M.Sc. (Previous)
CHEMISTRY SYLLABUS
(To be effective form session 2019-2020)

The examination shall comprise five theory papers each of three hours duration and a practical examination of 18 hours duration (spread over three days).

The course has been divided as follows-

Paper	***Course***	
	Marks	
I	Inorganic Chemistry	100
II	Organic Chemistry	100
III	Physical Chemistry	100
IV	Group Theory, Spectroscopy and Diffraction methods	100
V	Environmental Chemistry	50
		450

Practical's

	Marks	
1.	Inorganic Chemistry	30
2.	Organic Chemistry	30
3.	Physical Chemistry	30
4.	Viva Voce	20
5.	Records	10
6.	Assignment/Seminar lecture	30
		150
	Total Marks (Theory and Practicals)	**600**

M.Sc. (Previous)
Chemistry
Paper I

Inorganic Chemistry

I **Stereochemistry and Bonding in Main Group Compounds.**

VSEPR, Walsh diagrams (tri- and penta-atomic molecules), dπ-pπ bonds, Bent rule and energetics of hybridisation, some simple reactions of covalently bonded molecules.

II **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.

III **Reaction mechanism of Transition Metal Complexes**

Energy profile of a reaction, reaction reactivity of metal complexes, inert and labile complexe, kinetics 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 reactions, reactions without metal ligand 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.

IV **Metal-Ligand Bonding**

Limitation of crystal field theory, molecular orbital theory, octahedral, tetrahedral and square planar complexes, π-reactions.

V **Electronics Spectra and magnetic Properties of Transition Metal Complexes**

Spectroscopic ground states, correlation, Orgel and Tanabe-Sugano diagrams for transition metal complexes (d^1-d^9 states), calculations of Dq. B and β parameters, charge transfer spectra, spectroscopic method of assignment of absolute configuration in optically active metal chelates and their stereo-chemical information, anomalous magnetic moments, magnetic exchange coupling and spin crossover.

VI **Metal π-Complexes**

Metal carbonyl, 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.

VII **Metal Clusters**

Higher boranes, carboranes, Metalloboranes and metallocarboranes. Metal carbonyl and halide clusters, compounds with metal-metal multiple bonds.

VIII **Isopoly and Heteropoly Acids and Salts**

BOOKS SUGGESTED

1. Advanced Inorganic chemistry, F.A. Cotton and Wilkinson, John Wiley.
2. Inorganic Chemistry, J.E. Huhey, Harpes & Row.
3. Chemistry of the elements, N.N. Greenwood and A. Earnshow, Pergamon.
4. Inorganic Electronic Spectroscopy, A.B.P. Lever, Elsevier.
5. Megnetochemistry, R.L. Carlin, Springer Verlag.
6. Comprehensive Coordination Chemistry eds., G. Wilkinson, R.D. Gillars and J.A. Cleverty. Pergamon.

M.Sc. (Previous)
CHEMISTRY
Paper-II

Organic Chemistry

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, alternant and non-alternant hydrocarbons, Huckel's rule, energy level of pimolecular orbitals, annualenes, antiaromaticity, homoaromaticity.

II Stereochemistry

Conformational analysis of cycloalkanes, decalines, effect of conformation of reactivity, conformation of sugars steric strain due to unavoidable crowding. Elements of symmetry, chirality, molecule with more than one chiral center, threo and erythroisomers, stereospecific and stereoselective synthesis.

Asymmetric synthesis, Optical activity in the absence of chiral carbon (biphenyles aleines and spiranes), chirality due to helical shape. Stereochemistry of compounds containing nitrogen.

III Aliphatic nucleophilic substitution

The SN2, SN1 mixed SN1 and SN2 and SET mechanism, the neighbouring group mechanism, neighbouring group participation by Pi and Sigma bonds, anchimeric assistance Classical and non classical carbonations. The SNi mechanism nucleophilic substitution at n allylic, aliphati trigonal and a vinylicarbon. Reactivity effects of substracte structre, attacking nucleophile, leaving group and reaction medium, ambident nucleophile, regioselectivity.

IV. Aromatic electrophilic substitution

The arenium ion mechanism, orientation and reactivity, energy profile diagrams. The Ortho/Para ratio, ipso attack, orientation in other ring systems. Quantitative treatment of reactivity in substrates and electrophiles. Vilsmeir reaction, Gattermann Koch reaction.

V Aromatic nucleophilic substitution

The SNAr. SN1, Benzyne and SRN1 mechanism. Reactivity effect of substrate structure, leaving group and attacking nucleophile. The Von Richter, sommelet-Hauser, and Smdes rearrangements.

VI **Free radical reactions**

Free radical substitution mechanism, mechanism at an aromatic substrate, neighboring group assistance. Reactivity for aliphatic and aromatic substrates at a bridgehead. Reactivity in the attacking radicals. The effect of solvent on reactivity. Arylation of aromatic compounds by diazonium salt. Sandmeyer reaction, free radical rearrangement. Hunsdiecker reaction.

VII **Addition to carbon-carbon multiple bond**

Mechanistic and stereochemical 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.

VIII **Elimination reactions**

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

IX **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 diagrams. FMO and PMO approach. Electrocyclic reactions conrotatory and disrotatory motions, 4n, 4n+2 and allyl systems. Cyclo additions-antarafacial and suprafacial additions, 4n and 4n+2 system, 2+2 adition of ketenes, 1,3 dipolar cyclo addition and cheleotropic reactions. Sigmatropic rearrangements-superafacial and antarafacial shifts of H, sigmatropic shifts involving carbon moieties, 3,3 and 5,5 sigmatropic rearrangements. Claisen-Cope and Azacope 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, 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. Reaction Mecnanism in Organic Chemistry S.M. Mukherji and S.P. Singh, Macmillan.
9. Stereochemistry of Organic Compounds D. Nasipuri, New Age International.
10. Stereochemistry of Organic Compounds, P.S. Kalsi, New Age International.

M.Sc. (Previous)
Chemistry
Paper III
Physical Chemistry

I 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). Applications of variation method and perturbation theory to the Helium atom.

(d) ***Molecular Orbital Theory***

Huckel theory of conjugated systems, bond order and charge density calculations. Applications to ethylene, butadiene cyclobutadiene and Benzene molecules.

II 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, Gibgs-Duhem equation, concept of fugacity, determination 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 microcanonical ensembles, The Boltzman distribution law. Partition functions-transnational, rotational, vibrational and electronic partition functions. Calculation of thermodynamic

properties and equilibrium constant in terms of partition functions. Fermi-Dirac and Bose-Einstein statistics.

(c) ***Non-Equilibrium Thermodynamics***

Thermodynamic criteria for non-equilibrium states, entropy production and entropy flow, entropy balance equations for different irreversible processes (e.g. heat flow, chemical reaction etc.) transformations of the generalized fluxes and forces, non-equilibrium stationary states, phenomenological equations, onsager's reciprocity relations, electrokinetic phenomena.

III **Chemical Dynamics**

Methods of determining rate laws, collision theory of reaction rates, steric factor, activated complex theory, Arrhenius equation and the activated complex theory, ionic reactions, kinetic salt effects, steady state kinetics.

