dynamics: Methods of determining rate law, collision theory of reaction rates steric factors Activated complex theory Arrhenius equation and the activated complex theory, ionic reactions kinetic salt effect, steady state kinetics. Dynamic chain (hydrogen-bromine reaction pyrolysis of acetaldehyde) photochemical (hydrogen bromine reaction hydrogen-chloride reactions) and oscillatory reactions (Belousov Zhabotinsky reaction) homogeneous catalysis, kinetics of enzyme reaction General features of fast reaction study of fast reaction by relaxation method flash photolysis and the nuclear magnetic resonance method. Dynamics of unimolecular reactions (Lindemann Hinshelwood and Rice-Ramsperger-kassel-marcus {RRKM} theories of unimolecular reactions).

BOOKS SUGGESTED

1. Modern Spectroscopy, IM Hallin, John Wiley
2. Physical methods in Chemistry, RS Drages, Saunders College Introduction to Molecular Spectroscopy G.Mares Mill
3. Physical Chemistry P W Atkins, ELBS
4. Introduction to Quantum Chemistry, A.K. Chandra, Tan McGraw H
5. Quantum Chemistry, Ira Levine Prentice Hall
6. Condun Valence. R.McWeeny, ELBS
7. Chemical Kinetics, Kasdien. McGraw-
8. Kinetics and Mechanism of Chemical Reactions, Tamas Rajaraman and Kuriacne McMillan

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Paper-IV

[CHE-104A]

Credit-2

Sec-A: Computers for Chemists (Compulsory for all students)

This is a theory-cum-laboratory course with more emphasis on laboratory work.

UNIT-I

Introduction to Computer and Computing:

Basic structure and functioning of computers with a PC as an illustrative example. Memory, I/O devices, Secondary storage. Computer languages. Operating systems with DOS as an example. Introduction to UNIX and WINDOWS Data Processing principles of programming, algorithms and flow charts.

UNIT-II

Computer Programming in FORTRAN/C/BASIC:

The language features are listed here with reference to FORTRAN. The instructor may choose another language such as BASIC or C and the features may be replaced appropriately. Elements of the computer language. Constants and variables, operations and symbols, expressions. Arithmetic assignment statement. Input and Output. Format statement. Termination statements. Branching statements such as IF or GO TO statement. LOGICAL variables. Double precision variables, Subscripted variables and DIMENSION. DO statement FUNCTION and SUBROUTINE COMMON and DATA statements. (Students learn the programming logic and these language features by hands on experience on a personal computer from the very beginning of this topic)

UNIT-III

Programming in Chemistry:

Development of small computer codes involving simple formulae in chemistry such as van der Waals equation, pH titration, kinetics, radioactive decay. Evaluation of lattice energy and ionic radii from experimental data. Linear simultaneous equations to solve secular equations within the Huckel theory. Elementary structural features such as bond lengths, bond angles, dihedral angles etc. of molecules extracted from a database such as Cambridge data base.

UNIT-IV

Use of Computer Programmes:

The students will learn how to operate a PC and how to run standard programmes and packages. Execution of linear regression, X-Y plot. Numerical integration and differentiation as well as differential equation solution programmes. Monte Carlo and Molecular dynamics. Programmes with data preferably from physical chemistry laboratory. Further, the students will operate one or two of the packages such as MATLAB EASYPLOT LOTUS FOXPRO and Word processing software such as WORDSTAR/MS WORD.

Books Suggested

1. Computers and common Sense, R.Hunt and I.Shelley. Prentice Hall.
2. Computational Chemistry, A.C.Norris.
3. Microcomputer Quantum mechanics, J.P.Killingbeck. Adam Hilger.
4. Computer Programming in FORTRAN IV, V.Rajaraman, Prentice Hall.
5. An Introduction to Digital Computer Design. V.Rajaraman and T. Radhakrishna Prentice Hall.

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Paper-IV

Sec-B: Mathematics For Chemists

[CHE-104B]

Credit-2

(For students without Mathematics in B.Sc.)

UNIT-I

Vectors and matrix Algebra

A-Vectors

Vectors, dot, Cross and triple products etc. The gradient, divergence and curl.

B-Matrix Algebra

Addition and multiplication: inverse, adjoint and transpose of matrices, special matrices (Symmetric, skew-symmetric Hermitian, skew-Hermitian, unit, diagonal, unitary etc) and their properties Matrix equations: homogeneous, non-homogeneous linear equations and conditions for the solution, matrix eigen-values diagonalisation determinants (examples from Huckel theory)

UNIT-II

Calculus

A-Differential Calculus: Functions, continuity and differentiability, rules for differentiation, applications of differential calculus including maxima and minima (examples related to maximally populated rotational energy levels. Bohr's radius and most probable velocity from Maxwell's distribution etc) exact and inexact differentials with their applications to thermodynamic properties.

B- Integral calculus: Basic rules for integration, integration by parts, partial fraction and substitution. Reduction formulae applications of integral calculus. Functions of several variables. partial differentiation, co-ordinate transformations (e.g. cartesian to spherical polar).

UNIT-III

Elementary Differential Equations

Variables-separable and exact first-order differential equations. homogeneous. exact and linear equations. Applications to chemical kinetics, secular equilibria, quantum chemistry etc. Solutions of differential equations by the power series method, Fourier series, solutions of harmonic oscillator and Legendre equation etc., spherical harmonics second order differential equations and their solutions.

UNIT-IV

Permutation and Probability

Permutations and combinations, probability and probability theorems, probability curves, average, root mean square and most probable errors, examples from the Kinetic theory of gases etc.

Books Suggested:

1. The chemistry Mathematics Book, E. Steiner, Oxford University Press.
2. Mathematics for Chemistry, Doggett and Sucliffe. Longman.
3. Mathematical preparation for Physical Chemistry. F.Daniels McGraw Hill.
4. Chemical Mathematics, D.M.Hurst, Longman.
5. Applied Mathematics for Physical Chemistry. J.R.Barrante. Prentice Hall.
6. Basic Mathematics for Chemists, Tebbutt. Wiley.

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Paper-IV (Section-C)

[CHE-104C]

Credit-2

Biology for Chemist (For students without Biology in B.Sc.)

UNIT-I

A-Cell Structure and Functions

Structure of prokaryotic and eukaryotic cells, intracellular organelles and their functions, comparison of plant and animal cells. Overview biological energy currency. Introduction to biomolecules. building blocks of biomacromolecules.

B-Carbohydrates: Structure and functions of important derivatives of monosaccharides like glycosides, deoxy sugars, myoinositol, amino sugars. N-acetylmuramic acid, sialic acid, disaccharides and polysaccharides. Structural polysaccharides-cellulose and chitin. Structure and biological functions of glucosaminoglycans or mucopolysaccharides. Carbohydrates of glycoproteins and glycolipids. Role of sugars in biological recognition. Blood group substances. Carbohydrate metabolism, Kerb's cycle, glycolysis, glycogenesis, gluconeogenesis pentose-phosphate pathway.

UNIT-II

Lipids: Fatty acids, essential fatty acids, structure and function of triacylglycerols, glycerophospholipids, sphingolipids, cholesterol, bileacids, prostaglandins, properties of lipid aggregates-micelles, bilayers, liposomes and their possible biological functions. Biological membranes. Fluidmosaic model of membrane stucture Lipid metabolism β -oxidation of fatty acids.

UNIT-III

Amino-acids

Peptidesandproteins: Chemical and enzymatic hydrolysis of proteins to peptides, amino acid sequencing, secondary structure of protein, forces responsible for holding of secondary structure. A helix, β -sheets, Super secondary structure, triple helix structure of collagen. Tertiary structure of protein, folding and domain structure of proteins. Quaternary structure. Amino acid metabolism, degradation and biosynthesis of amino acids. Sequence determination chemical/enzymatic/mass spectral. racemization/detection. Chemistry of oxytocin and tryptophan releasing hormone (TRH).

UNIT-IV

Nucleic Acids

Purine and pyrimidine bases of nucleic acids, base pairing via H-bonding structure of ribonucleic acid (RNA) and deoxyribonucleic acids (DNA), double helix model of DNA and forces responsible for holding it. Chemical and enzymatic hydrolysis of nucleic acids. The chemical basis for heredity and overview of replication of DNA, transcription, translation and genetic code. Chemical synthesis of mono and trinucleoside.

