Punyashlok Ahilyadevi Holkar Solapur University, Solapur

NAAC Accredited-2022
'B^{++}' Grade (CGPA 2.96)

Name of the Faculty: Science & Technology

CHOICE BASED CREDIT SYSTEM

Syllabus: CHEMISTRY

Name of the Course: M.Sc. I (Sem.– I & II)

(Syllabus to be implemented from 2023)

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

Revised Syllabus for the Master of Science in Chemistry
(As per NEP - 2020)

Applicable from the Academic Year 2023 –2024

1. **Title**: M.Sc. Chemistry
2. **Faculty**: Faculty of Science and Technology.
3. **Year of Implementation**: For M. Sc. I (Semester I and Semester II): From August 2023 and for M. Sc. II (Semester III and Semester IV): From 2024.

4. Program Outcomes (POs):

a) To demonstrate, solve, and have an understanding of major concepts in all disciplines of Chemistry.

b) To solve problems, think methodically, and independently and draw logical conclusions.

c) To employ critical thinking and scientific knowledge to design, carry out, record, and analyze the resultsof chemical reactions.

d) To create an awareness of the impact of Chemistry on the environment, society, and development among the scientific community.

e) To find the green routes for the chemical reaction for sustainable development.

f) To inculcate scientific temperament in the students.

g) To use modern techniques, sophisticated equipment, and various Chemistry softwares

5. Program-Specific Outcomes (PSOs):

a) Students will develop critical thinking and the Analytical mind by taking knowledge in advanced-levelChemistry

b) Analytical or experimental skills make the students capable of doing higher-level research work in theemerging fields of Chemistry

c) Students will gain a thorough Knowledge of the subject to work on projects at different research and academic institutions.

d) Students will become familiar with the different branches of Chemistry like Analytical, Organic, Inorganic, Physical, Environmental, Polymer, and Biochemistry. They will also learn to apply appropriate techniques for the qualitative and quantitative analysis of chemicals in laboratories and industries.

e) Employability Skills shall enable the students to find jobs in core Chemistry and other related fields.

f) Entrepreneurial Skills shall empower the students to start their industries/businesses in core Chemistryfields.

6. The entire course of M. Sc. (Chemistry) will be of **four Semesters** spread over two years.

7. Pattern of Examination: The Examinations will be conducted **semester wise for theory and practical.**

8. **Fee structure**: As per Punyashlok Ahilyadevi Holkar Solapur University, Solapur guidelines.

9. **Eligibility criteria for Admission**: B.Sc. in Chemistry.

10. **Medium of Instruction**: English

11. Structure of course: Given in Framework Chart

The University department and University affiliated college centers offers following programs at

M. Sc. II (Semester III and IV):

School of Chemical Sciences

i. **M.Sc. (Polymer Chemistry)**

ii. **M.Sc. (Industrial Chemistry)**

iii. **M.Sc. (Organic Chemistry)**

iv. **M.Sc. (Medicinal Chemistry)**

University affiliated college centers

v. **M.Sc. (Physical Chemistry**)

vi. **M.Sc. (Pharmaceutical Chemistry**)

vii. **M.Sc. (Organic Chemistry**)

viii. **M.Sc. (Analytical Chemistry**)

12. Scheme of Teaching and Examination:

(Applicable to University Department and University affiliated college centers)

a. Each unit in theory course shall comprise 15 lectures, each of 60 minutes duration and there shall be fourlectures per theory course per week.

b. Entire program of M. Sc. Chemistry will be of **2200** marks (550 Marks per semester)

c. Examination of each **theory course** shall be of **100 marks** (80 university examination + 20 internal assessment). University examination of 80 marks (3 hours' duration) will be conducted at the end of eachSemester. Internal assessment of 20 marks will be done before the semester examination during each semester.

d. Examination of practical course shall be of 150 marks per semester.

e. Research Project is compulsory at second year. (10 Credits)

f. On-the Job training is mandatory at second semester (4 Credits)

g. Question papers will be set in the view of the entire syllabus and preferably covering each unit of thesyllabus. Equal weightage should be provided to each unit.

13. Standard of Passing:

There will be separate passing for theory courses and practical courses. Minimum 40% marks will be required for passing separately for theory and practical courses.

14. Nature of Question paper and scheme of marking:

- Theory question paper: Maximum marks -80
- Total No. of questions – 7
- All questions are of equal marks. Out of these seven questions five questions are to be attempted. Question No.1 is compulsory and objective/short answer type. Total number of bits is 16 with one mark each. Total marks – 16 (which cover multiple choices, fill in the blanks, definition, true or false). These questions will be answered along with other questions in the same answer book.
- Question No. 2 is also compulsory (4 sub questions having 4 Marks each).
- Remaining 5 questions have 2 sub questions of 8 Marks each. Any three questions are to be attempted. The answers are to be written in the same answer book.

M. Sc. I Chemistry Syllabus (w.e.f. academic year 2023-24)
Credit Frameworks for M.Sc. Programs as per NEP to be implemented in 2023-24

Semester	Paper Code	Title of the Paper	Semester exam			L	T	P	Credits
I		**Mandatory**	**Theory**	**IA**	**Total**				
	DSC-1	Physical Chemistry -I	80	20	100	4	--	-	4
	DSC-2	Organic Chemistry -I	80	20	100	4		-	4
		Elective (any one)							
	DSE-1	A. Inorganic Chemistry -I	80	20	100	4		-	4
		B. Chemistry in Life Sciences	80	20	100	4		-	
		C. Medicinal Chemistry	80	20	100	4		-	
		RM							
	RM	Research Methodology	80	20	100	4	-	-	4
		Practicals							
	DSC-1P	Practical I	40	10	50	-	-	4	6
	DSC-2P	Practical II	40	10	50	-	-	4	
	DSE-1P	Practical III	40	10	50	-	-	4	
		Total for Semester-I	**440**	**110**	**550**				**22**
II									
		Mandatory							
	DSC-3	Physical Chemistry -II	80	20	100	4	--	-	4
	DSC-4	Organic Chemistry -II	80	20	100	4		-	4
		Elective (any one)							
	DSE-2	A. Inorganic Chemistry -II	80	20	100	4		-	4
		B. Green Chemistry	80	20	100	4		-	
		C. Industrial Chemicals and Environment	80	20	100	4			
	OJT	OJT/In-house Project/ Internship/Apprenticeship	80	20	100	4		-	4
		Practicals					-		
	DSC-3P	Practical IV	40	10	50	-	-	4	6
	DSC-4P	Practical V	40	10	50	-	-	4	
	DSE-2P	Practical VI	40	10	50	-	-	4	
		Total for Semester-II	**440**	**110**	**550**				**22**
		Total M.Sc. I	**880**	**220**	**1100**				**44**

