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ताळगांव पठार,
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(Accredited by NAAC with Grade A+)

GU/Acad –PG/BoS -NEP/2025-26/14 Date: 09.04.2026

# CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP/2025-26/603 dated 18.11.2025

In supersession to the above referred Circular, the syllabus of Semester III & IV of the **Master of Science in Inorganic Chemistry** Programme approved by the Standing Committee of the Academic Council in its meeting held on 24th & 25th November 2025 is attached.

The syllabus of Semester II approved earlier by the Academic Council on 13th September 2025 and the syllabus of Semester I approved by the Academic Council on 13th & 14th June 2025 is also attached.

The Dean & Vice-Dean (Academic) of the School of Chemical Sciences and the Principals of affiliated Colleges offering the **Master of Science in Inorganic Chemistry** are requested to take note of the above and bring the contents of the Circular to the notice of all concerned**.**

ASHWIN V LAWANDE
Digitally signed by ASHWIN V LAWANDE
Date: 2026.04.09 16:24:12 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,
1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Dean (Academic), School of Chemical Sciences, Goa University.
3. The Principals of affiliated Colleges offering the Master of Science in Inorganic Chemistry Programme.

Copy to:
1. Chairperson, BoS in Chemistry, Goa University.
2. Programme Director, M.Sc. Inorganic Chemistry, Goa University.
3. Controller of Examinations, Goa University.
4. Assistant Registrar Examinations (PG), Goa University.
5. Director, Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

# GOA UNIVERSITY

## MASTER OF SCIENCE IN INORGANIC CHEMISTRY

(Effective from the Academic Year 2025-26)

### ABOUT THE PROGRAMME

This program is designed by integrating academics with research and industrial needs. Students with this degree will be ready for careers in the pharmaceutical, chemical, healthcare, environmental, material science and related industries. Students are equipped with hands-on research experience and skills through projects and dissertations to pursue advanced degrees like Ph.D. programs and contribute to research in the field. Students with this knowledge would excel in competitive exams like NET, GATE, and others.

### OBJECTIVES OF THE PROGRAMME

1. To provide a deep understanding of the fundamental principles and concepts of inorganic chemistry, including bonding theories, structure, and reactivity.
2. To impart systematic understanding of the chemistry of different groups of elements and their compounds.
3. To provide the principles and applications of coordination compounds, including their structure, bonding, and reactivity.
4. To expose students to advanced concepts like nanotechnology, materials science, and their applications in various fields like catalysis, energy, and environment.

| INORGANIC CHEMISTRY (CHI)<br>PROGRAMME SPECIFIC OUTCOMES (PSO) | |
|---|---|
| **PSO 1.** | Understand the properties of elements and compounds and use concepts like molecular symmetry and tools such as spectroscopy, diffraction, thermal techniques and others, to study chemical structures and solve both theoretical and practical problems in inorganic chemistry. |
| **PSO 2.** | Apply inorganic chemistry principles to explain and model biological, environmental, and industrial processes. |
| **PSO 3.** | Analyse environmental and industrial samples, including pollutants, ores, and alloys that will prepare students for careers in science and industry. |
| **PSO 4.** | Design experiments, interpret results, and propose effective solutions to chemical challenges that will help create and develop materials for use in areas like catalysis, energy, environment, electronics, and healthcare using eco-friendly and sustainable methods. |

| ANALYTICAL CHEMISTRY (CHA)<br>PROGRAMME SPECIFIC OUTCOMES (PSO) | |
|---|---|
| **PSO 1.** | Understand different chemical and instrumental methods of analysis and apply appropriate methods for qualitative and quantitative analysis. |
| **PSO 2.** | Select technique for synthesis, separation, structural characterization and microscopic analysis. |
| **PSO 3.** | Interpret data pertaining to optical techniques, diffraction techniques and spectral techniques such as IR, UV, NMR, Mass, X-Ray, and others. |
| **PSO 4.** | Develop expertise through hands on training for qualitative and quantitative estimation using chemical and instrumental methods. |

| PHYSICAL CHEMISTRY (CHP)<br>PROGRAMME SPECIFIC OUTCOMES (PSO) | |
|---|---|
| **PSO1** | Understand the fundamental principles and core concepts of Quantum chemistry, Electrochemistry, Spectroscopy, Thermodynamics & Reaction Kinetics, and the scientific theories cum models that govern them. |
| **PSO 2** | Demonstrate a proficient understanding of the principles of Group Theory and their applications in chemistry, i.e. molecular symmetry, hybridization, and electronic structure, facilitating the interpretation of spectroscopic data and chemical phenomena. |
| **PSO 3** | Understand and interpret spectroscopic data of industrially important compounds using microwave, IR, Raman, NMR, and ESR spectroscopy and elucidate their chemical structure and properties. |
| **PSO 4** | Demonstrate hands-on expertise in handling instruments like conductometer, potentiometer, pH meter, colorimeter, linear sweep and cyclic voltammeter, and bomb calorimeter, and use them to monitor the kinetic rates and thermodynamic properties of chemical reactions. |
| **PSO 5** | Design, synthesize, and characterize nano-catalysts and use them to address societal problems of wastewater pollution, using adsorption and photocatalytic technology. |
| **PSO 6** | Acquire the ability to fabricate efficient electrodes and test their efficiency in electrocatalytic and spectro-electrochemical reactions such as HER and $CO_2$ reduction, electrochemical energy generation and storage systems such as batteries, fuel cells, photovoltaics, and supercapacitors. |
| **PSO 7** | Determine the fundamental physical properties such as density, viscosity, specific gravity, etc., and use them to construct phase diagrams. |
| **PSO 8** | Acquire the ability to write computer programs. Ab-initio programs like Gaussian are used to calculate the molecular and spectroscopic properties of chemical compounds. |

| ORGANIC CHEMISTRY (CHO)<br>PROGRAMME SPECIFIC OUTCOMES (PSO) | |
|---|---|
| **PSO 1.** | Demonstrate understanding of Organic Chemistry principles, apply them to scientific theories, communicate effectively with critical reasoning, and follow safe practices in handling chemical reagents, laboratory equipment, and glassware |
| **PSO 2.** | Utilize knowledge of synthetic organic chemistry, stereochemistry, pericyclic reactions, and photochemistry to synthesize organic molecules and elucidate their structures using various spectroscopic techniques |
| **PSO 3.** | Undertake synthetic methodologies towards organic compounds of commercial and scientific interest and also apply the concepts in chemistry of pharmaceuticals, natural products, polymers, synthetic intermediates, petroleum products, etc. |
| **PSO 4.** | Develop interdisciplinary approach of the subject of organic chemistry and related fields and augment the new progresses in the arena of Bioorganic Chemistry, Green Chemistry, Pharmaceutical Chemistry, Agrochemicals and relevant fields. |

**PROGRAMME STRUCTURE**

**Master of Science in Inorganic Chemistry**

**Effective from the Academic Year 2025-2026**

| Bridge Course | | | |
|---|---|---|---|
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** |
| **1** | **CHC-1000** | Bridge Course in mathematical concepts for chemistry | 1 |
| **2** | **CHC-1001** | Bridge Course in organic chemistry | 1 |

| SEMESTER I | | | | |
|---|---|---|---|---|
| **Discipline Specific Core (DSC) Courses (16 credits)** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| **1** | **CHO-5000** | Fundamental Concepts in Organic Chemistry | 4 | 400 |
| **2** | **CHI-5000** | Concise Inorganic Chemistry | 4 | 400 |
| **3** | **CHP-5000** | Fundamentals of Physical Chemistry | 4 | 400 |
| **4** | **CHA-5000** | Analytical Chemistry Techniques | 4 | 400 |
| **Total Credits for DSC Courses in Semester I** | | | **16** | |
| **Discipline Specific Elective (DSE) Course (4 credits)** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| **1** | **CHO-5201** | Organic Chemistry Practical - I | 2 | 400 |
| **2** | **CHO-5202** | Organic Chemistry Practical - II | 2 | 400 |
| **3** | **CHI-5201** | Inorganic Chemistry Practical - I | 2 | 400 |
| **4** | **CHI-5202** | Inorganic Chemistry Practical - II | 2 | 400 |
| **5** | **CHP-5201** | Physical Chemistry Practical - I | 2 | 400 |
| **6** | **CHP-5202** | Physical Chemistry Practical - II | 2 | 400 |
| **7** | **CHA-5201** | Analytical Chemistry Practical - I | 2 | 400 |
| **8** | **CHA-5202** | Analytical Chemistry Practical - II | 2 | 400 |
| **Total Credits for DSE Courses in Semester I** | | | **4** | |
| **Total Credits in Semester I** | | | **20** | |

| Semester II | | | | |
|---|---|---|---|---|
| **Discipline Specific Core (DSC) Courses** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| **1** | **CHI-5001** | Coordination and Organometallic Compounds: Bonding to Reactivity | 4 | 500 |
| **2** | **CHI-5002** | Solid State Chemistry | 4 | 500 |
| **3** | **CHI-5003** | Molecular Symmetry and Spectroscopy | 4 | 500 |
| **4** | **CHI-5004** | Concepts and Applications in Inorganic Chemistry | 4 | 500 |
| **Total Credits for DSC Courses in Semester II** | | | **16** | |
| **Discipline Specific Elective (DSE) Courses (4 credits)** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| **1** | **CHO-5201** | Organic Chemistry Practical - I | 2 | 400 |
| **2** | **CHO-5202** | Organic Chemistry Practical - II | 2 | 400 |
| **3** | **CHI-5201** | Inorganic Chemistry Practical - I | 2 | 400 |
| **4** | **CHI-5202** | Inorganic Chemistry Practical - II | 2 | 400 |
| **5** | **CHP-5201** | Physical Chemistry Practical - I | 2 | 400 |
| **6** | **CHP-5202** | Physical Chemistry Practical - II | 2 | 400 |
| **7** | **CHA-5201** | Analytical Chemistry Practical - I | 2 | 400 |
| **8** | **CHA-5202** | Analytical Chemistry Practical - II | 2 | 400 |
| **Total Credits for DSE Courses in Semester II** | | | **4** | |
| **Total Credits in Semester II** | | | **20** | |

| SEMESTER III | | | | |
|---|---|---|---|---|
| **Research Specific Elective (RSE) Courses (12 Credits)** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| 1 | CHI-6000 | Inorganic Chemistry Practical - III | 4 | 500 |
| 2 | CHI-6001 | Inorganic Chemistry Practical - IV | 4 | 500 |
| 3 | CHI-6002 | Concepts in Catalysis | 4 | 500 |
| 4 | CHI-6003 | Bioinorganic Chemistry | 4 | 500 |
| 5 | CHI-6004 * | Research Methodology in Inorganic Chemistry-I | 4 | 500 |
| 6 | CHI-6005 * | Research Methodology in Inorganic Chemistry-II | 4 | 500 |
| **Total Credits for RSE Courses in Semester III** | | | **12** | |
| **Discipline Specific Vocational Elective (DSVE) Courses (8 Credits)** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| 1 | CHI-6401 | Environmental Chemistry and Sustainability | 2T+2P | 500 |
| 2 | CHI-6402 | Industrial Applications of Inorganic Chemistry | 2T+2P | 500 |
| 3 | CHI-6403 | *p*-block elements and their compounds | 2T+2P | 500 |
| **Total Credits for DSVE Courses in Semester III** | | | **8** | |
| **Total Credits in Semester III** | | | **20** | |

* Note: Either one may be opted by students

| Discipline Specific Dissertation (DSD) (40 Credit Dissertation) | | | | |
|---|---|---|---|---|
| **Discipline Specific Dissertation (DSD)** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| 1 | CHI-6501 | Discipline Specific Dissertation (DSD) | 40 | 500 |

| SEMESTER IV | | | | |
|---|---|---|---|---|
| **Generic Electives** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| 1 | CHI-6201 | Selected Topics in Inorganic Chemistry | 4 | 500 |
| 2 | CHI-6202 | Advanced Inorganic Chemistry | 4 | 500 |
| 3 | CHI-6203 | Advanced Spectroscopic Techniques | 4 | 500 |
| 4 | CHI-6204 | Framework Materials and Polyoxometalates | 4 | 500 |
| 5 | CHI-6205 | Inorganic Chemistry Practical – V | 4 | 500 |
| 6 | CHI-6206 | Inorganic Chemistry Practical – VI | 4 | 500 |
| 7 | CHI-6207 | Inorganic Chemistry Practical – VII | 4 | 500 |
| **Total Credits for GE courses in Semester IV** | | | **20** | |

| Discipline Specific Dissertation (DSD)/ Internship (20 Credit Dissertation) | | | | |
|---|---|---|---|---|
| **Discipline Specific Dissertation (DSD)** | | | | |
| **Sr. No.** | **Course Code** | **Title of the Course** | **Credits** | **Level** |
| 1 | CHI-6502 | Discipline Specific Dissertation (DSD) | 20 | 500 |

| Blooms Taxonomy Cognitive Levels | |
|---|---|
| **Cognitive Level** | **Notations** |
| K1 | Remembering |
| K2 | Understanding |
| K3 | Applying |
| K4 | Analyzing |
| K5 | Evaluating |
| K6 | Create |

**BRIDGE COURSES**

| | |
|---|---|
| **Title of the Course** | Bridge Course in Mathematical Concepts for Chemistry |
| **Course Code** | CHC-1000 |
| **Number of Credits** | 1 |
| **Theory/Practical** | Theory |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | Yes |
| **Course for advanced learners** | No |

| | | | | |
|---|---|---|---|---|
| **Pre-requisites for the Course:** | NIL | | | |
| **Course Objectives:** | To introduce mathematical concepts to the students of MSc Part-I (Chemistry). | | | |
| **Course Outcomes:** | Students will be able to solve problems based on: | | **Mapped to PSO** | |
| | CO 1. Matrices in M.Sc. Chemistry | | PSO1 | |
| | CO 2. Determinants in M.Sc. Chemistry | | PSO1 | |
| | CO 3. Differential calculus in M.Sc. Chemistry | | PSO1 | |
| | CO 4. Integral calculus in M.Sc. Chemistry | | PSO1 | |
| **Content:** | | **No of** | **Mapped** | **Cognitive** |

| | | hours | to CO | Level |
|---|---|---|---|---|
| **Module 1:** | 1. Calculus for thermodynamics and kinetics<br>a. Introduction to Differentiation: Notation, Differentiating various f functions, Differentiating a Sum, Product Rule, Quotient Rule, Chain Rule, Partial Differentiation: exact and inexact differentials.<br>b. Introduction to Integration: Notation, Rules for Integrals, Integrating various functions, Definite and indefinite Integrals. | **8** | CO3, CO4 | K5 |
| **Module 2:** | 2. Matrices, Determinants and vector algebra:<br>a. Types of Matrices: Identity, reflection, rotation, inversion, distance matrix, Matrix Algebra, Matrix similarity transformation.<br>b. The Determinant, Minors and Cofactors, Inverse of a Matrix, Character of a matrix, Linear algebra.<br>c. Vectors and molecular structure. | **7** | CO1, CO2 | K5 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions can preferably be interactive to enable peer group learning. | | | |
| **Texts:** | Robert G. Mortimer, Mathematics for Physical Chemistry, Elsevier, New York. 4th ed., 2013 | | | |
| **References/ Readings:** | James R. Barrante, Applied Mathematics for Physical Chemistry, 3rd ed., Prentice-Hall, New Jersey, 1998 | | | |

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| | |
|---|---|
| **Title of the Course** | Bridge Course in Organic Chemistry |
| **Course Code** | CHC-1001 |
| **Number of Credits** | 1 |
| **Theory/Practical** | Theory |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | Yes |
| **Course for advanced learners** | No |

| | | | | |
|---|---|---|---|---|
| **Pre-requisites for the Course:** | NIL | | | |
| **Course Objectives:** | • To understand various principles of organic chemistry.<br>• To apply the importance of chirality in organic syntheses.<br>• To analyse stereoselective reactions.<br>• To interpret oxidation and reduction reactions. | | | |
| **Course Outcomes:** | Students will be able to: | | **Mapped to PSO** | |
| | CO 1. understand knowledge of basic reaction mechanisms in organic transformation. | | PSO2 | |
| | CO 2. apply chirality in organic synthesis. | | PSO2 | |
| | CO 3. compare configurations/ conformations of organic molecules. | | PSO2 | |
| | CO 4. assess oxidizing and reducing reagents in organic synthesis. | | PSO2 | |
| **Content:** | | **No of** | **Mapped** | **Cognitive** |

| | | hours | to CO | Level |
|---|---|---|---|---|
| **Module 1:** | 1. Fundamentals of organic chemistry:<br>Electron movement with arrows, half and double headed arrows (Cleavage of bonds: homolysis and heterolysis) in organic reaction mechanisms; inductive effect, electromeric effect, resonance and hyperconjugation, steric hindrance, hydrogen bonding; reactivity of organic molecules: nucleophiles and electrophiles; reactive intermediates: carbocations, carbanions and free radicals; strength of organic acids and bases, aromaticity, benzenoids and Huckel's rule. | **8** | CO1 | K1, K2 |
| **Module 2:** | 2. Stereochemistry:<br>Conformations with respect to butane and cyclohexane; interconversion of wedge formula, Newmann, Sawhorse and Fischer representations; CIP Rules: R/S configurations. | **3** | CO2, CO3 | K2, K3, K4 |
| **Module 3:** | 3. Substitution, elimination and addition reactions:<br>Substitution and elimination reactions (SN1, SN2, E1 and E2), addition of different groups on olefins. | **2** | CO1 | K2, K3 |
| **Module 4:** | 4. Oxidation and reduction reactions:<br>Basic concepts, oxidizing and reducing reagents and some examples. | **2** | CO4 | K3, K4 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions can preferably be interactive to enable peer group learning. | | | |
| **Texts:** | 1. D. Nassipuri, Stereochemistry of Organic compounds - Principles and Application, 4th ed., Wiley Eastern Limited, New Academic Science Limited, Lucknow, India, 2013<br>2. E. L. Eliel, Stereochemistry of carbon compounds, Tata MacGraw Hill Publishing Company Ltd., New Delhi, 1990.<br>3. J. March, Advanced Organic Chemistry: Reaction, Mechanism and Structure, 4th ed., Wiley, USA, 2010.<br>4. J. Clayden, N. Greeves, S. Warren & Wothers, Organic Chemistry, 2nd ed., Oxford University Press, Oxford, 2012<br>5. I. L. Finar Stereochemistry and Chemistry of Natural products, Vol. 2, 3rd ed., , Longmans, ELBS London, 1963<br>6. F. A. Carey and R.J. Sundberg, Advanced Organic Chemistry, Vol. I & II. Plenum Press, New York, 1977<br>7. E. S. Gould et al., Mechanism and structure in Organic Chemistry, Holt, Rinehart And Winston, New York, 1965<br>8. F. A. Carey, Organic Chemistry, 4th ed., McGraw-Hill Higher Education, USA, 2000 | | | |