Dynamic chain (hydrogen-bromine reaction, pyrolysis of acetaldehyde) photochemical (hydrogen-bromine and hydrogen chlorine reactions and oscillatory, reactions (Belousov-Zhabotinsky reaction), homogeneous catalysis, kinetics and enzyme reactions, general features of fast reactions, study of fast reactions by resonance method, dynamics of unimolecular reactions (Lindemann Hinshelwood and Rice-Ramsperger-Kassel-Marcus (RRKM) theories of unimolecular reactions).

IV **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 interaction, critical micellar concentration (CMC), factors affecting the CMC of surfactants, counter ion binding to micelles, solubilization, micro emulsion, reverse micelles.

V **Electrochemistry**

Debye-Huckel theory of activity coefficient of electrolytic solutions, applicability and limitations of Debye-Huckel limiting law, ionic strength, structure of electified interfaces, Helmhholzperrin, Guoy-chapman and stern models.

Over potentials, exchange current density, derivation of Butler-volumer equation, Tafel plot.

Electrocatalysis, Influence of various parameters, Hydrogen electrode.

Polarography theory, interpretation of a polarographic curve, instrumentation, limiting current, residual and charging current, diffusion current. Supporting electrolytes, llkovic equation, half wave potential and its significance.

Introduction to corrosion, homogeneous theory, forms of corrosion, corrosion monitoring and prevention methods.

BOOKS SUGGESTED

1. Physical Chemistry P.W. Atkins, ELBS.
2. Introduction to Quantum Chemistry, A.K. Chandra, Tata Mc Grew Hill.
3. Quantum Chemistry, Ira N. Levine. Prentice Hall.
4. Coulson's Valence, R.M. Weeny, ELBS.
5. Chemical Kinetics, K.J. Laidler, Mcgraw-Hill.
6. Kinetics and Mechanism of Chemical Transformations J. Rajaraman and J. Kuriacose Mc Millan.
7. Micelles, Theoretical and Applied Aspects, V. Moroi, Plenum.
8. Modern Electrochemistry Vol. I and Vol. II, J.O.M. Bockris and A.K.N. Reddy, Plenum.
9. Introduction to Polymer Science V.R. Gowarikar, N.V. Vishwanathan and J. Sridhar, Wiley Easter.

M.Sc. (Previous)
Chemistry
Paper IV
Group theory, spectroscopy and Diffraction Methods

I. Symmetry and Group theory in Chemistry

Symmetry element and symmetry operation, definitions of group, subgroup, 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. The great orthogonality theorem (without proof) and its importance. Character tables and their use in spectroscopy.

II Unifying Principles

Electromagnetic radiation, interaction of electromagnetic radiation with matter-absorption, emission, transmission, reflection, refraction, dispersion, polarisation 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 leaves.

III Microwave Spectroscopy

Classification of molecules, rigid rotor model, Effect of isotopic substitution on the transition frequencies intensities, non rigid rotor. Stark effect, nuclear and electron spin interaction and effect of external field. Applications.

IV Vibrational Spectroscopy

(a) ***Infrared Spectroscopy***

Review of linear harmonic oscillator, vibrational energies of diatomic molecule, zero point energy, force constant and bond strength; anharmonicity, vibration-rotation spectroscopy. P.Q.Q. 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.

V Electronic Spectroscopy

(a) ***Atomic Spectroscopy***

Energies of atomic orbitals, spectra of hydrogen atom and alkali metal atoms.

(b) ***Molecular spectroscopy***

Energy levels, molecular orbitals, vibronic transitions, vibrational progressions and geometry of the excited states; Franck-Condon principle, electronic spectra of polyatomic molecules. Emission spectra; Radioactive and non-radioactive decay, internal conversion, spectra of transition metal complexes, charge-transfer spectra.

(c) ***Photoelectron Spectroscopy***

Basic Principles; photo-electric effect, ionization process, Koopman's theorem. Photoelectron spectra of simple molecules, ESCA, chemical information from ESCA Auger electron spectra of simple molecules.

VI **Magnetic Resonance Spectroscopy**

(a) ***Nuclear magnetic Resonance Spectroscopy***

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

(b) ***Electron Spin Resonance-Spectroscopy***

Basic principles, Zero field splitting and Kramer's degeneracy, Factors affecting the 'g' value. Isotropic and anisotropic hyperfine coupling constants, spin Hamitonian, spin densities and Mc Connell relationship, measurement techniques and applications.

VII **Photoacoustic Spectroscopy**

Basic principles of photoacoustic spectroscopy (PAS), PAS-gases and condensed systems, chemical and surface applications.

BOOK SUGGESTED

1. Modern Spectroscopy, J.M. Hollas, John Wiley.

2. Applied Electron spectroscopy for Chemical Analysis ed. H. Windawi and F.L. Ho. Wiley interscience.
3. NMR, NQR, EPR and Mossbauer Spectroscopy in inorganic chemistry, R. V. Parish, Ellis Harwood.
4. Physical methods in Chemistry, R.S., Drago, Saunders College.
5. Chemical Application of Group, F.A. Cotton.
6. Introduction of Molecular Spectroscopy G.M. Barrow, Mc Graw Hill.
7. Basic Principles of Spectroscopy, R. Chang. Mc Graw Hill.
8. Theory and Applications of UV Spectroscopy, H.H. Jaffer and M. Orchin. IBH-oxford.
9. Introduction to Photoelectron Spectroscopy. P.K. Ghosh. John Wiley.
10. Introduction to Magnetic Resonance, A Carrington and A.D. Maclachalan, Harper & Row.

M.Sc. (Previous)
Chemistry
Paper V

Environmental Chemistry

I **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, Bio-distribution of elements.

II **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, 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.

III **Soils**

Composition, micro and macro nutrients. Soil pollution and pollutants-fertilizers, pesticides, plastics, and metals. Waste treatments.

IV **Atmosphere**

Chemical composition of atmosphere-particles, ions and radicals and other their formation Chemical and photochemical reactions in atmosphere, smog formation, oxides of N.C.S.O and their effect, pollution by chemicals, petroleum, minerals chlorofluorohydrocarbons Greenhouse effect, acid rain, air pollution controls and their chemistry.

Analytical methods for measuring air pollution Continuous monitoring instruments.

V **Industrial Pollution**

Cement, sugar, distillery, drug, paper and pulp, thermal power plants, nuclear power plants, metallurgy, polymers, drugs etc. Radionuclide analysis, Disposal of wastes and their management.

VI **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.

BOOKS SUGGESTED

1. Environmental Chemistry, S.E. Manahan, Lewis Publishers.
2. Environmental Chemistry, Sharma & Kaur, Krishna Publishers.
3. Environmental Chemistry, A.K. De, Wiley Eastern.
4. Environmental Pollution Analysis, S.M. Khopkar, Wiley Eastern.
5. Standard method of Chemicals Analysis, F.J. Welcher Vol. III. Van Nostrand Reinhold Co.
6. Environment Toxicology. Ed. J. Rose, Gordon and Breach Science Publications.
7. Elemental Analysis of Airborne Particles. Ed. S. Landsberger and M. Creatchman, Gordon and Breach Science Publication.
8. Environmental Chemistry, C. Baird, W.H. Freeman.

M.Sc. (Previous)
Chemistry Practical

Note:-

(a) A complete records 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.

(b) Total duration of practical examination will be 18 hours spread over three days.

