Swami Vivekanand Shikshan Sanstha's

Vivekanand College, Kolhapur (Autonomous)

Syllabus

For

Master of Science

M. Sc. Part - II Inorganic Chemistry

(Semester III, IV)

Under Choice Based Credit System

Syllabus with effect from the June, 2022

(Subject to modifications in the future)

Vivekanand College, Kolhapur (Autonomous)

Department of Chemistry

M. Sc. Part-II, (Sem III and IV)

Inorganic Chemistry Syllabus (CBCS) 2022 - 23

Total No. of Semester – 02

Total No. of Papers – 08

No. of papers (theory) per semester – 04

No. of practical course per semester – 02

Maximum marks per paper (practical) -100

Distribution of Marks – Internal evaluation - 20

External evaluation - 80

(Semester exam.)

Total Marks for M. Sc. Degree

Theory Paper: 1600

Practical course: 800

Total: 2400

Course Structure

M. Sc. Part - II (Sem – III)

Paper No. - IX: Inorganic Chemical Spectroscopy (CC – 2100C)

Paper No. - X: Organometallic and Bioinorganic Chemistry (CC – 2101C)

Paper No. - XI: Coordination Chemistry – I (CC – 2102C)

ELECTIVE PAPERS

Paper No. - XII (A): Material Science (CC – 2103C)

Paper No. - XII (B): Nuclear Chemistry (CC – 2104C)

Practical Course: V and VI (CC – 2105C)

M. Sc. Part - II (Sem – IV)

Paper No. - XIII: Instrumental Techniques (CC – 2106D)

Paper No. - XIV: Coordination Chemistry-II (CC – 2107D)

Paper No. - XV: Energy and Environmental Chemistry (CC – 2108D)

ELECTIVE PAPERS

Paper No. - XVI (A): Inorganic Nanomaterials (CC – 2109D)

Paper No. - XVI (B): Radiation Chemistry (CC – 2110D)

Practical Course: VII and VIII (CC – 2111D)

Vivekanand College (Autonomous), Kolhapur
M. Sc. Part - II (Inorganic Chemistry)
CBCS Syllabus with effect from June - 2022
Semester - III
Paper No. - IX: Inorganic Chemical Spectroscopy (CC – 2100C)
Theory: 60hrs

Course Outcomes: After the completion of the course, the student will be able to:

CO1: Interpret the symmetry elements and their operations as required to specify molecular symmetry and possible point groups from symmetry elements and be able to find point group of molecules by systemic procedure.

CO2: Explain the principle and instrumentation of infra-red (IR) and Raman spectroscopy and interpret infrared and Raman spectra for chemical analysis inorganic compounds.

CO3: Explain the principle and instrumentation of Mass spectroscopy and interpret Mass spectrum for chemical analysis of inorganic compounds.

CO4: Explain the principle and instrumentation of nuclear magnetic resonance (NMR) and X-ray photoelectron spectroscopy (XPS) and interpret the spectrum for chemical analysis of inorganic compounds.

Unit I: Molecular Symmetry and Group Theory **15 Hrs**

Introduction to symmetry, Symmetry operations, Symmetry elements, Point group and its classification (Cn-type, Dn-type and Special-type), Schoenflies symbol for point groups, Determination of point group for AB_2 (Bent), AB_3 (Trigonal pyramid), AB_3 (Trigonal Planar), AB_4 (Square planar), AB_5 (Trigonal bipyramidal), AB_6 (Octahedral), CO_2, HCl, CO, ortho–, meta– and para–disubstituted benzene molecules. Symmetry, dipole moment and optical activity of molecules, Group and its properties, Group multiplication table, Matrix representation of symmetry elements.

Unit II: IR and Raman Spectroscopy

A) Infrared spectroscopy: **7 Hrs**

Principle of IR Spectroscopy, Instrumentation: principle and working, The diatomic vibrating rotator, Vibration– rotation spectrum of carbon monoxide, The vibration of polyatomic molecules, The influence of rotation of the spectra of polyatomic molecules, Applications of IR Spectroscopy.

B) Raman spectroscopy: **8 Hrs**

Raman Scattering, Raman Spectrometer: Fourier Transform Raman Spectrometer, Classical and quantum theory, Pure rotational and vibrational Raman spectra, Rule of mutual exclusion, Overtone and combination vibrations, Rotational fine structure, Modes of vibrations, Applications, Selection rules for Infrared and Raman spectra, Structure determination using IR and Raman Spectroscopy.

Unit III: Mass Spectroscopy **15 Hrs**

Basic principle, Instrumentation, Electron-impact and induced ionisation, Fast Atom Bombardment (FAB) spectrometry, Qualitative and semiquantitative theories including QET, Concept of metastable ions transitions, Stevensons's rules, Applications for metal compounds containing carbonyl, alkyl, cyclopentadienyl and acetylacetonate.

Unit IV: NMR and X-ray Photo electron Spectroscopy (XPS)

A) NMR Spectroscopy: **8 Hrs**

Principle, Instrumentation of NMR, Chemical shift, Shielding and deshielding, Factors affecting on chemical shift, Local and remote effect, Spin-spin splitting, Applications of spin coupling for structural determination, Double resonance techniques, The contact and pseudo contact shifts, Factors affecting nuclear relaxation, Overview of NMR of metal nucleus of ^{195}Ag & ^{119}Sn, Applications of solid-state NMR technique.

B) X-ray Photo electron Spectroscopy (XPS): **7 Hrs**

Introduction and basic theory, Instrumentation, Sample selection and preparation, Spectral analysis, Argon ion sputtering technique, Applications of XPS.