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|---|---|
| | 9. S. H. Pine, Organic Chemistry, 5th ed., McGraw-Hill International Education, New York, 2010 |
| **References/ Readings:** | 1. V. M. Potapov, Stereochemistry, MIR Publishers, Moscow, 1979<br>2. J. M. Harris & C.C. Wamser, Fundamentals of Organic Reaction Mechanisms, John Wiley & Sons. Inc. New Jersey, 1976.<br>3. F. M. Menger, D.J. Goldsmith & L. Mendell, Organic Chemistry, A concise approach, 2nd ed., Addison Wesley Longman, Boston 1975. |

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**SEMESTER I**

**Discipline Specific Core Courses**

| | |
|---|---|
| **Title of the Course** | Fundamental Concepts in Organic Chemistry |
| **Course Code** | CHO-5000 |
| **Number of Credits** | 4 |
| **Theory/Practical** | Theory |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

| | | |
|---|---|---|
| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To study the various concepts based on molecular orbital theory, Aromaticity, Acids and bases.<br>• To understand the concepts of stereochemistry and their significance in determining the structure, reactivity, and properties of organic molecules<br>• To understand the mechanistic aspects of various type of reactions in organic synthesis and the use of selective reagents in organic transformations. | |
| **Course Outcomes:** | Students will be able to: | **Mapped to PSO** |

| | | | | |
|---|---|---|---|---|
| | CO 1. Understand the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds. | | PSO1, PSO 2 | |
| | CO 2. Apply various concepts in stereochemistry to understand stereochemical outcome in a reaction. | | PSO1, PSO 2 | |
| | CO 3. Evaluate plausible mechanisms of organic reactions. | | PSO1, PSO2, PSO3 | |
| | CO 4. Apply various reagents for desired organic transformations. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1.1 Molecular orbitals and delocalized chemical bonding**<br>a. Qualitative description of molecular orbitals of simple acyclic and monocyclic systems, frontier molecular orbitals.<br>b. Conjugation, cross conjugation, hyperconjugation and tautomerism (types and examples).<br>c. Aromaticity: Origin of Huckel's rule, examples of aromatic, non-aromatic and antiaromatic compounds; concept of Mobius aromaticity.<br>**1.2 Structure & Reactivity**<br>a. Acidity, basicity and pKa of organic compounds; Acid and base strengths; HSAB concept & Factors affecting it, effect of structure & medium on acid and base strength.<br>b. Concept of superacids and superbases.<br>c. Electrophilicity & nucleophilicity, examples of ambident nucleophiles & electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution) | **15** | CO1 | K1, K2, K3, K4,K5 |
| **Module 2:** | **2. Stereochemistry**<br>a. Brief revision of configurational nomenclature: R & S; D & L; E & Z; cis & trans and *syn* & *anti* nomenclature. Chirality in molecules with two and more chiral centers.<br>b. Conformational analysis of open chain compounds (Butane, 2, 3-butane | **15** | CO2, CO3 | K1, K2, K3, K4, K5 |

| | | | | |
|---|---|---|---|---|
| | diol, 2,3-dibromobutane etc.). *Erythro* and *threo* nomenclature.<br>c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and diastereotopic, ligands and faces.<br>d. Chemoselective, regioselective and stereoselective reactions with examples.<br>e. Conformation and reactivity of cyclohexane and substituted cyclohexanes, cyclohexene / cyclohexanone. Conformational isomerism and analysis in acyclic and simple cyclic systems substituted ethane, cyclopentane, cyclohexane.<br>f. Optical isomerism - optical activity - molecular dissymmetry and chirality - elements of symmetry. optical isomerism in biphenyls, allenes and spirans - optical isomerism of nitrogenous compounds racemisation and resolution. | | | |
| **Module 3:** | **3.1 Reaction Mechanism**<br>a. Structure, stability and reactivity of reactive intermediates (carbocations, carbanions, free radicals, carbenes, arynes and nitrenes)<br>b. Types of mechanisms, types of reactions, thermodynamic and kinetic control.<br>c. Methods of determining reaction mechanisms:<br>i. Identification of products.<br>ii. Determination of the presence of intermediates (isolation, detection, trapping and addition of suspected intermediate.<br>iii. Isotopic labelling.<br>iv. Stereochemical evidence.<br>v. Kinetic evidence and Isotope effect.<br>(at least two examples to be covered for above methods)<br>**3.2 Selective reagents for Organic transformation**<br>a. Oxidation of organic compounds: PCC, PDC and $MnO_2$, ozonolysis, | **15** | CO2, CO3 | K1, K2, K3, K4, K5 |

| | | | | |
|---|---|---|---|---|
| | peracids.<br>b. Reduction of organic compounds: $NaBH_4$, LAH, DIBAL reduction and reduction with borane and dialkylboranes. Clemmensen reduction, Birch reduction and Wolff-Kishner reduction | | | |
| **Module 4:** | **4.1 Aliphatic Nucleophilic substitution**<br>a. Nucleophilic substitutions with respect to mechanism and various factors affecting such reactions.<br>b. The Neighbouring Group Participation (NGP)/ Anchimeric assistance: General approach to various NGP processes; NGP by unshared/lone pair of electrons; NGP by π-electrons; NGP by aromatic rings (formation of phenonium ion intermediate); NGP by sigma bonds with special reference to bornyl and nor- bornyl system (formation of nonclassical carbocation)<br>**4.2 Elimination reactions**<br>a. The E2, E1 and E1cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule.<br>b. Effects of substrate, base, leaving group and medium on:<br>i. Overall reactivity<br>ii. E1 vs. E2 vs. E1cB<br>iii. Elimination vs substitution, mechanism and orientation in pyrolytic *syn* elimination (various examples involving cyclic and acyclic substrates to be studied). | **15** | CO3. CO4 | K1, K2, K3, K4, K5 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. R. T. Morrison, R. N. Boyd, S. K. Bhattacharjee, Organic Chemistry, 7th ed. Pearson Education, New Delhi, 2010<br>2. D. Nassipuri, Stereochemistry of Organic Compounds: Principles and Applications, 4th ed. New Age International, New Delhi, 2020<br>3. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, 2nd ed. Oxford University Press, Oxford, 2012 | | | |

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|---|---|
| | 4. J. March, Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 4th ed. Wiley Student Edition, New York, 2003.<br>5. P. S. Kalsi, Stereochemistry: Conformation and Mechanism, 11th ed. New Age International, New Delhi, 2022<br>6. E. L. Eliel, S. H. Wilen, Stereochemistry of Organic Compounds, 1st ed. John Wiley and Sons, New York, 1994<br>7. H. O. House, Modern Synthetic Reactions, 2nd ed. W. A. Benjamin, New York, 1965<br>8. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, 5th ed. Springer India Private Limited, New Delhi, 2007 |
| **References/ Readings:** | 1. R. Bruckner, Advanced Organic Chemistry: Reaction Mechanisms, 1st ed. Harcourt/Academic Press, San Diego, 2002.<br>2. P. Y. Bruice, Organic Chemistry, 8th ed, Pearson, New Delhi, 2020 |

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| | |
|---|---|
| **Title of the Course** | Concise Inorganic Chemistry |
| **Course Code** | CHI-5000 |
| **Number of Credits** | 4 |
| **Theory/Practical** | Theory |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

| | | |
|---|---|---|
| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To explain fundamentals of solid state, coordination, organometallic, bioinorganic, and environmental chemistry.<br>• To describe atomic structure, molecular structure, bonding, and symmetry in molecules.<br>• To know fundamental aspects of elements & their compounds.<br>• To comprehend the effects of pollution, and its treatments. | |
| **Course Outcomes:** | Students will be able to: | **Mapped to PSO** |
| | CO 1. explain basic concepts in solid state, coordination, organometallic, bioinorganic, and environmental chemistry. | PSO1, PSO2 |
| | CO 2. illustrate characteristic of inorganic compounds related to biology and environment. | PSO2, PSO3 |
| | CO 3. analyze molecular structure and their properties. | PSO1, PSO3 |

| | CO 4. design compounds for various applications. | | PSO4 | |
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| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Atomic structure, molecular structure and bonding**<br>a. Atomic Structure: Structures of hydrogenic atoms: some principles of quantum mechanics, atomic orbitals. Many electron atoms: penetration & shielding, building up principle, classification of elements. Spectroscopic terms. Atomic properties: atomic radii, ionic radii, ionization energy, electron affinity, electronegativity, polarizability.<br>b. Molecular Structure & bonding: Lewis structures: octet rule, resonance. VSEPR model: basic shapes, modification of the basic shapes. Valence bond theory: hydrogen molecule, homonuclear diatomic molecules, polyatomic molecules, promotion, hypervalence, hybridization. Molecular orbital theory: approximation, boding & antibonding orbitals. Homonuclear diatomic molecules & heteronuclear diatomic molecules. | **10** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Module 2:** | **2. Solid state chemistry**<br>a. Structures of solids: crystal structures, lattices and unit cells, fractional atomic coordinates and projections, close packing of spheres, holes in closed-packed structures.<br>b. Structures of metals & alloys: polytypism, nonclosed-packed structures, polymorphism of metals, atomic radii of metals, alloys, substitutional and interstitial solid solutions, intermetallic compounds.<br>c. Ionic solids: characteristic structures of ionic solids, binary phases, ternary phases, rationalization of structures, ionic radii, radius ratio, structure maps, energetics of ionic bonding, lattice energy and Born Haber cycle, calculation of lattice enthalpies (numerical expected). | **10** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Module 3:** | **3. Molecular Symmetry and chemistry of *d*- and *f*- block elements**<br>a. Symmetry elements and symmetry operations, equivalent symmetry elements and equivalent atoms, symmetry point groups and molecular symmetry. Systematic | **15** | CO1, CO2, CO3, | K2, K3, K4, K5 |

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| | procedure for symmetry classification of molecules. Dipole moment, optical activity and point groups.<br>b. *d*-block elements**:**<br>Zinc, cadmium and mercury: occurrence and properties. Transition element: IUPAC definition, occurrence and physical properties, chemical properties, metal halides, metal oxides & oxido compounds, metal sulfides and sulfide compounds, metal-metal bonded compound and clusters, magnetic properties.<br>c. *f*-block elements:<br>Lanthanides; occurrence and physical properties, lanthanide contraction, oxidation states, compounds of lanthanides, electronic, optical and magnetic properties.<br>Actinoid; occurrence and properties, oxidation states, general trends, electronic spectra, thorium and uranium. | | CO4 | |
| **Module 4:** | **4. Coordination, Organometallic and Bioinorganic Chemistry**<br>a. Coordination chemistry: Introduction, representative ligands, nomenclature. Constitution and geometry, isomerism & chirality in square planar and octahedral complexes, ligand chirality.<br>Electronic properties of metal complexes: CFT applied to octahedral and tetrahedral complexes, magnetic moments, CFSE.<br>Electronic spectroscopy: basic concepts, Orgel diagram for octahedral and tetrahedral complexes of $d^1$ & $d^9$ ions.<br>b. Organometallic Chemistry: Introduction to organometallic chemistry, nomenclature, stability and inert gas rules (neutral atom, and donor pair electron count methods). Homoleptic metal carbonyls - synthesis, properties, and spectroscopic studies.<br>c. Bioinorganic Chemistry: Macronutrients/micronutrients. Role of elements in biology. Metallobiomolecules, metalloporphyrins, structure of porphin and heme group, iron porphyrins (Haemoglobin and myoglobin), examples of metalloenzymes of Cu and Zn. | **15** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Module 5:** | **5. Environmental Chemistry**<br>Directive of the Supreme Court in 1993 to introduce environmental education at all levels. | **10** | CO1, CO2, CO3, | K2, K3, K4, K5 |

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| | a. Air Pollution: Classification of air pollutants and photochemical reactions in the atmosphere. Common air pollutants (e.g. CO, NOx, $SO_2$, hydrocarbons and particulates)<br>i. sources<br>ii. physiological and environmental effect<br>iii. monitoring,<br>iv. various remedial & technological measures to curb pollution. Air quality standards.<br>b. Water pollution: Importance of buffer & buffer index in waste water treatments. Chemical, physical & biological characteristics of water pollution, specific & non-specific characterization of water. DO, BOD, COD, and chlorine demand, typical water treatment & waste water treatment (Municipal). Impact of plastic pollution and its effect. | | CO4 | |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature toenable peer group learning. | | | |
| **Texts:** | 1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed., Oxford University Press, Oxford, 2009.<br>2. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed., Wiley India, New delhi, 2008 (reprint).<br>3. F. A. Cotton, Chemical applications of group theory, 3rd Ed., Wiley India, New Delhi, 2012 (reprint).<br>4. A. K. De, Environmental Chemistry, 3rd Ed., New Age Intl. Publishers, New Delhi, 2005.<br>5. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed., Pearson, New Delhi, 2011.<br>6. J. D. Lee, Concise Inorganic Chemistry, 5th Ed., Wiley India, New Delhi, 2008.<br>7. H. V. Keer, Principles of Solid State Chemistry, 1st Ed., New Age Intl. Ltd, New Delhi, 1993, (reprint 2008).<br>8. A. R. West, Solid State Chemistry and Its Applications, 1st Ed., Wiley India, New Delhi, 1984 (reprint 2007).<br>9. D. K. Chakrabarty, Solid State Chemistry, 2ed Ed., New Age Intl. Publishers, New Delhi, 2010.<br>10. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., New Delhi, 2017.<br>11. A. V. Salker, Environmental Chemistry: Pollution and Remedial Perspective, 1st Ed., Narosa Publication, New | | | |

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| | Delhi, 2017. |
| **References/ Readings:** | 1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6rd Ed., Wiley India, New Delhi, 2003 (reprint 2012).<br>2. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed., Pearson, New Delhi, 2004. |

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| **Title of the Course** | Fundamentals of Physical Chemistry |
| **Course Code** | CHP-5000 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To introduce various mathematical and computational concepts of chemistry<br>• To gain knowledge of core concepts of physical chemistry i.e. thermodynamics, kinetics, quantum chemistry and electrochemistry<br>• To inculcate critical thinking and apply the knowledge of physical chemistry concepts in problem solving<br>• To understand and apply physical chemistry principles to other areas of chemistry | |
| **Course Outcomes:** | Students will be able to: | **Mapped to PSO** |
| | CO 1. Explain various concepts in physical chemistry. | PSO1, PSO2 |
| | CO 2. Utilise concepts of electrochemistry and their applications in renewable energy generation and storage. | PSO1, PSO6 |
| | CO 3. Demonstrate the concepts during the lab course in physical chemistry. | PSO3, PSO4, PSO5 |

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| | CO 4. Apply fundamentals of chemical kinetics and thermodynamics for understanding reaction processes and mechanisms | | PSO3, PSO7 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Mathematical Preparations**<br>a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. complex numbers and complex functions.<br>b. Linear equations, vectors, matrices and determinants.<br>c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting.<br>d. Introduction to series, convergence and divergence, power series, Fourier series<br>e. Probability (permutations and combinations). | **10** | CO1, CO3 | K1, K2, K3 |
| **Module 2:** | **2. Quantum Chemistry**<br>a. Operators, Functions, Eigen value equations, Postulates.<br>b. Schrödinger equation, application to simple system viz. free particle, particle in one dimensional, two dimensional and three-dimensional box (quantization, separation of variables, degenerate wave functions).<br>c. Hydrogen like atoms, Schrödinger equation and its solutions, atomic orbital wave functions and interpretation.<br>d. Hückel MO theory, Secular equations, Secular determinant, delocalization energy, charge density, π-bond order, free valence, applications to $C_2H_4$, $C_3H_5$ (radical), $C_4H_6$, $C_4H_4$, $C_6H_6$, $C_6H_8$. | **20** | CO1, CO3 | K1, K2, K5 |
| **Module 3:** | **3. Thermodynamics**<br>a. Thermodynamic properties: Gas laws, real gases, Boyle temperature, critical temperature, state and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy and | **12** | CO1, CO3, CO4 | K1, K2, K3, K5 |