L = Lecture T = Tutorials P = Practical

4 Credits of Theory = 4 Hours of teaching per week
2 Credit of Practical = 4 hours per week
DSC- Discipline Specific Course
DSE- Discipline Specific Elective Course
RM- Research Methodology
OJT- On Job Training

M. Sc.-I (Semester-I)
Paper DSC-1: Physical Chemistry-I

Unit-I: Wave Mechanics **15L**

Origin of quantum theory, black body radiation, atomic spectra, photoelectric effect, matter waves, wave nature of the electron, Heisenberg's uncertainty principle, Schrodinger wave equation, particle in one dimensional box, the particle in three dimensional box, the hydrogen atom, transformations of coordinates, separation of variables and their significance, the Φ equation, the Θ equation and the Radial equation.

Unit-II: Chemical Thermodynamics **15L**

Review of Thermodynamics laws, Derivations of Maxwell's Relations, Thermodynamic equation of state, Entropy and Third law of thermodynamics, residual entropy. Concept of fugacity and determination of fugacity, Activity and activity coefficients of solute and solvent, their determination by freezing point depression and vapour pressure measurement, criteria for equilibrium between phases, Derivation of phase rule, application of phase rule to three component system.

Unit-III: Thermodynamics of Solutions **15L**

Thermodynamics of ideal solutions, Raoult's and Henrey's law, Deviations, partial molar quantities, Gibbs-Duhem equation, Duhem-Margules equation, Excess and mixing thermodynamic properties of Non- ideal solutions and their determination.

Unit-IV: Statistical Thermodynamics: **15L**

Weights and configurations, the most probable configuration, thermodynamic probability and entropy: Boltzmann – Planck equation. Ensembles, ensemble average and time average of property. Maxwell-Boltzmann (MB) distribution law and its application to viscosity and diffusion of gases. Physical significance of distribution Law.

RECOMMENDED BOOKS

1. Quantum Chemistry- R. K. Prasad
2. Quantum Chemistry – Donald A. MacQuarrie
3. Physical Chemistry- P.W. Atkins
4. Text book of Physical Chemistry- S.Glasstone
5. Principles of Physical Chemistry – Marron and Prutton
6. Physical Chemistry- G.M.Barrow
7. Thermodynamics for Chemists – S.Glasstone
8. Thermodynamics – Lewis and Randall, revised by Pitzer
9. An introduction to Chemical Thermodynamics- R. R. Mishra and R. P. Rastogi
10. Kinetics and Mechanism – Frost and Pearson
11. Chemical and Kinetics by K. J. Laidler
12. An Introduction to Statistical Thermodynamics – T.L. Hill, Addison-Wesley. 1960.
13. Statistical Mechanics – Donald A. McQuarrie, 2000.
14. Elements of statistical thermodynamics - L. K. Nash, 2nd Ed. Addison Wesley. 1974.

M. Sc.-I (Semester-I)

Paper DSC-2: Organic Chemistry-I

Unit I: Nature of Bonding in Organic Molecules **15L**

Delocalized chemical bonding, conjugation, cross conjugation, Resonance, Hyperconjugation, Tautomerism, Bonding in Fullerenes. Acidity and Basicity, Aromaticity in benzenoid and non–benzenoid compounds, Alternant and non–alternant compounds, Huckel rule, Aromaticity, Annulenes, Azulenes, Antiaromaticity, homo–aromaticity, Crown ethers complexes and cryptands, Inclusion compounds.

Unit II A: Structure, Stability and Reactions of Reactive Intermediates **05L**

Generation, structure, stability and reactivity of Carbocation, Carbanion, Free Radical, Carbenes and Nitrenes. Effect of structure on reactivity, Resonance and field effect, Steric effect, Quantitative treatment, The Hammett equation, Linear free energy relationship, Substituents and reaction constants, Taft equation.

Unit II B: Rearrangements **10L**

Curtius, Schmidt, Lossen, Wolff, Bayer-villiger, Sommelet-Hauser, Favorskii, Pinacol-pinacolone, Benzil-benzilic acid, Fries migration, Tiffeneau Demjanov, Wittig.

Unit III: Aliphatic Nucleophilic & Electrophilic Substitution reactions **15L**

The SN^2, SN^1, mixed SN^1 and SN^2 and SET mechanism. The neighbouring group mechanism, The Neighbouring group participation by π & σ bonds, anchimeric assistance, classical and non-classical carbocations, phenonium ions, norbornyl system, carbocation rearrangements in neighbouring group participation. The SN^i mechanism. Nucleophile Substitution at an allylic, aliphatic trigonal and vinylic carbon. Reactivity effects of structure, attacking Nucleophile, leaving group and reaction medium. ambident nucleophile and regioselectivity. Bimolecular mechanisms $-SE^1$, $SE^2$and SE^i mechanisms. Electrophilic substitution accompanied by double bond shifts.

Unit IV: Stereochemistry **15L**

Elements of symmery, Chirality, Enantiomeric and diastereomeric Relationships, R and S, E and Z nomenclature, Molecules with more than one chiral center, Threo and Erythro isomers, Prochiral relationships, groups and faces, stereospecific and stereoselective reactions. Optical activity in the absence of Chiral carbon (Biphenyls, allenes and Spiranes), Chirality due to helical shape, Methods of resolution, optical purity, stereochemistry of the compounds containing Nitrogen, Sulphur and phosphorous, Conformations analysis of cycloalkanes, Mono and disubstituted cyclohexanes, decalins, Effect of conformation on reactivity.