Inorganic Chemistry:

1. Qualitative analysis of mixture containing trace elements T1, Mo, W, Zr, Ti, Th, V, U (Two metal ions in cationic/anionic forms) and isoluble oxides, sulphates and halides. The mixture should not contain more than five cations and should be analysed by semi-micro technique. M.M. 15

2. Quantitative estimation of two metal ions Cu-Ni, Ni-Zn, Cu-Fe etc. involving volumentric and gravimetric methods. M.M. 15

3. Paper chromatography separation of a mixture of the following by IR and magnetic susceptibility measurements. M.M. 10

   (i) $VO(acac)_2$

   (ii) $Na[Cr(NH_3)_2(SCN_4]$

   (iii) $K_3[Fe(C_2O_4)_3]$

   (iv) Prussian Blue

   (v) $[Co(Py)_2Cl_2]$

   (vi) $[Ni(NH_3)_6]Cl_2$

   (vii) $(Ni[dmg]_2)$

   (viii) $[Cu(NH_3)_4]SO_4H_2O$

Organics Chemistry

1. ***Qualitative Analysis*:** M.M. 15

   Seperation, purification and identification of compounds of binary mixture (one liquid and one solid) using TLC and column chromatography, chemical tests.

2. ***Organics Synthesis*:** M.M. 15

   (i) Adipic acid by chromic acid oxidation of cyclohexanol.

   (ii) Triphenyl methanol from Benzoic acid.

   (iii) Dibenzal acetone from Benzalehyde.

(iv) p-Chlorotolune from p-toludine.

(v) Synthesis of p-nitroaniline and p-bromoaniline.

3. ***Quantitative synthesis*** M.M. 10

(i) Determination of the percentage or number of hydroxyl groups in an organic compounds by acetylation method.

(ii) Estimation of amine/phenols using bromate 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

A list of experiments under different headings is given below. Typical experiments are to be selected from each type. Students are required to perform atleast 10 experiments during the session including a minimum of two experiments from Electrochemistry.

In examination, two experiments of Physical Chemistry are to be performed out of which one must be from Electrochemistry (2×20=40 M.M).

Adsorption

To study surface tension-concentration relationship for solutions (Gibbs equation)

Phase Equilibria

(i) Determination of congruent composition and temperature of a binary mixture e.g. diphenylamine-benzophenone system.

(ii) Determination of glass transition temperature of a given salt (e.g., $CaCl_2$) conductometrically.

(iii) To construct the phase diagram for three component system (e.g. chloroform-acetic acid-water).

Chemical Kinetics

(i) Determination of the effect of (a) change of temperature (b) change of concentration of reactants and catalysts and (c) ionic strength of the media on the velocity constant of hydrolysis of an ester/ionic reactions.

(ii) Determination of the velocity constant of hydrolysis of an ester/ionic reaction in micellar media.

(iii) Determination of the rate constant and order of reaction between H_2O_2 and HI.

(iv) Determination of the velocity Constant of decomposition of Benzene diazonium chloride.

(v) Determination of the primary salt effect on the kinetics of ionic reactions and testing of the Bronsted Relationship (iodine ion oxidized by persulphate ion)

Solutions

(i) Determination of molecular weight of nonvolatile and non electrolyte/electrolyte by crysoscopic 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.

Electrochemistry

(a) ***Conductometry***

(i) Determination of the velocity constant, order of the reaction and energy of activation for saponification of ethyl acetate by sodium hydroxide conductometrically.

(ii) Determination of solubility and solubility product of sparingly soluble salts (e.g. $PbSO_4$, $BaSO_4$) conductometrically.

(iii) Determination of the strength of strong and weak acids in a given mixture conductometrically.

(iv) Determination of the activity coefficient of Zinc ions in the solution of 0.002M Zinc Sulphate using Debye-Huckel's limiting law.

(b) ***Potentionmetry/PH metry***

(i) Determination of strength of halides in a mixture potentiometrically.

(ii) Determination of volency of mercurous ions potentiometrically.

(iii) Determination of the strength of strong and weak acids in a given mixture using potentiometer/pH meter.

(iv) Determination of the temperature dependence of E.M.F. of a cell.

(v) Determination of the formation constant of silver-ammonia complex and stoichiometry of the complex potentiometrically.

(vi) Acid-Base titration in non-aqueous media using a pH meter.

(vii) Determination of the dissociation constant of monobasic/diabasic acid by Albert Serjeant method.

Polarimetry

(i) Determination of rate constant for hydrolysis/inversion of sugar using polarimeter.

(ii) Enzyme kinetics-inversion of sucrose.

BOOK SUGGESTED

1. Vogel's Textbook of Quantitative Analysis Revised, J. Bas set R.C. Denney. G.H. Jeffery and J. Mendham ELBS.
2. Synthesis and Characterisation of inorganic compounds-W.L. Jolly, Prentice Hall.
3. Experiments and Techniques in Organic Chemistry-D Pasto, C. Johnson and M. Miller-Prentice Hall.
4. Systematic Qualitative Organic Analysis-H. Middleton, Edward Arnold.
5. Handbook of Organic Analysis-H. Middleton, Edward Arnold.
6. Vogels Textbook of Practical Organic Chemistry-A.R. Tatchell, John Wiley.
7. Practical Physical Chemistry-A.M. James and F.E. Prichard.
8. Findley's Practical Physical Chemistry-S.P. Levitt, Longman.
9. Experimental Physical Chemistry-R.C. Das and B. Behera, Tata Mac Graw Hill.

Assignment/Seminar Lecture

Topic and supervisor will be decided by the respective head of the department.

Notes-

In M.Sc. (Previous) Chemistry practical examination, there will a Board of three Examiners belonging to three different branches of Chemistry such as Inorganic, Organic and Physical. The Internal examiner of the Board should be a permanent faculty member of the College where the examination is to be conducted and the Chairman of the Board will be from some other College of this University where the subject is taught in P.G. classes. The third examiner of the Board will be an external one.

M.Sc. (Final)

Inorganic Chemistry Syllabus
(To be effective from session 2020-21)

The examination shall comprise five theory papers each of three hours duration and a practical examination of 6 hours duration and Master thesis/ Research Project presentation on another day. The details of papers are given below-

(a) Theory Papers-

Paper No.	Course	Marks
I	Application of Group Theory and Spectroscopy	100
II	Bio-inorganic and Supramolecular Chemistry	100
III	Organotransition Metal Chemistry	100
IV	Photoinorganic Chemistry	100
V	Analytical Chemistry	50
		450

(b) Practical

1.	Preparation of Inorganic Complexes	30
2.	Spectrophotometric /Flame photometric Determination of Elements	30
3.	Chromatographic Separation	30
4.	Viva Voce	20
5.	Records	10
6.	Master Thesis/Research Project	30
		150
	Total Marks (Theory and Practicals)	**600**

Note: Seminars are to be held for an hour in every week of the session.

M.Sc. (Final) Inorganic Chemistry
Paper I
Application of Group Theory and Spectroscopy

I **Symmetry and Group Theory in Chemistry**

Character tables for C_2V and C_3V point groups. Representation reducible and irreducible, analysis of reducible representation. Simple Applications of the character table.

II **Vibrational Spectroscopy**

Symmetry and shapes of AB_2, AB_3, and AB_4, mode of bonding of ambidenate ligands such as thiocynanate, nitrate, sulphate and urea, application of Raman spectroscopy particularly for the study of ionic equilibrium in solution.

III **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)

IV **Nuclear Quadrupole Resonance Spectroscopy**

Quadrupole nuclei quadrupole moments, electric field gradient, coupling constant, splittings, applications.