—Anja



Books Suggested



R. D. Wainwright



1. Principles of Biochemistry, A.L. Lehninger Worth Publishers.
2. Biochemistry, L. Stryer, W.H. Freeman.
3. Biochemistry, J. David Rawn, Nell Patterson.
4. Biochemistry Voet and Voet, John Wiley.
5. Outlines of Biochemistry, E.E. Conn and P.K. Stumpf, John Wiley.

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Practicals

Note:-

1) A complete record of practical exercises; in Inorganic, Organic and Physical Chemistry done during the session must be produced by the candidates in three separate Record Books at the time of practical examination.

Inorganic Chemistry**1. Qualitative analysis of mixtures**

Qualitative analysis of mixture containing trace elements Ti, Mo, W, Zr, Th, V, U (Two metal ions in cationic/anionic forms) and insoluble oxides, sulphates and halides. The mixture should not contain more than five cations and should be analyzed by semi micro technique. 05

2. Paper chromatography

Paper chromatography separation of a mixture of the following and measurements of R_f-values.

- a) Pb⁺², Ag⁺², Hg⁺²
- (b) Co⁺², Ni⁺², Cu⁺²
- (c) Ba⁺², Ca⁺², Sr⁺²

Organic Chemistry**1. Qualitative Analysis**

Separation, purification, and identification of binary mixture. Preparation of derivatives if possible

2. Organic Synthesis

- i. Adipic acid by chromic acid oxidation of cyclohexanol.
- ii. Triphenyl methanol from Benzoic acid.
- iii. Dibenzal acetone from Benzaldehyde.
- iv. p-chlorotoluene from p-toluidine
- v. Synthesis of p-nitroaniline and p-bromoaniline.

Physical Chemistry (Anyone of the following)

- 1. Study the adsorption of acetic acid on charcoal and draw the Freundlich isotherm.
- 2. Show that the order of reaction between acetone and Iodine is zero with respect to Iodine.
- 3. Determination of congruent composition and temperature of a binary mixture e.g. diphenylamine-benzophenone system.
- 4. Determination of glass transition temperature of a given salt (e.g., CaCl₂) conductometric ally.
- 5. Determination of the velocity constant of hydrolysis of an ester/ionic reaction in micellar media.
- 6. Determination of the velocity Constant of decomposition of Benzene diazonium chloride.

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Inorganic-II (Paper-I)

[CHE-201]

Credit-4

UNIT-I

Reaction mechanism of Transition Metal Complexes

Energy profile of a reaction, reaction reactivity of metal complexes, inert and labile complexes, kinetic application of valence bond and crystal field theories, kinetics of octahedral substitution, acid hydrolysis, factors affecting acid hydrolysis, base hydrolysis conjugate base mechanism, direct and indirect evidences in favour of conjugate mechanism, anation reaction, reactions without metal ligands bond cleavage. Substitution reaction in square planar complexes. Redox reactions, electron transfer reactions, mechanism of one electron transfer reactions, outer sphere type reactions., cross-reactions and Marcus-Hush theory, inner sphere type reactions.

UNIT-II

Electronic spectra and Magnetic Properties of Transition Metal Complexes.

Spectroscopic ground states; Orgel energy level and Tanabe-Sugano diagrams for transition metal complexes (d^1 - d^9 states); Charge transfer spectra; electronic spectra of octahedral and tetrahedral Co(II) and Ni(II) complexes and calculation of ligand-field parameters.

UNIT-III

Metal π -Complexes

Metal carbonyls, structure and bonding, vibrational spectra of Metal carbonyls for bonding and structural elucidation, important reactions of Metal carbonyls, preparation, bonding. Structure and important reactions of transition metal nitrosyl, dinitrogen and dioxygen complexes, tertiary phosphine as ligand.

UNIT-IV

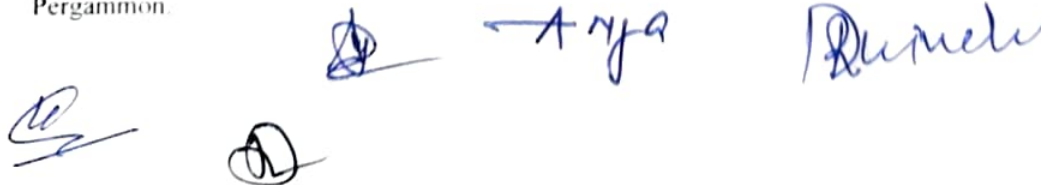
A-Metal Clusters

Higher boranes, carboranes, metallocarboranes

B- Isopoly and hetero poly acids and salts

Books Recommended

1. F.A.Cotton and G. Wilkinson Advanced Inorganic Chemistry, 6th Edn. (1999). John Wiley & Sons, New York.
2. James E. Huheey, Inorganic Chemistry, 4th Edn. (1993). Addison-Wesley Pub.Co., New York.
3. Chemistry of the elements, N.N.Greenwood and A.Earnshaw, Pergammon.
4. Inorganic Electronic Spectroscopy, A.B.P.Lever, Elsevier.
5. Comprehensive Coordination Chemistry eds., G.Wilkinson, R.D.Gillars and J.A. Mc Cleverty, Pergammon.



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[CHE-202]

UNIT-I

Free radical reactions: Free radical substitution mechanism, mechanism at an aromatic substrate, neighboring group assistance. Reactivity for aliphatic and aromatic substrates at a bridge head. The effect of solvent on reactivity Arylation of aromatic compounds by diazonium salt, Hunsdiecker reaction.

UNIT-II

A-Addition to carbon-carbon multiple bond: Mechanistic and stereo-chemical aspects of addition reactions involving electrophile, nucleophile and free radicals, regio and chemo selectivity, orientation and reactivity. Hydrogenation of aromatic rings. Hydroboration, Michael reaction, Sharpless asymmetric epoxidation

B-Addition to carbon hetero atom multiple bonds Mechanism of metal hydride reduction of saturated and unsaturated carbonyl compounds, acids, esters and nitriles. Wining reaction mechanism of condensation reactions involving enolate, Knoevenagel, Mannich, Stobbe reactions. Hydrolysis of esters and amides, ammonolysis of esters.

UNIT-III: Elimination reactions:

The E2, E1 and E1cB mechanism. Orientation of double bond. Reactivity, effect of substrate, structures. Attacking base, the leaving group and the medium. Mechanism and orientation on Pyrolytic elimination.

UNIT-IV: 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 correlation diagram. FMO and PMO approach. Electrocyclic reactions- conrotatory and disrotatory motions, $4n$, $4n+2$ and allyl systems. Cycloadditions-antarafacial and Suprafacial additions, $4n$ and $4n+2$ system, Sigma tropic rearrangements-sup -suprafacial an antarafacial shift of H. sigmatropic shifts involving carbon moieties. 3, 3 and 5,5 sigmatropic rearrangements. Claisen-Cope and Aza Cope rearrangement. Fluxional tautomerism. Ene reaction.

BOOKS SUGGESTED

1. Advanced Organic Chemistry- Reactions, Mechanism and Structure, Jerry March, John Wiley.
2. Advanced Organic Chemistry. F.A.Carey and R.J.Sundberg Plenum.
3. A Guide Book to Mechanism in Organic Chemistry, Peter Sykes, Longman.
4. Structure and Mechanism in Organic Chemistry, K.Ingold, Cornell University press.
5. Organic Chemistry, R.T.Morrison and R.N.Boyd, Prentice Hall.
6. Modern Organic Reactions H.O.House, Benjamin
7. Principles of Organic Synthesis, R.O.C.Normon and J.M. Coxon, Blackie Academic and professional.
8. Pericyclic Reactions, S.M.Mukherji, Macmillan India.
9. Reaction Mechanism in Organic Chemistry S.M.Mukherji and S.P.Singh, Macmillan.
10. Stereochemistry of Organic Compounds D.Nasipuri, New Age International.

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Mishra

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Physical-II (Paper-III)

[CHE-203]

Credit 4

UNIT-I

Thermodynamics

A-Classical Thermodynamics: Brief resume of concepts of laws of thermodynamics, free energy and chemical potential. Partial, molar properties partial molar free energy, partial molar volume and its determination, Gibbs - Duhem equation, concept of fugacity (by graphical method), Activity and Activity coefficient.