RECOMMENDED BOOKS

1. Advanced Organic Chemistry, IV Edn –J. March
2. Stereochemistry of carbon Compounds: E. L. Eliel
3. Advanced organic chemistry: F. A. Carey and R. J. Sundberg
4. A guide book to mechanism in organic chemistry: Peter Sykes.
5. Mechanism and Structure in organic Chemisry, E.S.Gould
6. Principle of Organic Synthesis: R.O.C. Norman.
7. Modern Methods of Organic Synthesis: W. Carruthers
8. Organic Chemistry: Clayden, Greeves, Warren and Wothers
9. Stereochemistry of Organic Compounds: D. Nasipuri
10. Stereochemistry: P. S. Kalsi
11. Basic Stereochemistry of Organic Molecules: Subrata Sen Gupta

M. Sc. Part-I (Semester-I)
Paper DSE 1 A: Inorganic Chemistry– I

Unit I: Chemistry of Transition Elements 15L

General characteristic properties of transition elements, co-ordination chemistry of transition metal ions, ligand field theory, ligand field energy parameters (Racah parameters B and C, Slater Condon Parameters, Slater Condon Shortly Parameters), splitting of d orbitals in low symmetry environment, Janh-Teller effect, interpretation of electronic spectra including charge transfer spectra, spectrochemical series, nephelauxetic effect and nephelauxetic series. Diapara-ferro and antiferromagnetism, quenching of orbital angular moments, spin orbit coupling.

Unit-II: A) Stereochemistry and Bonding 08L

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

Unit-II: B) Inorganic Materials 07L

Insulators and semiconductors, electronic structure of solids, band theory, intrinsic and extrinsic semiconductors, doping of semiconductors and conduction mechanism, semiconductor devices, rectifiers, transistors, photoconductors, photovoltaic cell.

Unit-III: Nuclear Chemistry 15L

Radioactive decay and equilibrium, Nuclear reactions, Q values, cross sections, types of reactions. Chemical effects of nuclear transformations, fission and fusion, fission products and fission yields. Radioactive techniques, tracer techniques, neutron activation analysis, counting techniques such as G.M., ionization and proportional counters, fissile and fertile isotopes, nuclear reactors, application of radio isotopes.

Unit- IV Metal Cluster and Metal Carbonyls 15L

Metal Cluster: Introduction, Classification of metal clusters, Structures of Carbonyl Clusters (LNCC and HNCC), Structural aspects of Halide type Clusters (Di, tri, tetra & hexa nuclear clusters)

Metal Carbonyls: Introduction, Classification of carbonyl complexes, Formation of CO molecule, Coulson's modification and explanation of strong field effect of Co ligand, Bonding in metal carbonyl complexes (mono, di & tri nuclear carbonyl complexes, synergic relationship between metal and CO ligands), Preparation, properties & structures of mono, di & tri nuclear carbonyl complexes [$V(CO)_6$, $Cr(CO)_6$, $Ni(CO)_4$, $Fe(CO)_5$, $Mn_2(CO)_{10}$, $Co_2(CO)_8$,$Fe_2(CO)_9$, $Fe_3(CO)_{12}$], EAN rules for metal carbonyls and problems based on EAN, 18 electron rule for metal carbonyls and problems based on 18 electron rule.

RECOMMENDED BOOKS

1. A. F. Wells, Structural Inorganic Chemistry – 5th Edition (1984), Oxford Science Publication
2. James H. Huheey, Inorganic Chemistry- Principle, Structure and Reactivity,
3. J. D. Lee, Concise Inorganic Chemistry, ELBS with Chapman and Hall, London
4. A.R. West, Solid State Chemistry and its applications, Plenum-John Wiley and Sons
5. N.B. Hanny, Solid State Physics
6. H.V. Keer, Solid State Chemistry
7. S.O. Pillai, Solid State Physics, New Age International Publication
8. W.D. Callister, Material Science and Engineering: An Introduction, John Wiley and Sons
9. R. Raghwan, First Course in Material Science
10. R.W. Cahan, The coming of Material Science
11. A.R. West, Basic Solid State Chemistry, 2nd Edition, John Wiley and Sons
12. U. Schubest and H. Husing, Synthesis of Inorganic Materials, Wiley VCH (2000)
13. M.C. Day and Selbin, Theoretical Inorganic Chemistry, Reinhold, EWAP
14. A.H. Hanny, Solid State Chemistry, A.H. Publication
15. John Wullf, The Structure and Properties of Materials, Vol. 4, Electronic properties, Willey Estern
16. L.V. Azoroff and J.J. Brophy, Elecronic Processes in Materials, McGraw Hill –I
17. Prakash G. More, Comprehensive Industrial Chemistry, PragatiPrakashan,Meerut
18. F.A. Cotton and R.G. Wilkinson, Advanced Inorganic Chemistry, Wiley Students Edition
19. Williams and L. Jooly, Modern Inorganic Chemistry, McGraw-Hill International Edition
20. ManasChanda, Atomic Structure and Bonding, TMH Publication
21. N.N. Greenwood and A. Earnshaw, Chemistry of Elements, Pergamon
22. Chakrabarty, Solid State Chemistry, New Age International Publication
23. J.J. Lipard, Progress in Inorganic Chemistry, Vol 18 and 38, Wiley
24. E. Konig, Structure and Bonding, Vol 9, 1971, 175
25. H.J. Arnikar, Essentials of Nuclear Chemistry, New Age International Publication
26. Friendlander, Kennedy and Miller, Nuclear and Radiochemistry, Wiley and Sons

M. Sc. Part-I (Semester-I)
Paper DSE 1 B: Chemistry in Life Sciences

Unit I: Introduction to cell biology and Structure of different cell organelles 15L

Prokaryotic (archaea and eubacteria) and eukaryotic cell (animal and plant cells), cells as experimental models. Structure of nuclear envelope, nuclear pore complex. ER structure. Organization of Golgi. Lysosome. Structure and functions of mitochondria, chloroplasts and peroxisomes. Zellweger syndrome.

Unit II: Amino acids and Nucleic acids 15L

Structure and classification, physical, chemical and optical properties of amino acids Nucleotides - structure and properties. Nucleic acid structure – Watson-Crick model of DNA.Structure of major species of RNA - mRNA, tRNA and rRNA.