Reference Books:

1. K. Burger, Coordination Chemistry-experimental methods, Butterworth's
2. R. Drago: Physical method in Inorganic Chemistry, DUSAP.
3. Hill & Day advanced methods in Inorganic Chemistry, J.Weily
4. F.A. Cotton, chemical application of group theory, Weily eastern
5. Figgis, Introduction to ligand field theory field
6. Schaefer & Gilman: Basic principles of ligand field Theory, J. Wiely
7. P.R. Backer: Molecular symmetry and Spectroscopy A.P.
8. Ferraro Ziomeek, Introduction to Group theory, plenum
9. Scotland Molecular symmetry DVN
10. Dorian: symmetry in Chemistry EWAP

11. Hall: Group theory and symmetry in Chemistry MGLt
12. Nakamoto Infrared R Raman Spectra of Inorganic & Coordination compounds, J. Weily
13. Nakanisha: Spectroscopy and structure J. Weily
14. Ferroro: Metal ligand and related vibrations
15. CNR Rao Spectroscopy in Inorganic Chemistry Vol I, II, III
16. Durie: vibrations spectra and structure Vol. I to IV, Elsevier
17. Dudd, chemical Spectroscopy Elsevier
18. Popel; H.N.M.R. Spectroscopy J. Weily
19. R.J. Abraham, J. Fisher and P Loftus Wiley Introduction to NMR spectroscopy.
20. P.K. Bhattacharya: Group Theory & Its Chemical Applications
21. K.V. Reddy: Symmetry & spectroscopy of Molecules.
22. M. R. Litzow and T R Spelding, Mass Spectroscopy of Inorganic & Organometallic Compounds, Elsevier, 73.

Paper No. - X: Organometallic and Bioinorganic Chemistry (CC – 2101C)
Theory: 60hrs

Course Outcomes: After the completion of the course, the student will be able to:

CO1: Explain methods of properties, preparation, stability and applications of organometallic compounds in organic synthesis.

CO2: Interpret structure and bonding transition metal pi-complexes and their applications in organic synthesis relating to nucleophilic and electrophilic attack on ligands.

CO3: The students will get a basic understanding of medicinal use of metal complexes as antibacterial, antiviral, antibiotics and related compounds.

CO4: Understand transport and storage of dioxygen through different carriers, Study Electron Transfer in Biology involving metaloproteins and cytochromes and Role of Metals in Medicine.

Unit I: Organo transition Metal Chemistry — 15 Hrs

A] Alkyls and Aryls of Transition Metals: Types, Routes of synthesis, Stability and decomposition pathways, Organocopper compounds of alkyls and aryls in synthesis.

B] Compounds of Transition Metal: Metal-carbon multiple bonds: Alkylidenes, alkylidynes, low valent carbenes and carbines, Synthesis, Nature of bonds, Structural characteristics, Nucleophilic and electrophilic reactions on ligands, Applications in organic synthesis.

Unit II: Transition Metal π-Complexes — 15 Hrs

Metal-carbon multiple bonds, Nature of bonding, Structural characteristics and Synthesis, Properties of transition metal π-complexes with unsaturated organic molecules: alkenes, alkynes, allyl, diene, dienyl, arene and trienyl complexes, Applications of transition metal πcomplexes and their intermediates in organic synthesis relating to nucleophilic and electrophilic attack on ligands.

Unit III: Metal Compounds in Medicine — 15 Hrs

Medicinal uses of metal complexes as antibacterial, anticancer ,antibiotics and antiviral activity of metal complexes, Use of cis-platin as antitumor drug, Metal deficiency and diseases: iron, zinc and copper deficiency, Use of metals and metal compounds in the diagnosis and chemotherapy, Chemotherapy with compounds of some non essential elements;

Chelate therapy, Gold and gold complexes as anticancer drugs and their use in therapy of Rheumatic-Arthritis, Use of Lithium complexes as psycho pharmacological drugs.

Unit IV: Oxygen Transport and Storage **15 Hrs**

Hemocyanins and hemerythrin, Synthetic oxygen carriers: Collmans compound; Vaskas complex; Co(II) Schiff base complexes and Perflurochemicals (PFCs), Perutz mechanism for structural changes in porphyrin ring system, Oxygenation and deoxygenation, Oxygen adsorption isotherm and cooperativity, Role of globin chain in gaemoglobin, Siderophores, Vanadium compounds as insulin mimetic agents in the treatment of diabetics.

Reference Books:

1. Bioinorganic Chemistry, A. K. Das
2. Organometallic and Bioinorganic Chemistry, Ajaykumar
3. Bioinorganic Chemistry, K. Hussain Reddy
4. Organometallic Compounds, Dr. Indrajeet Kumar, Pragati Prakashan Meerut
5. Yamamoto, Organo Transition Metal Chemistry, Wiley (1986).
6. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals (4^{th} edn.), John Wiley (2005).
7. A. J. Pearson. Metallo-Organic Chemistry, John Wiley & Sons (1985).
8. M. Bochmann. Organometallics-I Complexes with Transition Metal-Carbon σ-Bonds, 13 Oxford Chemistry Primers (1994).
9. Principles of Biochemistry, A. L. Lehinger, Worth Publications.
10. Biochemistry, L. Stryer, W. H. Freeman
11. D. F. Shriver, P. W. Atkins and C. H. Langford, Inorganic Chemistry, Oxford Univ. Press, 1990.
12. J. E. Huheey, E. A. Keiter and R.L. Keiter Inorganic Chemistry, Principles of Structure and Reactivity, Pearson Education, 2004.
13. S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry, Univ. Science Books, 1994.
14. W. Kaim and B. Schwederski, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life (An introduction and Guide), John Wiley & Sons, 1994.