B-Statistical Thermodynamics: Concept of distribution, thermodynamic probability and most probable distribution. Canonical, grand canonical and micro canonical ensembles, The Boltzmann distribution law. Partition Functions-translational, rotational, vibrational and electronic partition function. Calculation of thermodynamic properties and equilibrium constant in terms of partition function. Fermi-Dirac and Bose Einstein statistics.

C-Non-Equilibrium Thermodynamics: Thermodynamic criteria for non-equilibrium states, entropy production and entropy flow, Entropy balance equation for different irreversible processes (eg heat flow chemical reaction etc. Transformation of the generalized fluxes and forces non-equilibrium stationary phenomenological equations, Onsager reciprocity relation, electrokinetic phenomena.

UNIT-II

Surface chemistry:

A-Adsorption: Gibbs adsorption isotherm estimation of surface area (BET equation), surface films on liquids (Electro kinetic phenomenon), catalytic activity at surfaces.

B-Micelles: Surface active agents, classification of surface active agents, micellization hydrophobic interactions, Critical micellar concentration (CMC) Factors affecting CMC of surfactants counterion binding to Micelles, solubilization micro emulsion reverse micelles.

UNIT-III

Macromolecules: Polymer-definition, types of polymer, electrically conducting fire resistant, liquid crystal polymer, Kinetics of polymerization, Molecular mass, number and mass average molecular mass molecular mass determination (Osmometry, Viscometry diffusion and light scattering method) sedimentation chain configuration of macromolecules, Calculation of average dimension of various chain structures.

UNIT-IV

Electrochemistry: Debye- Huckel theory of activity coefficient of electrolytic solutions, applicability and limitations of Debye-Huckel limiting law, ionic strength, structure of electrified interfaces, Helmholtz- perrin, Guoy- Chapman and stern models. Over potentials, exchange current density, derivation of Butler-volmer equation, Tafel plot. Electrocatalysis, Influence of various parameters, Hydrogen electrode. Polarographytheory, interpretation of a polarographic curve, instrumentation, limiting current, residual and charging current, diffusion current. Supporting electrolytes, Likovicequation, half wave potential and its significance. Introduction to corrosion, homogeneous theory, forms of corrosion, corrosion monitoring and prevention methods.

BOOKS SUGGESTED

@ Anpa \$ D. R. M. 12

1. Kinetics and Mechanism of Chemical Transformations J. Rajaraman and J. Kuriacose Me Millan.
2. Micelles. Theoretical and Applied Aspects, V. Moroi, Plenum.
3. Modern Electrochemistry Vol. I and Vol. II J.O.M. Bockris and AK.N. Reddy, Plenum.
4. Introduction to Polymer Science V.R. Gowarikar, N.V. Vishwanathan and J.Sridhar, Wiley Eastern.
5. Physical Chemistry P.W.Atkins, ELBS.

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Research Methodology and Spectroscopic Technique (Paper IV)

[CHE-204]

Credit 4

Unit-I

Research Methodology Meaning, Objective, Motivation and Types of research. Research Approaches its significance and methods vs methodology. Scientific methods of research. Research

Problem Selection, Necessity Basic Principle of Experimental and different research design.

Separation technique involved in research- Distillation, Crystallization, Filtration, Evaporation, Extraction, Adsorption, Centrifugation, TLC, HPLC, Paper Chromatography

UNIT-II

Nuclear Magnetic Resonance Spectroscopy

Nuclear spin, nuclear resonance, saturation, shielding of magnetic nuclei, chemical shift and its measurements, factors influencing chemical shift deshielding, spin-spin interactions, factors influencing coupling constant Effect of chemical exchange, spin decoupling, basic ideas about instrument, NMR studies of nuclei other than proton- ^{13}C , ^{19}F and ^{31}P . FT NMR, advantages of FT NMR use of NMR in medical diagnostics.

UNIT-III

Electron Spin Resonance-Spectroscopy

Basic principles, zero field splitting and Kramer's degeneracy. Factors affecting the 'g' value. Isotropic' and anisotropic hyperfine coupling constants, measurement techniques and applications.

UNIT-IV

A-X-ray Diffraction

Bragg method of X-ray structural analysis of crystals, index reflections. Structure of simple lattices and X-ray intensities.

B-Electron Diffraction

Scattering intensity vs. scattering angle, Wierl equation, measurement technique, elucidation of structure of simple gas phase molecules.

BOOKS SUGGESTED

1. Modern Spectroscopy, J.M.Hollas, John Wiley
2. Applied Electron Spectroscopy for Chemical Analysis ed. H. Windawi and F.L. Ho. Wileyinterscience.
3. NMR, NOR EPR and Mossbauer Spectroscopy in inorganic Chemistry, R.V.Parish, Ellis Harwood.
4. Introduction to Molecular Spectroscopy G.M.Barrow, McGraw Hill
5. Basic principles of Spectroscopy, R. Chang McGraw Hill.
6. Introduction to Magnetic Resonance, Acarrington and A.D.maclachalan, Harper & Row.
7. J. D. Seader, and J. Ernest Henley, Separation Process Principles, Wiley, 2nd edition (2013).
8. C.R. Kothari, Research Methodology, methods and techniques, New Age International.





Practical Semester-II
(CHE-205)

credit 4

A complete record of practical exercises; in Inorganic, Organic and Physical Chemistry done during the session must be produced by the candidates in three separate Record Books at the time of practical examination.

Inorganic Chemistry

I. Quantitative estimation of two metal ions Cu-Ni, Ni-Zn, Cu-Fe etc involving volumetric and gravimetric methods. 20

II. Preparation of selective inorganic compounds (any one)

- (a) $\text{VO}(\text{acac})_2$,
- (b) $\text{Na}[\text{Cr}(\text{NH}_3)_2(\text{SCN})_4]$,
- (c) $\text{K}_3[\text{Fe}(\text{C}_2\text{O}_4)_3]$
- (d) Prussian Blue
- (e) $[\text{Co}(\text{Py})_2\text{Cl}_2]$
- (f) $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4 \cdot \text{H}_2\text{O}$

Organic Chemistry

Quantitative Synthesis (Any Two)

- I. Determination of the percentage or number of hydroxyl groups in an organic compound by acetylation method.
- II. Estimation of amine/phenols using bromated bromide solution or acetylation method.
- III. Determination of iodine and saponification values of an oil sample.
- IV. Determination of DO, COD and BOD of water sample.

Physical Chemistry (Anyone)

(25)

- I. Determination of molecular weight of non-volatile and non-electrolyte/electrolyte by cryoscopic method and to determine the activity coefficient of an electrolyte.
- II. Determination of the degree of dissociation of weak electrolyte and to study the deviation from ideal behaviour that occurs with a strong electrolyte.
- III. Determination of the velocity constant, order of the reaction and energy of activation for saponification of ethyl acetate by sodium hydroxide conductometrically.
- IV. Determination of solubility and solubility product of sparingly soluble salts (e.g. PbSO_4 , BaSO_4) conductometrically.
- V. Determination of the strength of strong and weak acids in a given mixture conductometrically

VI. Viva

(15)

VII. Records

(10)



UNIT-I

Applications of Spectroscopy in Inorganic Chemistry

A. Vibrational Spectroscopy: Symmetry and shapes of AB_2 , AB_3 , and AB_4 , mode of bonding of ambidentate ligands such as thiocyanate, nitrate, sulphate and urea, application of Raman spectroscopy particularly for the study of ionic equilibrium in solution.

B-Electron Spin Resonance Spectroscopy: Hyperline coupling, spin polarization for atoms and transition metal ions, spin-orbit coupling and significance of g-tensors, application to transition metal complexes having one unpaired electron and inorganic free radicals such as PH_4^{+} , F_2 , and BH_3 .

C-Mossbauer Spectroscopy: Basic principles, spectral parameters and spectrum display. Application of the techniques to the studies of: (1) bonding and structures of Fe^{+2} and Fe^{+3} compounds including those of intermediate spin and, (2) Sn^{+2} and Sn^{+4} compounds, nature of M-L bond, coordination number, structure.

UNIT-II

Applications of Spectroscopy-I

A-Ultraviolet and Visible Spectroscopy: Various electronic transitions (185-800 nm). Beer Lambert law. Effect of solvent on electronic transitions, ultraviolet bands for carbonyl compounds, unsaturated carbonyl compounds, dienes, conjugated polyenes, ultraviolet spectra of aromatic and heterocyclic compounds.