Nucleic acid chemistry - UV absorption, effect of acid and alkali on DNA. Other functions ofnucleotides - source of energy, component of coenzymes, second messengers

Unit : III: Protein Chemistry 15L

Polypeptide backbone, covalent and non-covalent interactions, end-group analysis by chemical and enzymatic methods, Conformation, Configuration, Details of primary, secondary, tertiary and quaternary structures, problems based on determination of primary structure, Ramchandran Plot, structure- function relation of protein (Ex. Haemoglobin) Chemical modification and cross-linking in proteins, dynamic properties and mechanisms of protein folding

Unit IV: Introduction to bioenergetics 15L

Laws of thermodynamics, state functions, equilibrium constant, coupled reactions, energy charge, ATP cycle, phosphorylation potential, phosphoryl group transfers. Chemical basis ofhigh standard energy of hydrolysis of ATP, other phosphorylated compounds and thioesters.Redox reactions, standard redox potentials and Nernst equation. Universal electron carriers.

RECOMMENDED BOOKS

1. Principles of Biochemistry, Lehninger C Rs. Publ. (1982).
2. Biochemistry, L. Stryer, W.H. Freeman, San Francisco.
3. Schaum's Outline Series of Theory and Problems of Biochemistry, Philip W. Kucheland G.B. Ralston. Int. Ed., McGraw-Hill Book Co.
4. Molecular Biology of the cell – Bruce Alberts – J.D. Watson et al Garlandpublishing Inc., N.Y. (1983).
5. Cell and Molecular Biology – DeRobertis and Saunders (1980).
6. The cell – C.P. Swanson, Prentice Hall (1989)
7. Cell Biology – C.J. Avers, Addision Wesley Co. (1986).
8. Metabolic Pathways - Greenberg.
9. Biochemistry – G. Zubay, Addision Wesley Publ. (1983).
10. Biochemistry – Stryer (1988) 3rd Edition W.H. Freeman and Co.

M. Sc. Part-I (Semester-I)
Paper DSE 1 C: Medicinal Chemistry

Unit –I **15L**

a) **Drugs:** Essential Drugs, Nomenclature of Drugs, Routes of Drug Administration, Adverseeffects of Drugs, IUPAC Naming of Drugs.

b) **Drug Design:** Development of New Drugs, Factors Affecting Development of New Drugs.Sources of lead compounds, Concept of prodrugs and soft drugs, Drug Receptors, Theoriesof Drug Action.

Unit –II **15L**

a) **Pharmacokinetics:** Introductions, Drug Absorption, Distribution and Disposition ofDrugs, Excretion and Elimination, Pharmacokinetics of Elimination.

b) **Pharmacodynamics:** Introduction, Enzyme Stimulation, Enzyme Inhibition, MembraneActive Drugs, Drugs Metabolism, Biotransformation, Toxicology, Types of Interactions.

Unit-III **15L**

a) **Cardiovascular Drugs:** Introductions, Classification, Cardiovascular Diseases, Synthesisof Diltiazem, Verapamil, Methyldopa, Atenolol.

b) **Non Steroidal Anti-inflammatory Drugs (NSAIDs):** Introductions, Classification, Synthesis, Mechanism of action of Indomethacin, Ibuprophen, Dichlorophenac, Naproxen, Allorpurinol.

Unit –IV **15L**

a) Antibiotics: Introductions, Classification, β-Lactum antibiotics, Cephalosporins, AnticancerAntibiotics. Synthesis of Penicillin-G, Penicillin-V, Ampicillin, Amoxycillin, Chloramphenicol, Cephalophalosporin, Tetracyclin and Strectomycin.

b) General anaesthetics and local anaesthetics: Introduction, Classification, Mode of Actionand mechanism of action of general and local anaesthetics.

Reference books:

1. Medicinal Chemistry by Ashutosh Kar, New Age International Publishers.
2. Medicinal Chemistry by Alka L. Gupta.

M. Sc. Part-I (Semester-I)
Paper RM: Research Methodology

Unit I: Foundations of Research: 15L

Meaning of research, objectives of research, criteria of good research, types of research, meaning of research problem, selection of research problem, review of related literature: meaning, necessity and sources, hypothesis meaning, function and types of hypothesis, Null/alternative hypothesis, research design: types-exploratory, descriptive, diagnostic and experimental, Execution of the research-Sampling: types, steps involved in sampling, sample size, advantages and limitations, Measurement: Concept of measurement, Problem in measurement in research, Validity and Reliability.

Unit II: Data Interpretation and Paper Writing: 15L

Observation and Collection of data, Methods of data collection, Data processing, data analysis. Layout of a Research Paper: Introduction, experimental, results and discussion, Referring style MLA style, APA style, Review writing, Journals in chemical sciences, citation, h-index, Impact factor of Journals, Ethical issues related to publishing, Plagiarism and Self-Plagiarism, Use of e-tools for Research: Google scholar, Scopus, Sci-Finder, Reference Management Software: Mendeley, Software for paper formatting: LaTeX/ MS Office, Software for detection of Plagiarism: iThenticate, drawing software: chemdraw, data plotting softwares: origin and MS excel.

Unit III A: Electroanalytical Techniques **10L**

Polarography: - Introduction, Instrumentation, Ilkovic equation and its application in quantitative analysis. Half wave potential. Derivation of wave equation, Determination of halfwave potential, qualitative and quantitative applications Amperometry: - Principles, instrumentation, nature of titration curves, analytical applications.

Unit-III B: Thermal method of analysis: 5L

Thermogravimetry [TG]: Principle, instrumentation, applications to inorganic compounds Differential thermal analysis [DTA]: Principle, instrumentation, applications to inorganic compounds (problems are expected)

Unit-IV A: X-ray diffraction & ICP: 5L

Theory of X-ray diffraction, diffraction of X-rays by crystals, Instrumentation, application of X-ray diffraction in determination of crystal structure.

Inductively coupled plasma spectroscopy (ICP): Introduction, instrumentation, Applications.