Paper No. - XI: Co-ordination chemistry-I (CC – 2102C)
Theory: 60hrs

Course Outcomes: After the completion of the course, the student will be able to:

CO1: Know the fundamentals in photochemistry, to explain different types of photochemical reactions and photochemistry of coordination compounds.

CO2: Explain non-chelate forming and chelate forming reactions.

CO3: Understand Magnetic properties of Complexes and explain with respect to spin orbit coupling.

CO4: Understand and explain mixed ligand complexes and use of transition metal complexes in catalysis.

Unit I: Photochemistry of Metal Complexes **15 Hrs**

Absorption, Excitation, Photochemical laws, Quantum yield, Electronically excited states of Metal complexes, Types of photochemical reactions; substitution reactions, rearrangement reactions and redox reactions, Photochemistry of coordination compounds, Charge transfer spectra, Charge transfer excitations, Methods for obtaining charge transfer spectra.

Unit II: Reactions of Coordinated Ligands **15 Hrs**

A] Non-chelate forming reactions: Reaction of donor atoms (Halogenation of coordinated N, Alkylation of coordinated S and N, Solvolysis of coordinated P atoms), Reactions of nondonor atoms (nucleophilic and electrophilic behaviour of ligands).

B] Chelate ring forming reactions: Reactions involving thermodynamic template and kinetic effects.

Unit III: Magnetic Properties of Transition Metal Complexes **15 Hrs**

Introduction, Types of magnetic behaviour, Diamagnetism, Origin of paramagnetism, Temperature dependent paramagnetism, Spin-orbit interaction, Pascal constants, Ferromagnetism and antiferromagnetism of metal complexes, Van Vleck's equation: derivation and applications, Spin orbit coupling and magnetic moment, Spins crossover phenomenon, Determination of magnetic susceptibility.

Unit IV: Mixed Ligand Complexes and Catalysis of Transition Metal Complexes

A] Mixed ligand complexes **7 Hrs**

Stabilities and dynamics of formation of ternary complexes, Reaction of coordination ligand in ternary complexes, Mimicking reactions in biological systems, Enzyme models, Amino

acids, ester hydrolysis, Peptide synthesis and its hydrolysis, Detarbodylation of β keto acids.

B] Catalysis of transition metal complexes **8 Hrs**

Introduction, General principle, Catalysis by transition metal complexes, Oxidation of hydrocarbons by O_2, Oxidation, polymerization and hydrogenation of olefins, Metal complex catalyzed reactions of arenes, Catalysis in condensation polymerization, Current and future trends in catalysis.

Reference Books:

1. K. K. Rastogi and Mukharjee, Fundamentals of Photochemistry, Wiley eastern.
2. J. G. Calverts and J. N. Pits, Photochemicals of Photochemistry, John Wiley.
3. Wells, İntroduction to 4Photochemistry.
4. V. Balzani& V. Cavassiti, Photochemistry of Coordination compounds, AP, London, 1970.
5. Comprehensive Coordination Chemistry, Vol.1. G Wilkinson (Ed) Wiley, New York, 1967.
6. Inorganic Chemistry by J.E. Huheey, E.A. Keiter and R.L. Keiter 4^{th} edn. Harper Collins, 1993
7. Mechanisms of Inorganic Reactions, by C.F. Basolo and R.G. Pearson, Wiley, New York, 1967
8. Earnshaw: Introduction to Magneto Chemistry

9 Mabbs & Machin Magnetism & transition metal complexes Chamman hall

10. Calvin, Magnetic properties of transition metal complexes.
11. L.N. Maley: Magneto Chemistry
12. Datta & Shymlal: Elements of Magneto Chemistry
13. James E. Huheey: Inorganic Chemistry Principles of Structure and reactivity, Harber & Row, Publishers Inc. New York 1972.
14. K.P. Purcell & J.C. Kote: An Introduction to Inorganic Chemistry Holt Sounders, Japan 1980.
15. William L. Jolly: Modern Inorganic Chemistry, Mecgrow Hill USA,1984
16. F.A. Cotton & R.G. Willkinson: Advanced Inorganic Chemistry.

Paper No. – XII (A): Material Science (CC – 2103C)
Theory: 60hrs

Course Outcomes: After the completion of the course the student will be able to:

CO1: Explain mechanism of superconductors, classify super conductors, explain BCS theory of superconductivity and know the applications of different materials.

CO2: Explain magnetic materials and their applications in different fields.

CO3: Explore new areas of research in both ceramics and composite materials manufacturing.

CO4: Understand and apply core principles and concepts in catalysis using different inorganic complexes as catalyst.

Unit I: Superconductivity Materials, Crystal defects and Non stoichiometry **15 Hrs**

A] Superconductivity materials: Introduction, Superconductivity, Critical temperature, Critical field, BCS theory, Properties and classification of superconductors, High Tc superconductors; examples with structure and applications, Fullerenes, Intermetallic superconductors; synthesis, applications.

B] Crystal defects and non-stoichiometry: Point defects: vacancies, interstitials, impurities, expression for schottky and frenkel defects. Line defects: edge and screw dislocation. Stacking faults in grain boundaries, Phase transformation in solids, Solid state reactions and crystal growth, Preparation methods of solids.

Unit II: Magnetic Materials **15 Hrs**

Introduction, Atomic magnetism and solids, Types of magnetic materials, Exchange interactions, Magnetic order (Ferro, Antiferro and Ferri), Hysteresis loop and their classification, Calculation of magnetic moment from saturation magnetization, Magnetic domains, Examples of magnetic materials, Soft and hard ferrites, Structure and magnetic interactions in spinel, Garnet hexagonal ferrites, Application of magnetic materials

Unit III: Ceramic and Composite Materials **15 Hrs**

Ceramic Materials:

Classification of ceramics, Dielectric and polarization properties of ceramics, Piezo, pyro and ferro-electric effect of ceramics, Sol-gel processing of ceramics. Examples and application of ceramics: oxides, carbides, borides, nitrides.