B-Infrared Spectroscopy Characteristic vibrational frequencies of aromatic compounds, alcohols, ethers, phenols and amines. Detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides and acids), effect of hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination bands and Fermi resonances.

UNIT-III

Applications of Spectroscopy-II

A-Nuclear Magnetic Resonance Spectroscopy General introduction and definition, chemical shift, spin-spin interaction, shielding mechanism, mechanism of measurement, chemical shift values and correlation for protons bonded to carbon (aliphatic, olefinic, aldehydic and aromatic) and other nuclei (alcohols, phenols, enols and carboxylic acids) chemical exchange, effect of deuteration, complex spin-spin interaction between two, three, four and five nuclei (first order spectra)

B-Carbon-13 NMR Spectroscopy General considerations, chemical shift (aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl carbon), coupling constants.

UNIT-IV

Applications of Spectroscopy-III

Mass spectrometry: Introduction, ion production- EI, CI, FD and FAB, factors affecting the fragmentation, ion analysis, ion abundance, mass spectral fragmentation of organic compounds, common functional groups, molecular ion peak, metastable peak, McLafferty rearrangement, Nitrogen rule.

Books suggested

1. Physical Methods for Chemistry, R.S.Dargo, Saunders Company
2. Structural Methods in Inorganic Chemistry, E.A.V.Ebsworth, Rankin and Cradock-ELBS
3. Infrared and Raman Spectra Inorganic and Coordination Compounds, K.Nakamoto, Wiley.
4. Progress in Inorganic Chemistry, 8 edition, F.A.Cotton
5. Transition Metal Chemistry, R.L. Carlin, vol.3, Dekker.
6. Inorganic Electronic Spectroscopy, A.P.B.Lever, Elsevier.
7. NMR, NOR, EPR and Mossbauer Spectroscopy in Inorganic Chemistry, R.V. Parish, Ellis Horwood
8. Practical NMR Spectroscopy, M.L.Martin, J.J. Delpuech and G.J.Martin, Heyden.



9 Spectrometric Identification of Organic Compounds, R. M. Silverstein, G. C. Bassler and T. C. Morrill, John Wiley

10. Introduction to NMR Spectroscopy, R. J. Abraham, Fischer and P. Lathes, Wik

11 Application of Spectroscopy of Organic Compound, 18. Dyer, Prentice Hall

12. Spectroscopic Methods in Organic Chemistry, D. H. Williams, Flaming, Tata-Mo-Grill

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Bioinorganic Chemistry and Bioorganic Chemistry (Paper-II)
[CHE-302] **credit 4**

Section-'A': (Bioinorganic Chemistry)

Unit- I

A-Metal Ions in Biological Systems

Essential and trace metals

B - Na/K Pump

Role of metal ions in biological processes

UNIT-II

A-Bioenergetics and ATPcycle: DNA polymerization, glucose storage, metal complexes in transmission of energy: chlorophylls

B-Transport and Storage of Dioxygen: Heme proteins and oxygen uptake, structure and function of haemoglobin, myoglobin, haemocyanins and hemerythrin model synthetic complexes in iron, cobalt and copper.

UNIT III

Electron Transfer in Biology: Structure and function of metalloproteins in electron transport processes- cytochromes and iron-sulphur proteins.

UNIT-IV

Nitrogenase: Biological nitrogen fixation, molybdenum nitrogenase

Books suggested

1. Principle of Bioinorganic Chemistry, S.J.Lippard and J.M.Berg, University Science Books
2. Books Bioinorganic Chemistry, Bertini H.B. Gray, S.J.Lippard and J.S. Valentine, University Science
3. Inorganic Biochemistry, vols.I and II, G.L. Eichhorn, Elsevier.
4. Progress in Inorganic Chemistry, Vols 18 & 38ed. J.J.Lippard, Wiley.

Section-'B' Bio-organic Chemistry

UNIT-I

A-Introduction: Basic consideration Proximity effects and molecular adaptation

B-Enzymes: Introduction and historical perspective chemical and biological catalysis, remarkable properties of enzymes like catalytic power, specificity and regulation. Nomenclature and classification, Fischer's lock and key and koshland's induced fit hypothesis, concept and identification of active site by the use of inhibitors. Enzyme kinetics, Michaelis Menten and Lineweaver Burk plots, reversible and irreversible inhibition.

Unit II

A-Mechanism of Enzyme Action: Transition-state theory, orientation and steric effect, acid-base catalysis, covalent catalysis, strain or distortion. Examples of some typical enzyme mechanisms for chymotrypsin, ribonuclease, lysozyme and carboxypeptidase-A.

B-Kinds of Reactions Catalysed by Enzymes: Nucleophilic displacement on a phosphorus atom, multiple displacement reactions and the coupling of ATP cleavage to endergonic processes Transfer of sulphate, addition and elimination reactions, enolic intermediates in isomerization reactions, 1, 3-cleavage and condensation, some isomerization and rearrangement reactions. Enzyme catalyzed carboxylation and decarboxylation

UNIT-III

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A-Co-Enzyme Chemistry: Cofactor as derived from vitamins coenzyme S. Prosthetic groups, apoenzymes structure, and biological functions of coenzyme-A, thiamine pyrophosphate, pyridoxal phosphate. NAD. NADP, FMN, FAD, lipoic acid, vitamin B₁₂

B-Enzyme Models: Host-guest chemistry, chiral recognition and catalysis, molecular recognition, molecular asymmetry and prochirality Biomimetic chemistry, crown ethers, cryptates Cyclodextrins cyclodextrin based enzyme models calixarenes ionophores, micelles, synthetic enzymes or synzymes.

Unit IV

Biotechnological Applications of Enzymes: Large-scale production and purification of enzymes, techniques and methods of Immobilization of enzymes, effect of immobilization on enzyme activity, application of immobilized enzymes, one of enzymes as targets for drug design Clinical uses of enzymes, enzyme therapy

Books Suggested

1. Bioorganic Chemistry: Achemical Approach to Enzyme Action, Hermanes Dugas and C. Penny Springer Verlag
2. Understanding Enzymes, Trevor Palmer, Prentice Hall
3. Enzyme Chemistry: Impact and Applications, Ed Collin I. Suck Chapman and Hall
4. Enzyme Mechanisms De M1 Page and A. Williams Royal Society of Chemistry
5. Fundamentals of Eruymology, NC. Price and L. Stevens Odard University Press
6. Immobilized Enzymes: An introduction and application in Biotechnology Michael D. Trevan- John Wiley
7. Enzyme Structure and Mechanom, Af ersht, W. H.Freeman
8. Biochemistry The Chemical Reactions of Living Celis D.E. Metzler. Academic Press

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Photochemistry and Environmental Chemistry (Paper-III)

[CHE-303]

Credit-4

UNIT-I

Photochemical Reactions: Interaction of electromagnetic radiation with matter, types of excitations, fate of excited molecule, quantum yield, transfer of excitation energy actinometry.

Photochemistry of Alkenes: Intramolecular reactions of the olefinic bond-geometrical isomerism, cyclization reactions, rearrangement of 1,4- and 1,5- dienes.

UNIT-II

Photochemistry of Aromatic Compounds: Isomerizations, additions and substitutions.

Photochemistry of Carbonyl Compounds: Intramolecular reactions of carbonyl compounds- saturated cyclic, acyclic β , γ unsaturated and α,β unsaturated compounds, cyclohexadienones. Intermolecular cycloaddition reactions-dimerization and oxetane formation.

UNIT- III

A-Environment: Introduction, Composition of atmosphere, vertical temperature, heat budget of the earth atmospheric system, vertical stability atmosphere. Biogeochemical cycles of C, N, P, S and O. Biodistribution of elements.

B- Hydrosphere: Chemical composition of water bodies-lakes, streams, rivers and wet lands etc. Hydrological cycle. Aquatic Pollution- inorganic, organic, pesticide, agricultural industrial and sewage, detergents, oil spills and oil pollutants. Water quality parameters-dissolved oxygen biochemical oxygen demand, solids, metals, content of chloride, sulphate, phosphate, nitrate and micro-organisms. Water quality standards. Analytical methods for measuring BOD, DO, COD, F, Oils, metals (As, Cd, Cr, Hg, Pb, Se, etc.), residual chloride and chlorine demand. Purification and treatment of water.