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| | their relations and significances. Maxwell relations. Thermodynamic equations of state.<br>b. Joule-Thomson effect. Joule-Thomson coefficient for van der Waals' gas. Joule-Thomson effect and production of low temperature, adiabatic demagnetization, Joule-Thomson coefficient, inversion temperature.<br>c. The third law of thermodynamics. Need for the third law. Apparent exceptions to third law. Application of third law. Use of thermodynamic functions in predicting direction of chemical change. Entropy and third law of thermodynamics.<br>d. Phase equilibria: Phase rule, Discussion of two component systems forming solid solutions with and without maximum or minimum in freezing point curve. Systems with partially miscible solid phases.<br>e. Three component systems: Graphical representation. Three component liquid systems with one pair of partially miscible liquids. Influence of temperature. Systems with two pairs and three pairs of partially miscible liquids. The role of added salts. | | | |
| **Module 4:** | **4. Electrochemistry**<br>a. EMF series, cell potential: Nernst equation, Cells at equilibrium. Determination of thermodynamic functions.<br>b. Decomposition potential and overvoltage, electronegativity, basic principles, completeness of deposition, separation with controlled potentials, constant current electrolysis, composition of electrolyte, potential buffers, physical characteristics of metal deposits.<br>c. Electroplating and electroless plating, electrosynthesis.<br>d. Concepts of acid-base aqueous and non-aqueous solvents, hard and soft acid-base concept and applications. | **9** | CO1, CO2, CO3 | K1, K2, K3, K5, K6 |
| **Module 5:** | **5. Chemical Kinetics**<br>a. General introduction to various types of order of reaction including fractional order, molecularity of the reaction. | **9** | CO1, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. van't Hoffs equation and analysis of Gibbs free energy of equilibrium reactions.<br>c. Collision theory and Maxwell Boltzmann distribution of energies of colliding molecules. The concept of collisional cross section and reactive cross section and its significance.<br>d. Comparative study of transition state and collision state theory.<br>e. Reaction Mechanisms: elementary reactions, consecutive elementary reactions, steady state approximation, the rate determining step and pre-equilibria.<br>f. Free radical reactions, complex reactions such as acetaldehyde decomposition and reaction between $H_2$ and $Br_2$. Homogeneous reactions and acid-base catalysis.<br>g. Elementary enzyme reactions. Lineweaver-Burk plot and its analysis. | | | |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. P. W. Atkins and J. D. Paula, Physical Chemistry, 8th ed., Oxford University Press, New Delhi. 2007<br>2. G. M. Barrow, Physical Chemistry, 5th ed., Tata McGraw Hill, New Delhi. 2016<br>3. J. E. House, Principles of Chemical Kinetics, 2nd ed., Academic Press, Elsevier Burlington, USA, 2007<br>4. I. N. Levine, Quantum Chemistry, 7th ed., Prentice-Hall, New Delhi. 1999.<br>5. S. Glasstone, Text Book of Physical Chemistry, D. Van Nostrand Company, New York, Reprint 1942. | | | |
| **References/ Readings:** | 1. B. R. Puri, L. R. Sharma and M. S. Pathania, Principles of Physical Chemistry, 49th ed., Vishal Publishing Co., New Delhi, 2020<br>2. A. Saggion, R. Faraldo, M. Pierno, Thermodynamics - Fundamental Principles and Applications, Springer, Switzerland, 2019<br>3. J. Bockris, A. K.N. Reddy, M. E. Gamboa-Aldeco, Modern Electrochemistry: Fundamentals of Electrodics, Vol. 2A, 2nd ed., Kluwer Academic Publishers, New York, 2002<br>4. J. Bockris, A. Reddy, Modern Electrochemistry: Ionics, Vol. 1, 2nd ed., , 2nd Ed., Kluwer Academic Publishers, New York, 2002 | | | |

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| | 5. J. E. House, Principles of Chemical Kinetics, 2nd ed., Academic Press, Burlington MA, 2007<br>6. J. P. Lowe, K. Peterson, Quantum Chemistry, 3rd ed., Elsevier, Burlington MA, 2006<br>7. R. G. Mortimer, Physical Chemistry, 3rd ed., Elsevier, Burlington MA, 2008 |

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| **Title of the Course** | Analytical Chemistry Techniques |
| **Course Code** | CHA-5000 |
| **Number of Credits** | 4 |
| **Theory/Practical** | Theory |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To learn various methods of data handling in analysis.<br>• To explain the significance of sampling and calibration techniques.<br>• To understand principles and applications of various types of techniques<br>• To train the students to deduce structures based on IR, NMR, MS combined data. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the role of statistical tools for determination of error and organize data management for systematic interpretation. | PSO1 |
| | CO 2. analyse the appropriate technique for thermoanalytical studies. | PSO1 |
| | CO 3. explain basic principles and scope of different methods of separation and techniques of analysis | PSO1. PSO2 |

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| | CO 4. solve problems based on IR, NMR, MS combined spectral data. | | PSO1, PSO2, PSO3 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1.1. Analytical Objectives and Data Handling:**<br>Importance of analytical chemistry in research and industry; statistics and data handling in analytical chemistry, standard operating procedures, good laboratory practices: quality assurance, method validation and quality control. | **5** | CO1 | K1, K2, K3, K4 |
| | **1.2. Sampling and Calibration Techniques:**<br>Sampling and sample preparation, general steps in chemical analysis, calibration of glassware. Finding the best straight line - least square regression, correlation coefficient; Calibration curves, standard addition, external standards and internal standards. Chemical concentrations.<br>Classical methods of Analysis: Gravimetry and Titrimetric methods: Principle, methodology, advantages & disadvantages over instrumental methods. | **5** | CO1 | K1, K2, K3, K4 |
| | **1.3. Thermoanalytical techniques:**<br>Principle, instrumentation and applications of Thermogravimetric Analysis (TGA), Differential Thermal Analysis (DTA), and Differential Scanning Calorimetry (DSC). Numericals based on TGA. | **5** | CO1, CO2 | K1, K2, K3, K4, K5 |
| **Module 2:** | **2.1. Concepts in Chromatography**<br>Principles of chromatography, classification of chromatographic techniques based on mechanism of retention, configuration, mobile and stationary phase.<br>Efficiency of separation- plate theory (theoretical plate concept) and rate theory (van Deemter equation). | **4** | CO3 | K1, K2, K3, K4, K5 |
| | **2.2. Chromatographic techniques**<br>Principles and applications of Paper chromatography, thin layer chromatography, HPTLC, Size exclusion and Ion exchange chromatography. Counter-current chromatography for isolation of natural products. | **4** | CO3 | K1, K2, K3, K4, K5 |

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| | **2.3. Gas and Liquid Chromatography**<br>Introduction; Instrumental Modules; Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, GCIR, LCMS: Applicability, interpretation and numericals. | **7** | CO3 | K1, K2, K3, K4, K5 |
| **Module 3:** | **3.1. Spectroscopic Techniques**<br>Interaction of Electromagnetic Radiation with Matter, Electromagnetic spectra, regions of spectrum, numericals.<br>Ultraviolet and visible Spectroscopy: Electronic spectra and Molecular structure: types of electronic transition, Chromophore and auxochrome, absorption by isolated chromophore, conjugated chromophores, aromatic<br>compounds, inorganic chelates. Choices and effect of solvents on UV-Vis. Quantitative Calculations: Beer-Lambert Law; Mixtures of absorbing species-laws of additivity of absorbance; calibration curve for calculation of unknown; Spectrometric errors in measurement; Deviation from Beer-Lambert Law - chemical deviation, instrumental deviation; Numericals for quantitative analysis using UV-Vis spectroscopy.<br>Infrared Spectroscopy: Infrared absorption and molecular structures, molecular vibrations, types of vibrations, IR spectra, overtones and bands-basis of NIR absorption.<br>Spectrometric instrumentation of UV-Vis and IR: Sources, monochromators, sample cells, detectors, instrumental wavelength and absorption calibration. | **10** | CO4 | K1, K2, K3, K4, K5, K6 |
| | **3.2. Applications of UV-Vis spectroscopy for qualitative analysis**<br>Calculating λmax for Conjugated Dienes, Trienes, polyenes, α,β-unsaturated carbonyl compounds, Numericals.<br>Applications of IR spectroscopy for qualitative analysis: Spectra interpretation, Frequencies of functional group, Spectral Databases, Identification of unknown compounds. | **5** | CO4 | K3, K4, K5 |

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| **Module 4:** | **4.1. Raman Spectroscopy**<br>Theory, Basic instrumentation and Structural analysis using Raman Spectra.<br>Mass Spectrometry: Principle, Instrumentation and various fragmentation patterns. | **5** | CO4 | K2, K3, K4 |
| | **4.2. Proton and Carbon NMR Spectroscopy**<br>Theory of NMR, Instrumentation, Chemical shift, factors influencing chemical shift, solvents used in NMR, spin-spin splitting, coupling constant calculation, factors influencing coupling constant. | **5** | CO4 | K1, K2, K3, K4, K5, K6 |
| | **4.3. Conjoint spectrometry problems**<br>Structural elucidation of organic molecules using IR, UV, NMR and MS. | **5** | CO4 | K3, K4, K5, K6 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. G. D. Christian, Analytical Chemistry, 6th Ed., Wiley, Singapore, 2004.<br>2. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th Ed., McGraw- Hill Int., New York, 1985.<br>3. W. Kemp, Organic Spectroscopy, 3rd Ed., Palgrave, New York, 1991.<br>4. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed., Cengage learning, USA, 2014.<br>5. R. M. Silverstein, F. X. Webster, Spectrometric identification of Organic Compounds, 6th Ed., Wiley, USA, 1998.<br>6. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2009<br>7. F. J. Holler, D. A. Skoog, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed., Thomson Books, London, 2007.<br>8. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7th Ed., HCBS Publishing, India, 2004.<br>9. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., Tata McGraw- Hill, India, 2006.<br>10. P. S. Kalsi, Spectroscopy of Organic Compounds, 2nd Ed., New Age International, New Delhi, 2000. | | | |
| **References/ Readings:** | 1. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990.<br>2. H. Gunzler, A. Williams, Handbook of Analytical Techniques, 1st Ed., Wiley, Germany, 2001.<br>3. E. Pretsch, P. Buhlmann, C. Affolter, Structural Determination of Organic Compounds, 2nd Ed., Springer, | | | |

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| | Germany, 2005.<br>4. L. D. Field, S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4th Ed., Wiley, Singapore, 2007.<br>5. R. A. Day, A. L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, USA, 2001.<br>6. B. K Sharma, Instrumental methods of chemical analysis, Goel Publishing House, Meerut, 2004.<br>7. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 6th Ed., Wiley, USA, 2009.<br>8. P. J. Larkin, Infrared and Raman Spectroscopy: principles and spectral interpretation, 2nd Ed., Elsevier, Netherland, 2018. |

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**SEMESTER II**

**Discipline Specific Core (DSC) Courses**

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| **Title of the Course** | Coordination and Organometallic Compounds: Bonding to Reactivity |
| **Course Code** | CHI-5001 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2025-26 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Nil |
| **Course Objectives:** | • To understand the bonding, spectroscopic, and magnetic properties of compounds.<br>• To explain the thermodynamic and kinetic principles governing reaction mechanisms.<br>• To learn reaction pathways of coordination and organometallic compounds.<br>• To learn synthetic strategies for transformation of transition metal compounds. |

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| **Course Outcomes:** | Students will be able to | | **Mapped to PSO** | |
| | CO 1. explain the bonding, properties and reaction mechanisms of coordination and organometallic compounds. | | PSO1, PSO2 | |
| | CO 2. utilize spectroscopic data, mechanistic principles and bonding model to predict properties, stability, and reactivity of transition metal compounds. | | PSO1, PSO2 | |
| | CO 3. analyze spectroscopic data and deduce mechanistic pathways to correlate with the structural, electronic, and catalytic features of coordination and organometallic compounds. | | PSO1, PSO3 | |
| | CO 4. design synthetic routes, propose catalytic cycles, and critically assess mechanistic alternatives for transformations involving coordination and organometallic compound. | | PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Bonding, electronic and magnetic properties of coordination compounds**<br>Electronic structure and bonding: Crystal field theory and its applications in (i) Octahedral compounds; (ii) tetrahedral compounds; (iii) square-planar compounds and (iv) tetragonally distorted compounds (Jahn-Teller Effect); Molecular orbital theory (MOT): σ & π-bonding in octahedral, tetrahedral, square planar compounds.<br>Electronic spectra of compounds: Selection rules, colour and intensities; Charge transfer bands; Correlation diagrams: examples and problem solving using (i) Orgel diagrams and (ii) Tanabe-Sugano diagrams.<br>Magnetic studies: Cooperative magnetism, basic concepts of magnetic properties: diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, temperature dependent magnetism, Curie law, Curie Weiss law, Spin cross over phenomenon. | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| **Module 2:** | **Inorganic reaction mechanisms**<br>Thermodynamics of complex formation: Formation constants; Trends in successive formation constants; The chelate and macrocyclic effects; Steric effects and electron delocalization.<br>Ligand substitution reactions and mechanisms: Rates of ligand substitution; The classification of mechanisms; Ligand substitution in square-planar compounds: the nucleophilicity of the entering group, the shape of the transition state; Ligand substitution in octahedral compounds: rate laws and their interpretation, the activation of octahedral compounds, and stability of coordination compounds; Hydrolysis reaction: acid and base hydrolysis.<br>Redox reactions: The classification of redox reactions; The inner-sphere mechanism; The outer-sphere mechanism: self-exchange and cross exchange reaction, Marcus equation; Photochemical reactions: Prompt and delayed reactions; Transitions in metal–metal bonded systems. | **15** | CO1, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 3:** | **Organometallic chemistry of transition metals**<br>Organometallic compounds with ligands such as Carbon monoxide, Phosphines, Hydrides and dihydrogen compounds, $\eta^1$-Alkyl, -alkenyl, -alkynyl, and - aryl ligands, $\eta^2$-Alkene and -alkyne ligands, nonconjugated diene and polyene ligands, butadiene, cyclobutadiene, and cyclooctatetraene, benzene and other arenes, the allyl ligand, cyclopentadiene and cycloheptatriene, carbenes, alkanes, agostic hydrogens, and noble gases, dinitrogen and nitrogen monoxide.<br>Metal carbonyls: Classification, bonding, evidences for synergistic bonding, factors affecting the magnitude of stretching frequency; Carbonylate ions: synthesis, properties, reactions and synthetic applications.<br>Metal clusters: metal carbonyl clusters, electron counting in clusters, metal–metal bonding, binuclear clusters containing metal-metal bonds; Metallocenes: bonding, | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | molecular orbital diagram, synthesis, properties and reactions of metallocene; Isolobal analogy; fluxionality in cyclic polyene compounds. | | | |
| **Module 4:** | **Reactions and mechanism of organometallic compounds**<br>Ligand substitution reactions, Oxidative addition and reductive elimination, σ-Bond metathesis, 1,1-Migratory insertion reactions, 1,2-Insertions and β-hydride elimination, α-, β-, and δ-Hydride eliminations and cyclometallations.<br>Catalysis: general concepts, catalytic cycle for isomerization of prop-2-en-l-ol to prop-1-en-l-ol, alkene metathesis, hydrogenation of alkenes, hydroformylation, Wacker oxidation of alkenes, asymmetric oxidations, palladium catalyzed C-C bond forming reactions, methanol carbonylation (Monsanto acetic acid process). | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd ed., Wiley India, New delhi, 2008 (reprint).<br>2. J. D. Lee, Concise Inorganic Chemistry, 5th ed., Wiley India, New Delhi, 2008.<br>3. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th ed., Pearson, New Delhi, 2011.<br>4. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th ed., Oxford University Press, Oxford, 2009. | | | |
| **References/ Readings:** | 1. A. Kumar, Organometallic and Bioinorganic Chemistry, 4th Ed; Aaryush Education, Muzaffarnagar, 2021.<br>2. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6rd ed., Wiley India, New Delhi, 2003 (reprint 2012).<br>3. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd ed., Pearson, New Delhi, 2004. | | | |

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|---|---|
| **Title of the Course** | Solid State Chemistry |
| **Course Code** | CHI-5002 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2025-26 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites For the Course:** | Nil | |
| **Course Objectives:** | • To understand the fundamentals of solid-state chemistry, including atomic structure, bonding, defects, and properties of solids and their reactivity and transformations.<br>• To gain knowledge about the synthesis of materials and characterization techniques.<br>• To study the relationship between the structure, composition, and material properties.<br>• To learn material synthesis with desired properties and applications. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the fundamental relationship between the crystal structure, method of preparation, reactivity and properties of various materials. | PSO1, PSO2, PSO4 |

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| | CO 2. apply different preparative techniques for synthesis of materials and establish the structure-property relationship. | | PSO1, PSO2, PSO3, PSO4 | |
| | CO 3. correlate the properties of the materials with respect to various types of bonds and preparation methods. | | PSO1, PSO2, PSO3 | |
| | CO 4. design materials for various applications in electronics, catalysis, sensors, etc. | | PSO1, PSO2, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Structure, bonding, crystal defects & non-stoichiometry in Solids**<br>Materials Chemistry: properties, structure and applications of materials.<br>Structure and bonding in solid materials: Crystal lattice; unit cell; Miller indices and planes; X-Ray diffraction method; Molecular, Metallic, Covalent and Ionic solids, Hydrogen bonding; Structural classification of binary and tertiary compounds; Spinel and Perovskite structures.<br>Crystal defects & Non-stoichiometry in Solids: Types of defects: Point defects, Dislocations: Line defects and Plane defects, Oxygen deficient oxides; Metal deficient oxides and classification of non-stoichiometry. | **15** | CO1, CO2, CO3 | K1, K2, K3, K4, K5 |
| **Module 2:** | **Materials preparation techniques**<br>Broad Classification of methods: Ceramic method, and Different wet chemical methods.<br>Types of Materials: Powdered bulk materials, Single crystal and Thin films, Amorphous materials, and Nanomaterials.<br>Preparation methods for different materials with their advantages and disadvantages:<br>i. Powder materials: Co-precipitation method, Precursor method, Combustion method: Solid state and solution method, Precursor-combustion method, Sol-gel method, Spray roasting method, Freeze drying method, Flux method. | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K6 |