Unit IV B: ^{1}H-NMR Spectroscopy 10L

Basic principle of NMR, Chemical and Magnetic equivalence and nonequivalence, Homotopism, Enantiotopism, Diastereotopism, Chemical shifts and factors influencing chemical shift: electronegativity, NMR solvent polarity, temperature, anisotropic effect, chemical shifts of acidic protons, D_2O exchange, Multiplicity patterns and Coupling Constants: Pascal's triangle, tree diagram, complex splitting patterns in aromatic, vinylic, and saturated monocyclic compounds, Nuclear over Hauser effect (NOE), Problems based on spectral data of ^{1}H-NMR.

References:

1. Kumar, R., Research Methodology - A Step-By-Step Guide for Beginners, Pearson Education, Delhi (2006).
2. Montgomery, D. C., Design & Analysis of Experiments, 5th Ed., Wiley India (2007).
3. Kothari, C. K., Research Methodology-Methods and Techniques, 2nd Ed., New Age International, New Delhi.
4. Principles of Instrumental Analysis- D. Skoog and D. West.
5. Treatise on Analytical Chemistry: Vol. I to Vol. II-I .M. Kolthoff.
6. The principles of ion selective electrodes and membrane transport.-W.E Mort
7. Instrumental Methods of Analysis: Chatwal and Anand.
8. Instrumental Methods of Analysis (CBS)-H. H. Willard, L. L. Merrit, J.A. Dean & F. A. Settle.
9. Applications of Spectroscopy techniques in Organic Chemistry – (Wiley Eastern)-P.S.Kalsi.
10. Spectroscopic methods in Organic Chemistry (T. M .Hill)-D .H.Williams and I.Fleming.
11. Introduction to Spectroscopy, D.L. Pavia, G.M. Lampman, G.L. Nelson.
12. Spectroscopic identification of Organic Compound (J.W.)R. M. Silverstein and G. C. Bassler.
13. Absorption Spectroscopy of Organic molecules (Addison-Wesley) V.M.Parikh.
14. Introduction to spectroscopy by D. L. Pavia, G. M. Lamplan
15. Principles of Instrumental Analysis- D. Skoog and D. West.
16. Elements of X-ray diffraction, B.D. Cullity, Addison Wisley, 1967
17. Spectroscopy by H. Kour

M.Sc.- I (Semester-II)

Paper DSC 3: Physical Chemistry-II

Unit-I: Photochemistry [15]

Introduction, Franck–Condon principle, electronic excitation, photo-dissociation and Pre-dissociation, photo-reduction, photo-oxidation, role of photochemistry in environment (Green house effect, ozone depletion).

Photophysical phenomenon. Jablonski diagram. Kasha's rule, fluorescence, phosphorescence, delayed fluorescence, differences between phosphorescence and delayed fluorescence. Inter & intra molecular excitation energy transfer (EET) processes. Quenching offluorescence and kinetics of biomolecluar quenching processes, Stern-Volmer equation, formation of photodimer, (with suitable examples) excimer and exciplex.

Unit-III: Electrochemistry [15]

Electrical double layer and its significance (Helmholtz, Gouy-Chapmann and Stern model), evaluation of mean activity coefficients of ions from e.m.f. data, determination of dissociation constant of monobasic acid by e.m.f. method. Debye Huckel theory (without derivation) and limiting law. Storage batteries: acid and alkali storage cells.

Unit-IV: Chemical Kinetics [15]

Rate determining step, steady state approximation. fractional order kinetics, Higher order kinetics and their examples.

Reaction mechanism: Thermal decomposition of acetaldehyde, ethane, reaction between hydrogen and halogens, reaction between NO_2 and F_2, Decomposition of Ozone. Ionicreactions: Primary and secondary salt effect, Effect of ionic strength and dielectric constant of medium on the rate of ionic reactions in solution.

UNIT-IV Macromolecules [15]

Introduction, molecular weight of a polymer (Number andmass average) viscosity average molecular weight.. Degree of polymerization and molecular weight, practical significance of polymer molecular weight, methods of determining molecular weights (Osmometry, viscometry, light scattering, diffusion and ultra centrifugation)

Chemistry of polymerization: Free radical polymerization (Initiation, propagation and termination), kinetics of free radical polymerization, step growth polymerization (Polycondensation), molecular weight distribution, kinetics of step polymerization, cationic and anionic polymerization. Electronically conducting polymers, Glass transition temperature and molecular weight, factors influencing Glass transition temperature,

determination of glass transition temperature, Numerical Problems

RECOMMENDED BOOKS

1. Photo chemistry- J.G.Calverts & J.N.Pits
2. Fundamentals of Photochemistry- K.K.Rohatgi, Mukharji
3. Photochemistry of Solutions – C. A. Parker
4. Chemical Kinetics – K.J.Laidler
5. Kinetics and Mechanism - R. A. Frost and R. G. Pearson
6. Electrochemistry – S. Glasstone
7. Modern electrochemistry – Bockris & Reddy
8. Physical Chemistry – P. W. Atkins
9. Physical Chemistry – G. M. Barrow
10. Physical Chemistry: A molecular Approach – Donald A. McQuarrie and John D. Simon,Viva Books, New Delhi, 1998.
11. Introduction to Photochemistry-Wells
12. Electrolytic Solutions by R. A. Robinson and R. H. Strokes, 1959
13. Basic chemical Kinetics- G. L. Agarwal, Tata-McGraw Hill
14. Physical Chemistry of macromolecules- D. D. Deshpande, Vishal Publications.
15. Polymer Chemistry- F. W. Billmeyer Jr, John-Wiley&Sons, 1971.

M. Sc. - I (Semester-II)

Paper DSC 4: Organic Chemistry-II

Unit I: Aromatic Electrophilic & Nucleophilic Substitution reactions (15)

The arenium ion mechanism, orientation and reactivity, energy profile diagram, ortho/para ratio, ipso substitution, orientation in other ring system, recapitulation of halogenations, nitration, sulphonation and Friedel craft's reactions, Diazonium coupling.