Composite Materials:

Introduction, Glass transition temperature, Fibers for reinforced plastic composite materials (glass fibers, carbon fibres, and aramid fibers), Concretes and asphalt materials. Application of composite materials.

Unit IV: Catalysis **15 Hrs**

Basic principle, Thermodynamic and Kinetic aspects, Industrial requirements, classification, theories of catalysis, Homogeneous and heterogeneous catalysis, Types and characteristics of substrate-catalyst interactions, Kinetics and energetic aspects of catalysis, Selectivity, stereochemistry, orbital symmetry and reactivity. Catalytic reactions of coordination and organometallic compounds including polymerization activation of small molecules, addition to multiple bonds, hydrogenation, Zeigler-Natta polymerization of olefins, monsanto acetic acid process.

Reference Books:

1. Solid state Chemistry: An Introduction – L.E. Smart & E.A. Moore, CRC, Taylor & Francis, 3rd Edn.
2. Materials Science & Engineering – V. Raghvan, 2nd Edn.
3. Introduction to Solids – L.V. Azarroff, 2nd Edn. 1980
4. Elements of materials science and engineering – Van Vleck, 5th Edn.
5. Insight to Speciality Inorganic Chemicals – D. Thompson, Royal Society of Chemistry, 1995.

Paper No. – XII (B): Nuclear Chemistry (CC – 2104C)

Theory: 60hrs

Course Outcomes: After the completion of the course the student will be able to:

CO1: Understand types of radioactive decay, natural decay series, nuclear models, nuclear properties, Mass energy, relationships, nuclear reactions, rates of radioactive decay, interaction of radiation with matter.

CO2: Explain nuclear structure and stability, define binding energy and mass defect and be able to calculate each for a given nucleus, To understand nuclear models to understand nuclear structure and their properties.

CO3: Identify and define various types of nuclear changes or processes including fission, fusion and decay reactions, to understand nuclear reactions and mechanism behind that.

CO4 : Understand the basics of nuclear chemistry applications: nuclear power, nuclear reactor, medical treatment, isotopic labelling, andcarbon dating.

Unit I: Systematic Study of Alpha, Beta and Gamma Decays **15 Hrs**

Alpha, beta and gamma decay, Energy curve, Spectra of alpha and beta particles, Giger Nuttal law, Theory of alpha decay, Penetration of potential barrier, Range of energy relationship, Sergeants curve, Fermi theory of beta decay, Matrix elements, Allowed and forbidden transitions, Curie plots, Nuclear energy levels, Selection rule isomeric transitions, Internal conversion, Auger effect.

Unit II: Nuclear Structure and Stability **15 Hrs**

Binding energy, Empirical mass equation, Nuclear models; liquid drop, Single particle shell, Fermi gas and collective/lunified nuclear models, Nuclear spin, Parity and magnetic moments of odd mass number nuclei, numerical problems.

Unit III: Nuclear Reactions and Nuclear Fission **15 Hrs**

Introduction, Production of projectiles, Nuclear cross section, Nuclear dynamics, Threshold energy of nuclear reaction, Coulomb scattering, Potential barrier, Potential well, Formation of a compound nucleus, Nuclear reactions; direct nuclear reactions, heavy ion induced nuclear reactions and photonuclear reactions. Liquid drop model of fission, Fission barrier and threshold, Fission cross section, Mass energy and charge distribution of fission products, Symmetric and asymmetric fission, Decay chains and delayed neutrons.

Unit IV: Reactor Theory and Applications of Radioactivity **15 Hrs**

Nuclear fission as a source of energy, Nuclear chain reacting systems, Critical size of a reaction, Research reactors; graphite moderated, enriched uranium, light water moderated, heterogeneous, aqueous homogeneous reactors and thermonuclear reactors, Gamma interactions, Shielding and health protection, Reactors in India, Tracer techniques; structure determination, elucidation of reaction mechanism, isotopic dilution analysis, neutron activation analysis, applications in biological, medical, industrial fields and age determination.

Reference Books:

1. Friedlander, Kennedy and Miller, Nuclear and Radio Chemistry: John Wiley
2. B. G. Harvey, Nuclear Chemistry
3. Hassinsky: Translated by D. G. Tuck, Nuclear Chemistry and its application: Addison Wiley
4. B.G. Harvey, Introduction to Nuclear Physics and Chemistry
5. Maeclefort: Nuclear Chemistry: D. Van Nostrand
6. An N. Nesmeyannoy: Radiochemistry: Mir
7. Jacobs et al: Basic Principles of nuclear Science and Reactors, V. Nost & EWAP
8. N. Jay: Nuclear Power Today Tomorrow: ELBS
9. Kenneth: Nuclear Power Today, Tomorrow: ELBS
10. Essentials of Nuclear Chemistry, W. J. Arnikar, John Wiley
11. Nuclear and Radiation Chemistry: B. K. Sharma, Krishna Publication 12
12. A Introduction to Nuclear Physics: R. Babber. And Puri.
13. Essential of Nuclear Chemistry by H. J. Arnikar

M. Sc. Part - II (Semester - III) Inorganic Chemistry Practical Course
ICHP-V and ICHP-VI (CC – 2105C)

I] Non-Instrumental

A] Analysis of Ores and Alloys

1. **Ore Analysis** – Bauxite and Illeminite Ore
2. **Alloy Analysis** – Bronze and Stainless Steel alloy