V **Mossbauer Spectroscopy**

Basic principles, spectral parameters and spectrum display. Application of the technique to the studies of (1) bonding and structures of Fe^{+2} and Fe^{+3} compounds including those of intermediate spin. (2) Sn^{+2} and Sn^{+4} compounds-nature of M-L bond, coordination number, structure and (3) detection of oxidation state and inequivalent MB atoms.

BOOKS SUGGESTED

1. Physical Methods for chemistry, R.S. Drago, 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. Willey.

4. Progress in Inorganic Chemistry Vol. 8 ed., F.A. Cotton. Vol. 15 ed. S.J. Lippard Wiley.
5. Transition Metal Chemistry ed. R.L. Carlin Vol. 3 Dekker.
6. Inorganic Electronic spectroscopy. A.P.B. Level Elsevier.
7. NMR, NQR, EPR and Mossbauer spectroscopy in Inorganic Chemistry, R.V. Parish, Ellis Horwood.
8. Chemical Applications of Group Theory: by F.A. Cotton.
9. Group Theory and Symmetry in Chemistry: by Lowell H. Hall.

M.Sc. (Final) Inorganic Chemistry
Paper II
Bio-Inorganic Chemistry and Supramolecular Chemistry

I **Metal ions in Biological Systems**

Essential and trace metals.

II **Na^+/K^+ Pump**

Role of metals ions in Biological processes.

III **Bioenergetics and ATP cycle**

DNA polymerisation, glucose storage, metal complexes in transmission on energy: chlorophylls, photosystem I and photosystem II in cleavage of water.

IV **Transport and Storage of Dioxygen**

Heme proteins and oxygen uptake. Structure and function of hemoglobin, myoglobin. hemocyanins and hemerythrin model synthetic complexes of iron, cobalt and copper.

V **Electron Transfer in Biology**

Structure and function of metalloproteins in electron transport process-cytochromes and ion-sulphur proteins.

VI **Nitrogenase**

Biological nitrogen fixation, molybdenum nitrogenase.

VII **Supramolecular Chemistry**

(a) Molecular recognition: Molecular receptors for different types of molecules including arisonic substrates. Design and synthesis of co-receptor molecules and multiple recognition.

(b) Supramolecular reactivity and catalysis.

(c) Transport processes and carrier design.

(d) Supramolecular devices, supramolecular photochemistry, supramolecular electronic. Ionic and switching devices. Some example 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. Bertini H.B. Gray, S.J. Lippartd and J.S. Valentine, University Science Books.
3. Inorganic Biochemistry Vols I and II ed. G.L. Eichhorn Elsevier.
4. Progress in Inorganic Chemistry, Vols 18 and 38 ed. J.J. Lippard Wiley.
5. Supramolecular Chemistry. J.M. Lehn, VCH.

M.Sc. (Final) Inorganic Chemistry
Paper III
Organotransitions Metal Chemistry

I **Alkyls and Aryls of Transition Metals**

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

II **Compounds of Transition metal-Carbon Multiple Bonds**

Alkylidenes, Alkylidynes, low valent carbenes and carbines-synthesis, nature of bond, structural characteristics, nucleophilic and electrophilic reactions on the ligands, role in organics synthesis.

III **Transitions Metal π-Complexes**

Transition metal π-complexes with unsaturated organic molecules, alkenes, alkynes, allyldiene, dienyl, arene and trienyl complexes preparations, properties, mature of bonding and structural features. Important reactions relations to mucleophilic and electrophilic attack on ligands and to organic synthesis.

IV **Transitional Metal Compounds with Bonds to Hydrogen**

V **Homogeneous Catalysis**

Stoichiometric reactions for catalysis, homogeneous catalytic hydrogenation, Zeigler-Nattapolymerization of olefins. Catalytic reactions involving carbon monoxide such as hydrocarbonylation olefine (oxo reaction), oxopaladation reactions, activation of C-H bond.

VI **Fluxional Organometallic Compounds**

Fluxionality and dynamic equilibria in compounds such as η^2 olefin, η^3-allyl and dienyl complexes.

BOOKS SUGGESTED

1. Principles and application of Organotransition Metal Chemistry J.P. Collman. I.S. Hegsdus. J.R. Norton and R.G. Finke University Science Books.
2. The Organometallic Chemistry of the Transition Metals, R.h. Crabtree, John Wiley.
3. Metalloorganic Chemistry, A.J. Pearson. Wiley.
4. Organometallic Chemistry, Rc. Mehrotra and A. Singh. New Age International.

M.Sc. (Final) Inorganic Chemistry
Paper IV
Photoinorganic Chemistry

I Basics of Photochemistry

Absorption, excitation, Photochemical laws, quantum yield electronically 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.

II Properties of Excited States

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

III 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.

IV 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.

V Redox Reactions by Excited metal Complexes

Energy transfer under conditions of weak interaction and strong interaction-exciplex formation; conditions of the excited state to be useful as redox reactants, excited electron transfer, metacomplexes as attractive candidates (2,2-bipyridine and 1.10 phenonotroline complexes), illustration of reduction and oxidising character of Ruthenium^{+2} (bipyridal complex, comparison with F(bipy)$_3$ role of spin-orbit coupling-life time of these complexes. Application of redox processes of electronically excited state for catalytic purpose, transformation of low energy reactant into high energy products, chemical energy into light.

VI 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. 39, 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.

M.Sc. (Final) Inorganic Chemistry
Paper V
Analytical Chemistry

I Introduction

Role of analytical chemistry. Classification of analytical methods-classical and instrumental. Types of instrumental analysis. Selecting an analytical methods. Neatness and cleanliness, Laboratory operations and practices. Analytical balance. Techniques of weighing errors. Volumetric glassware cleaning and calibration of glassware. Sample preparations dissolution and decompositions. Gravimetric. Techniques selecting and handling of reagents. Laboratory notebook Safety in the analytical laboratory.

II Errors and Evaluation

Definition of terms in mean and median. Precision-standard deviation. Relative standard deviation. Accuracy-absolute error relative error. Types of error in experimental datadeterminant (systematic), indeterminate (of random) and gross. Sources of errors and the effect upon the analytical results. Methods for reporting analytical data Statistical evaluation of data indeterminate errors. The uses of statistics.

III Food Analysis

Moisture, ash, crude protein, fat, crude fiber. Carbohydrates calcium, potassium, sodium and phosphate. Food adulteration common adulterants in food, contamination of food stuffs Microscopic examination of foods for adulterants. Pesticide analysis in food products. Extraction and purification of sample HPLC. Gas chromatography for organophosphates. Thin-layer chromatography for identification of chlorinated pesticides on food products.

IV Analysis of Water Pollution

Origin of waste water types water pollutants and effects. Source of water pollution domestic industrial, agricultural soil and indio-active wastes as sources of pollution objectives of analysis parameter for analysis-colour turbidity total solids conductivity acidity, alkalinity, hardness, chloride, sulphate, fluoride, silicon phosphates and different forms of nitrogen Heavy metal pollution public health significance of

cadmium, Chromium copper, lead zinc manganese. Mercury and arsenic. General survey of instrumental technique for the analysis of heavy metals in aqueous systems. Measurements at DO BOD and COD. Pesticides as water pollutants and analysis Water pollution laws and standards.

V **Analysis of Soil, Fuel, Body, Fluids and Drugs**

(a) Analysis of soil: moisture, pH, total nitrogen, Phosphorus, silicon, lime, magnesia, manganese, sulphur and alkali salts.