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| | ii. Single crystals: (a) Growth from melt (b) from solution (c) using Flux method (d) Epitaxial growth of single crystal thin films: Using Chemical and Physical methods (e) Chemical vapour transport (f) Hydrothermal method (g) Dry high pressure method.<br>iii. Amorphous Materials: Synthesis & applications.<br>Nanomaterials: Synthesis, properties: structural, optical and magnetic and applications. | | | |
| **Module 3:** | **Reactivity and phase transformations in solid materials**<br>Reactivity in solids: Tarnish reactions, decomposition reaction, solid-solid reactions, addition reactions, double decomposition reaction, electron transfer reaction, solid-gas reactions, sintering, factors influencing reactivity of solids.<br>Phase transformations in solid: Thermodynamic consideration, Burgers classification, structural change in phase transformation, Martensite transformation, temperature and pressure induced transformations, order-disorder transitions, electronic transition, transformation with a change in composition, enantiotropy and monotropy, Ehrenfest classification, ternary phase diagram. | **10** | CO1, CO2, CO3 | K1, K2, K3, K4 |
| **Module 4:** | **Electrical, magnetic, optical, and dielectric Properties**<br>Electrical conductivity, free electron theory, Fermi energy, insulators, semiconductors and conductors, band theory of semiconductor, Brillouin zones, Hall effect, Peltier effect, Seebeck effect, photo conductivity and ionic conductivity, Semiconductor devices: Diodes and transistors, Junction field effect transistor and metal oxide semiconductor field effect transistor, light meter, photodiode, phototransistor, solar cells, light emitting diodes. Laser materials. Superconductivity: BCS theory, Meissner effect, high temperature superconductor.<br>Introduction to magnetism, behavior of substance in a magnetic field, magnetic moments, diamagnetism, paramagnetism, experimental determinations of susceptibility, | **20** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | ferromagnetism, anti-ferromagnetism and ferrimagnetism, magnetization of ferromagnetic substance.<br>Luminescence, piezoelectric, ferroelectric materials and applications, thermal conductivity, phonon interaction, thermal expansion coefficient. | | | |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. R. West, Solid State Chemistry and Its Applications, 2st Ed., John Wiley & Sons, Singapore, 2022.<br>2. D. K. Chakraborty, Solid State Chemistry, 2nd Ed.; New Age International Publisher, New Delhi, 2010.<br>3. H. V. Keer, Principles of the Solid State, 1st Ed., New Age International (P) Ltd., (Wiley Eastern Ltd,), New Delhi, 1993, (Reprint 2008).<br>4. L. V. Azaroff, Introduction to solids, 1st Ed., McGraw Hill Education, Delhi, 2016, (40th Reprint).<br>5. N. B. Hannay, Treatise on Solid State Chemistry Vol.4 Reactivity of Solids, 1st Ed.; Plenum Press, New York, 1976. | | | |
| **References/ Readings:** | 1. B. D. Fahlman, Materials Chemistry, 2nd Ed.; Springer, Michigan, 2011.<br>2. C. N. R Rao & Gopalkrishnan, New directions in solid state chemistry, 2nd Ed.; Cambridge University Press, Cambridge, 1997.<br>3. C. N. R. Rao & K. J. Rao, Phase Transitions in Solid, 1st Ed.; McGraw Hill, England, 1977.<br>4. H. R. Allcock, Introduction to materials chemistry, 1st Ed.; John Wiley & Sons, New Jersey, 2011.<br>5. W. D. Callister, Materials Science and Engineering: An Introduction, 7th Ed.; John Wiley, New Jersey, 2007. | | | |

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| **Title of the Course** | Molecular Symmetry and Spectroscopy |
| **Course Code** | CHI-5003 |
| **Number of Credits** | 4 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2025-26 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Nil | |
| **Course Objectives:** | • To describe concepts in molecular symmetry and spectroscopy.<br>• To understand fundamental aspects of molecular symmetry and spectroscopy.<br>• To study the spectral data for structure determination of molecules.<br>• To learn the application of molecular symmetry and spectroscopy. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain symmetry and spectroscopic aspects of molecules. | PSO1 |
| | CO 2. apply concepts of molecular symmetry and spectroscopy in structural analysis. | PSO2 |

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| | CO 3. analyse spectra of molecules to determine molecular geometry. | | PSO3 | |
| | CO 4. evaluate molecular symmetry and spectroscopic data for chemical analysis. | | PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Molecular symmetry**<br>Group and it's defining properties, order of the group, examples of group, group multiplication table, cyclic group, acyclic group, abelian group, non-abelian group. Sub groups, classes, properties of conjugate elements. Symmetry elements and operations, symmetry planes and reflections, the inversion centre, proper axes and proper rotations, improper axis and improper rotations. Products of symmetry operations, equivalent symmetry elements and equivalent atoms, relations among symmetry elements and operations, symmetry elements and optical isomerism, symmetry point groups, symmetries with multiple high order axes, classes of symmetry operations, procedure for symmetry classification of molecules.<br>Representation of groups, some properties of matrices and vectors, the great orthogonality theorem, reducible and irreducible representations, irreducible representations and their characters, character tables. Basis for irreducible representations, direct product. Symmetry Adapted Linear Combinations and its applications. Symmetry aspects of molecular orbital theory and molecular vibrations in organic, inorganic and organometallic compounds.<br>Crystal symmetry, crystallographic point groups, space groups and X-ray Crystallography. | **30** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 2:** | **Spectroscopy**<br>Magnetic Resonance Spectroscopy; interaction between electron spin / nuclear spin and magnetic field, Resonance condition, instrumental requirements, Presentation of | **30** | CO1, CO2, CO3, | K1, K2, K3, K4, K5 |

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| | ESR (electron spin resonance) and NMR (nuclear magnetic resonance) spectra, line widths of ESR and NMR spectra, number of expected ESR signals for one electron paramagnetic species, hyperfine coupling in isotropic systems (e.g. H atom, methyl radical etc.), anisotropic system, zero field splitting and Kramer's degeneracy, Spin energy levels of octahedral Mn(II) compounds, spin Hamiltonian, nuclear quadrupole interaction, Electron delocalization, ESR spectra of some transition metal compounds, NMR spectral interpretation of a few nuclei like $^{19}F$, $^{29}Si$, $^{31}P$.<br>Mössbauer spectroscopy; Mössbauer effect, Mössbauer principle, Recoilless emission and absorption spectral line widths, Doppler shift, experimental arrangement of Mössbauer spectroscopy, chemical shift (isomer shift), quadrupole splitting, magnetic hyperfine interaction, discussion of selected Mössbauer nuclei like $^{57}Fe$, $^{129}I$.<br>Vibrational spectroscopy: Infrared spectroscopy and Raman spectroscopy, principle, their use in determination of molecular structure. | | CO4 | |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.; Tata McGraw Hill, New Delhi, 1994.<br>2. F. A. Cotton, Chemical applications of group theory, 3rd Ed.; Wiley Eastern, New York, 2012 (reprint).<br>3. G. Aruldhas, Molecular structure and spectroscopy, Prentice Hall of India, New Delhi, 2001.<br>4. G. R. Desiraju, J. J. Vittal, A. Ramanan, Crystal Engineering, 1st Ed.; IISC Press, world Scientific, New York, 2011.<br>5. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, Chennai, 2011.<br>6. R. L. Dutta, A. Syamal, Elements of Magnetochemistry, 2nd Ed.; Affiliated East-West Press, New Delhi, 1993.<br>7. R. S. Drago, Physical Methods in Inorganic Chemistry, 1st Ed.; Affiliated East West Press Pvt. Ltd., New Delhi, | | | |

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| | 2017. |
| **References/ Readings:** | 1. A.K. Brisdon, Inorganic Spectroscopic Methods, 1st Ed.; Oxford University Press, New York, 1998.<br>2. E. A. V. Ebsworth, D. W. H. Rankin, S. Cradock, Structural Methods in Inorganic Chemistry, 1st Ed.; Blackwell Scientific Publications, New York, 1988.<br>3. J.M. Hollas, Symmetry in Molecules, 1st Ed.; Chapman & Hall Ltd., London, 1972.<br>4. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part A: Theory and Applications in Inorganic Chemistry, 6th Ed.; Wiley, New Jersey, 2009.<br>5. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part B: Applications in Coordination, Organometallic and Bioinorganic Chemistry, 6th ed.; Wiley, New Jersey, 2009.<br>6. L.-L. Ooi, Principles of X-ray Crystallography, 1st Ed.; Oxford University Press, New York, 2010.<br>7. P. Atkins, J. De Paula, J. Keeler, Atkins' Physical Chemistry, 1st Ed.; Oxford University Press, New York, 2018.<br>8. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, New York, 2009. |
| **Web Resources:** | https://symotter.org/ |

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| **Title of the Course** | Concepts and Applications in Inorganic Chemistry |
| **Course Code** | CHI-5004 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2025-26 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Nil | |
| **Course Objectives:** | • To develop a comprehensive understanding and explore the applications of s-block compounds.<br>• To introduce the role of inorganic compounds in medicinal chemistry.<br>• To establish a strong conceptual foundation in nuclear chemistry.<br>• To strengthen theoretical and practical understanding of acid-base chemistry. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the fundamental principles of inorganic chemistry including atomic structure, periodic properties, acid-base theories, and chemical bonding. | PSO1, PSO2, PSO3, PSO4 |

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| | CO 2. analyze the roles and applications of inorganic compounds in medicine, nuclear chemistry, and industry. | | PSO1, PSO2, PSO3, PSO4 | |
| | CO 3. evaluate the physico chemical behavior of inorganic compounds under various conditions, including redox processes, solubility patterns, and the effects of solvents and acids and bases. | | PSO1, PSO2, PSO3, PSO4 | |
| | CO 4. demonstrate awareness of the societal and technological relevance of inorganic chemistry, including its impact in healthcare, energy, and environmental management. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **s-Block elements and their compounds**<br>Hydrogen and hydrides; Electronic structure, position in periodic table, abundance, preparation, properties, isotopes, ortho and para hydrogen. Classification of hydrides, preparation & properties of hydrides; hydrogen ion, hydrogen bonding and its influence on properties.<br>Group 1 elements; Introduction, abundance, extraction, physical and chemical properties, solubility and hydration, solutions of metal in liquid ammonia, complexes, crowns and cryptands, electrides, alkalides, difference between lithium and the other group 1 elements, diagonal relationship between Li and Mg.<br>Group 2 elements; Introduction, abundance, extraction, physical and chemical properties, solutions of metal in liquid ammonia, complexes, anomalous behaviour of beryllium, difference between beryllium and the other group 2 elements, diagonal relationship between Be and Al, preparation and properties of Grignard reagent. | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 2:** | **Inorganic medicinal chemistry**<br>Anticancer agents; Platinum and Ruthenium complexes as anticancer drugs, chemotherapy, phototherapy, radiotherapy using borane compounds. | **15** | CO1, CO2, CO3, | K1, K2, K3, K4, K5, K6 |

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| | Chelation therapy.<br>Gadolinium and technetium complexes as MRI contrast agents, X-ray contrast agents.<br>Anti-arthritis drugs.<br>Anti-bacterial agents (Ag, Hg, Zn and B compounds).<br>Antiseptic and anti-biotic.<br>Deodorants and anti-perspirants. | | CO4 | |
| **Module 3:** | **Chemistry of radioactive elements**<br>Atomic nucleus; Classification of nuclides and nuclear stability.<br>Review of Nuclear models.<br>Radioactivity, Decay processes and decay energy, half-life of radioactive elements.<br>Nuclear reactions; Nuclear fission and fusion processes.<br>Nuclear Reactors; Nuclear reactor components and functions, Q values for nuclear reactions.<br>Detection and measurement of activity; Radiation detection principles.<br>Physical and Chemical separation techniques of radioactive elements.<br>Radio-analytical techniques, Activation analysis.<br>Nuclear waste management.<br>Applications of radioactivity. | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 4:** | **Acids and Bases**<br>Brønsted acidity; Proton transfer equilibria in water, Solvent levelling, The solvent system definition of acids and bases, Characteristics of Brønsted acids, Periodic trends in aqua acid strength, Simple oxoacids, Anhydrous oxides, Polyoxo compound formation, Nonaqueous solvents. | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |

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| | Lewis acidity, Examples of Lewis acids and bases, Group characteristics of Lewis acids.<br>Reactions and properties of Lewis acids and bases; The fundamental types of reaction, Hard and soft acids and bases, Thermodynamic acidity parameters, Solvents as acids and bases.<br>Applications of acid–base chemistry, Superacids and superbases, Heterogeneous acid–base reactions. | | | |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, India, 2008 (reprint).<br>2. H. J. Arnikar, Essentials of Nuclear Chemistry, 4th Revised Ed.; New Age Intl. Publishers, India, 2011.<br>3. J. D. Lee, Concise Inorganic Chemistry, 5th Ed.; Wiley, India, 2008.<br>4. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, India, 2011.<br>5. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford University Press, Great Britain, 2009. | | | |
| **References/ Readings:** | 1. A. G. Sykes, Advances in Inorganic Chemistry, 1st Ed.; Academic Press Ltd., UK, 1990.<br>2. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley Eastern, India, 2001.<br>3. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, India, 2004.<br>4. G. R. Choppin, J-O. Linjenzin, J. Rydberg, C. Ekberg, Radiochemistry and Nuclear Chemistry, 4th Ed.; Academic Press, USA, 2013.<br>5. K.A. Strohfeldt, Essentials of Inorganic Chemistry, 1st Ed.; John Willey & Sons, UK, 2015.<br>6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd Ed., Butterworth-Heinemann Ltd, UK, 1997. | | | |

**SEMESTER I & II**

**Discipline Specific Elective Courses**

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| **Title of the Course** | Organic Chemistry Practical - I |
| **Course Code** | CHO-5201 |
| **Number of Credits** | 2 |
| **Theory/Practical** | Practical |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To understand essential laboratory equipment, safety protocols, and fundamental experimental purification techniques<br>• To create practical skills in basic organic synthesis through key reactions, including electrophilic substitution and other important transformations.<br>• To understand the methods of isolation and purification of naturally occurring organic compounds. | |
| **Course Outcomes:** | Students will be able to: | **Mapped to PSO** |
| | CO 1. Understand stoichiometric requirements during organic syntheses. | PSO1, PSO3, PSO4 |

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| | CO 2. Apply safe and good laboratory practices and develop skills in handling laboratory glassware, equipment and chemical reagents. | | PSO1, PSO3, PSO4 | |
| | CO 3. Create the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC). | | PSO1, PSO3, PSO4 | |
| | CO 4. Assess their expertise in isolation of some important natural products. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1.1 Introduction to laboratory equipment, apparatus and safety**<br>a. Use of common laboratory equipment like fume hood, vacuum pump, weighing balance.<br>b. Introduction to various types of quick fit joints and apparatus.<br>c. Safety Techniques:<br>i. Disposal of chemicals<br>ii. Personal Protective Equipment (PPE)<br>iii. First aid<br>iv. Fire extinguishers, types of fire<br>v. Chemical hazards and risk assessment<br>**1.2 Laboratory Techniques-I**<br>a. Simple distillation (any one):<br>i. Toluene-dichloromethane mixture using water condenser.<br>ii. Nitrobenzene and aniline using air condenser.<br>b. Steam distillation (any one):<br>i. Separation of o- and p- nitrophenols.<br>ii. Naphthalene from its suspension in water.<br>iii. Clove oil from cloves.<br>c. Crystallisation: Concept of induction of crystallization (any one)<br>i. Crystallisation of phthalic acid from hot water using fluted filter paper and stemless funnel. | **16** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | ii. Acetanilide from boiling water<br>iii. Naphthalene from ethanol.<br>iv. Decolorisation and crystallization of brown sugar (sucrose) with animal charcoal using gravity filtration. | | | |
| **Module 2:** | **2 Laboratory Techniques-II**<br>a. Sublimation: Simple or vacuum sublimation of camphor, naphthalene, anthracene or succinic acid (any one).Vacuum distillation (any one): o-dichlorobenzene, diphenyl ether. Explanation of use of nomograph.<br>b. Thin layer Chromatography (any one):<br>i. Separation of o and p-nitroanilines.<br>ii. Separation of analgesic drugs (ibuprofen/paracetamol)<br>iii. Separation of o and p-nitrophenols | **12** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 3:** | **3. Organic synthesis (Any Four experiments)**<br>a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol & acetone.<br>b. Aromatic electrophilic substitution (any one):<br>i. Preparation of p-bromoacetanilide.<br>ii. Bromination of acetophenone to phenacyl bromide<br>iii. Nitration of napththalene to 1-nitronaphthalene<br>iv. Nitration of benzaldehyde to 3-nitrobenzaldehdye.<br>c. Oxidation (any one)<br>i. Benzoic acid from toluene.<br>ii. Cyclohexanone from cyclohexanol.<br>iii. Isoborneol to camphor using Jones reagent.<br>d. Reduction (any one)<br>i. Reduction of o-nitroaniline to o-phenylenediamine using Sn/HCl<br>ii. Reduction of p-nitro benzaldehyde to p-nitrobenzyl alcohol using $NaBH_4$.<br>e. Bromination of an alcohol using $CBr_4$/ triphenylphosphine.<br>f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. | **16** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | g. Aldol condensation: Dibenzalacetone from benzaldehyde<br>h. Acetoacetic ester condensation: Preparation of ethyl n-butylacetoacetate or ethyl acetoacetate. | | | |
| **Module 4:** | **Organic synthesis and synthetic reagents (Any two)**<br>a. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate.<br>b. Friedel Craft's reaction<br>i. using toluene and succinic anhydride<br>ii. Resorcinol to resacetophenone, benzene and maleic anhydride to benzoylacrylic acid.<br>c. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation.<br>d. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, $MnO_2$.<br>e. Preparation of cuprous chloride.<br>**Isolation from natural sources (Any two)**<br>i. Caffeine from tea powder.<br>ii. Piperine from pepper.<br>iii. Cinnamaldehyde from cinnamon<br>iv. Lemongrass oil from lemongrass | **16** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |
| **Pedagogy:** | Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. | | | |
| **Texts:** | 1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th ed. Prentice Hall, New Delhi, 2011<br>2. K. Tanaka, Solvent-Free Organic Synthesis, 2nd ed, Wiley-VCH, Weinheim, 2009.<br>3. L. F. Fieser, K. L. Williamson, Organic Experiments, 7th ed. D. C. Heath, Lexington, 1992.<br>4. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th ed. Cengage Learning, Boston, 2010<br>5. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5th ed. New Age International, New Delhi, 2016<br>6. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory: Standard and Microscale Experiments, 3rd | | | |

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| | ed. Saunders College Publishing, Philadelphia, 2009 |
| **References/ Readings:** | 1. S. Delvin, Green Chemistry, 1st ed. Sarup & Sons, New Delhi, 2005<br>2. J. Mohan, Organic Analytical Chemistry, 1st ed. Narosa Publishing House, New Delhi, 2014<br>3. T. Laue, A. Plagens, Named Organic Reactions, 1st ed. John Wiley and Sons, Inc., Hoboken, 2005 |