UNIT- IV

A- Atmosphere: Chemical composition of atmosphere-particles, ions and radicals and their formation Chemical and photochemical reactions in atmosphere, smog formation, oxides of N,C,S,O. and their effect, Green house effect, acid rain, air pollution controls and their chemistry.

B-Environmental toxicology: Chemical solutions to environmental problems, biodegrade ability, principles of decomposition better industrial processes. Bhopal gas tragedy, Chernobyl, three mile island, Sewozo and Minamata disasters.

Book Suggested

1. Introductory Photochemistry, A. Cox and T. Camp, McGraw Hill.
2. Photochemistry, R. P. Kundall and A. Gilbert, Thomson Nelson.
3. Organic Photochemistry, J. Coxon and B. Halton, Cambridge University Press.
4. Environmental Chemistry, Sharma & Kaur, Krishna Publishers
5. Environmental Chemistry, A K. De, Wiley Eastern
6. Environmental Pollution Analysis, S.M. Khopkar, Wiley Eastern

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UNIT-II

A-Biopolymer Interactions

Forces involved in biopolymer interactions. Electrostatic charges and molecular expansion, hydrophobic force, dispersion force interactions. Multiple equilibria and various types of binding processes in biological systems. Hydrogen ion titration curves.

B-Thermodynamics of Biopolymer Solutions

Thermodynamics of biopolymer solutions, osmotic pressure membrane equilibrium, muscular contraction and energy generation in mechano-chemical system.

UNIT-III

A-Cell membrane and Transport of ions

Structure and functions of cell membrane, ion transport through cell membrane, irreversible thermodynamic treatment of membrane transport. Nerve conduction.

B-Biopolymers and their Molecular Weights

Evaluation of size shape molecular weight and extent of hydration of biopolymers by various experimental techniques. Sedimentation equilibrium, hydrodynamic methods, diffusion, sedimentation velocity viscosity electrophoresis and rotational motions.

UNIT-IV

Solid state chemistry

A-Solid State Reactions

General Principles for reaction between two solids: Reaction conditions, structural considerations, surface area, reactivity, kinetics of solid-state reactions.

B-Crystal Defects and Non-Stoichiometry

Perfect and imperfect crystals, intrinsic and extrinsic defects- point defects, vacancies- Schottky defects and Frenkel defects. Thermodynamics of Schottky and Frenkel defect formation, non-stoichiometry and defects.

C-Electronic Properties and Band Theory

Metals, insulators and semiconductors, electronic structure of solids-band theory, band structure of metals, insulators and semiconductors, intrinsic and extrinsic semiconductors, doping semiconductors, p-n junctions, super conductors. Optical properties- optical reflectance, photoconduction- photoelectric effects.

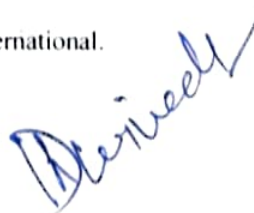
Book Suggested

1. Principles of Biochemistry, A.L. Lehninger, Worth Publishers
2. Biochemistry, L. Stryer, W.H. Freeman.
3. Biochemistry, J. David Rawn, Neil Patterson.
4. Biochemistry, Voet and Voet, John Wiley.
5. Outlines of Biochemistry, E.E. Conn and F. K. Stumpf, John Wiley.
6. Bioorganic Chemistry: A Chemical Approach to Enzyme Action, H. Dugas and C. Penny, Springer Verlag
7. Macromolecules: Structure and Functions, F. Wold, Prentice Hall.
8. Solid state Chemistry and its Applications, A.R. West, Plenum.
9. Principles of the Solid State, H.V. Keer, Wiley Eastern.
10. Solid State Chemistry, N.B. Hannay.
11. Solid State Chemistry, D.K. Chakrabarty, New Age International.

—Anja









Practicals

Inorganic Chemistry

25

1. Preparation of selected inorganic compounds and structural elucidation on the basis of given spectra (IR, ESR and MS) Selection can be made from the following

- 1- Sodium amide
- 2- Dichlorophenyl borane (PhBCl_2)
- 3- Sn(IV) iodide, Sn(IV) chloride and Sn(II) iodide
- 4- Ammonium hexa chlorostannate $[(\text{NH}_4)_2 \text{SnCl}_6]$
- 5- Trichlorodiphenyl antimony(v) hydrate
- 6- Sodium Tetrathionate ($\text{Na}_2\text{S}_4\text{O}_6$)
- 7- Metal Complexes of dimethyl Sulfoxide, CuCl_2 , 2DMSO.
- 8- Metal acetylacetonate.
9. Ion exchange separation of oxidation state of V.
- 10- Preparation of Fe(II) Chloride.
- 11- Phosphine Ph_3P and its transition metal complexes.
- 12- Ferrocene
- 13- Copper glycine Complex

II. Chromatographic Separations:

- a. Thin layer chromatographic separation of Nickel, Manganese Cobalt and Zinc. Determination of R_f values.
- b- Cadmium and Zinc
- c- Zinc and Magnesium

ORGANIC CHEMISTRY

25

I. Qualitative Analysis

Separation and identification of components of a mixture of three organic compounds (three solids or two liquids and one solid, or two solids and one liquid). Suitable derivatives to be prepared where possible. Purity of the separated components should also be checked on TLC plates. Chemical analysis.

II. Isolation of the following

- i) Caffeine from tea leaves.
- ii) Casein from milk
- iii) Lactose from milk
- iv) Nicotine dipicrate from tobacco
- v) Lycopene from tomatoes



Thermodynamics:

I- Determination of partial molar volume of solute (e.g. KCl) and solvent in a binary mixture.

II- Determination of the temperature dependence of the solubility of a compound in two solvents having similar intermolecular interactions (benzoic acid in water and in DMSO water mixture) and to calculate the partial molar heat solution

Spectroscopy

I Determination of pKa of an indicator (e.g. Methyl red) (a) aqueous and (b) micellar media.

ii. Determination of stoichiometry and stability constant of inorganic (e.g. ferric-salicylic acid) and organic (e.g. amine iodine) complexes. Characterization of the complexes by electronic and IR spectral data

Viva-voce

15

Records

10

Anya    

Elective Paper I

Organo transition metal chemistry

[CHE-400A]

CREDIT- 04

UNIT-I

A-Alkyls and Aryls of Transition metals

Types, routes of synthesis, stability and decomposition pathways, organocopper in organic synthesis

B-Compounds of Transition metal-Carbon Multiple Bonds

Alkylidenes, alkylidynes, low valent carbenes and carbynes-synthesis, nature of bond, structural characteristics, nucleophilic and electrophilic reactions on the ligands, role in organic synthesis.

UNIT II

A-Transition Metal π -Complexes

Transition metal π -complexes with unsaturated organic molecules, alkenes, alkynes, allyldiene, dienyl, arene and trienyl complexes preparations, properties, nature of bonding and structural features. Important Reaction relating to nucleophilic and electrophilic attack on ligands and to organic synthesis.

B-Transition metal compounds with Bonds to Hydrogen

UNIT-III

Homogeneous Catalysis

Stoichiometric reaction for catalysis, homogenous catalytic hydrogenation, Zeigler-Natta polymerization of olefins, catalytic reaction involving carbon monoxide such as hydrocarbonylation olefin (oxo reaction), oxopalladation reaction, activation of C-H bond.

UNIT-IV

Fluxional Organometallic Compounds

Fluxionality and dynamic equilibria in compounds such as η^1 olefine, η^1 allyl and dienyl complexes.

Books Suggested

1. Principles and application of Organotransition Metal Chemistry, J.P. Collman, L.S. Hegsdus, JR Norton and R.G. Finke, University Science books
2. The organometallic chemistry of transition metals, R.H.Crabtree, John Wiley
3. Metallo-organic Chemistry, A.J. Pearson Wiley
4. Organometallic Chemistry, R.C.Mehrotra and A. Singh, New age International.

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Elective Paper II

Bioinorganic and Supramolecular Chemistry.