The SN^{Ar}, SN^1, SN^2 and benzyne mechanism, Effect of substrate structure, leaving group and attacking nucleophilic on reactivity

Unit IIA: Addition to Carbon–Carbon and Carbon –Hetero multiple bond (10)

Mechanism and stereochemical aspects of addition reaction involving electrophile, nucleophile and free radical, Regio-selectivity and chemo selectivity, orientation and reactivity, Michael addition, Robinson annulation.

Addition of Grignard reagent, Organo zinc, Organo copper and Organo lithium reagent to carbonyl and unsaturated carbonyl compounds, Detailed mechanism and applications of Simon-Smith, Mc-Murry, Hunsdiecker, Nef reaction, Pummerer, Mitsunobu and Wittig reaction.

Unit II B: Elimination Reactions (**05)**

The E1, E2 and E1cb mechanism. Orientation of double bond, reactivity: Effect of substrate substance, attacking base, the leaving group and the medium, pyrolytic elimination (Xanthate ester, Sulphoxides).

Unit III: Oxidation reactions (15)

Introduction, different oxidative process, CrO_3 (Jones reagent), PDC, PCC, $KMnO_4$, MnO_2, Swern, $Pb(OAc)_4$, Pd-C, RuO_4, m-CPBA, Per acids, O_3, H_2O_2, $NaIO_4$, HIO_4, TEMPO (2,2,6,6-tetramethylpiperidine 1-oxyl radical), IBX (O-Iodoxybenzoic acid), CAN (*Ceric Ammonium Nitrate*), Dess-Martin Periodate (DMP), Iodobenzene diaacetate and Thallium (III) nitrate.

Unit IV: Reduction reactions (15)

Introduction, different reductive process, Catalytic hydrogenation using Pt, Pd, Ni, Wilkinson's catalyst and Wolff-Kishner reduction, Birch reduction, Clemmenson reduction, Rosenmund, Lindlars catalyst, Bu_3SnH (TBTH), Reduction using $NaBH_4$, LAH and DIBAL-H, $NaCNBH_3$, Triphenyl phosphine.

RECOMMENDED BOOKS

1. Advanced Organic Chemistry: IV Edn. J. March
2. Stereochemistry of carbon Compounds: E. L. Eliel
3. Advanced organic chemistry: F. A. Carey and R. J. Sundberg
4. A guide book to mechanism in organic chemistry: Peter Sykes.
5. Mechanism and Structure in organic Chemisry: E. S.Gould
6. Principle of Organic Synthesis: R.O.C. Norman.
7. Modern Methods of Organic Synthesis: W. Carruthers
8. Organic Chemistry: Clayden, Greeves, Warren and Wothers
9. Stereochemistry of Organic Compounds: D. Nasipuri
10. Stereochemistry: P. S. Kalsi
11. Basic Stereochemistry of Organic Molecules: Subrata Sen Gupta
12. Synthetic Organic Chemistry: H.O. House
13. Organic Chemistry: J. Clayden, N. Greeves

M. Sc.-I (Semester-II)
Paper DSE 2A: Inorganic Chemistry – II

Unit-I: Chemistry of Non- transition Elements (15)

General discussion of the properties of non- transition elements, special features of the individual elements, synthesis, properties and structure of their halides and oxides, polymorphism of carbon, phosphorous, sulphur. Synthesis, structure and properties of boranes, carboranes, borazines, silicates, carbides, silicones, phosphazenes, sulphur nitrogen compounds, oxyacids of nitrogen, phosphorous, sulphur and halogen, interhalogens, pseudohalides and noble gas compounds.

Unit-II: Organometallic Chemistry of Transition Elements (15)

Synthesis, structure and bonding, organometallic reagents in organic synthesis and in homogenous catalytic reactions (hydrogenation, hydroformylation, isomerization,Monsanto acetic acid process, synthesis gas, Wacker Process), Ziegler and Natta catalysis, pi-metal complexes, activation of small molecules by coordination.

Unit-III: A) Metal- Ligand Equillibria in Solution (07)

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

Unit-III: B) Chemistry of Lanthanides and Actinides (08)

Lanthanides: Introduction, spectral and magnetic properties. Classical methods of separation of lanthanides: (i) precipitation (ii) thermal reaction, (iii) fractional crystallization, (iv) complex formation, (v) solvent extraction and (vi) ion exchange, Applications of lanthanides.

Actinides: Introduction, spectral and magnetic properties. Methods of separation of actinides from lanthanide, Preparation of trans-uranic elements. Applications of actinides.

Unit-IV: A) Metallurgy (08)

Occurance, extraction, properties and applications of silver, gold, tin and lead.

Unit-IV: B) Bioinorganic Chemistry (07)

Role of metals in medicines, Role of metal ions in biological processes, molecular mechanism of ion transport across membranes, ionophores, photosynthesis PS I and PS II, nitrogen fixation, oxygen uptake proteins: Hemocyanin, Hemerythrin, cytochromes, rubredoxin and ferredoxins, Calcium biochemistry, coenzyme B12.

RECOMMENDED BOOKS

1. A. F. Wells, Structural Inorganic Chemistry – 5th Edition (1984), Oxford Science Edition
2. James H. Huheey, Inorganic Chemistry- Principle, Structure and Reactivity, Harper and Row Publisher Inc., New York
3. J. D. Lee, Concise Inorganic Chemistry, ELBS with Chapman and Hall, London
4. M.C. Day and Selbin, Theoretical Inorganic Chemistry, Reinhold, EWAP
5. Jones, Elementary Coordination Chemistry
6. Morttel, Coordination Chemistry
7. T.S. Swain and D.S.T. Black, Organometallic Chemistry
8. Prakash G. More, Comprehensive Industrial Chemistry, PragatiPrakashan, Meerut
9. John Wullf, The Structure and Properties of Materials, Vol. 4, Electronic properties, Willey Eastern
10. L.V. Azoroff and J.J. Brophy, Elecronic Processes in Materials, McGraw Hill –I
11. F.A. Cotton and R.G. Wilkinson, Advanced Inorganic Chemistry, Wiley Student Edition
12. Williams and L. Jooly, Modern Inorganic Chemistry, McGraw Hill International Edition
13. ManasChanda, Atomic Structure and Bonding,TMH Publication
14. P.L. Pausan, Organometallic Chemistry
15. Cullen, Dolphin and James, Biological Aspects of Inorganic Chemistry
16. Williams, An Introduction to Bioinorganic Chemistry
17. M.N. Hughes, Inorganic Chemistry of Biological Processes
18. Ochi, Bioinorganic Chemistry
19. O.A. Phiops, Metals and Metabolism
20. S.J. Lipard and J.M. Berg, Principles of Bioinorganic Chemistry, U niversity Science Books
21. G.L. Eichhron, Inorganic Bichemistry, Vol I and II, Elsevier