(b) Fuel analysis: solid, liquid and gas, Ultimate and proximate analysis-heating valuesgrading of coal. Liquid fuels-flash point, aniline point, octane number and carbon residue. Gaseous fuels-producer gas and water gas-calorific value.

(c) Clinical chemistry: Composition of blood-collection and preservation of samples. Clinical analysis. Serum electrolytes, globulins, barditurates, acd and alkaline phosphatases. Immunoassay: principles of radio immunoassay (RIA) and applications. The blood gas analysis trace elements in the body.

(d) Drug analysis: Narcotics and dangerous drugs. Classification of drugs. Screening by gas and thin-layer chromatography and (spectrophotometric) measurements.

BOOKS SUGGESTED

1. Analytical Chemistry, G.D. Christian, J. Wiley.
2. Fundamentals of Analytical Chemistry, D.A. Skoog, D.M. West and F.J. Holler, W.B. Saunders.
3. Analytical Chemistry-Principles J.S. Kennedy, W.B. Saunders.
4. Analytical Chemistry-Principles and Techniques, L.G. Hargis Prentice Hall.
5. Principles of Instrumental Analysis, D.A. Skoog. and J.L. Loary., W.B. Saunders.
6. Principles of Instrumental Analysis. D.A. Skoog, W.B. Saunders.
7. Quantitative Analysis, R.A. Day. Jr. and A.L. Underwood. Prentice Hall.
8. Environmental Solution Analysis, S.M. Khopkar, Wiley Eastern.
9. Basic Concepts of Analytical Chemistry. S.M. Khopkar Wiley Eastern.
10. Handbook of Instrumental Techniques for Analytical chemistry, F. Settle, Prentice Hall.

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M.Sc. (Final) Inorganic Chemistry
Practicals

Preparation M.M. 20

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-

(a) Sodium amide

(b) Dichlorophenyl borane $PhBCl_2$

(c) Sn (IV) iodide, Tin (IV) chloride and Tin (II) iodide

(d) Ammonium hexachorostannate $(NH_4)_2\ SnCl_6$

(e) Trichlorodiphenyl antimony (V) hydrate

(f) Sodium Tetrathionate, $Na_2S_4O_6$

(g) Metal Complexes of Dimethyl Sulfoxide, $CuCl_2$ 2D MSO

(h) Metal acetylacetonate.

(i) Ion exchange separation of oxidation state of V.

(j) Preparation of Fe (II) Chloride.

(k) Phosphine Ph_3P and its transition metal complexes.

(l) Ferrocene

(m) Copper Glycine Complex

(n) Determination of Cr (III) Complex

2. Any two of the following headings. M.M. 10+10

(a) Spectrophotometric Determinations

(i) Manganese/chromium/vanadium in steel sample.

(ii) Nickel/molybdenum/tungsten/vanadium/uranium by extractive spectrophotometric method.

(iii) Fluoride/nitrate/phosphate

(iv) Iron-phenanthroling complex: Job Method.

(b) Flame Photometric Determinations

(i) Sodium and Potassium when present together.

(ii) Lithium/calcium/Barium/Strontium

(iii) Cadmium and Magnesium in tap water

(c) Chromatographic Separations

(i) Thin layer chromatographic separation of Nickel, (Manganese Cobalt and Zinc. Determination of R_f values.

(ii) Cadmium and Zinc

(iii) Zinc and Magnesium

Master Thesis/Research Project

Topic and supervisor will be decided by the respective head of the department.

M.Sc. (Final)
Organic Chemistry Syllabus
(To be effective from session 2020-21)

The examination shall comprise five theory papers each of three hours duration and a practical examination of 6 hours duration and Master thesis/ Research Project presentation on another day. The details of papers are given below-

(a) Theory Papers-

Paper No.	Course	Marks
I	Application of Spectroscopy and Photochemistry	100
II	Bio-Organic Chemistry	100
III	Organic Synthesis	100
IV	Medicinal Chemistry	100
V	Chemistry of Natural Products	50
		450

(b) **Practical**

7.	Qualitative analysis	30
8.	Spectrophotometric /Flame photometric Determination of Elements	30
9.	Chromatographic Separation	30
10.	Viva Voce	20
11.	Records	10
12.	Master Thesis/Research Project	30
		150
	Total Marks (Theory and Practicals)	**600**

Note: Seminars are to be held for an hour in every week of the session.

M.Sc. (Final) Organic Chemistry Specialization
Paper I
Application of Spectroscopy and Photochemistry

I **Ultraviolet and Visible Spectroscopy**

Various electronic transitions (185-800 mm). 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 compound.

II **Infrared Spectroscopy**

Instrumentation and sample handling. Characteristics vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines, detailed study of vibrational frequencies of carbonyal compounds (ketones, aldehydes, esters, amides, and acids), Effect of hydrogen bonding and solvent effect on vibrational frequencies overtones, combination bands and Fermi resonance.

III **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 (aplihatic, 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), virtual coupling. Stereochemistry, hindered rotation, Karplus curvevariation of coupling constant with dihedral angles.

Carbon-13 NMR Spectroscopy

General considerations. Chemical shift (aliphatic. olefinic. alkyne, aromatic, heteroaromatic and carbonyal carbon). Coupling constants.

IV **Mass Spectrometry**

Introduction, ion production- El. Cl. FD. and FAB. Factors affecting fragmentation, ion analysis, ion abundance. Mass spectral fragmentation of organic compounds. Common functional groups. Molecular ion peak, metastable peak, Mc Lafferty rearrangement. Nitrogen rule.

V **Photochemical Reactions and Determination of Reaction Mechanism**

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

Classification rate constants and life times of reactive energy states-determination of rate constants of reactions. Effect of light intensity on the rate of photochemical reactions.

VI **Photochemistry of Alkenes, Carbonyl Compounds and Aromatic Compounds**

(a) **Photochemistry of Alkenes** Intramolecular reactions of the olefinic bond-geometrical isomerism; cyclisation reactions. Rearrangement of 1,4- and 1,5-dines.

(b) **Photochemistry of Carbonyl Compounds**

Intramolecular reactions of carbonyl compounds-saturated cyclic and acyclic β, γ unsaturated and α, β unsaturated compounds, Cyclohexadienones. Intemolecular cycloaddition reactions-dimerisation and oxetane formation.

(c) **Photochemistry of Aromatic Compounds**

Isomerisations, additions and substitutions.

BOOKS SUGGESTED

1. Practical NMR Spectroscopy. M.L. Martin, J.J. Delpeuch and G.J. Martin, Heyden.
2. Spectrometric Identification of Organic Compounds. R.M. Silverstein. G.C. Bassler and T.C. Morill. John. Wiley.
3. Introduction to NMR Spectroscopy. R.J. Abraham. J. Fisher and P. Loftus. Wiley.
4. Application of Spectroscopy of Organic Compounds, J.R. Dyer. Prentice Hall.
5. Spectroscopic Methods in Organic Chemistry. D.H. Williams. I Fleming. Tata Mc Graw-Hill.
6. Fundamentals of Photochemistry. K.K. Rohtagi Mukherji, Wiley Eastern.
7. Essentials of Molecular Photochemistry A. Gilbert, Baggot Blackwell Scientific Publication.
8. Introductory Photochemistry. A. Cox and T. Camp. Mc Graw Hill.
9. Photochemistry. R.P. Kundal and A. Gilbert. Thomson Nelson.
10. Organic Photochemistry. J. Coxon and B. Halton. Cambridge University Press.