[CHE-400B)

CREDIT 04

UNIT-I

A-Metal Storage Transport and Biomineralization Ferritin, transferrin, and siderophores

B-calcium in Biology

Calcium in living cells, transport and regulation, molecular aspects of intramolecular processes, extracellular binding proteins.

UNIT II

Metalloenzyme

Zinc enzymes-carboxypeptidase and carbonic anhydrase, Iron enzymes-catalase, peroxidase and cytochrome P-450, Copper- enzymes-superoxide dismutase, Molybdenum oxatransferase enzymes-xanthine oxidase, Coenzyme vitamin B₁₂

UNIT-III

A-Metal-Nucleic Acid Interactions

Metal ion and metal complex interactions, Metal complexes-nucleic acids

B-Metals in Medicine

Metal deficiency and disease, toxic effects of metals, metals for diagnosis and chemotherapy with particular reference to anticancer drugs.

UNIT-IV

Supramolecular Chemistry

(A) **molecular recognition:** Molecular receptors for different types of molecules including arisonic substrates. Design and synthesis of coreceptor molecules and multiple recognition.

(B) **Supramolecular reactivity**

(C) **Transport processes and carrier design**

(D) **Supramolecular devices:** supramolecular photochemistry, supramolecular electronic, ionic and switching devices. Some examples of self-assembly in supramolecular chemistry.

Books Suggested

1. Principles of Bioinorganic Chemistry S J. Lippard and J. M. Berg University Science Books.
2. Bioinorganic Chemistry, T. Bertini, R.B. Gray, S.J. Lippard J.S. Valentine, University Science Books
3. Inorganic Biochemistry vols I and II, ed. G.T. Eichborn, Elsevier.
4. Progress in Inorganic Chemistry, Vols 18 and 38 ed. J.J. Lippard, Wiley.
5. Supramolecular Chemistry, J. M. Lehn, VCH

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Elective Paper III

Photo-inorganic chemistry

CHE-400 C

Credit-4

UNIT-I

Basics of Photochemistry

Absorption excitation, photochemical laws, quantum yield electronic excited states, life times-measurements of the times flash photolysis, stopped flow techniques. Energy dissipation by radiative and non-radiative processes. absorption spectra, Franck-Condon principle, photochemical stages-primary and secondary processes.

UNIT-II

A- Properties of excited states

Structure, dipole moment, acid-base strengths, reactivity-photochemical kinetics calculation of rates of radiative processes. Biomolecular deactivation-quenching

B-Excited states of metal complexes

Excited states of metal complexes: comparison with organic compounds, electronically excited states of metal complexes, charge transfer spectra, charge transfer excitations methods for obtaining charge-transfer spectra.

UNIT-III

A- Ligand field photochemistry

Photosubstitution photooxidation and photoreduction, lability and selectivity, zero vibrational levels of ground state and excited state, energy content of excited state, zero, zero spectroscopic energy. Development of the equations for redox potentials of the excited states.

B- Redox reactions by excited metal complexes

Energy transfer under conditions of weak interaction and strong interaction-excimer formation; conditions of the excited states to be useful as redox reactants, excited electron transfer, metal complexes as attractive candidates (2,2-bipyridine and 1,10-phenanthroline complexes), illustration of reducing and oxidizing character of ruthenium (bipyridyl complex, comparison with Fe (bipy), role of spin coupling life time of these complexes. Application of redox processes of low energy reactants into high energy products, chemical energy into light.

UNIT IV

Metal complex sensitizers

Metal complex sensitizer, electron relay, metal colloid systems, semiconductor supported metal or oxide systems, water photolysis nitrogen fixation and carbon dioxide reduction.

Books suggested:

1. Concepts of inorganic photochemistry. A.W. Adamson and P.D. Fleischauer, Wiley.
2. Inorganic photochemistry, J.Chem Educ. Vol. 60, no. 10,1983
3. Progress in inorganic chemistry, vol. 30, Ed. S.J.Lippard, Wiley.

4. Coordination chem. revs. 1981, vol.29, 121, 131-1975,15, 321 (1990) 97313

5. photochemistry of coordination compounds. V. Balzan and V. Carassiti, academic press.

6. Elements of inorganic photochemistry. G.J.Ferraudi, Wiley.

Aya   Durmady 

Elective Paper IV
[CHE-400 D] **Credit-4**
Analytical Chemistry and Techniques

Unit I

A: Introduction: Scope & objectives, Analytical chemistry and chemical analysis, Classification of analytical methods, Method selection, Sample processing, Steps in a quantitative analysis, Quantitative range (bipartite classification), Data organization, Analytical validations, Limit of detection and limit of quantitation, The tools of analytical chemistry and good lab practices.

B: Statistical Evaluation: Determinant and indeterminant errors, Normal error curve, Accuracy and Precision, Relative and standard deviation, Methods for minimizing errors, Criteria for rejection of observation, Significant figures and computation rules, Error propagation.

Unit II

A: Separation Methods: Principle of chromatography, Classifications of chromatography, Techniques of planar and column chromatography, Gas chromatography, High-performance liquid chromatography.

B: Analytical Reagents: Theoretical and practical aspects of the use of EDTA, cerate, iodate, bromate, chloramine-T, Karl Fischer and Malaprade (periodate) reagents in chemical analysis.

Unit III

A: Spectroscopic Techniques: Theory, Instrumentation and applications of X-rays (emission, absorption, diffraction and fluorescence methods), Atomic absorption Spectroscopy, Atomic fluorescence spectrometry, atomic emission spectrometry.

B: Molecular Spectroscopy: UV-visible molecular absorption spectrometry (instrumentation and application), Molecular luminescence spectroscopy (fluorescence, phosphorescence, chemiluminescence).

Unit IV

A: Thermal Analysis: Theory, methodology and applications of thermogravimetric analysis (TGA), Differential Thermal Analysis (DTA), and Differential scanning calorimetry (DSC). Principles, techniques and applications of thermometric titration methods.

B: Radio-Analytical Methods: Elementary theory, Isotope dilution and Neutron activation methods and applications.

Books Recommended

1. D.A. Skoog, Principles of Instrumental Analysis, 5th Edition (1998), Saunders College Publishing, Philadelphia, London.
2. G. D. Christian, Analytical Chemistry, 5th Edition (1994), John Wiley & Sons, New York.
3. D. A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Analytical Chemistry - An Introduction, 7th Edition (2000), Saunders College Publishing, Philadelphia, London.
4. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Edition (1990), Saunders Holt, London.
5. R. L. Pecsok, L. D. Shields, I. Cairns and L.C. Mc William, Modern Methods of Chemical Analysis, 2nd Edition (1976), John Wiley, New York.
6. G.W. Ewing, Instrumental Methods of Chemical Analysis, 5th Edition (1978), McGraw Hill Books Co., New York.



Elective Paper-V

[CHE-400 E]

Credit- 4

Polymers

UNIT- I

Basics: Importance of polymers. Basic concepts: Monomers, repeat units, degree of polymerization. Linear, branched and network polymers. Classification of polymers Polymerization: condensation, addition, radical chain-ionic and co-ordination and copolymerization. Polymerization conditions and polymer reactions. Polymerization in homogeneous and heterogeneous systems.

UNIT-II

Polymer Characterization

Polydispersion-average molecular weight concept. Number, weight and viscosity average molecular weights. Polydispersity and molecular weight distribution. The practical significance of molecular weight. Measurement of molecular weights. End group, viscosity, light scattering, osmotic and ultracentrifugation methods. Analysis and testing of polymers. Chemical analysis of polymers, spectroscopic methods. X-ray diffraction study. Microscopy. Thermal analysis and physical testing-tensile strength. Fatigue, impact, tear resistance. Hardness and abrasion resistance.

UNIT III

Structure and Properties

Morphology and order in crystal fine polymers-configurations of polymer chains. Crystal structures of polymers. Morphology of crystalline polymers, strain-induced morphology, crystallization and melting. Polymer structure and physical properties- crystalline melting point (T_m), melting points of homogeneous series, effect of chain flexibility and other steric factors, entropy and heat of fusion. The glass transition temperature (T_g). Relationship between T_m and T_g . Effects of molecular weight, diluents, chemical structure, chain topology, branching and cross linking. Property requirements and polymer utilization.

UNIT IV

A-Polymer Processing

Plastics, elastomers and fibers Compounding Processing techniques Calendering diecasting, rotational casting film casting injection moulding, blow moulding, extrusion moulding thermolforming, foamian, reinforcing and fibre spinning.