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| **Title of the Course** | Organic Chemistry Practical - II |
| **Course Code** | CHO-5202 |
| **Number of Credits** | 2 |
| **Theory/Practical** | Practical |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To familiarize students with essential laboratory equipment, safety protocols, and fundamental experimental purification techniques<br>• To develop practical skills in basic organic synthesis through key reactions, including electrophilic substitution and other important transformations.<br>• To introduce the methods of isolation and purification of naturally occurring organic compounds. | |
| **Course Outcomes:** | Students will be able to: | **Mapped to PSO** |
| | CO 1. Understand stoichiometric requirements during organic syntheses. | PSO1, PSO3, PSO4 |
| | CO 2. Apply safe and good laboratory practices and develop skills in handling laboratory glassware, equipment and chemical reagents. | PSO1, PSO3, PSO4 |
| | CO 3. Create the practical knowledge to perform experiments involving common | PSO1, PSO3, PSO4 |

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| | laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC). | | | |
| | CO 4. Assess their expertise in isolation of some important natural products. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1.1 Introduction to laboratory equipment, apparatus and safety**<br>a. Common Hazards in Chemical Laboratory, Risk assessment<br>b. Accidents and Emergency procedures<br>**1.2 Laboratory Techniques (Any Three)**<br>a. Simple distillation:<br>i. Simple distillation of thionyl chloride under anhydrous condition<br>ii. Simple distillation under Nitrogen atmosphere of THF<br>b. Fractional distillation:<br>i. Chloroform-dichloromethane mixture using water condenser.<br>ii. Toluene and cyclohexane using fractionating column.<br>c. Vacuum distillation under inert atmosphere:<br>Distillation of DMF, o-dichlorobenzene, $POCl_3$<br>d. Thin layer Chromatography:<br>i. Purification and isolation of mixture of acids (o-nitrobenzoic acid and p-nitrobenzoic acid) by using Preparative TLC.<br>ii. Purification and isolation of mixture of phenols (o and p-nitrophenols) by using Preparative TLC.<br>iii. Purification and isolation of pharmaceutical drugs (ibuprofen tablet) using Preparative TLC. | **16** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 2:** | **Organic Synthesis (Any Four)**<br>a. p-Iodonitrobenzene by Sandmeyer reaction<br>b. Pinacol- Pinacolone rearrangement | **16** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | c. Hydrogenation of Maleic acid (Hydrogen balloon)<br>d. Preparation of nitrostyrene from aldehyde<br>e. Preparation of dibromocinnamic acid<br>f. Reduction of nitro compounds<br>g. Synthesis of Urea from ammonium cyanate | | | |
| **Module 3:** | **3. Two-step Organic Synthesis (Any Two)**<br>a. Benzamide-Benzoic acid-Ethyl Benzoate<br>b. Phthalic anhydride-Phthalimide-Anthranilic acid.<br>c. Methyl benzoate- m-nitrobenzoate- m-nitrobenzoic acid<br>d. Chlorobenzene-2, 4 -dinitrochlorobenzene-2,4 dinitrophenol<br>e. Acetanilide-p-Bromoacetanilide-p-Bromoaniline<br>f. Acetophenone-Oxime-Acetanilide | **16** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 4:** | **4.1 Solvent Free Organic synthesis (Any One)**<br>a. Reduction using ball milling technique<br>b. Oxidation of 2° alcohol using $KMnO_4$/Alumina by grinding technique.<br>c. Synthesis of 1,1'-Bi-2-naphthol (BINOL)<br>d. Hunsdiecker reaction of cinnamic acid derivatives<br>e. Beckmann rearrangement of oxime derivatives<br>**4.2 Separation, Isolation and Identification of Organic compounds (Any One)**<br>Separation, purification and identification of compounds of binary mixture (Solid-Solid, Solid-liquid and Liquid-liquid) using the TLC and column chromatography, chemical tests.<br>IR spectra to be used for functional group identification. | **12** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |
| **Pedagogy:** | Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. | | | |
| **Texts:** | 1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th ed. Prentice Hall, New Delhi, 2011<br>2. K. Tanaka, Solvent-Free Organic Synthesis, 2nd ed, Wiley-VCH, Weinheim, 2009 | | | |

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| | 3. L. F. Fieser, K. L. Williamson, Organic Experiments, 7th ed. D. C. Heath, Lexington, 1992<br>4. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th ed. Cengage Learning, Boston, 2010<br>5. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5th ed. New Age International, New Delhi 2016<br>6. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory: Standard and Microscale Experiments, 3rd ed. Saunders College Publishing, Philadelphia, 2009 |
| **References/ Readings:** | 1. S. Delvin, Green Chemistry, 1st ed. Sarup & Sons, New Delhi, 2005.<br>2. J. Mohan, Organic Analytical Chemistry, 1st ed. Narosa Publishing House, New Delhi, 2014.<br>3. T. Laue, A. Plagens, Named Organic Reactions, 1st ed. John Wiley and Sons, Inc., Hoboken, 2005 |

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| **Title of the Course** | Inorganic Chemistry Practical-I |
| **Course Code** | CHI-5201 |
| **Number of Credits** | 2 |
| **Theory/Practical** | Practical |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To acquire skills in synthetic inorganic chemistry.<br>• To gain knowledge about various laboratory chemicals.<br>• To determine metal and ligand content in a material.<br>• To evaluate compounds molecular formula to find lattice water molecules. | |
| **Course Outcomes:** | Students will be able | **Mapped to PSO** |
| | CO 1. explain the synthesis of coordination compounds. | PSO1, PSO4 |
| | CO 2. estimate metals in the coordination compounds by classical methods of analysis. | PSO1, PSO3 |
| | CO 3. characterise commercially available ores and alloys. | PSO2, PSO3 |

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| | CO 4. choose the appropriate instrumental methods of analysis for characterization ofcompounds | | PSO1, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Preparations of Inorganic Compounds (ANY 07)**<br>a. Preparation of hexaamminenickel(II) chloride or hexaamminenickel(II) sulfate.<br>b. Preparation of tris(ethylenediamine)cobalt(III) chloride.<br>c. Preparation of potash alum from scrap aluminum.<br>d. Preparation of potassium trioxalatoaluminate(III) trihydrate.<br>e. Preparation of potassium hexathiocyanato-$\kappa N$-chromate(III) tetrahydrate.<br>f. Preparation of potassium trioxalatochromate(III) trihydrate.<br>g. Preparation of $\alpha$- and $\gamma$-$Fe_2O_3$.<br>h. Preparation of Zinc acetate or $[Zn_4O(CH_3CO_2)_6]$.<br>(Powder X-Ray Diffraction (PXRD), Infrared (IR), UV-vis spectroscopy and magnetic studies is expected) | **28** | CO1, CO2 | K2, K3, K4, K5 |
| **Module 2:** | **2. Estimations / Determinations (ANY 08)**<br>a. Estimation of nickel by complexometry or Gravimetry.<br>b. Estimation of cobalt in $[Co(en)_3]Cl_3$ by complexometry.<br>c. Estimation of oxalate in $K_3[Al(C_2O_4)_3]\cdot xH_2O$ or $K_3[Cr(C_2O_4)_3]\cdot xH_2O$<br>d. Estimation of nitrite by redox titration.<br>e. Estimation of calcium from calcite ore.<br>f. Iodometric determination of copper in commercial copper compounds / alloys.<br>g. Estimation of sulfate by gravimetry.<br>h. Estimation of zinc by complexometric titration.<br>i. Determination of chromium in chrome alum and $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ and to determine degree of hydration. | **32** | CO3, CO4 | K2, K3, K4, K5 |

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| | j. Estimation of potassium from synthesized compounds.<br>k. Colorimetric/Spectrophotometric determination of nickel or chromium or manganese. | | | |
| **Pedagogy:** | Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th Ed., Pearson, New Delhi, 2002.<br>2. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed., Pearson, New Delhi, 2011.<br>3. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>4. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed., Chapman & Hall, New York, 1974.<br>5. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970.<br>6. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972. | | | |
| **References/ Readings:** | 1. S. De Meo, J. Chem. Ed., 80 (2003) 796-798.<br>2. A. J. Elias, General Chemistry Experiments, Revised Ed., University Press, Hyderabad, 2008. | | | |

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| **Title of the Course** | Inorganic Chemistry Practical-II | |
| **Course Code** | CHI-5202 | |
| **Number of Credits** | 2 | |
| **Theory/Practical** | Practical | |
| **Level** | 400 | |
| **Effective from AY** | 2025-26 | |
| **New Course** | Yes | |
| **Bridge Course/ Value added Course** | No | |
| **Course for advanced learners** | No | |

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| **Pre-requisites for the Course:** | Nil | |
| **Course Objectives:** | • To acquire skills in synthetic inorganic chemistry.<br>• To gain knowledge about various laboratory chemicals.<br>• To determine metal and ligand content in a material.<br>• To evaluate compounds molecular formula to find lattice water molecules. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. understand methodologies related to compound synthesis. | PSO1, PSO4 |
| | CO 2. experiment with various reagents and metal salts to synthesize useful compounds. | PSO1, PSO4 |

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| | CO 3. analyse synthesized and commercially available compounds. | | PSO1, PSO3 | |
| | CO 4. interpret the chemical composition of materials using chemical methods and instrumental techniques. | | PSO1, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Preparations / Estimation of Inorganic Compounds: (Any Nine)**<br>a. Preparation of hexaamminecobalt(III) nitrate.<br>b. Estimation of cobalt in hexaamminecobalt(III) nitrate by volumetric titration.<br>c. Preparation of Potassium Trioxalatoferrate(III) Trihydrate<br>d. Estimation of iron and oxalate by redox titration<br>e. Synthesis of metal nanoparticles (Cu, Ag, Au, Ni) and determining the absorption maxima by UV-visible spectrophotometer.<br>f. Estimation of amount of calcium in given sample by gravimetric method.<br>g. Estimation of amount of nickel in given sample by gravimetric method.<br>h. Estimation amount of zinc present in given sample by gravimetric method.<br>i. Estimation of iron by colorimetric / spectrophotometry method.<br>j. Estimation of barium by complexometric titration method.<br>k. Estimation of manganese in presence of iron by complexometric titration method.<br>(Powder X-Ray Diffraction (PXRD), Infrared (IR), UV-vis spectroscopy and magnetic studies is expected) | **40** | CO1, CO2, CO3 | K2, K3, K4, K5 |
| **Module 2:** | **2. Semi-micro qualitative analysis of cation and anion in a given inorganic mixture: (Any four mixture)**<br>Mixture containing total six cations and/or anions. | **20** | CO3, CO4 | K2, K3, K4, K5 |

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| | **Cations :** $Pb^{2+}$, $Cu^{2+}$, $Cd^{2+}$, $Sn^{2+}$, $Fe^{2+}$, $Fe^{3+}$, $Al^{3+}$, $Cr^{3+}$, $Zn^{2+}$, $Mn^{2+}$, $Ni^{2+}$, $Co^{2+}$, $Ba^{2+}$, $Sr^{2+}$, $Ca^{2+}$, $Mg^{2+}$, $(NH_4)^{+}$, $K^{+}$<br>**Anions:** $Cl^{-}$, $Br^{-}$, $I^{-}$, $NO_2^{-}$, $NO_3^{-}$, $SO_3^{2-}$, $CO_3^{2-}$, $SO_4^{2-}$, $PO_4^{3-}$, $S^{2-}$ | | | |
| **Pedagogy:** | Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2002.<br>2. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed., Pearson, New Delhi, 2011.<br>3. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>4. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed., Chapman & Hall, New York, 1974.<br>5. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972.<br>6. A. J. Elias, General Chemistry Experiments, Revised Ed., University Press, Hyderabad, 2008.<br>7. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970. | | | |
| **References/ Readings:** | 1. S. De Meo, J. Chem. Ed., 80 (2003) 796-798. | | | |

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| **Title of the Course** | Physical Chemistry Practical-I |
| **Course Code** | CHP-5201 |
| **Number of Credits** | 02 |
| **Theory/Practical** | Practical |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To develop experimental skills on basic lab techniques in physical chemistry<br>• To understand fundamental laboratory concepts and acquire skills for data acquisition, analysis and interpretation<br>• To understand and follow safety protocols for handling chemicals, equipment and instruments.<br>• To apply the practical laboratory concepts for synthesis, problem solving and critical thinking<br>• To develop research skills through the principles of laboratory chemical research. | |
| **Course Outcomes:** | Students will be able to: | **Mapped to PSO** |
| | CO 1. Explain and perform various fundamental lab techniques and experiments. | PSO1 |
| | CO 2. Handle and operate basic laboratory equipment and use it for research work. | PSO1, PSO4 |
| | CO 3. Apply the laboratory knowledge and skills for their dissertation and research work. | PSO4, PSO5, PSO6, PSO7 |

| | CO 4. Design synthesis and/or experimental methods. | | PSO5, PSO6, PSO7 | |
|---|---|---|---|---|
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Non- instrumental Experiments (Any 08)**<br>1. To study the kinetics of hydrolysis of ethyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.<br>2. To determine the order of reaction between potassium persulphate and potassium iodide by graphical, fractional change and differential methods.<br>3. To study the three-component system such as acetic acid, chloroform and water and obtain tie line.<br>4. To determine the molecular weight of polyvinyl alcohol by viscosity measurement.<br>5. To study the electro-kinetics of rapid reaction between $SO_4^{2-}$ and $I^-$ in an aqueous solution.<br>6. To determine the buffer capacity of acidic buffer solution.<br>7. To determine the partial molal volume of ethanol-water mixture at a given temperature.<br>8. To measure energy content of various types of plastics using bomb calorimetry<br>9. To determine number average molecular weight of a polymer sample with an indirect titration method.<br>10. To investigate basic hydrolysis of ethyl acetate at four different temperatures and find out energy of activation<br>11. To construct a phase diagram for a two-component system by plotting cooling curves for mixtures of different compositions.<br>12. To find the surface tension of methyl alcohol, ethyl alcohol and n-hexane at room temperature and then calculate the atomic parachors of carbon, hydrogen and oxygen. | **32** | CO1, CO3, CO4 | K2, K3, K4, K5 |
| **Module 2:** | **2. Instrumental Experiments (Any 07)**<br>1. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometer. | **28** | CO2, CO3, CO4 | K3, K4, K5 |

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| | 2. To determine the dissociation constants of a tribasic acid (Phosphoric acid obtain derivative plot to get equivalence point.<br>3. To determine formal redox potential of $Fe^{2+}/Fe^{3+}$ and $Ce^{3+}/Ce^{4+}$ system obtain derivative plot to get equivalence point.<br>4. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate)<br>5. To determine Avogadro's number by improved electroplating.<br>6. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids.<br>7. To verify the Kohlrausch's law for weak electrolyte by conductometry.<br>8. To determine the transport numbers of $Cu^{2+}$ and $SO_4^{2-}$ ions in $CuSO_4$ solution by Hittorf's method. | | | |
| **Pedagogy:** | Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions can preferably be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. V. D. Athawale, P. Mathur, Experimental Physical Chemistry, New Age International Publishers, 1st ed., New Delhi, 2001.<br>2. J.N. Gurtu, A. Gurtu, Advanced Physical Chemistry Experiments, Pragati Publications, 1st ed., Meerut, 2008.<br>3. A. Findlay & J. A. Kitchener, Practical Physical Chemistry, Longmans, Green and Co., 1st ed., London 1954.<br>4. F. Daniels & J. H. Mathews, Experimental Physical Chemistry, McGraw-Hill, 1st ed., New York, 1941. | | | |
| **References/ Readings:** | 1. A. M. James, Practical Physical Chemistry, Prentice Hall Press, 3rd ed., 1974.<br>2. D.P. Shoemaker & C. W. Garland, Experiments in Physical Chemistry, McGraw-Hill, 1st ed., New York, 1962.<br>3. T. Kandow & F. Mafune, Progress in experimental and theoretical studies of clusters, World Scientific publishers, 1st ed., New Jersey, 2002.<br>4. C. Arora & S. Bhattacharya, Advanced Physical Chemistry Practical Guide, Bentham Science Publishers, 1st ed., UAE, 2022.<br>5. A. K. Hagi, L. Pogliani, A. C. F. Ribeiro, Practical applications of Physical Chemistry in food science and technology, 1st ed., Apple Academic Press, USA, 2021. | | | |

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|---|---|
| **Title of the Course** | Physical Chemistry Practical-II |
| **Course Code** | CHP-5202 |
| **Number of Credits** | 02 |
| **Theory/Practical** | Practical |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | NIL | |
| **Course Objectives:** | • To develop experimental skills on basic lab techniques in physical chemistry<br>• To understand fundamental laboratory concepts and acquire skills for data acquisition, analysis and interpretation<br>• To understand and follow safety protocols for handling chemicals, equipment and instruments.<br>• To apply the practical laboratory concepts for synthesis, problem solving and critical thinking<br>• To develop research skills through the principles of laboratory chemical research. | |
| **Course Outcomes:** | Students will be able to: | **Mapped to PSO** |
| | CO 1. Explain and perform various fundamental lab techniques and experiments. | PSO1 |
| | CO 2. Handle and operate basic laboratory equipment and use it for research work. | PSO1, PSO4 |
| | CO 3. Apply the laboratory knowledge and skills for their dissertation and research work. | PSO4, PSO5, PSO6, PSO7 |

| | CO 4. Design synthesis and/or experimental methods. | | PSO5, PSO6, PSO7 | |
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| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Non- instrumental Experiments (Any 09)**<br>1. To determine the radius of a molecule by viscosity measurements.<br>2. To determine ΔG, ΔH and ΔS of silver benzoate by solubility product method.<br>3. To investigate the adsorption of oxalic acid by activated charcoal and test the validity of Freundlich and Langmuir's isotherms.<br>4. To determine the molecular weight of a given polymer by turbidimetry.<br>5. To study the rate of reaction between ethyl bromoacetate and sodium thiosulphate kinetically.<br>6. To determine the percentage composition of a given mixture of two liquids by stalagmometer method.<br>7. To study the kinetics of hydrolysis of methyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.<br>8. To study the kinetics of the reaction between potassium persulphate ($K_2S_2O_8$), and potassium iodide (KI), and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.<br>9. To determine the order of reaction for hydrolysis of ethyl acetate by graphical, fractional change and differential methods.<br>10. To determine the molecular weight of polystyrene by viscosity measurement. | **36** | CO1, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 2:** | **2. Instrumental Experiments**<br>1. To determine the relative strength of chloroacetic acid and acetic acid by conductometry.<br>2. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry.<br>3. To determine the composition of a mixture of acetic acid, dichloroacetic acid and hydrochloric acid by conductometric titration.<br>4. To determine the dissociation constants of monobasic acid and dibasic acid and obtain derivative plot to get equivalence point. | **24** | CO2, CO3, CO4 | K2, K3, K4, K5 |