B] Inorganic Preparations

1. Preparation of [tris-(acetyl-acetanato) ferrate III]
2. Preparation of [cobalt (II) 8-hydroxy quinoline]
3. Preparation of [cobalt (salicyladoxime)$_2$]
4. Synthesis of ZnO Nanoparticles
5. Synthesis of Nickel Ferrite

C] Percentage Purity

1. Determination of percentage purity of [tris-(acetyl-acetanato) ferrate III]
2. Determination of percentage purity of [cobalt (II) 8-hydroxy quinoline] 3. Determination of percentage purity of [cobalt (salicyladoxime)$_2$]

II] Instrumental Experiments

A] Spectrophotometry

1. To study the spectra and determine extinction coefficient of potassium permagnate and potassium dichromate.
2. To determine the solubility contact of ferric ammonium sulphate and sulpho-salicylic acid by Job's variation method and slope ratio method and mole ratio method.
3. To determine the PKa value of Bromocresol indicator by using spectrophotometer.

B] pH metry

1. To determine the dissociation constant of orthophosphoric acid pH metrically.
2. To determine the pKa value of acetic acid pH metrically.

C] Conductometry

1. To determine the normality of acetic acid and hydrochloric acid conductometrically.
2. Analysis of Ibuprofen in given tablet by conductometrically.

D] Nephelometry

1. To determine sulphate content in water by nephelometrically.
2. To determine sulphate ion concentration in water by nephelometrically.

(Any other experiments may be added when required)

Reference Books:

1. A Text book of Quantitative Inorganic Analysis; A. I. Vogel
2. Practical inorganic chemistry; Pass Geoffrey and haydn Sutcliffe.
3. Advance Inorganic Analysis – S K Agarwala, KeemtiLal , Pragati Prakashan
4. Advanced Practical inorganic chemistry; Gurudeep Raj.
5. Experiments in Chemistry, D. V. Jahagirdar, Himalaya Publishing House
6. Systematic experimental physical chemistry – T. K. Chondhekar& S.W. Rajbhoj
7. Experiments in chemistry – D.V. Jahagirdar
8. Textbook of quantitative Inorganic Analysis – IV Edn. J. Bassett, R. C. Denny, G.H.Gefery and J. Mendham

Vivekanand College (Autonomous), Kolhapur
M. Sc. Part - II (Inorganic Chemistry)
CBCS Syllabus with effect from June - 2022
Semester - IV
Paper XIII: Instrumental Techniques (CC – 2106D)
Theory: 60hrs

Course Outcomes: After the completion of the course, the student will be able to:

CO1: Understand and use various crystallographic databases. Process data, solve/refine and interpret a single crystal structure. Apply the concepts of unit cells and lattices to describe observed diffraction patterns in reciprocal space.

CO2: Acquire Knowledge of Nuclear Quadrupole Resonance and X-ray fluorescence Spectroscopy and to apply to interpret data.

CO3: Understand the principal instrumentation and to apply for structural elucidation and investigation of compounds.

CO4: Understand ESR measurements, acquire information about the existence of unpaired electrons, as well as quantities, type, nature, environment and behaviour and to interpret structure.

Unit I: X-ray Diffraction Techniques

A] X-ray powder diffraction (XRD): **10 Hrs**

X-ray source, Diffraction of X-rays with powder diffraction, Instrumentation, Use of standards, Identification of compounds using powder diffraction, Significance of intensities, Determination of cubic crystal structure, Determination of parameters using XRD: qualitative analysis; quantitative analysis-percent crystallinity, crystallite size, surface area, unit cell dimension.

B] Single Crystal X-ray Diffraction: **5 Hrs**

Determination of single crystal structures, Refining of a structure, X-ray crystal structures in the literature.

Unit II: NQR Spectroscopy and XRF Spectrometry

A] Nuclear Quadra pole Resonance Spectroscopy [NQR]: **8 Hrs**

Basic concepts of NQR; Nuclear electric quadruple moment, Electric field gradient, Energy levels and NQR frequencies, Effect of magnetic field on spectra, Factors affecting the resonance signal; line shape and position of resonance signal, Relationship between electric field gradient and molecular structure, Interpretation of NQR data.

B] X-ray Fluorescence Spectrometry (XRF): **7 Hrs**

Introduction and basic theory, Instrumentation; dispersive systems and detectors, Matrix effects, XRF with synchrotron radiation, Spectral analysis, Analytical information, Elementary theory of recoil free emission and resonant absorption of gamma rays, Applications.

Unit III: Mossbauer Spectroscopy **15 Hrs**

Introduction and Basic principles of ^{57}Fe Mössbauer spectroscopy, Instrumentation, Mössbauer parameters; recoilless emission and absorption of x-rays, isomer shifts, magnetic dipole hf splitting and electric quadrupole hf splitting, Magnetic hyperfine interaction, Line broadening.Application of Mössbauer spectroscopy with respect to (i) Oxidation states of metal ion in compounds, (ii) Structural elucidation, investigations of compounds of iron and tin, (iii) Covalent and ionic compoundsand (iv) High spin low spin behaviour.

Unit IV: Electron Spin Resonance Spectroscopy **15 Hrs**

Principle of ESR Spectroscopy, Presentation of spectrum, Hyperfine splitting in proton systems, Rules for evaluating ESR lines of Naphthalene anion radical, Pyrazine anion radical, Isomers of Xylene anion radicals, VO_2^+, Quinoline radical, Isoquinoline radical, Quinoxaline radical, Anthracene radical, Phenanthracne radical, Pyrene radical, Alkyl halide radicals, Quinone and Isoquinone anion radicals, nitrogen/deuterium containing radicals, Superhyperfine splitting, Instrumentation, 'g' value and factors affecting on 'g' value, Zero field splitting, Karmers's degeneracy, Applications, Numericals problems.