B- Properties of Commercial Polymers

Polyethylene, Polyvinyl chloride polyamides polyesters, phenolic resins, epoxy resins and silicone polymers. Functional polymers, fire retarding polymers and electrically conducting polymers. Biomedical polymers-contact lens, dental polymers, artificial heart, kidney, skin and blood cells.

Books Suggested

1. Textbook of Polymer Science, F. W. Billmeyer Jr. Wiley
2. Polymer Science, V.R. Gowarker, N.V. Viswanathan and Sreedhar, Wiley-Eastern

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3. Functional Monomers and Polymers, K. Takemoto, Y. Inaki and RM. Rttanbrite. 4. Contemporary Polymer Chamistry, HR. Alcock and F.W. Lambe, Prentice Hall.

5. Physics and Chemistry of Polymer, I.M.G. Cowie, Blackie Academic and Professional.

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Organic Synthesis-I
UNIT-I

Organometallic reagents

Principles, preparations, properties and applications of the following in organic synthesis with mechanistic details.

A. Group I and II metal organic compounds Li, Mg, Hg, Cd, Zn compounds.

B. Transition metals Cu, Pd, Ni, Fe, Co, Ti compounds.

UNIT-II

A-Oxidation

Introduction different oxidative processes.

Hydrocarbons-alkenes, aromatic rings, saturated C-H groups (activated and unactivated), Alcohols, diols, aldehydes, ketones, ketals and carboxylic acid. Amines, hydrazines and sulphides.

Oxidation with ruthenium tetraoxide, iodobenzene diacetate and thallium(III) nitrate.

B- Reduction

Introduction, different reductive processes.

Hydrocarbons-alkanes, alkynes and aromatic rings.

Carbonyl compound-aldehydes, ketones, acids and their derivatives. Epoxides.

Nitro, nitroso, azo and oxime groups. Hydrogenolysis.

UNIT-III

Rearrangements

General mechanistic consideration: nature of migration, migratory aptitude, memory effects.

A detailed study of the following rearrangements

Pinacol-pinacolone, wagner-meerwein, Demjanov, Benzil-Benzilic acid, Favorskii, Aarndt-Eistert synthesis, Neber, Beckmann, Curtius, Schmidt, Baeyer-Villiger, Shapiro reaction.

UNIT- IV

Metallocenes. Non-benzenoid Aromatic and polycyclic aromatic compound, General consideration, synthesis and reactions of some representative compounds.

Books suggested

1. Modern synthetic reactions, H.O.House, W.A.Benjamin.
2. Some modern methods of organic synthesis, W.Carruthers, Cambridge Univ. Press.
3. Advanced organic chemistry, reactions mechanisms and structure, J. March, John Wiley.
4. Principles of organic synthesis, R.O.C. Norman and J.M.Coxon, Blackie academic and professional.
5. Advanced organic chemistry part B, F.A.Carey and R.J.Sundberg, Plenum Press.
6. Rodd's chemistry of carbon compounds, Ed.S.Coffey Elevier.

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Elective Paper-VII

CHE-400G

Credit-4

Organic Synthesis II

UNIT-I

Disconnection approach

An introduction to synthons and synthetic equivalents, disconnection approach, functional group interconversions, the importance of the order of events in organic synthesis, one group C-X and two group C-X disconnections, chemoselectivity, reversal of polarity, cyclisation reactions, amine synthesis.

UNIT-II

A-Protecting groups

Principle of protection, for alcohols, amine, carbonyl and carboxyl groups.

B-one group C-C disconnections

Alcohols and carbonyl compounds, regioselectivity. Alkene synthesis, use of acetylenes and aliphatic nitro compounds in organic synthesis.

UNIT-III

Two group C-C disconnections

Diels-Alder reaction, 1,3-disubstituted compounds, β unsaturated carbonyl compounds, control in carbonyl condensations, 1,5-disubstituted compound. Michael addition and Robinson annulation.

UNIT-IV

Ring synthesis

Saturated heterocycles, synthesis of 3,4,5 and 6 membered rings, aromatic heterocycles in organic synthesis.

Synthesis of some complex molecules

Application of the above in the synthesis of following compounds: camphor, longifoline, cortisone, reserpine, vitamin D, juvabione, aphidicolin and fredericamycin A

Books suggested

1. Designing organic synthesis, S. Warren, Wiley.
2. Organic synthesis-concept, methods and starting materials, J. Fuhrhop and G. Penzlin, verlag VCH.
3. Some modern methods of organic synthesis, W. Carruthers, Cambridge Univ. Press.
4. Modern synthetic reactions, H.O. House, W.A. Benjamin.
5. Advanced organic chemistry: reactions mechanism and structure, J. March, Wiley.
6. Principles of organic synthesis, R. Norman, J.M. Coxon, Blackie academic and professional.
7. Advanced organic chemistry part B, E.A. Carey and R.J. Sundberg, Plenum press.

Elective Paper-VIII
Heterocyclic chemistry

[CHE-400 H]

Credit-4

UNIT-I

A- Nomenclature of Heterocycles

Replacement and systematic nomenclature (Hantzsch Widman system) for monocyclic, fused and bridged heterocycles.

B- Aromatic heterocycles

General chemical behavior of aromatic heterocycles, classification (Structural type), criteria of aromaticity (bond lengths ring current and chemical shifts in $^1\text{H-NMR}$ - spectra. Empirical resonance energy) resonance energy, delocalization energy and deqar resonance energy, diamagnetic susceptibility exaltations). Heteroaromatic reactivity and tautomerism in aromatic heterocycles.

C-Non-aromatic Heterocycles

Strain bond angle and torsional strains and their consequence in small ring heterocycles.

Conformation of six membered heterocycles with reference to molecular geometry, barrier to ring inversion, pyramidal inversion and 1,3- diaxial interaction. Stereo-electronic effects-anomeric and related effects. Attractive interactions-hydrogen bonding and intermolecular nucleophilic interactions.

Unit II

A- Heterocyclic Synthesis

Principles of heterocyclic synthesis, cyclization reactions and cycloaddition reactions.

B- Small Ring Heterocycles

Three membered and four membered heterocycles-synthesis and reaction of aziridine, oxiranes, Thiranes, azetidines, oxetanes and thietanes.

UNIT III

A- Benzo-Fused Five-membered Heterocycles

Synthesis and reactions including medicinal application of benzopyrroles, benzofurans and benzothiophenes.

B- Meso-ionic Heterocycles

General classification, chemistry of some important mesoionic heterocycles of type A and B and their applications.

C- Six-membered Heterocycles with one Heteroatoms

Synthesis and reaction of pyrylium salts and pyrones and their comparison with pyridinium and thiopyrylium salts and pyridines.

Synthesis and reactions of quinolizinium and benzpyrinium salts, coumarins and chromones.

UNIT- IV

A- Six-membered Heterocycles with two or more Heteroatoms

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Synthesis and reaction of diazines, triazines and thiazines.

B-Seven-and large-Membered Heterocycles

Synthesis and reaction of azepines, oxepines, thiepinines, diazepines, thiazepines, azocine, diazocines, dioxocines and dithiocines.

Books Suggested

1. "Heterocyclic Chemistry" Vol, 1-3 R.R. Gupta, M.Kumar and V. Gupta, Springer, Verlag
2. The Chemistry of Heterocycles, T. Eicher and S. Hauptmann, Thieme.
3. Heterocyclic chemistry, J.A. Joule, K. Mills and G.F.Smith, Chapman and Hall.
4. Heterocyclic chemistry, T.L. Gilchrist, Longman Scientific Technical.
5. Contemporary Heterocyclic chemistry, G.R. Newkome and W.W. Paudler, Wiley-Inter Science.
6. An Introduction to the Heterocyclic Compounds, R.M. Acheson, John Wiley.
7. Comprehensive Heterocyclic Chemistry, A. R. Katritzky and C.W. rees. Eds. Pergamon Press.

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Elective Paper-IX
Chemistry of Natural products
CHE-400 IJ **Credit-4**

UNIT-I

Trapezoids and carotenoids

Classification, nomenclature, occurrence, isolation, general methods of structure determination, isoprene rule. Structure determination stereochemistry, biosynthesis and synthesis of the following representative molecules: Citral Geraniol, α -terpeneol, Menthol, farnesol, Ziniberene, Santonin, Phytol, Abietic acid and B-Carotene.