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M.Sc. (Final) Organic Chemistry
Paper II
Bioorganic Chemistry

I **Introduction**

Basic consideration proximity effects and molecular adaptation.

II **Enzymes**

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

III **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.

IV **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 suplphate, addition and elimination reactions, enolic intermediates in isomerization reactions, β-cleavage and condensation, some isomerization and rearrangement reactions. Enzyme catalyzed carboxylation and decarboxylation.

V **Co-Enzyme Chemistry**

Cofactor as derived from vitamins coenzymes S, prosthetic groups, apoenzmes structure and biological functions of coenzyme A thiamine pyrophosphate, pyridoxal phosphate. $NAD^{+}1$, $NADP^{+}$, FMN, FAD, lipoic acid, vitamin B_{12}.

VI **Enzyme Models**

Host-guest chemistry, chiral recognition and catalysis, molecular recognition, molecular asymmetry and prochirality. Biommetic chemistry crown ethers, cryptates Cyclodextrins, cyclodextrin based enzme modes calixarenes ionophores, micelles. synthetic enzymes or synzymes.

VII **Biotechnological Application 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, use of enzymes as targets for drug design. Clinical uses of enzymes, enzyme therapy.

BOOKS SUGGESTED

1. Bioorganic Chemistry: A chemical Approach to Enzyme Action, Hermann Dugas and C. Penny Springer Verlag.
2. Understanding Enzymes, Trevor Palmer, Prentice Hall
3. Enzyme chemistry ; Impact and Applications, Ed. Collin J. Suck Chapman and Hall.
4. Enzyame Mechanisms De. M.I. Page and A. Williams. Royal Society of Chemistry.
5. Fundamentals of Enzymology. N.C. Price and L. Stevens. Oxford University Press.
6. Immobilized Enzymes: An introduction and application in Biotechnology-Michael D. Trevan-John Wiley.
7. Enzyme Structre and Mechanism, A Fersht, W.H. Freeman.
8. Biochemistry: The Chemical Reactions of Living Cells. D.E. Metzler. Academic Press.

M.Sc. (Final) Organic Chemistry
Paper III
Organic Synthesis

I **Organometallic Reagents**

Principle, Preparations, Properties and applications of the following in organic synthesis with mechanistic details.

Li, Mg, Hg, Cd, Zn, Ce, Cu, Pd, Fe, and Rh compounds.

II **Oxidation**

Introduction. Different oxidative processes.

Hydrocarbons-alkenes, aromatic rings, saturated C–H groups (activated and inactivated). Alcohols, diols, aldehydes, ketones, ketals and carboxyalic acids.

III **Reduction**

Introduction. Different reductive processes.

Hydrocarbons-alkanes, alkynes and aromatic rings.

Carbony compounds-aldehydes, ketones, acids and their derivatives. Epoxides.

IV **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, Favorskil, Arndt-Eistert synthesis, Neber, Beckmann, Hofman, Curtius, Schmidt, Baeyer-Villiger. Shapiro reaction.

V **Disconnection Approach**

An introduction to synphons and synthetic equivalents, disconnection approach, functional group inter-conversions, 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.

VI **Protecting Group**

Principle of protection of alcohol, amine, cabonyl and carboxyl groups.

VII **One Group C-C Disconnections**

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

VIII **Two Group C-C Disconnections**

Diels-Alder reaction 1,3-difunctionalized compounds, αβ-unsaturated carbonyl compounds, control in carbonyl condensations, 1,5-difunctionalized compounds. Micheal addition and Robinson annelation.

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 & Professional.
5. Advanced Organic Chemistry Part B, F.A. Carey and R.L. Sundherg, Plenum Press.
6. Rodd's Chemistry of Carbon Compounds, Ed. S. Coffey Elevier.
7. Designing organic Synthesis, S. Warren. Wiley.
8. Organic Synthesis-Concept, methods, and Starting Materials, J. Fuhrhop and G. Penzillin. Verlage VCH.
9. Some modern methods of organic Synthesis. W. Carruthers Cambridge University Press.
10. Modern Synthetic Reactions, H.O. House W.A. Benjamin.

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M.Sc. (Final) Organic Chemistry
Paper IV
Medicinal Chemistry

I **Drug Design**

Development of new drugs, procedures following in drug design, concepts of lead modification, concepts of prodrugs and soft drugs, structure-activity relationship (SAR), factors affecting bioactivity, resonance, inductive effect, isosterism, bioisosterism spatial considerations. Theories of drug activity occupancy theory, induced fit theory. Quantitative structure activity relationship. History and development of QSAR. Concepts of drug receptors. Elementry treatment of drug receptor interactions. Physico-chemical parameters: lipophilicity, partition coefficient, electronic ionization constants, steric, Shelton and surface activity parameters and redox potentials. Free-Wilson analysis, Hansch analyysis, relationships between Free-Wilson and Hansch analysis LD-50, ED-50 (Mathematical derivations of equations excluded).

II **Pharmacokinetics**

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

III **Pharmocodynamics**

Introduction, elementary treatment of enzyme stimulation, enzyme inhibition sulphonamides, membrane active drugs, drug metabolism, xenobiotics, biotransformation, significance of drug metabolism in medicinal chemistry.

IV **Antineoplastic Agents**

Introduction, cancer chemotherapy, special problems, role of alkylating agents and anti-metabolites in treatment of cancer. Mention of carcinolytic antibiotics and mitotic inhibitors.

Synthesis of mechalorethamine, cyclophosphamide, melphalan, uracil, mustards and 6 mercaptopurine, recent development in cancer chemotherapy, Hormone and natural products.

V **Cardiovascular Drug**

Introduction, cardiovascular diseases, drug inhibitors of peripheral sympathetic function central intervention of cardiovascular output. Direct acting arteriolar dilators. Synthesis of amyl nitrate, sorbitarte, diltiazem quinidine, veramil, methylodopa, atenolol oxyprenolol.

VI Local Antinfective Drugs

Introduction and general mode of action.

Synthesis of sulphonamides, furazolidone, nalidixic acid, ciprofloxacin, norfloxacin, dapson,e amino salicylic acid, isoniazid, ethionamid, thambutal, fluconazole, econozole, griseofylvin, chloroquin and primaquin.

VII Psychoactive Drugs-The Chemotherapy of Mind

Introduction, neurotransmitters, CNS depressant, general anaesthetics, mode of action of hypnotics, sedatives, antianxiety drugs, benzodiazepines, buspirone, neurochemistry of mental diseases. Antipsychotic drug-the neuroleptics, antidepepressants, butyrophenones, serendipity and drug development, sterochemical aspects of psychotropic drugs. Synthesis of diazepam, oxazepam, chlorazepam, alprazolam, phenytoin ethosuximide, trimethadione barbiturates, thiopental sodium glutethimide.

VIII Antibiotics

Cell wall biosynthesis, inhibitors, β-lactam rings, antibiotics inhibiting protein synthesis. Synthesis of penicillin G, penicillin, ampicillin, amoxycillin, chloramphenicol, cephalosporin, tetracyclin and streptomycin.

BOOK 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 of Drug Design, S.S. Pandeya and J.R. Dimmock, New Age International.
4. Burger's Medicinal chemistry and Drug Discovery, Vol. I, (Chapter 9 and Chapter 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. Silvermann, Academic Press.
7. Strategies for Organic Drug Synthesis and Design. D. Lednicer, John Wiley.