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| | 5. To determine the redox potential of $Fe^{2+}/Fe^{3+}$ system by titrating it with standard $K_2Cr_2O_7$ solution.<br>6. To study the electrodeposition of metal. | | | |
| **Pedagogy:** | Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions can preferably be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. V. D. Athawale, P. Mathur, Experimental Physical Chemistry, New Age International Publishers, 1st ed., New Delhi, 2001.<br>2. J.N. Gurtu, A. Gurtu, Advanced Physical Chemistry Experiments, Pragati Publications, 1st ed., Meerut, 2008.<br>3. A. Findlay & J. A. Kitchener, Practical Physical Chemistry, Longmans, Green and Co., 1st ed., London 1954.<br>4. F. Daniels & J. H. Mathews, Experimental Physical Chemistry, McGraw-Hill, 1st ed., New York, 1941. | | | |
| **References/ Readings:** | 1. A. M. James, Practical Physical Chemistry, Prentice Hall Press, USA 3rd ed., 1974.<br>2. D.P. Shoemaker & C. W. Garland, Experiments in Physical Chemistry, McGraw-Hill, 1st ed., New York, 1962.<br>3. T. Kandow & F. Mafune, Progress in experimental and theoretical studies of clusters, World Scientific publishers, 1st ed., New Jersey, 2002.<br>4. C. Arora & S. Bhattacharya, Advanced Physical Chemistry Practical Guide, Bentham Science Publishers, 1st ed., UAE, 2022.<br>5. A. K. Hagi, L. Pogliani, A. C. F. Ribeiro, Practical applications of Physical Chemistry in food science and technology, 1st ed., Apple Academic Press, USA, 2021. | | | |

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| **Title of the Course** | Analytical Chemistry Practical - I |
| **Course Code** | CHA-5201 |
| **Number of Credits** | 2 |
| **Theory/Practical** | Practical |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Nil | |
| **Course Objectives:** | • To perform various experimental techniques for analysis.<br>• To learn data analysis, handling and interpretation of spectra.<br>• To determine concentration of solutions.<br>• To use techniques for qualitative and quantitative estimation. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain data analysis, handling and interpretation of spectra. | PSO1, PSO3, PSO4 |
| | CO 2. apply different techniques for qualitative and quantitative estimation. | PSO1, PSO4 |
| | CO 3. determine concentration of solutions. | PSO1, PSO4 |
| | CO 4. perform various experimental techniques for analysis. | PSO1, PSO2, PSO3, PSO4 |

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| **Content:** | This course consists of 8 units of experiments in various areas of Analytical chemistry. Minimum 15 experiments which include at least 01 experiment from each unit to be performed. | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Statistics**<br>a. Calibration of selected Volumetric apparatus<br>b. Calibration of selected Laboratory instruments<br>c. Preparation of standard solutions and standardisation. | 4 | CO1, CO3 | K3, K4 |
| **Module 2:** | **2. Colorimetry/ UV-Visible Spectrophotometry**<br>a. Estimation of Iron from Pharmaceutical sample (Tablet/capsule) by thiocyanate method<br>b. Estimation of phosphoric acid in cola drinks by molybdenum blue method.<br>c. Estimation of $KNO_3$ by UV spectroscopy and $K_2Cr_2O_7$ by Visible spectroscopy<br>d. Simultaneous determination and Verification of law of additivity of absorbances ($K_2Cr_2O_7$ and $KMnO_4$). | 8 | CO2, CO3 | K3, K4, K5 |
| **Module 3:** | **3. Flame Spectrophotometry and AES/AAS/ICP Spectroscopy**<br>a. Estimation of Na and K in food supplements or cosmetic products.<br>b. Estimation of Pb in water sample by AES/AAS/ICP.<br>c. Estimation of Fe and Al in Iron ore sample by AES/AAS/ICP. | 8 | CO1, CO2 | K4, K5 |
| **Module 4:** | **4. Ion Exchange Chromatography and High-Performance Liquid Chromatography (HPLC)**<br>a. Separation and Estimation of chloride and bromide using Ion exchange chromatography.<br>b. Separation of anthracene and naphthalene using reverse phase chromatography<br>c. Separation of benzaldehyde and benzyl alcohol using normal phase chromatography. | 8 | CO2, CO4 | K4, K5 |
| **Module 5:** | **5. Volumetric Titrations**<br>a. Estimation of Ca in pharmaceutical tablet.<br>b. Estimation of Al and Mg in antacid tablet.<br>c. Estimation of CaO in cement. | 8 | CO3, CO4 | K4, K5 |

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| **Module 6:** | **6. Solvent Extraction and spectrophotometry**<br>a. Extraction of Cu as copper dithiocarbamate (DTC) using solvent extraction and estimation by spectrophotometry.<br>b. Determination of Ni as dimethylglyoxime complex by spectrophotometry.<br>c. Determination of silver as ion association complex with 1,10- phenanthroline and bromopyrogallol red. | 8 | CO3, CO4 | K4, K5 |
| **Module 7:** | **7. Demonstration and Interpretation Exercises**<br>a. Thermal studies: TG/DTA and Isothermal weight loss studies of various hydrated solids like $CuSO_4 \cdot 5H_2O$, $CaC_2O_4 \cdot H_2O$, $FeC_2O_4 \cdot 2H_2O$.<br>b. X-ray powder diffractometry: Calculation of lattice parameters from X-ray powder pattern of cubic system such as $NiMn_2O_4$, $CoFe_2O_4$.<br>c. IR spectra of urea, benzoic acid, copper sulphate pentahydrate etc. | 8 | CO1, CO2 | K3, K4 |
| **Module 8:** | **8. Demonstration**<br>a. Turbidimeter.<br>b. KF instrument.<br>c. Polarimeter.<br>d. LCMS.<br>e. NMR. | 8 | CO1, CO2 | K3, K4 |
| **Pedagogy:** | Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2009.<br>2. R. A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Pearson Education India, 2015.<br>3. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, USA, 2002.<br>4. R. M. Silverstein, F. X. Webster, D. Kiemle, D. Bryce, S. Samant, V. S. Nadkarni, Spectrometric Identification of Organic compounds, An Indian Adaptation, Wiley, India, 8th Ed., 2022<br>5. A. J. Elias, Collection of interesting chemistry experiments, University press, Hyderabad, 2002. | | | |
| **References/ Readings:** | 1. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, USA, 1994<br>2. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990. | | | |

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| | 3. A. Kar, Pharmaceutical Drug Analysis, New Age International, India, 2005.<br>4. M. Asadi, Beet-Sugar Handbook, John Wiley & Sons, USA, 2006.<br>5. R. E. Ardrey, Liquid Chromatography - Mass Spectrometry: An Introduction, John Wiley & Sons, England, 2003. |

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| **Title of the Course** | Analytical Chemistry Practical - II |
| **Course Code** | CHA-5202 |
| **Number of Credits** | 2 |
| **Theory/Practical** | Practical |
| **Level** | 400 |
| **Effective from AY** | 2025-26 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Nil | |
| **Course Objectives:** | • To perform various experimental techniques for analysis.<br>• To learn data analysis, handling and interpretation of spectra.<br>• To determine concentrations of solution.<br>• To use techniques for qualitative and quantitative estimation. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain data analysis, handling and interpretation of spectra. | PSO1, PSO3, PSO4 |
| | CO 2. apply different techniques for qualitative and quantitative estimation. | PSO1, PSO4 |
| | CO 3. determine concentration of solutions. | PSO1, PSO4 |
| | CO 4. perform various experimental techniques for analysis. | PSO1, PSO2, PSO3, PSO4 |

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| **Content:** | This course consists of 8 units of experiments in various areas of Analytical chemistry. Minimum 15 experiments which include at least 01 experiment from each unit to be performed. | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **1. Statistics**<br>a. Calibration of selected Volumetric apparatus<br>b. Calibration of selected Laboratory instruments<br>c. Preparation of standard solutions and standardisation. | 4 | CO1, CO3 | K3, K4 |
| **Module 2:** | **2. Titrimetric Analysis**<br>a. Standardisation and estimation of Chloride using precipitation titration (Mohr's method)<br>b. Analysis of commercial caustic soda by neutralisation method.<br>c. Determination of sulphates by complexometric titration. | 8 | CO2, CO3 | K3, K4, K5 |
| **Module 3:** | **3. Flame Spectrophotometry and AES/AAS/ICP Spectroscopy**<br>a. Estimation of sodium and potassium in food supplements or cosmetic products using flame photometer.<br>b. Estimation of chromium in water sample by AES/AAS/ICP.<br>c. Estimation of nickel, molybdenum in Hastelloy C-22 using AES/AAS/ICP. | 8 | CO1, CO2, CO3 | K4, K5 |
| **Module 4:** | **4. Natural product isolation and Ion Exchange Chromatography**<br>a. Isolation of cinnamaldehyde from cinnamon.<br>b. Isolation of caffeine from tea powder.<br>c. Separation and estimation of cadmium and zinc. | 8 | CO2, CO4 | K4, K5 |
| **Module 5:** | **5. UV-Visible Spectrophotometry and High-Performance Liquid Chromatography (HPLC)**<br>a. Estimation of $KNO_3$ and $K_2Cr_2O_7$ using UV- Visible spectroscopy.<br>b. Separation of benzaldehyde and benzoic acid using reverse phase HPLC.<br>c. Quantification of naphthalene in a sample using reverse phase HPLC. | 8 | CO3, CO4 | K4, K5 |
| **Module 6:** | **6. Solvent Extraction and spectrophotometry**<br>a. Spectrophotometric determination of aspirin/phenacetin/caffeine in APC tablet using | 8 | CO3, CO4 | K4, K5 |

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| | solvent extraction.<br>b. Colorimetric determination of iron with salicylic acid.<br>c. Determination of copper in brass sample by colorimetry. | | | |
| **Module 7:** | **7. Data Interpretation Exercises**<br>a. NMR/Mass spectra.<br>b. HPLC and GC chromatograph.<br>c. XRD powder pattern of cubic systems.<br>d. Thermogram of coordination compounds. | 8 | CO1, CO2 | K3, K4 |
| **Module 8:** | **8. Demonstration**<br>a. Turbidimeter.<br>b. KF instrument.<br>c. Polarimeter.<br>d. LCMS.<br>e. NMR. | 8 | CO1, CO2 | K3, K4 |
| **Pedagogy:** | Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2009.<br>2. R. A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Pearson Education India, New-Delhi, 2015.<br>3. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, USA, 2002.<br>4. R. M. Silverstein, F. X. Webster, D. Kiemle, D. Bryce, S. Samant, V. S. Nadkarni, Spectrometric Identification of Organic compounds, An Indian Adaptation, Wiley, India, 8th Ed., 2022<br>5. A. J. Elias, Collection of interesting chemistry experiments, University press, Hyderabad, 2002.<br>6. A. Kar, Pharmaceutical Drug Analysis, New Age International, India, 2005. | | | |
| **References/ Readings:** | 1. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, USA, 1994.<br>2. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990.<br>3. M. Asadi, Beet-Sugar Handbook, John Wiley & Sons, USA, 2006.<br>4. R. E. Ardrey, Liquid Chromatography - Mass Spectrometry: An Introduction, John Wiley & Sons, England, 2003. | | | |

**SEMESTER III**

**Research Specific Elective (RSE) Courses**

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| **Title of the Course** | Inorganic Chemistry Practical - III |
| **Course Code** | CHI-6000 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course:** | No |
| **Bridge Course/ Value added Course:** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses |
| **Course Objectives:** | 1. To acquire practical knowledge in purification of starting materials and synthesis of metal compounds.<br>2. To learn techniques of crystallization, separation and purification of synthesized metal compounds.<br>3. To study characterization of compounds by chemical and instrumental methods.<br>4. To gain experience in data analysis. |

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| **Course Outcomes:** | Students will be able to | | **Mapped to PSO** | |
| | CO 1. explain basic principles, procedures, and safety measures in chemical experiments. | | PSO1, PSO2, PSO3, PSO4 | |
| | CO 2. apply laboratory and instrumental techniques for synthesis and analysis of compounds. | | PSO1, PSO2, PSO3, PSO4 | |
| | CO 3. analyze experimental data to determine composition and properties of substances. | | PSO1, PSO2, PSO3, PSO4 | |
| | CO 4. evaluate accuracy of results and identify sources of error in experiments. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | *Minimum 28 experiments from the entire list shall be conducted* | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Experiments in coordination chemistry**<br>**Preparations (Any Five)**<br>i. Purification (distillation/recrystallisation) of ligands like acacH, en, carboxylic acids etc.<br>ii. Preparation of *bis*(acetylacetonate)manganese(II).<br>iii. Preparation of *tris*(acetylacetonate)manganese(III).<br>iv. Preparation of *tris*(thiourea)copper(I) sulfate.<br>v. Preparation of isomers *cis*-dichloro(ethylenediamine)cobalt(III) chloride and *trans*-dichloro(ethylenediamine)cobalt(III) chloride.<br>vi. Preparation and resolution of *tris*(ethylenediamine)cobalt(III) ion.<br>vii. Preparation of *cis*-potassium dioxalatodiaquochromate(III) and *trans*-potassium dioxalatodiaquochromate(III). | **36** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |

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| | viii. Preparation of nitrito-*O*-pentaaminecobalt(III) and nitrito-*N*-pentaaminecobalt(III) chloride.<br>ix. Preparation of manganese(III) porphyrin complex.<br><br>**Estimations (Any Four)**<br>i. Estimation of manganese in *bis*(acetylacetonate)manganese(II) and *tris*(acetylacetonate)manganese(III).<br>ii. Estimation of copper in tris(thiourea)copper(I) sulfate.<br>iii. Estimation of cobalt in *cis*-dichloro(ethylenediamine)cobalt(III) chloride and *trans*-dichloro(ethylenediamine)cobalt(III) chloride.<br>iv. Estimation of cobalt in *tris*(ethylenediamine)cobalt(III) ion.<br>v. Estimation of chromium in *cis*-potassium dioxalatodiaquochromate(III) and *trans*-potassium dioxalatodiaquochromate(III).<br>vi. Estimation of cobalt in nitrito-*O*-pentaaminecobalt(III) and nitrito-*N*-pentaaminecobalt(III) chloride.<br>vii. Estimation of manganese in manganese(III) porphyrin complex.<br><br>NOTE: *student is expected to recrystallize the product, carry out estimations like volumetric, gravimetric, instrumental analysis (such as IR, UV-Vis, AES, CHNS, optical rotation, Gouy's balance) and describe crystal structure.* | | | |
| **Module 2:** | **Experiments in Solid state chemistry (Any Nine)**<br>i. Preparation of nickel(II) oxalate dihydrate by precursor method.<br>ii. Estimation of nickel (II) and oxalate in nickel oxalate dihydrate by titrimetric method. | **36** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |

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| | iii. Characterization of nickel(II) oxalate dihydrate by IR and thermal analysis.<br>iv. Preparation of cobalt(II) oxalate dihydrate by precursor method.<br>v. Estimation of cobalt and oxalate in cobalt(II) oxalate dihydrate by titrimetric method.<br>vi. Characterization of cobalt(II) oxalate dihydrate by IR and thermal analysis.<br>vii. Isothermal studies of nickel(II) oxalate dihydrate and cobalt(II) oxalate dihydrate.<br>viii. X-ray diffraction studies of spinel oxides such as $Fe_3O_4$, $NiFe_2O_4$, $ZnFe_2O_4$, $Ni_{0.5}Zn_{0.5}Fe_2O_4$.<br>ix. Raman studies of spinel oxides such as $Fe_3O_4$, $NiFe_2O_4$, $ZnFe_2O_4$, $Ni_{0.5}Zn_{0.5}Fe_2O_4$.<br>x. XPS studies of spinel oxides such as $Fe_3O_4$, $NiFe_2O_4$, $ZnFe_2O_4$, $Ni_{0.5}Zn_{0.5}Fe_2O_4$.<br>xi. Direct current electrical resistivity of semiconductor (Ge/Si) by Four Probe method.<br>xii. Curie temperature determination of dielectric material (PZT) by measurement of dielectric constant v/s temperature.<br>xiii. Measurement of saturation magnetization, $M_s$, $M_r$ and $H_c$ of ferromagnetic materials.<br>xiv. Determination of Curie temperature of magnetic oxides by A.C. susceptibility studies.<br>xv. Preparation of $CuO/SiO_2$ or $NiO/SiO_2$ by wet impregnation method. | | | |
| **Module 3:** | **Instrumental methods / spectral analysis / ion exchange (Any Six)**<br>i. Determination of stability constant of Fe(III)–salicylic acid compound (Job's Method). | **24** | CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |

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| | ii. Determination of stability constant of Fe(III)–thiocyanate compound (Job's Method).<br>iii. Determination of stability constant of Fe(II)–1,10-phenanthroline compound (Job's Method).<br>iv. Determination of instability constant for the reaction between $Ag^+$ and $NH_3$ / $Cu^{2+}$ and $NH_3$.<br>v. Determination of instability constant for the reaction between $Ag^+$ and en / $Cu^{2+}$ and en.<br>vi. Ion exchange chromatography: Separation of $Mg^{2+}$ and $Co^{2+}$ by anion exchange column.<br>vii. Determination of magnetic moment in mononuclear compounds containing metals such as $Mn^{2+}$ / $Co^{2+}$ / $Ni^{2+}$ / $Cu^{2+}$. | | | |
| **Module 4:** | **Metal analysis in Alloys and Ores: Analysis using Titrimetry / Gravimetry / Spectroscopy method (Any Six)**<br>**Alloy**<br>i. Analysis of copper & zinc percentage in Brass.<br>ii. Analysis of copper & tin percentage in Bronze.<br>iii. Analysis of lead & tin percentage in solder.<br>iv. Analysis of nickel & aluminium percentage in Nickel aluminide.<br>**Ore**<br>i. Analysis iron percentage in Hematite.<br>ii. Analysis of manganese percentage in Pyrolusite.<br>iii. Analysis of aluminium percentage in Bauxite. | **24** | CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |
| **Pedagogy:** | Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be | | | |