Reference Books:

1. Principles of Instrumental analysis, Skoog, III rd edn., Sounders, 1985
2. Mossbaur Spectroscopy, Greenwood N.N., Gibbs T.C., Chapmann Hall, 1971.
3. Chemical Application of Mossbaur Spectroscopy, Goldanski V.I & Harber R.H., Academic Press 1968.
4. Mössbauer Spectroscopy and Transition Metal Chemistry, P. Gütlich, R. Link, A.Trautwien, Springer-Verlag (1978).
5. Mössbauer Spectroscopy, N.N. Greenwood, T.C. Gibb, Chapman and Hall Ltd. (1971).
6. Instrumental method of analysis (7th edition) By- H.H. Willard, L.L. Merritt. Jr. J.A. Deanand F.A. Settle, Jr (Publisher: CBS Publishers and distributors Pvt .Ltd. (Copyright – wards worth publishing copy USA .2000).
7. Element of X-ray Diffraction - B.D. Cullity (1967)

8. CNR Rao Spectroscopy in Inorganic Chemistry Vol I, II, III
9. Powder Diffraction Theory and Practice, Edited by R E Dinnebier and S J L Billinge, RSC publishing, 2008.
10. In situ X-ray diffraction study of the hydrothermal crystallization of hierarchical Bi_2WO_6 nanostructures, Y. Zhou, et al., Nanoscale, 2010, 2, 2412-2417, RSC Publishing Journal.
11. Physical Methods for Chemists, Russel Drago, Surfside Scientific Publishers, 1992

Paper XIV: Co-ordination Chemistry-II (CC – 2107D)
Theory: 60hrs

Course Outcomes: After the completion of the course, the student will be able to:

CO1: Explain lability and inertness of complexes and with respect to VBT and CFT.

CO2: Explain the kinetics and mechanism of substitution and electron transfer reactions in octahedral and square planar complexes.

CO3: Understands the classification of coordination polymers and learns the chemical background of individual polymers.

CO4: Know the applications of coordination compounds in industrial processes.

Unit I: Inorganic Reaction Mechanism **15 Hrs**

Types of mechanisms: Basic concepts, as stability and lability, stability constants; HSAB principle, chelate effect, macrocyclic effect, Ligand and electron transfer reactions in coordination compounds, Intimate and stoichiometric mechanism of ligand substitution. Substitution in square planar complexes: trans effect, trans series, applications of trans effect, Electron transfer reactions: Potential energy diagrams as a conceptual tool, Marcus equation, Types and factors affecting electron transfer reactions.

Unit II: Reaction Mechanism of Transition Metal Complexes **15 Hrs**

Substitution reaction, Reactions of transition metal complexes, kinetics and mechanism of substitution reactions of octahedral complexes, Stereochemical aspects of substitution reaction of octahedral complexes: Stereochemical changes in dissociation (SN^2) and displacement (SN^2) mechanism through various geometries of coordination compounds, Isomerization and racemization reactions in octahedral complexes. Steric effects on substitutions.

Unit III: Coordination Polymers **15 Hrs**

General introduction, Natural polymers, Synthesis of coordination polymers, Use of polymeric ligands in synthesis of coordination polymers, synthesis and uses of Metal coordination polymers, Silicon polymers and Organosilicon polymers.

Unit IV: Applications of Coordination Compounds **15 Hrs**

General introduction, Metal complexes in Inorganic qualitative analysis, The 'brown ring' test, complexometric titrations, Complexes in colourimetry, Coordination compounds in gravimetry, Stabilization of oxidation states, Complexes in separation of metals. Metal

complexes in medicinal chemistry and therapy: Complexation in food poisoning, Metal complexes in industrial processes:-Heavy metals-protein complexes in the Rasching Process, Metal complexes in alkene conversions, Complexes in Electroplating, Complexes in Metallurgy, Complexes in water softening, Metal complexes in Agriculture.

Reference Books:

1. R. Gopalan and V. Ramlingam: Concise Coordination Chemistry.
2. J. E. Huheey, Ellen A. Keiter and Okhil K. Medhi: Inorganic Chemistry: Principle of Structure and Reactivity.
3. A.K. Das and M. Das, Fundamental Concepts of Inorganic Chemistry, Vol. 1 to Vol. 7, CBS Publishers.
4. F. Basolo and R. Pearsons: Mechanism of Inorganic Reactions: A Study of Metal Complexes in Solution.
5. Obe, M. L. Inorganic reaction mechanism, Nelson, London, 1972.
6. Taube, Electron transfer reactions of metal complex ions in solution. Academic Press.
7. E. S. Gould, Inorganic Chemistry.
8. K. Burger, Coordination Chemistry Experimental methods, Butterworths.
9. Heterogeneous catalysis 2nd edn. Bond C. Chapman all (1987).
10. The application & Chemistry of catalysis by suitable transition metal complexes Parashall. W. Weily N. 1980.
11. Homogeneous transition metal catalysis, A general art, Masters C. Chapman and Hall, London 1981.
12. Introduction to the principles of heterogeneous catalysis, Thomas J.M., Thomas W.J. Academic press N.Y. 1967.
13. K. M. Macky, R. A. Macky, Modern Inorganic Chemistry, 4th edn., Blackie, London1989.
14. B. R. Puri, L. R. Sharma, K. C. Kalia, Principles of Inorganic Chemistry, Vallabh Publications, Delhi,2005.