M.Sc. (Final) Organic Chemistry
Paper V
Chemistry of Natural Products

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 Geranoil, α-Terpeneol, Menthol, Farnesol, Ziniberene, Santonin, Phytol, Abietic acid and β-Carotene.

II 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.

Structre, Stereochemistry, synthesis and biosynthesis of the following: Ephedrine, (+)-Conline, Nicotine, Atropine, Quinine and Morphine.

III Steroids

Occurrence, nomenclature, basic skeleton, Diel's hydrocarbon and stereochemistry.

Isolation, structure determination and synthesis of Cholesterol, Bile acid, Androsterone, Testosterone, Estrone, Progestorne, Aldosterone Biosynthesis of steroids.

IV Plant Pigments

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

V Porphyrins

Structure and synthesis of Haemoglobin and Chlorophyll.

VI Prostalandins

Occurrence, nomenclature, classification, biogenesis and physiological effects, synthesis of PGE_2 and PGE_{2x}.

VII **Pyrethroids and rotenones**

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

BOOKS SUGGESTED

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

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M.Sc. (Final) Organic Chemistry
Practicals

1. **Qualitative analysis** M.M. 30

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

2. **Multistep synthesis of organic compounds** M.M. 30

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.

3. **Any one of the following experiments (a/b/c)** M.M. 30

(a) 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 tamtoes.

(b) Paper chromatography

Separation and identification of the sugars present in the given mixture of glucose, fructose and sucrose by paper chromatography and determination R_f values.

(c) Identification of organic compounds on the basis of given spectral data (UV, IR, PMR, CMR and MS)

Master Thesis/Research Project

Topic and supervisor will be decided by the respective head of the department.

M.Sc. (Final)
Physical Chemistry Syllabus
(To be effective from session 2020-21)

The examination shall comprise five theory papers each of three hours duration and a practical examination of 6 hours duration and Master thesis/ Research Project presentation on another day. The details of papers are given below-

(a) Theory Papers-

Paper No.	Course	Marks
I	Solid State Chemistry and Spectroscopy	100
II	Bio-Physical Chemistry	100
III	Advance Quantum Chemistry	100
IV	Chemistry of Materials	100
V	Polymer Chemistry	50
		450

(b) **practical**

13.	Thermodynamics	30
14.	Spectroscopy	30
15.	Polarography and E.M.F. Measurement	30
16.	Viva Voce	20
17.	Records	10
18.	Master Thesis/Research Project	30
		150
	Total Marks (Theory and Practicals)	**600**

Note : Seminars are to be held for an hour in every week of the session.

M.Sc. (Final) Physical Chemistry

Paper I

Solid State Chemistry and Spectroscopy

I **Solid State Reactions**

General Principles for reaction between two solids: Reactions conditions, structural considerations, surface area, reactivity, Kinetics of solids state reactions.

II **Crystal Defects and Non-Stoichiometry**

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

III **Electronic Properties and Band Theory**

Metals, insulators and semiconductors, electronic structure of solids-band theory, band structure of metals, insulators and semiconductors, Inrinsic and extrinsic semiconductors, doping semiconductors, p-n junctions, super conductors.

Optical properties-Optical reflectance. Photoconduction-photoelectric effects.

IV **Crystal Lattice and Unit Cell**

Unit cell and Crystal lattices, brief concept of molecular symmetry, concept of Symmetry in crystal systems, Herman Mauguin notation for symmetry elements in crystal systems, representation of screw axis and glide planes, restriction of symmetry elements in crystals systems, representation of lattice planes and directions, Bravias lattices, concept of Miller indices and Weiss indices, hexagonal crystal system, Determination of miller indices in hexagonal systems, planes of form in crystals, zone rule ,possible combination of rotational symmetries, determination of d spacing in crystals.

V **Point Groups and Space Groups in Crystal Systems**

Point groups in crystals systems, Herman maugiun notation of point groups in crystal systems, centrosymmetric and non-centrosymmetric point groups, representation of point groups in crystallography, Concept of space groups, structural elucidation of the following space groups: P1,C2,C2/m,P2221, I41,determination of atomic coordinates and special positions of space groups ,systematic absent reflections, space group and crystal structure of perovskite (ABO3)

VI **X-Ray diffractions**

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

VII **Electron Diffraction**

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

BOOKS SUGGESTED

1. Solid State Chemistry and its Applications, A.R. West, Plenum.
2. Principles of the Solid State H.V. Keer Wiley Easter.
3. Solid State Chemistry, N.B. Hannay.
4. Solid State Chemistry, D.K. Chakrabarty, New Age International.
5. Macromolecules: Structure and Functions, F. World, Prentice Hall.

M.Sc. (Final) Physical Chemistry
Paper II

Biophysical Chemistry

I **Biological cell and its Constituents**

Biological cell, structure and functions of proteins, enzymes. DNA and RNA in living systems. Helix coil transition.

II **Bioenergetics**

Standard free energy change in biochemical reactions, exergonic, endergonic, Hydrolysis of ATP, synthesis of ATP from ADP.

III **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.

IV **Thermodynamics of Biopolymer Solutions**

Thermodynamics of biopolymer solutions, osmotic pressure membrane equilibrium, muscular contraction ion energy generation in mechanochemical system.

V **Cell membrane and Transport of ions**

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

VI **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 eletrophoresis and rotational motions.

BOOKS SUGGESTED

1. Principles of Biochemistry, A.L. Lehninger, Worth Publishers.
2. Biochemistry, L. Strayer, 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 P.K. Stumpf. John Wiley.
6. Bioorganic Chemistry: A Chemical Approach to Enzyme Action, H. Dugas and C. Penny, Springer-Verlag.

M.Sc. (Final) Physical Chemistry
Paper III

Advanced Quantum Chemistry

I **Theoretical and Computational Treatment of Atoms and Molecules, Hartree-Fock Theory**

Review of the principles of quantum mechanica, Born Oppenheimer Approximation. Slater-Condon Rules, Hartee-Fock equation, Koopmans and Brillouin theories, Roothan equation, Gaussian basis sets.

II **Configuration Interaction and MC-SCF**

Introduction to Cl, full and truncated Cl theories, size consistency. Introductory treatment of coupled cluster and MC-SCF methods.

III **Semi-Empirical Theories**

A review of the Huckel, EHT and PPP streatments, ZDO approximation, detailed treatment of CNDO and INDO theories. A discussion of electronic energies and properties. An introduction of MOPAC and AMI with hands on Experience of personal computer.

IV **Density Functional Theory**

Derivation of Hohenberg-Kohn theorem, Kohn-Sham formulation, N-and V-representabilites; review of the performance of the existing local (e.g. Slater Xa and other methods) and non-local functionals, treatment of chemical concepts with the density functional theory.

V **Electronic Structure of Atoms**

Russell-Saunders terms and coupling schemes, term symbols for the p^n and d^n configurations, spin orbit coupling and Zeeman splitting, introduction to the method of self-consistent field, slater type orbitals.

BOOKS SUGGESTED

1. Modern quantum chemistry, N.S. Ostlund and A. Szabo, Mc Graw Hill.

2. Methods of Molecular Quantum Mechanics R., Mc Weeny and B.T. Sutchliffe. Academic Press.
3. Exploring Chemistry with Electron Structure Methods. J.B. Foresman and E. Frish. Goussian Inc.
4. Semi-empirical MO theory, J. Pople and D.L. Beveridge.