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| | interactive in nature to enable peer group learning. |
| **Texts:** | 1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd ed., Chapman & Hall, New York, 1974.<br>3. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, New Delhi, 2011.<br>4. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th ed., Pearson, New Delhi, 2002.<br>5. S. De Meo, J. Chem. Ed., 80, 796-798, 2003.<br>6. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970. |
| **References/ Readings:** | 1. A. J. Elias, General Chemistry Experiments, Revised ed., University Press, Hyderabad, 2008.<br>2. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972. |

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| **Title of the Course** | Inorganic Chemistry Practical - IV |
| **Course Code** | CHI-6001 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To learn techniques of crystallization and synthesis of coordination compounds.<br>2. To study characterization of compounds using different instruments.<br>3. To provide experience of synthesis and characterization of materials.<br>4. To introduce analysis of ores for metal content. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. perform synthetic and analytical procedures safely and accurately to prepare inorganic, coordination, and solid-state compounds. | PSO1, PSO2, PSO3, PSO4 |

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| | CO 2. operate various analytical and instrumental techniques for characterization, separation, and quantification of inorganic substances. | | PSO1, PSO3, PSO4 | |
| | CO 3. interpret experimental and analytical data to deduce composition, and structure of compounds. | | PSO1, PSO3, PSO4 | |
| | CO 4. evaluate accuracy of results, and data reliability to improve laboratory practices and scientific reporting. | | PSO1, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Preparation of ligands (including distillation / recrystallization) / metal-ligand compounds / inorganic compounds (Any Seven)**<br>i. Preparation of Schiff's base and characterization by IR. Ex. Condensation of simple aldehydes with diammines (ethylene diammine, 1,3-propanediammine).<br>ii. Preparation of substituted benzoic acids and characterization by IR.<br>iii. Preparation of metal compound with substituted benzoic acid.<br>iv. Preparation of acetylacetonate complexes of Co(II) and estimation of cobalt.<br>v. Preparation of ammonium dichromate and ammonium heptamolybdate.<br>vi. Preparation of aluminium(III) tris(acetylacetonate) and estimation of aluminium.<br>vii. Preparation of potassium dihydroxodioxalatotitanate(IV) and estimation of titanium.<br>viii. Preparation of manganic acetate and estimation of manganese.<br>ix. Preparation of chromium(II) acetate hydrate and estimation of chromium.<br>x. Preparation of $K_2ON(SO_3)_2$ (Fremy's salt).<br>xi. Preparation of acetylacetonate complexes of Co(III) and estimation of cobalt. | **42** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5 |

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| | xii. Preparation of ferrocene.<br>xiii. Estimation of iron in ferrocene.<br>*xiv. Note: Wherever possible IR and other spectral studies should be undertaken for prepared compounds.* | | | |
| **Module 2:** | **Syntheses, characterization and solid state study of $ABO_3$/$AB_2O_4$ oxides (Any Seven)**<br>i. Preparation of Perovskite/Spinel oxide by oxalate precursor method.<br>ii. Characterization of precursor using CHN Analyser and estimation of metals in the precursors and oxides by gravimetric and volumetric analysis.<br>iii. Characterization of precursor and Perovskite/Spinel oxide by FTIR.<br>iv. Thermal analysis (TG/DTA) of prepared precursors.<br>v. Isothermal Mass Loss Studies.<br>vi. X-ray diffraction studies of Perovskite/Spinel oxide prepared.<br>vii. Powder processing for electrical and dielectric measurement.<br>viii. Electrical resistivity measurement of the prepared oxide by Two probe / Four Probe method.<br>ix. Dielectric studies of prepared oxide: Dielectric constant V/s I) Frequency and/or II) Temperature.<br>x. Dielectric studies of prepared oxide: Dielectric loss V/s I) Frequency and/or II) Temperature.<br>xi. Magnetic Characterization of prepared Spinel oxide by i) Hysteresis loop data (Ms, Mr, Hc) and ii) A.C Susceptibility.<br>*xii. Note: Wherever possible IR and other spectral studies should be undertaken.* | **42** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Module 3:** | **Instrumental experiments/separation of metal ions by ion exchange resins (Any Four)**<br>i. Determination of stability constant of Fe(III)-Sulfosalicylic acid compound | **24** | CO1, CO2, CO3, | K2, K3, K4, K5 |

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| | in the solution.<br>ii. UV-visible spectroscopy study of transition metal complexes.<br>iii. Potentiometric determination of cobalt/ nickel /zinc by EDTA.<br>iv. Conductance measurements: preparation and electrical conductivity measurements of some cobalt complexes.<br>v. Determination of magnetic susceptibility of Mn(II), Cu(II) etc. salts/complexes.<br>vi. Colorimetric estimation of Hg/Cd.<br>vii. IR and NMR studies of Inorganic compounds. Ex. $VO(acac)_2$. | | CO4 | |
| **Module 4:** | **Ore analysis/ Alloy analysis using Titrimetry / Gravimetry / spectroscopy method (Any Three)**<br>i. Analysis of Malachite.<br>ii. Analysis of Ilmenite.<br>iii. Analysis of Nickel Steel alloy.<br>iv. Analysis of Rolled Silver/Gold/Copper. | **12** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Pedagogy:** | Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd ed., Chapman & Hall, New York, 1974.<br>3. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, New Delhi, 2011.<br>4. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th ed., Pearson, New Delhi, 2002.<br>5. S. De Meo, J. Chem. Ed., 80(2003)796-798. | | | |

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| | 6. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970. |
| **References/ Readings:** | 1. A. J. Elias, General Chemistry Experiments, Revised ed., University Press, Hyderabad, 2008.<br>2. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972. |

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| **Title of the Course** | Concepts in Catalysis |
| **Course Code** | CHI-6002 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from A.Y.** | 2026-27 |
| **New Course :** | No |
| **Bridge Course/ Value added Course:** | No |
| **Course for advanced learners:** | No |

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| **Pre-requisites for the Course:** | Level 400 courses |
| **Course Objectives:** | 1. To understand the fundamental concepts in different types of catalytic processes and their applications in different fields.<br>2. To gain knowledge in synthesizing catalysts, and their characterization using different instrumental techniques.<br>3. To understand basic concepts of chemical reactions for developing higher productivity, mechanisms and viability.<br>4. To develop ability to design and select appropriate catalyst for specific reaction and make aware of catalytic approaches in energy and environment. |

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| **Course Outcomes:** | Students will be able to | | **Mapped to PSO** | |
| | CO 1. explain concepts, properties, and reaction mechanisms of various types of catalysts. | | PSO1, PSO2 | |
| | CO 2. illustrate the methods of preparation and characterization of various types of catalysts. | | PSO1, PSO4 | |
| | CO 3. analyse different factors influencing catalytic reactions. | | PSO1, PSO2, PSO3 | |
| | CO 4. develop reaction specific catalysts. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Origin and development of catalysts**<br>a. Introduction to heterogeneous, homogeneous and bio-catalysis, auto-catalysis, photo-catalysis, importance of catalysis in chemical reactions and its industrial applications.<br>b. Concepts of Atom Economy, Turnover number and Turnover frequency. | **05** | CO1, CO3 | K1, K2, K3, K4 |
| **Module 2:** | **Heterogeneous Catalysis**<br>Introduction to heterogeneous catalysis, energy profile diagram and diffusion of gas, general mechanisms such as Langmuir-Hinshelwood and Rideal-Eiley.<br>Adsorptions: Physical and chemical adsorption, chemisorptions of gases on solid surfaces, nature of adsorbed layer, dissociative adsorptions, scattering, trapping and sticking, simple adsorptions isotherm, Langmuir adsorption, the BET adsorption isotherm and Surface area determination.<br>Types of Catalysts: Preparations and separations of the catalysts, meso and micro porous materials, nano material catalysts and significance, zeolites and related molecular sieves, supported and bifunctional catalysts and catalyst regeneration, | **25** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | activity and life of the catalysts, active centers, promoters and poisons, catalyst deactivations.<br>Characterization of solid catalysts: Structure and surface morphology, porosity, pore volume and diameter, particle size, X-ray diffraction , Thermal analysis (DTA/TG and DSC), SEM, TEM, X-ray absorption spectroscopy, XPS and Auger Electron Spectroscopy to surface studies, TPD for acidity and basicity of the catalysts.<br>Heterogeneous reactions: Thermodynamic consideration in surface reactions, mechanism of catalytic reactions, ammonia synthesis, oxidation reduction reactions, CO oxidation, $N_2O$ decomposition, Fisher tropsch catalysis, selective catalytic reduction, method of finding reaction rate and the rate determining steps.<br>Theories of Catalysis: Boundary layer theory, catalysis by semiconductors, Wolkenstein theory, Balanding's approach, electronic factors in catalysis by metals, molecular orbital approach. | | | |
| **Module 3:** | **Homogeneous Catalysis**<br>Homogeneous catalytic reactions, merits and demerits, intermediate stages in homogenous catalysis, energy profile diagram, activation energy, general scheme for calculating kinetics of the reactions.<br>Decomposition of hydrogen peroxide, acid-base catalysis.<br>Homogeneous catalytic reactions: Hydrogenation, hydroformylation, isomerization, Monsanto acetic acid process, Carboxylation reactions, Wacker reaction, coupling reactions and asymmetric oxidations. | **10** | CO1, CO2, | K1, K2, K3, K4 |
| **Module 4:** | **Bio-catalysis, Photo-catalysis, Phase Transfer Catalysis, and Polymerizations Catalysis**<br>Bio-catalysis: Nomenclature and classification of enzymes, metal ions and metalloenzymes, general properties, enzymatic reactions such as redox and | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | decomposition, action of enzymes, mechanistic pathways of few enzymatic reactions, factors affecting enzymes and enzyme applications.<br>Photo-catalysis: Homogeneous photo-catalysis, photo-sensitized and photo-oxidations reactions, heterogeneous photo-catalysis, semiconductor photo-catalysts, generation of hydrogen by photo-catalysts and harnessing solar energy, photo-degradation of dyes.<br>Phase transfer catalysis: Mechanism of PTC, types of phase transfer catalysis with selected examples, advantages and disadvantage.<br>Polymerization catalysis: Homogeneous and heterogeneous catalysis in polymerization reactions (few examples), Ziegler – Natta catalyst in polymerization reactions. | | | |
| **Module 5:** | **Catalyst for energy and environment**<br>Catalytic gasification, electricity from gas turbine, steam reforming, electro-catalysis, fuel cells for energy production like methanol, molten carbonate and solid oxide fuel cells.<br>Catalysts for environmental pollution in emission control and selective catalytic reduction. | **05** | CO1, CO3, CO4 | K1, K2, K3, K4 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. A. Clark, The Theory of Adsorption and Catalysis, 1st Ed., Academic Press, New York, 1970.<br>2. A.V. Salker, Catalysis: Principles and Basic Concepts, 1st Ed., Scientific International Pvt. Ltd., New Delhi, 2020.<br>3. D. K. Chakraborty, Adsorption and Catalysis by Solids, 1st Ed., New Age International (P) Ltd., New Delhi, 2008.<br>4. G. M. Panchenov, V. P. Lebedev, Chemical Kinetics and Catalysis, 1st Ed., Mir publishers, Moscow, 1976.<br>5. J. M. Thomas, W.J. Thomas, 1st ed., Heterogeneous Catalysis, VCH publication, New York, 1997. | | | |

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| **References/ Readings:** | 1. E. R. Rideal, Concept in Catalysis, Academic Press, New York, 1968.<br>2. M. Beller, A. Renken, R. van Santen, Catalysis, Wiley VCH, Weinheim, 2012.<br>3. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed., Oxford University Press, Oxford, 2009.<br>4. R. A. Van Santen, J. W. Niemantsverdriet, Chemical Kinetics and Catalysis, 1st Ed., Plenum Press, New York, 1995.<br>5. S. J. Thomson, G. Webb, Heterogeneous Catalysis, Oliver and Boyd Publications, 1968. |

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| **Title of the Course** | Bioinorganic Chemistry |
| **Course Code** | CHI-6003 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course:** | No |
| **Bridge Course/ Value added Course:** | No |
| **Course for advanced learners:** | No |

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| **Pre-requisites for the Course:** | Level 400 courses |
| **Course Objectives:** | 1. To provide a foundational understanding of essential elements, coordination principles, and physical methods used in bioinorganic chemistry.<br>2. To explain the structural and functional roles of alkali, alkaline earth, and transition metal ions in biological systems, including photosynthesis and oxygen transport.<br>3. To study the structure, mechanism, and functions of metalloenzymes, redox proteins, and metal storage/transport systems.<br>4. To explore topics such as nitrogen fixation, biomimetic models, and oxygen activation in biological and synthetic systems. |

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| **Course Outcomes:** | Students will be able to | | **Mapped to PSO** | |
| | CO 1. explain the fundamental principles of bioinorganic chemistry, including the role of essential elements, metal ions, and biomolecules in biological systems. | | PSO1, PSO2 | |
| | CO 2. illustrate the use of coordination chemistry concepts to describe metal-dependent processes such as photosynthesis, oxygen transport, enzymatic catalysis, and nitrogen fixation. | | PSO2, PSO4 | |
| | CO 3. interpret structural, spectroscopic, and mechanistic data to deduce the function of metalloproteins, metalloenzymes, and biomimetic models. | | PSO1, PSO3, PSO4 | |
| | CO 4. assess the significance of metal ions in health, environment, and technology, and critically appraise biomimetic approaches that replicate biological functions. | | PSO2, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Essential elements in biology and bioinorganic research.**<br>Essential elements in biology: Periodicity, distribution in biosphere, natural abundance, bioavailability, and bio-stability.<br>Building blocks of biosphere: Biological importance of water, carbohydrates, nucleic acids, proteins, and Brief review of the chemistry of biopolymers.<br>Metallobiomolecules: Classification, metalloproteins, metalloenzymes, metal-activated proteins.<br>Principles of coordination chemistry related to bioinorganic research.<br>Physical methods in bioinorganic chemistry. | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 2:** | **Metals in Biological Systems**<br>Alkali and alkaline earth metals: Biological importance, cation transport through | **15** | CO1, CO2, CO3, | K1, K2, K3, K4, |

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| | membranes (ion pumps).<br>Photosynthesis: Hill reaction, chlorin macrocycle, chlorophyll absorption, extraction of chlorophyll from green leaves, role of metals, in-vitro photosynthesis.<br>Transition metals in biology: Role of Fe, Cu, Mo, and Ni.<br>Oxygen carriers and oxygen transport proteins: Hemoglobin, Myoglobin, Hemocyanin, Hemerythrin.<br>Synthetic models for oxygen-binding hemoproteins, other ligands for biological oxygen carriers. | | CO4 | K5 |
| **Module 3:** | **Metalloenzymes and Redox Proteins**<br>Zinc in biology: Structure and functions of zinc metalloenzymes: carboxypeptidase, carbonic anhydrase, alcohol dehydrogenase.<br>Redox enzymes: Cytochrome C, catalase, peroxidase, superoxide dismutase, blue copper proteins.<br>Coenzymes and cofactors: Vitamin B12 coenzymes and derivatives.<br>Iron–sulfur proteins: Structures, functions, synthetic analogues, core extrusion reactions.<br>Metal transport and storage: Iron transport (transferrin, ferritin, hemosiderin, siderophores), iron biomineralization. | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 4:** | **Nitrogen Fixation and Biomimetic Inorganic Chemistry**<br>Nitrogen fixation: Biological nitrogen fixation, nitrogenase, dinitrogen complexes.<br>Fundamentals of biomimetic chemistry: redox chemistry of free molecular dioxygen, dioxygen toxicity, geometry and electronic structure of coordinated dioxygen.<br>Oxygenases: Monooxygenases (Cytochrome P-450), Dioxygenases (Intradiol catechol dioxygenases): techniques used to probe the active sites, mechanistic studies and | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | proposed intermediates, reactions of metal-oxygen compounds. | | | |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. B. I. Britini, H. B. Gray, S. J. Lippard & J. S. Valentine, Bioinorganic Chemistry, University Science books, New Delhi Viva Books Pvt. Ltd. 2007.<br>2. D. E. Fenton, Biocoordination Chemistry, Oxford Chemistry Primers 25 Oxford University Press, 1995.<br>3. E. E. Conn, P.K. Stumpf, G. Bruening & R. H. Doi, Outlines of Biochemistry, 5th Ed.; John Wiley & Sons, New York, 2007.<br>4. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd ed., Wiley India, New Delhi, 2008 (reprint).<br>5. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed., Pearson, New Delhi, 2013.<br>6. S. J. Lippard & J. M. Berg, Principles of Bioinorganic Chemistry, Panima Publishing Corporation, 1997. | | | |
| **References/ Readings:** | 1. Housecroft, A. G. Sharpe, Inorganic Chemistry, 4th Ed; Pearson Publishing, 2012.<br>2. M. Weller, T. Overton, J. Rourke & F. Armstrong, Inorganic Chemistry, 6th Ed.; Oxford University Press, 2018.<br>3. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th ed., Oxford University Press, Oxford, 2009.<br>4. R. R. Crichton, Biological Inorganic Chemistry, Amsterdam Elsevier, First Edition, 2008. | | | |
| **Web Resources:** | 1. M. Guo, T. Corona, K. Ray, W. Nam, Heme and Nonheme High-Valent Iron and Manganese Oxo Cores in Biological and Abiological Oxidation Reactions, ACS Central Science, 5, pp. 13−28, 2019. https://doi.org/10.1021/acscentsci.8b00698<br>2. R. Breslow, Biomimetic Chemistry: Biology as an Inspiration, The Journal of Biological Chemistry, vol. 284, 3, pp. 1337–1342, 2009. https://doi.org/10.1074/jbc.X800011200 | | | |