M. Sc.-I (Semester-II)
Paper DSE 2B : Green Chemistry

UNIT I: **Green chemistry:** **(15)**

History, need, and goals. Green chemistry and Sustainability. Dimensions of sustainability, Limitations/Obstacles in pursuit of the goals of Green Chemistry. Opportunities for the next generation of materials designers to create a safer future. Hazard assessment and mitigation in chemical industry

UNIT II: Basic principles of Green Chemistry and their illustrations with examples. **(15)**

Prevention of waste/byproducts, Maximum Incorporation of the materials used in the process into the final product (Atom Economy): Green metrics,Prevention/Minimization of hazardous/toxic products,Designing safer chemicals - different basic approaches,Selection of appropriate auxiliary substances (solvents, separation agents etc),Energy requirements for reactions—use of microwave, ultrasonic energy,Selection of starting materials—use of renewable starting materials,avoidance of unnecessary derivatization—careful use of blocking/protection groups, Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents, Designing biodegradable products, Prevention of chemical accidents**.**

UNIT III: Examples of green synthesis/reaction and development of analytical techniques **(15)**

Green starting materials,2 Green reagents, Green solvents and reaction conditions,Green catalysis, Green synthesis- Real world cases (Traditional processes and green ones) Synthesis of Ibuprofen, Adipic acid.

Strengthening/development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes. Development of accurate and reliable sensors and monitors for real time in process monitoring.

UNIT IV: Future Trends in Green Chemistry: (15)

Oxidation-reduction reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; Non covalent derivatization. Biomass conversion, emission control. Biocatalysis.

RECOMMENDED BOOKS

1. Green Chemistry: Theory and Practice. P.T. Anastas and J.C. Warner. OxfordUniversity Press.

2. Green Chemistry: Introductory Text. M. Lancaster Royal Society of Chemistry (London).

3. Introduction to Green Chemistry. M.A. Ryan and M. Tinnesand, American ChemicalSociety (Washington).

4. Real world cases in Green Chemistry, M.C. Cann and M.E. Connelly. AmericanChemical Society (Washington).

5. Real world cases in Green Chemistry (Vol 2) M.C. Cann and T.P.Umile. AmericanChemical Society (Washington**)**

M. Sc.-I (Semester-II)
Paper DSE 2C : Industrial Chemicals and Environment

Unit I: Industrial Gases and Inorganic Chemicals

Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene. Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

Unit II Industrial Metallurgy

General Principles of Metallurgy Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon as reducing agent. Hydrometallurgy, Methods of purification of metals (Al, Pb, Ti, Fe, Cu, Ni, Zn): electrolytic, oxidative refining, Kroll process, Parting process, van Arkel-de Boer process and Mond's process. Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

Unit III: Environment and its segments

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur. Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal. Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange).

Unit IV: Energy & Environment Sources of energy:

Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc. Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

Reference Books:

- E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
- R.M. Felder, R.W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
- J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
- S. S. Dara: A Textbook of Engineering Chemistry, S. Chand & Company Ltd. New Delhi.
- K. De, Environmental Chemistry: New Age International Pvt., Ltd, New Delhi.
- S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi. 42
- S.E. Manahan, Environmental Chemistry, CRC Press (2005).
- G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).
- A. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).

M.Sc.- I Semester-I
Practicals
DSC-1P: Physical Chemistry

NON-INSTRUMENTAL

Kinetics (any two)

1. To investigate the auto-catalytic reaction between potassium permanganate and oxalic acid.
2. Iodination of acetone
3. Determination of energy of activation of acid catalyzed hydrolysis of an ester.

Viscosity

1. Determine the molecular weight of PVA by viscosity measurements.

Adsorption

1. Acetic acid on activated animal charcoal

Phase Equilibria :- (any one)

1. Three component system: Acetic acid, chloroform, water
2. To determine the CST of phenol-water system in presence of 1% NaCl

Surface Tension:

1. To determine the surface tension of a liquid by stalagmometer (drop number method)

INSTRUMENTAL

Refractometry

1. To determine the structure of given Organic Liquids

2. pHmetry: (any one)

1. Determination of pKa of dibasic acid (Oxalic acid)
2. Determination of hydrolysis constant of aniline hydrochloride

Conductometry (any one)

1. Titration of $ZnSO_4$ / $MgSO_4$ against $BaCl_2$ and $Ba(CH_3COO)_2$ and calculation of amount of Sulphate Present .
2. Conductometric estimation of NH4Cl with NaOH solution.

Potentiometry (Any one)

1. To determine the basicity and pKa value of organic acids by potentimetricmethod. (Orthophosphoric acid)
2. Determine the solubility and solubility product of sparingly soluble salts.

RECOMMENDED BOOKS

1. Findlay's Practical Physical Chemistry by J.A. Kitchnar
2. Text-book of Quantitative Inorganic Analysis including elementaryInstrumental Analysis- A.I.Vogel, Revised by J.Bassott, R.C.Banney
3. Experimental Physical Chemistry – F.Daniels&J.Williams
4. Experimental Physical Chemistry – R.C.Das&B.Behra
5. Systematic experimental Physical Chemistry by- Rajbhoj and Chondhekar.
6. Experimental physical Chemistry- V.D. Athawale and P. Mathur
7. Advanced practical physical Chemistry- J. B. Yadav
8. Advanced physical Chemistry Experiments- Gurtu and Gurtu

M.Sc.- I Semester-I
Practicals
DSC-2P: Organic Chemistry

Qualitative analysis:

1. Separation and identification of the two component mixtures using Chemical and physical methods. **(Minimum Five Mixtures)**

Demonstrative Experiments:

1. Thin layer chromatography (TLC).
2. Vacuum and steam distillation techniques.
3 Extraction by Soxhlet Method

RECOMMENDED BOOKS

1. A text book of practical Organic Chemistry- A. I. Vogel.
2. Practical organic Chemistry- Mann and Saunders.
3. A handbook of quantitative and qualitative analysis- H. T. Clarke.
4. Organic Synthesis Collective Volumes by Blat.
5. Systematic Lab Experiments in Organic Chemistry by ArunSethi
6. Advanced practical chemistry by Jagdamba Singh

M. Sc. Part – I Semester I Practicals

DSE-1P: Inorganic Chemistry

Ore Analysis:

1. Iron Ore
2. Dolomite Ore

Alloy Analysis: (any one)

1. Brass alloy
2. Bronze alloy

Preparation and determination of purity: (any two)

1. Potassium trioxalatochromate(III)
2. Nitritopentacyano ferrate (III) monohydrate
3. Copper acetate
4. Manganese acetate
5. Hexathioureaplumbus nitrate

Note: Any other relevant experiment shall be added

RECOMMENDED BOOKS

1. Vogel's Text Book of Quantitative Inorganic Analysis.
2. W. G. Palmer, Experimental Inorganic Chemistry, Cambridge at the University Press, 1965.
3. M. A. Malati, Experimental Inorganic/Physical Chemistry, Harwood publishingChichester.
4. A.J.E.Welch, Inorganic Preparations, George Allen & Unwin Ltd.

M.Sc.- I Semester-II
Practicals
DSC-3P: Physical Chemistry

NON-INSTRUMENTAL

Kinetics (any one)

1. Determination of order of reaction by differential method
2. Comparison of acid strength by hydrolysis of ester

Viscosity

1. To determine the radius of molecule by viscosity measurements. (glycerol / sucrose)

Adsorption

1. Oxalic acid on activated animal charcoal

Phase Equilibria :-

1. Three component system: Benzene, ethyl alcohol and water
2. To determine the CST of phenol-water system in presence of 0.5% naphthalene (or 1%succinic acid)

Surface Tension:

1. To determine the atomic parachor of C, H and Cl by surface tension measurements.

INSTRUMENTAL

Refractometry

1. To determine the electron polarization and electron polarizability of a liquid.

2. pHmetry: (any one)

1. Determination of pKa of acid (Succinic acid)
2. Determination of hydrolysis constant of aniline hydrochloride

Conductometry

1. Solubility and solubility product of spranigly soluble salts.
2. Titration of a mixture of HCl, CH_3COOH and $CuSO_4$ against alkali.

Potentiometer: (any one)

1. Estimate the amount of halides present in the given mixture by titrating with AgNO3 solution.
2. Titration of mixture of acids with base.

Polarimetry

1. To determine the percentage of two optically active substances (d-sucrose and d-tartaricacid) in a given solution.

Note: Any other relevant experiments may be added

RECOMMENDED BOOKS

1. Findlay's Practical Physical Chemistry by J.A. Kitchnar
2. Text-book of Quantitative Inorganic Analysis including elementaryInstrumental Analysis- A.I.Vogel, Revised by J.Bassott, R.C.Banney
3. Experimental Physical Chemistry – F.Daniels&J.Williams
4. Experimental Physical Chemistry – R.C.Das & B.Behra
5. Systematic experimental Physical Chemistry by- Rajbhoj and Chondhekar.
6. Experimental physical Chemistry- V.D. Athawale and P. Mathur
7. Advanced practical physical Chemistry- J. B. Yadav
8. Advanced physical Chemistry Experiments- Gurtu and Gurtu

M.Sc.- I Semester-II

Practicals

DSC-4P: Organic Chemistry

Preparations:

One stage preparation involving various types of reactions (Minimum Two)

1. Aldol condensation: Dibenzal acetone from benzaldehyde.
2. Sandmeyer reaction: p- Chlorotoulene from p-toluidine.
3. Cannizzaro reaction: 4-Chlorobenzaldehyde as a substrate.

2) Two stage preparations involving various types of reactions (Minimum Four)

1. Aceotophenone- Oxime- Acetanilide
2. Phthalic anhydride- o-Benzoyl benzoic acid- anthraquinone
3. Chloroenzene-2,4-dintrochlorobenzene-2,4-dinitrophenol
4. Benzoin-benzil-benzilic acid
5. Acetanilide-p-bromoacetanilide-p-bromoaniline
6. Acetanilide-p-nitroacetanilide-p-nitroaniline

3) Estimations: (minimum Two)

1) Estimation of amine by acetylation method.
2) Estimation of hydroxyl group by acetylation method
3) Estimation of an iodine value of an oil or fat.
4) Determination of percentage of Keto-enol form.

(Any other relevant experiments may be added).

RECOMMENDED BOOKS

1. A text book of practical Organic Chemistry- A. I. Vogel.
2. Practical organic Chemistry- Mann and Saunders.
3. A handbook of quantitative and qualitative analysis- H. T. Clarke.
4. Organic Synthesis Collective Volumes by Blat.
5. Systematic Lab Experiments in Organic Chemistry by ArunSethi
6. Advanced practical chemistry by Jagdamba Singh

M. Sc. Part – I Semester II

Practicals

DSE-2P: Inorganic Chemistry

Ore analysis: (any one)

1. Pyrolusite ore
2. Bauxite ore

Alloy analysis: (any two)

1. Type metal alloy
2. Solder alloy
3. Cupro-nickel alloy

Preparation and determination of purity: **(any two)**

1. Potassium hexathiocyanatochromate (III)
2. Hexamine cobalt nitrate
3. Manganous ammonium phosphate
4. Prussian blue

Note: Any other relevant experiments may be added

RECOMMENDED BOOKS

1. Vogel's Text Book of Quantitative Inorganic Analysis.
2. W. G. Palmer, Experimental Inorganic Chemistry, Cambridge University Press, 1965.
3. M. A. Malati, Experimental Inorganic/Physical Chemistry, Harwood publishing Chichester.
4. A.J.E.Welch, Inorganic Preparations, George Allen & Unwin Ltd.