M.Sc. (Final) Physical Chemistry
Paper IV

Chemistry of Materials

I **Multiphase Materials**

Ferrous alloys: Fe-C phase transformation in ferrous alloys: stainless steels, non-ferrous alloys, properties of ferrous and non-ferrous alloys and their applications.

II **Glasses, Ceramics, Composites and Nanomaterials.**

Glassy state, glass formers and glass modifiers, applications. Ceramic structures, mechanical properties, clay products. Refractories, characterizations, properties and application.

Microscopic composites; dispersion-strengthened and particle-reinforces, fibre-reinforced composites, macroscopic composite. nanocryastalling phase, preparation procedures, special properties, applcations.

III **Thin films and langmuir-Blodgett Films**

Preparation techniques; evaporation/sputtering. Chemical processes, MOCVD, sol-get etc. Langmuir-Blodgett (LB) film, growth techniques, photolithography, properties and applications of thin and LB films.

IV **Liquid Crystals**

Mesmorphic behaviour, thermotropic liquid crystals, positional order, bond orientational order, nematic and smectic mesophases; smectic-nematic transtion and clearning temperature-homeotropic, planar and schlieren textures, twisted nematics, chiral nemations, molecular arrangement in smectic A and smectic C phases, optical properties of liquid crystals. Dielectric susceptidility and dielectric comstants. Lyotropic phases and their description of ordering in liquid crystals.

V **Polymeric Materials**

Molecular shape, structure and configuration, crystallinity, and their applications. conducting and ferro-electric polymers.

VI **Ionic Conductors**

Types of ionic conductors, mechanism of ionia conduction, interstitial jumps (Frenkel), vacancy mechanism, diffusion superiohic conductors, phase teransitions

and mechanism of conduction in superionic conductors examples and applications of ionic conductors.

VII **High Tc Materials**

Defect perovskites, high Tc superconductivity in cuprates, preparation and characterization of 1-2-3 and 2-1-4 materials, normal state properies; anisotropy; anisotropy; temperature dependence of electrical resistance; optical phonon modes, supenerconducting state; heat capacity; coherence length, elastic constants, position lifetimes, microwave absorption-pairing and multigap structure in high Tc materials applications of high Tc materials.

VIII **Materials for solid State Devices**

Rectifiers, transistors, capacitors-IV-V compounds, low-dimensional quantum structures; optical properties.

IX **Organic Solids, Fullerences, molecular Devices**

Conducting organics, organic superconductors, magnetism in organic materials.

Fullerenes-doped, fullerences as superconductors, magnetism in organic materials.

Molecular rectifiers and transistors, artificial photosynthetic devices, optical storage memory and switches-sensors.

Non-linear optical materials; nonlinear optical effects, second and third order-molecular hyperpolarisability and second order electric susceptibility-materials for second and third harmonic generation.

BOOKS SUGGESTED

1. Solid State Physics, N.W. Ashcroft and N.D. Mermin Saunders College.
2. Material Science and Engineering. An Introduction. W.D. Callister, Wiley.
3. Principles of the Solid State, H.V. Keer, Wiley Eastern.
4. Materials Science, J.C. Anderson, K.D. Leaver, J.M. Alexander and R.D. Rawlings, ELBS.
5. Thermotropic Liquid Crystalism Ed. G.W. Gray. John Wiley.
6. Handbook of Liquid Crystals. Kelker and Hafz. Chemie Verlag.

M.Sc. (Final) Physical Chemistry

Paper V

Polymers

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.

II **Polymer Characterization**

Polydispersion-average molecular weight concept. Number, weight and viscosity average molecular weights. Polydispersity and molecular weight. Measurement of molecular weights. End-group, viscocity. 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.

III **Structure and Properties**

Morphology and order in crystalfine polymers-configurations of polymer chains. Crystal structures. Morphology of cryastalling polymers polymers, strain-induced morphology, crystallization and melting. Polymer structure and physical properties-crystaling melting point Tm-melting points of homogeneous series, effect of chain flexibility and other steric factors, entropy and heat of fusion. The glass transition temperature, Tg-relationship between Tm and Tg. Effects of molecular weight, diluents, chemical structure, chain topology, branching and cross linking. Property requirements and polymer utilization.

IV **Polymer Processing**

Plastics, elastomers and fibres compounding processing techniques calendaring die-casting, rotational casting film casting injection moulding. Blow moulding, extrusion moulding thermolorming, foamian, reinforcing and fibre spinning.

V **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 J. Sreedhar, Wiley-Eastern.
3. Functional Monomers and Polymers. K. Takemoto, Y. Inaki and R.M. Rttanbrite.
4. Contemporary polymer Chamistry, H.R. Alcock and F.W. Lambe, Prentice Hall.
5. Physics and chemistry of Polymer, J.M.g. Cowie, Blackie Academic and Professional.

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M.Sc. (Final) Physical Chemistry
Practicals

PHYSICAL CHEMISTRY

A list of experiments under different headings are given below. Typical experiments are to be selected from each type for practice during the session. In the annual examination, two experiments (selected from two different headings) as to be performed.

Thermodynamics M.M. 30

(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 inter molecular interactions (benzoic acid in water and in MDSO water mixture) and to calculate the partial molar heat of solution.

Spectroscopy M.M. 30

(i) Determination of pKa of an indicator (e.g. methyl red) in (a) inorganic (e.g. ferric-salicyclic acid) and organic (e.g. amineiodine) complexes.

(ii) Characterization of the complexes by electronic and IR spectral data.

Polarography/E.M.F. Measurement M.M. 30

(i) 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.

(ii) Determination of dissolved oxygen in aqueous solution of organic solvents.

(i) Determination of the equilibrium constant of the reaction-

$$\underset{\text{(Hydroquinone)}}{H_2Q + 2Ag} \equiv \underset{\text{(Quinhydrone)}}{Q + 2H^+ + 2Ag}$$

(ii) Determination of activity coefficient of electrolytes.

(iii) Potentiometric titration of a solution of Fe^{2+} against $Cr_2O_7^{2-}$ and the determination of the redox potential of $Fe^{2+} \equiv Fe^{3+}$ system.

(iv) Determination of ionic product of water (K_w)

Master Thesis/Research Project

Topic and supervisor will be decided by the respective head of the department.

BOOK SUGGESTED

1. Inorganic Experiments, J. Derek Woolline VCH.

2. Microscale Inorganic Chemistry, Z. Szafrsn, R.M. Pike, M.M. Singh, Wiley.
3. Practical Inorganic Chemistry, G. Mar and B.W. Bookett. Van Nostrand.
4. The Systematic Identification of Organic Compounds, R.L. Shnier and D.Y. Curtn5. Semimicro, Qualitative Organic Analysis, N.D. Cheronis, J.B. Extnkin and E.M. Hodentt.
5. Small Scale Organic Preparation, P.J. Hili
6. Organometallic Synthesis, J.J. Fisch and R.B. King Academic Press.
7. Experimental Physical Chemistry, D.P. Shoemaker, C.W. Garland and J.W. Niber, Mc Graw Hill Interscience.
8. Findlay's Practical Physical Chemistry, revised B.P. Lew Longman.
9. Experiments in Physical chemistry, J.C. Ghosh, Bharati Bhawan.

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