Paper XV: Energy and Environmental Chemistry (CC – 2108D)
Theory: 60hrs

Course Outcomes: After the completion of the course the student will be able to:

CO1: Understand the basic building blocks of various forms of energy and to know applications of fuel cells in various sectors, hydrogen production, storage, handling and safety issues.

CO2: Understand energy storage systems and to describe the parts in various Li-Ion Battery, materials and functionalities.

CO3: Explain the common principles, routes and processes in controlling the gaseous pollutants.

CO4: Understand meaning of important parameters for measuring water quality and To understand the principles and the practical approaches and technique required to effectively monitor the chemical, hydrological and microbiological elements of water quality.

Unit I: Energy Conversion Devices **15 Hrs**

A] Fuel Cells: Working of Fuel Cell, Types of fuel cells, Uses, Fuel cell stacks and systems, Hydrogen fuel cell.

B] Production of Hydrogen: Electrolysis, Thermochemical processes, Steam Reformer processes, Water gas process, Bosch process, Biosynthesis and photochemical processes, Coal Gasification, Steam Iron processes, Partial Oxidation processes, Storage, Transport and Handling of Hydrogen.

Unit II: Energy Storage Devices (Batteries) **15 Hrs**

Li ion Batteries: Principle of operation, Battery components and design, electrode material ($LiCoO_2$, $LiNiO_2$, $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$, $LiMn_2O_4$, $LiFePO_4$, graphitic carbon) their synthesis and characterization,Theoretical capacity, Energy density, power density, cycle life, electrode and battery fabrication, battery modules and packs, Li- polymer batteries and applications, Electrolytes for Li-ion batteries, Other solid state batteries, Future developments and beyond lithium batteries: Li-S battery, Li-air battery, Advanced Lead – acid batteries, sodium batteries, Battery Recycling technologies.

Unit III: Air Pollution and Control Methods **15 Hrs**

Introduction, Source Correction Methods; substitution of raw materials, process modification, existing equipment modification, maintenance of equipment, Control of Particulate

emissions, Selection of a particulate collector, Control of gaseous pollutants, NOx and SOx, Removal of H_2S, Control of CO-pollution, Control of hydrocarbon emission, Control of pollutant emission from mobile sources

Unit IV: Water Pollution and Monitoring Control Methods **15 Hrs**

A] Sewage and industrial wastes, COD and BOD, Estimation methods, Toxic heavy metal Analysis of Cd, Hg, As, Pb and Cr metals, Control Methods: Water softening and Municipal water purification

B] Techniques in environmental analysis – ND-IR , FT- IR, AAS, ICT- AES, GCMS, HPLC, Anodic Stripping, Voltametry etc.

References Books:

1. Fuel Cell Fundamentals, R.O. Hayre, et.al., John Wiley and Sons, 2016
2. Environmental Pollution, A.K. De
3. Environmental Pollution Analysis, S. M. Khopkar
4. Lithium Ion Batteries Materials, Technology and new Applications, K.Ozawa, Wiley.
5. Electronic Waste Magement. , Ed. Ramchandra, CRC Press 2015 1st edition.

Paper XVI (A): Inorganic Nanomaterials (CC – 2109D)
Theory: 60hrs

Course Outcomes: After the completion of the course the student will be able to:

CO1: Understand synthesis approaches of nanomaterials and challenges in Nano Technology

CO2: Describe different characterization techniques of materials, outline the principles on which they are based, and explain their limitations.

CO3: Understand the technological application of nanomaterial is usable in multiple sectors, from healthcare and mechanics to environmental preservation and air purification.

CO4: Acquire knowledge about the toxicity in Nanoscience, and their effects on Human as well as to learn various concepts of toxicity, and its effects.

Unit I: Advanced Synthetic Methods of Inorganic Nanomaterials **15 Hrs**

General Introduction to Nanomaterials, Nanoscience and nanotechnology, History, Chemical bath deposition: ionic and solubility products, preparation of binary semiconductors, Electrodeposition: Deposition mechanism and preparation of compound thin film, successive ionic layer adsorption reaction method (SILAR), Co-precipitation, Micelles-microemulsions, Reduction method.

Unit II: Characterization Techniques for Inorganic Nanomaterials **15 Hrs**

A] Principle and applications of X-Ray diffraction: Index reflections, Identifications of unit cell from systematic absences in diffraction pattern, Structure of simple lattices and X-Ray intensities.

B] Principle instrumentation and application of electron spectroscopy for chemical analysis (ESCA), transmission electron microscopy (TEM), HRTEM, Scanning electron microscopy (SEM), FESEM, EDAX, Probe Microscopy (STM & AFM), UV-Visible-NIR spectroscopy (optical microscopy), FTIR, BET, surface profiler, Electro chemical work station.

Unit III: Applications of Nanomaterials **15 Hrs**

Carbon nanomaterials, Nanocomposites including metal nanomaterials such as single particle as well as coreshell nanomaterials, Fuel cell, Solar cell, Medicinal applications, Agro-food applications, Polymer Nanotechnology, Organic electronics, Nanotribology and Nanobiotechnology.

Unit IV: Nanotoxicity and Biosafety **15 Hrs**

Introduction to Nanotoxicology, Nanoetymology, Nanotoxicology challenges, Physicochemical characteristic dependent toxicology, Epidemiological evidences, Mechanism of nanotoxicity, Assessment of nanomaterial toxicity: In vitro toxicity assessment-cell viability and in vivo toxicity assessment.