UNIT-II

A -Alkaloids

Definition, nomenclature and physiological action, occurrence, isolation, general methods of structure elucidation, degradation classification based on nitrogen heterocyclic ring role of alkaloids in plants Structure, stereochemistry, synthesis and biosynthesis of the following: ephedrine, (+)-Conine, Nicotine, Atropine, Quinine and morphine.

B- Steroids

Occurrence, nomenclature, basic skeleton, Diel's hydrocarbon and stereochemistry.
Isolation, structure determination and synthesis of Cholesterol, Bile acids, Androsterone, Testosterone, Estrone, Progesterone, Aldosterone, Biosynthesis of steroids.

UNIT-III

A-Plant Pigments

Occurrence, nomenclature and general methods of structure determination, Isolation and synthesis of Apigenin, Luteolin, quercetin, myricetin, Quercetin 3-glucoside, Vitexin Diadzein, Butein, Aureusin, Cyanidin-7-arabinoside, acid pathway.

B- Porphyrins

Structure and synthesis of Haemoglobin and Chlorophyll.

A- Prostaglandins

UNIT-IV

Occurrence, nomenclature, classification, biogenesis and physiological effects, Synthesis of PGE, PGF and

B- Pyrethroids and Rotenones

Synthesis and reaction of Pyrethroids and Rotenones (For structure elucidation, emphasis is to be placed on the use of spectral parameters wherever possible).

Books Suggested

1. Natural Products: Chemistry and Biological Significance.
2. Mann R.S. Davidson, J.B. Hobbs, D.V. Banthorpe and I.B. Harborne, Longman, Essex. 2
3. Organic Chemistry, Vol-2, I.L. Finar, ELBS
4. Stereo selective Synthesis: A Practical Approach, M. Nogradi, VCH.
5. Rodd's Chemistry of Carbon Compounds, Ed. S. Coffey, Elsevier.
6. Chemistry, Biological and Pharmacological Properties of Medicinal Plants from the Americas, Ed Kurt hostettmann, M.P. Gupta and A. Marston, Harwood Academic Publishers.
7. Introduction of Flavonoids, B.A. Bohm, Harwood Academic Publishers.
8. New Trends in Natural Product Chemistry, Atta-ur-Rahman and M.I. Choudhary, Harwood Academic Publishers.
9. Insecticides of Natural Origin, Sukh Dev, Harwood Academic Publishers.

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Elective Paper-X

Medicinal Chemistry

[CHE-400.J]

Credit-4

UNIT-I

A- Drug design:

Relationship between Chemical structure and biological activity (SAR). Receptor site theory approach to drug design. Introduction to combinatorial synthesis in drug discovery.

B- Pharmacokinetics:

Introduction of drug absorption, desorption, elimination using pharmacokinetics, important pharmacokinetics parameters in detining drug disposition and in therapeutics. Mention of uses of pharmacokinetics in drug development process.

UNIT-II

A- Antineoplastic Agents:

Introduction, cancer chemotherapy, role of alkylating agents and antimetabolites in treatment of cancer. Synthesis of mechlorethamine, cyclophosphamide, melphan, mechalorethamine, cyclophosphamide melphalan, uracil, mustards, and 6- mercaptopurine.di

B- Cardiovascular Drug:

Introduction, cardiovascular diseases, drug inhibitors of peripheral sympathetic function central intervention of cardiovascular output. Directacting arteriolar dialators. Synthesis of amyl nitrate sorbitrate, deltizem, quitridine, veramil and atenolal.

UNIT-III

A- Local Anti-infective Drugs:

Introduction and general mode of action. Synthesis of sulphonamides, turatolidone, ciprofloxacin, norfloxacin, dopone, amino salicylic acid, isoniazid, ethionamid, thambutal, fluconatole, ariseofulvin, chlorogenin, primaqion.

B- Psychoactive Drugs- The Chemotherapy of mind

Introduction, neurotransmitters, CNS depreseant, general anaesthetics, mode of action of hypnotics,

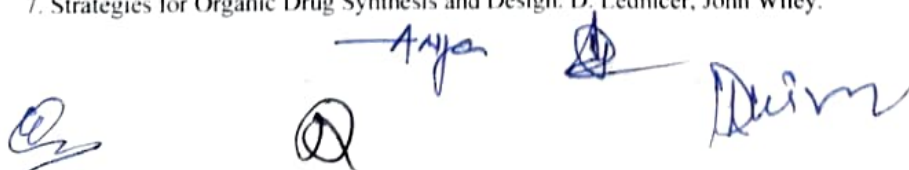
sedatives, antianxiety drugs, Antipsychotic drugs the neuroleptics, antidepressant, butyrophenones, serendipity and drug development. Synthesis of diatepam, oxatepam, chloratepam, alpratalam, phenyloin 2 barbiturates.

UNIT-IV

Antibiotics Cell wall biosynthesis inhibitors, B-lactam rings antibiotics inhibiting protein synthesis, synthesis of penicillin, chloramphenicol, cephalosponin and streptomycin.

Books Suggested

1. Introduction to Medical Chemistry, A. Gringuage, Wiley-VCH.
2. Wilson and Gisvold's Text Book of Organic Medicinal and Pharmaceutical Chemistry. Ed. Robert F.dorge
3. An Introduction to Drug Design, S.S. Pandeya and J.R. Dimmock. New Age International.
4. Burger's Medicinal Chemistry and Drug Discovery, Vol-1 (Chapter-9 and Ch-14) Ed.M.E. Wolff, John wiley.
5. Goodman and Gilman's Pharmacological Basis of Therapeutics, Mc Graw-Hill.
6. The Organic Chemistry of Drug Design and Drug Action, R.B. Silvernannm, Academic Press.
7. Strategies for Organic Drug Synthesis and Design. D. Lednicer, John Wiley.



Practicals

[CHE-404P]

Credit-4

Inorganic Chemistry

(25)

(A) Spectrophotometric Determination

- a- Manganese/ chromium vanadium in steel sample.
- b- Nickel/molybdenum/tungsten/vanadium/uranium by extractive spectrophotometric method.
- c Fluoride/nitrate/phosphate
- d-Iron-phenanthroline complex: Job's Method.

(B) Flame Photometric Determinations:

- a- Sodium and Potassium when Present together
- b- Lithium/calcium/Barium/Strontium
- c- Cadmium and Magnesium in tap water.

Organic Chemistry

(25)

(A) Multi Step Synthesis of organic Compounds

Preparation of organic compounds involving not more than three stages.

- i) Benzanilide from Benzene
- ii) Benzilic acid from Benzoin
- iii) Quinoline from Aniline
- iv) 2-phenylindole from phenyl hydrazine.
- v) Alkylation of diethyl malonate with an alkyl halide

(B) Paper Chromatography

Separation and identification of the sugars present in the given mixture of glucose, fructose and sucrose by paper chromatography and determination of R_f values. Identification of organic compounds on the basis of given spectral data (UV, IR, PMR, CMR and MS)

Physical Chemistry

(25)

(A) Polarography

- Estimation of Pb^{2+} and Cd^{2+} , Zn^{2+} and Ni^{2+} ions in a mixture of Pb^{2+} and Cd^{2+} , Zn^{2+} and Ni^{2+} by polarography.
- Determination of dissolved oxygen in aqueous solution of organic solvents.

(B) E.M.F. Measurement

- i-Determination of the equilibrium constant of the reaction

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$\text{H}_2\text{O} + 2\text{Ag}^{+1}$ changes into $\text{Q} + 2\text{W} + 2\text{Ag}$

(hydroquinone) (quinhydrone)

ii-Determination of activity coefficient of electrolytes.

i-Potentiometric titration of a solution of Fe^{+2} against Cr_2O_7 and the determination of the redox potential of Fe^{+2} into Fe^{+3} system.

iv) Determination ionic product of water (K)

Viva vice

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Records

10

Book Suggested

1. Inorganic Experiments. I. Derek Woollin VCH
2. Microscale Inorganic Chemistry, Z. Szafran R.M. Pike. M.M. Singh. Wiley.
3. Practical Inorganic Chemistry, G. Mar and B.W. Bookett. Van Nostrand.

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