Reference Books:

1. The Chemistry of Nanomaterials edited by C.N.R. Rao, A. Muller, A.K. Cheetham Wiley VCH Verlag GmbH & co. Volumes 1 & 2.
2. Nanomaterials by Dr. Sulbha Kulkarni.
3. T. Pradeep, "A Textbook of Nanoscience and Nanotechnology", Tata McGraw Hill Education Pvt. Ltd., 2012
4. Hari Singh Nalwa, "Nanostructured Materials and Nanotechnology", Academic Press, 2008
5. Handbook of Nanotoxicology, Nanomedicine and Stem Cell Use in Toxicology. Saura C Sahu, Daniel A Casciano
6. Nanomaterials and Nanochemistry, 2007, Catherine Brechignac, Philippe Houdy, Marcel Lahmani, ISBN 978-3-540-72992-1 Springer Berlin Heidelberg New York.
7. Nanomaterials Chemistry, Recent Developments and New Directions C.N.R. Rao, A. Muller, and A.K. Cheetham, ISBN 978-3-527-31664-9, 2007 WILEY-VCH Verlag GmbH and Co. KGaA, Weinheim.
8. Nano-Surface Chemistry, 2001, Morton Rosoff, ISBN: 0-8247-0254-9, Marcel Dekker Inc. New York.
9. Principles of Instrumentals Analysis: D. Skoog & West

Paper XVI (B): Radiation Chemistry (CC – 2110D)
Theory: 60hrs

Unit I: Isotopes and Biological effects of Radiation

A] Isotopes: **8 Hrs**

Intoduction, Difference between Isotopes and Isobars, Isotope separation, Thermodynamic and kinetic isotope effects, Isotope exchange reaction kinetics, Determination of exchange rate constant, Production and applications of radio isotopes.

B] Biological effects of Radiation: **7 Hrs**

Introduction, Genetic and somatic effect on human being, Effect of radiation on plants and aquatic environment.

Unit II: Radiochemical Separation **15 Hrs**

The need of radiochemical separation techniques, Carrier techniques, Isotope and nonisotopic carriers, Coprecipitation and adsorption, Ion exchange, Solvent extraction, Electrolytes behavior of carrier free tracer radionuclide.

Unit III: Principle of Tracer Chemistry **15 Hrs**

Introduction to tracers, application of tracers in physiochemical studies, Diffusion studies, Isotopic and exchange reactions, Tracer in the study of the mechanism of the inorganic chemical reactions, atom transfer and electron transfer mechanisms. Heterogeneous catalysis and surface area measurements, radio carbon dating, tracer studies with tritium, applications in metallurgy and preservation of food, geochemical applications and hot atom chemistry.

Unit IV: Radiation Detection and Measurements **15 Hrs**

Ionization current measurements, multiplicative ion collector, methods not based on ion collection, auxiliary instrumentation and health physical instruments and counting statistics. Working of Scintillation and Geiger Muller Counter.

Reference Books:

1. Friedlander, Kennedy and Miller, Nuclear and radio Chemistry, ohm Wiley.
2. B.G. Harvey, Nuclear Chemistry.
3. Haissinsky, Translated by D.G, Tuck, Nuclear physics and Chemistry.
4. Mark lefort, Nuclear Chemistry, D.V. Nostrand.
5. An N. Nesmeyanov, Radiochemistry, Mir.
6. Jacobs, et al, Basic Principles of nuclear science and reactors, V. Nost, EW AP.

7. N. Jay, Nuclear power, today tomorrow, ELBS.
8. Kenneth, Nuclear power, today and tomorrow, ELBS.
9. Essentials of Nuclear Chemistry, J. Arnikar, John Wiley.
10. D.C. Dayal, nuclear physics.

M. Sc. Part - II (Semester - IV) Inorganic Chemistry Practical Course

ICHP - VII and ICHP - VIII (CC – 2111D)

Practical courses include Submission of project work.

I] Non-Instrumental Experiments

A] Analysis of Ores, Alloys and Cement

1. **Ore Analysis** – Galena Ore
2. **Alloy Analysis** – Fernico and Nichrome alloy
3. **Cement AnalysisB] Inorganic Preparations**

1. Preparation of [trans Bis-(ethylene diammine) dichloro cobaltic] chloride
2. Preparation of [dinito tetra amino cobaltic] sulphate
3. Preparation of [copper (salicyladoxime)$_2$]

II] Instrumental Experiments

A] pH metry

1. To study the titration of HCl Vs NaOH pH metrically.
2. To study the titration of mixture of H_2SO_4 and CH_3COOH Vs NaOH pH metrically.

B] Conductometry

1. To determine the normality of sulphuric acid and nitric acid by conductometrically.
2. To study the titration of aluminium Potassium Sulphate and NaOH by conductometrically.

Reference Books:

1. A Text book of Quantitative Inorganic Analysis; A. I. Vogel
2. Practical inorganic chemistry; Pass Geoffrey and haydn Sutcliffe.
3. Advance Inorganic Analysis – S K Agarwala, KeemtiLal , Pragati Prakashan
4. Advanced Practical inorganic chemistry; Gurudeep Raj.
5. Experiments in Chemistry, D. V. Jahagirdar, Himalaya Publishing House
6. Systematic experimental physical chemistry – T. K. Chondhekar& S.W. Rajbhoj
7. Experiments in chemistry – D.V. Jahagirdar
8. Textbook of quantitative Inorganic Analysis – IV Edn. J. Bassett, R. C. Denny, G.H. Gefery and J. Mendham

- **Project/Industrial Training:**A variety of small projects designed by teachers based on the student's interest and capabilities should be worked out.

OR

- The students can also complete the industrial training for minimum 15 days and submit the report to the department.
- Project work or the review report or the industrial training report of 50 marks will be examined by internal and external examiners.
- Addition of other experiments in place of existing one may be allowed.
- Study tour is compulsory for M.Sc. Part- II students to visit chemical industries in India.

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