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| **Title of the Course** | Research Methodology in Inorganic Chemistry-I |
| **Course Code** | CHI-6004 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To understand the literature review process, safe laboratory practices and ethics in research.<br>2. To analyse and apply separation techniques.<br>3. To interpret data from characterization techniques.<br>4. To develop understanding of a variety of structural data. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. apply fundamentals of research to facilitate dissertation work. | PSO1, PSO3, PSO4 |
| | CO 2. practice the concepts of laboratory safety along with good laboratory practices. | PSO3, PSO4 |

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| | CO 3. implement and interpret advanced separation, characterization, and crystallographic methods to study chemical compounds and coordination complexes interpret. | | PSO1, PSO3, PSO4 | |
| | CO 4. asses the reliability and efficiency of experimental approaches and structural analyses to recommend improvements and validate scientific conclusions. | | PSO1, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Literature Review, Academic Writing**<br>Brief introduction to research methodology, concept and purpose, logical format of dissertation, types and components.<br>Sources for identifying research problem.<br>Literature Review: types of literature, sources of literature review, primary sources, secondary sources, databases.<br>Research methods: significance, purpose and characteristics of research, research process, necessity and scope.<br>Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals.<br>Key aspects of ethics in scientific conduct. | **15** | CO1 | K1, K2, K3 |
| **Module 2:** | **Safe Laboratory Practices**<br>Instructions for safe working and use of personal protective equipment (PPE).<br>The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances.<br>Handling, storage, quenching, and disposal of chemicals, solvents and glassware.<br>Experimental setup, choice of place and apparatus, precautions.<br>Fire Hazards (Class A, B, C, D and K), fire extinguishers and emergency procedures. | **5** | CO1 | K2, K3 |

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| **Module 3:** | **Separation Techniques**<br>Liquid-liquid extraction and partitioning.<br>Ion Exchange Chromatography: role in separation of charged metal-ligand complexes.<br>Gas Chromatography (GC): column selection, role of volatility in ligand-based separations, GC detection and quantification methods for separation and identification of ligands.<br>High Performance Liquid Chromatography (HPLC): method development and optimization.<br>Case studies on application of separation techniques for ligands and metal complexes. | **10** | CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Module 4:** | **Characterization Techniques and Data Interpretation**<br>Cyclic Voltammetry (CV): Introduction, instrumentation, experimental setup, electrochemical parameters, data analysis, reversibility, electrochemical mechanisms and case studies on applications of CV for metal complexes, introduction to Spectroelectrochemistry.<br>Liquid Chromatography-Mass Spectrometry (LC-MS)/ Gas Chromatography-Mass Spectrometry (GC-MS): Principles and instrumentation, ionization techniques and mass analyzers, comparison of LC-MS vs. GC-MS for different analytes and application for separation, identification of products, and isotope labelling studies.<br>Electrospray Ionization Mass Spectrometry (ESI-MS)/ Cold Spray Ionization Mass Spectrometry (CSI-MS): isotope distribution pattern, ionization of metal complexes in solution phase (fragments), interpretation of data, identifying metal-ligand stoichiometry, isotope labelling studies, applications in low-temperature analysis of weakly bound metal-ligand interactions, emerging trends in mass spectrometry. | **15** | CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Module 5:** | **Structure Characterization**<br>Introduction to powder and single-crystal X-ray diffraction. Understanding the | **15** | CO2, CO3, | K2, K3, K4, K5 |

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| | difference between amorphous materials, crystalline materials, nanomaterials, quasicrystals. Crystallisation techniques, Polymorphism, Enantiomorphism.<br>Organic, inorganic, organometallic, metal-organic compounds, Coordination polymers and metal-organic frameworks.<br>Software for structure interpretation and data simulation and data visualization. Crystal structure description. Hydrogen bonding and other interaction in solids.<br>Case studies on proper characterization of a solid by use of crystallographic aspects and other allied techniques.<br>Importance of correct space group assignment and chirality in space groups. | | CO4 | |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Textbook of Practical Organic Chemistry, 4th ed., Longman Group, England, 1986.<br>2. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., New-Delhi, 2004.<br>3. E. De Hoffmann, V. Stroobant, Mass Spectrometry: Principles and Applications, 2nd ed., Wiley, New York, 2007.<br>4. G. D. Christian, Analytical Chemistry, 6th ed., Wiley, New York, 2008.<br>5. G. R. Desiraju, J. J. Vittal, A. Ramanan, Crystal Engineering, IISC Press, World Scientific, 2011.<br>6. G. Svehla, Vogel’s Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson Education, New Delhi, 2011.<br>7. P. G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th ed., Cengage Learning, London, 2015.<br>8. R. M. Silverstein, F. X. Webster; Spectrometric Iidentification of Organic Compounds; 6th ed., Wiley, New York, 2011.<br>9. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th ed., Cengage Llearning, New York, 2022. | | | |

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| | 10. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th ed, Cengage learning, New York, 2017.<br>11. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., New Delhi, 2006. |
| **References/ Readings:** | 1. J. E. Huheey, E. A. Keiter, R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4th ed., Pearson, 2006.<br>2. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th ed., Pearson 2009.<br>3. J. T. Watson, O. D. Sparkman, Introduction to Mass Spectrometry: Instrumentation, Applications, and Strategies for Data Interpretation, 4th ed., Wiley, 2007. |

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| **Title of the Course** | Research Methodology in Inorganic Chemistry-II |
| **Course Code** | CHI-6005 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To understand the literature review process, safe laboratory practices and ethics in research.<br>2. To familiarise the students with various software for data analysis.<br>3. To introduce various instrumental techniques for characterisation of inorganic compounds.<br>4. To learn the importance of analysis and interpretation of data from various characterization techniques. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. apply fundamentals of research to facilitate dissertation work. | PSO1, PSO3, PSO4 |
| | CO 2. practice the concepts of laboratory safety along with good laboratory practices. | PSO3, PSO4 |

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| | CO 3. analyze data using chemistry-related software tools and interpret results from diffraction, microscopy, spectroscopy, thermal, and magnetic techniques. | | PSO1, PSO3, PSO4 | |
| | CO 4. evaluate scientific findings to solve problems, and communicate results effectively through academic writing and presentations. | | PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Literature Review, Academic Writing**<br>Brief introduction to research methodology, concept and purpose, logical format of dissertation, types and components.<br>Sources for identifying research problem.<br>Literature Review: types of literature, sources of literature review, primary sources, secondary sources, databases.<br>Research methods: significance, purpose and characteristics of research, research process, necessity and scope.<br>Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals.<br>Key aspects of ethics in scientific conduct. | **15** | CO1 | K1, K2, K3 |
| **Module 2:** | **Safe Laboratory Practices**<br>Instructions for safe working and use of personal protective equipment (PPE).<br>The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances.<br>Handling, storage, quenching, and disposal of chemicals, solvents and glassware.<br>Experimental setup, choice of place and apparatus, precautions.<br>Fire Hazards (Class A, B, C, D and K), fire extinguishers and emergency procedures. | **05** | CO2 | K1, K2, K3 |

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| **Module 3:** | **Softwares in Chemistry**<br>Data plotting using free software: Origin/Excel, XPSPEAK, ChemSketch/ChemDraw.<br>Reference management software: Mendeley, Zotero. | **10** | CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 4:** | **Diffraction and Microscopy techniques**<br>Principle, instrumentation and applications of**:**<br>a. Powder X-ray diffraction<br>b. Scanning electron microscopy (SEM)<br>c. Field emission scanning electron microscope (FESEM)<br>d. Transmission Electron Microscopy (TEM)<br>e. High-Resolution Transmission Electron Microscopy (HRTEM)<br>(Data analysis/numerical/problem solving expected) | **15** | CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 5:** | **Spectroscopy techniques, Thermal analysis and Magnetic studies**<br>Principle, instrumentation techniques and applications**:**<br>a. XPS and Raman<br>b. TG, DTA, DSC<br>c. AC Susceptibility<br>d. Gouy's Balance<br>(Data analysis/numerical/problem solving expected) | **15** | CO3, CO4 | K1, K2, K3, K4, K5 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer | | | |

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| | group learning. |
| **Texts:** | 1. A. R. West, Solid State Chemistry and Its Applications, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007).<br>2. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., New-Delhi, 2004.<br>3. H. V. Keer, Principles of the Solid State, 1st Ed., New Age International (P) Ltd., (Wiley Eastern Ltd,), New Delhi, 1993, (Reprint 2008).<br>4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., New Delhi, 2006. |
| **References/ Readings:** | 1. A. V. Salker, Catalysis: Principles and Basic Concepts, 1st Ed., Scientific International Pvt. Ltd., New Delhi, 2020.<br>2. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, UK, 1989.<br>3. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers, Oxford, 1986.<br>4. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed, Pearson, USA, 2011.<br>5. J. E. Huheey, E. A. Keiter, R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4th Ed.; Pearson, USA, 1993.<br>6. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson, USA, 2009.<br>7. K. H. Büchel, H.-H. Moretto & P. Woditsch, Industrial Inorganic Chemistry, 2nd completely revised Ed., Wiley VHC, Germany, 2000.<br>8. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & Oxford University Press, New York, 2006.<br>9. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, |

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| | The National Academies Press, USA, 2011.<br>10. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, USA, 2011.<br>11. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. Florida, 2016.<br>12. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning, USA, 2014.<br>13. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Cengage learning, USA, 2007. |

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**Discipline Specific Vocational Elective (DSVE) Courses**

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| **Title of the Course** | Environmental Chemistry and Sustainability |
| **Course Code** | CHI-6401 |
| **Number of Credits** | 04 (2T+2P) |
| **Theory/Practical** | Theory and Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses |
| **Course Objectives:** | 1. To introduce students to the chemical composition and reactions occurring in soil, water, and air.<br>2. To develop an understanding of water conditioning techniques and industrial effluent treatment processes, with emphasis on chemical methods and their environmental implications across various industries.<br>3. To equip students with practical skills in environmental analysis through laboratory experiments focused on detecting and quantifying contaminants in water and soil samples.<br>4. To develop the skills needed to plan and carry out safe, eco-friendly chemical methods that will help reduce pollution and protect the environment. |

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| **Course Outcomes:** | Students will be able to | | **Mapped to PSO** | |
| | CO 1. explain the chemical composition and reactions in soil and air, and analyze the impact of pollutants such as agrochemicals, particulate matter, and emissions on environmental quality. | | PSO2, PSO3 | |
| | CO 2. apply inorganic chemistry principles to water conditioning and evaluate industrial effluent treatment methods used in fertilizer, electroplating, cement, and paper industries | | PSO2, PSO3, PSO4 | |
| | CO 3. perform laboratory experiments to estimate and interpret the concentration of environmental contaminants such as heavy metals, nitrates, phosphates, and COD in water and soil samples. | | PSO1, PSO3 | |
| | CO 4. design sustainable chemical procedures for pollution control, using safe laboratory practices and eco-friendly approaches to address environmental challenges. | | PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1: (Theory)** | **Soil and Air Pollution**<br>Introduction, types of soil, air, water, inorganic and organic components in the soil, reactions in the soil, waste pollutants in the soil and soil contamination, excess usage of agrochemicals, adsorption and decomposition of organic matter in the soil.<br>Temperature profile of the atmosphere, lapse rate, temperature inversion. Types of emissions (natural and man-made), emission sources, air pollution dispersion models, estimation of dispersion parameters, types of plumes, global warming.<br>Particulate matter: introduction, particle size range, health hazards, analysis of particulate matter, control devices, inorganic particulates, radioactive particulates, organic particulates and other contaminants. | **15** | CO1, CO4 | K1, K2, K3, K4, K5 |

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| **Module 2: (Theory)** | **Water Conditioning and Selected Industrial Effluent Treatment.**<br>Introduction, hard water and water softening by chemical methods, carbonate and magnesium hardness removal by lime, and non-carbonated hardness removal by soda ash, calcium carbonate solubility, re-carbonation and acid process, barium-lime cold process, ion exchange process.<br>Industrial effluent treatment, effects of industrial effluents on surface water and land, manufacture process and treatment of fertilizers and pesticides, electroplating process and treatment of the waste from the cement, sugarcane and paper industry. | **15** | CO2, CO4 | K1, K2, K3, K4, K5 |
| **PRACTICAL (2 Credit)** | | | | |
| **Module 3: (Practical)** | **Experiments in Environmental Chemistry by Spectrophotometry, Titrimetry or Gravimetry (Any eight)**<br>i. To estimate the amount of chloride ion present in the water sample by Argentometric method (Mohr's method).<br>ii. To determine the concentration of sulphate of a given water sample (spectrophotometry/using turbidimeter).<br>iii. To determine the concentration of nitrite present in a given water sample.<br>iv. To determine the chemical oxygen demand (COD) of wastewater sample.<br>v. Determination of optimum lime and soda ash dose for hardness removal.<br>vi. Determination of oil and grease in given waste water sample.<br>vii. Determine the amount of lead present in given water/soil sample.<br>viii. Determine the amount of cadmium present in given water/soil sample.<br>ix. Determine the amount of chromium present in given water/soil sample.<br>x. Determine the amount of phosphate present in given water/soil sample.<br>xi. Determine the concentration of nitrate present in a given water sample. | **48** | CO3, CO4 | K1, K2, K3, K4, K5, K6 |

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| | xii. Determine the amount of aspirin present in given water sample. | | | |
| **Module 4: (Practical)** | **Field trip in Goa (Any two)**<br>i. Industrial wastewater treatment plant<br>ii. Municipal wastewater treatment plant<br>iii. Solid waste disposal<br>iv. Rain water harvesting | **12** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4 |
| **Pedagogy:** | Theory: Mainly lectures and tutorials. Prelab excersise/Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.<br>Practicals: Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. | | | |
| **Texts:** | 1. A. K. De, Environmental Chemistry, 3rd ed., New Age Intl. Publishers, New Delhi, 2005.<br>2. A. V. Salker, Environmental Chemistry: Pollution and Remedial Perspective, 1st ed., Narosa Publication, New Delhi, 2017.<br>3. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed.; Pearson, New Delhi, 2011.<br>4. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th ed., Pearson, New Delhi, 2011.<br>5. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, New Delhi, 2002.<br>6. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th ed., Oxford University Press, Oxford, 2009. | | | |
| **References/ Readings:** | 1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6rd ed., Wiley India, New Delhi, 2003 (reprint 2012).<br>2. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd ed., Wiley India, New Delhi, 2008.<br>3. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd ed., Pearson, New Delhi, 2004. | | | |

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| | 4. J. D. Lee, Concise Inorganic Chemistry, 5th Ed. (reprint); Blackwell Science Wiley, Oxford, 2015.<br>5. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd Ed. (reprinted); Elsevier, Oxford, 2014. |

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| **Title of the Course** | Industrial Applications of Inorganic Chemistry |
| **Course Code** | CHI-6402 |
| **Number of Credits** | 04 (2T+2P) |
| **Theory/Practical** | Theory and Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To introduce the importance of chemical industries and industrial raw materials.<br>2. To know the synthesis procedure for manufacture of various industrial products and their applications.<br>3. To gain knowledge of hands-on preparation of some recognized industrial products from raw materials.<br>4. To analyse important industrial products by chemical and instrumental methods. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the importance of chemical industries and industrial raw materials. | PSO1, PSO2 |
| | CO 2. apply the synthesis procedure for manufacture of various industrial products. | PSO1, PSO2, |

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| | | | PSO3, PSO4 | |
| | CO 3. analyze the process of manufacture of important industrial products | | PSO1, PSO2, PSO3 | |
| | CO 4. characterize the synthesized materials by chemical and instrumental methods. | | PSO1, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:**<br>**(Theory)** | **1. Chemical industry and raw materials**<br>Chemical industries & their economic importance.<br>Commodity, fine and speciality chemicals.<br>Occurrence/manufacture of raw materials: Water, nitrogen, hydrogen, carbon dioxide, ammonia, nitric acid, sulphuric acid, hydrochloric acid, phosphoric acid, rock phosphate, murate of potash, EDTA (ethylenediamine tetraacetic acid), DTPA (diethylene triamine pentaacetic acid), EDDHA (ethylenediamine-N,N′-bis(2-hydroxyphenylacetic acid), silicates, boric acid and its salts, metals (lithium, sodium, potassium, magnesium, calcium, strontium, barium, manganese, iron, cobalt, copper, zinc and molybdenum) and their salts. | **10** | CO1, CO2, CO3 | K1, K2, K3, K4 |
| **Module 2:**<br>**(Theory)** | **2. Mineral fertilizers**<br>Plant nutrients: Macro, primary, secondary and micronutrients.<br>Primary, secondary and micronutrient fertilizers: preparation and applications of urea, ammonium sulphate, ammonium nitrate, ammonium phosphates, nitrophosphates, single superphosphates, triple superphosphates, potassium chloride, potassium sulphate, potassium nitrate, Lime, Dolomite lime, gypsum, epsom salt, magnesium nitrate.<br>Types of fertilizers, properties and applications | **10** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |
| **Module 3:** | **Some important inorganic and metal organic solids** | **10** | CO1, | K1, K2, |

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| **(Theory)** | Inorganic and metal organic pigments: white, coloured, black and speciality pigments, physical and chemical properties, preparation, characterization and applications.<br>Construction materials: lime, cement, gypsum, physical and chemical properties, preparation, characterization and applications.<br>Catalyst: Metal organic catalyst and their applications in organic synthesis. | | CO2, CO3, CO4 | K3, K4, K5, K6 |
| **PRACTICAL (2 Credit)** | | | | |
| **Module 4: (Practical)** | **I. Preparations of materials (ANY 4)**<br>i. Preparation of nitrogen fertilizer such as ammonium sulphate, urea.<br>ii. Preparation of single superphosphates.<br>iii. Preparation of mixed fertilizers with different ratings of nutrients.<br>iv. Preparation of inorganic, metal organic pigment (white, coloured, black, speciality)<br>v. Preparation of sodium tetraborates.<br>vi. Preparation of lime / cement / gypsum.<br>vii. Preparation of zinc(II)bis(L-prolinate).<br>viii. Preparation of tetrakis(μ-acetato)-diaqua-di-copper(II).<br>ix. Preparation of asymmetric compounds by Aldol addition of aldehydes and ketones by using zinc(II)bis(L-prolinate) as catalyst.<br>x. Preparation of primary amides from aldehydes by using tetrakis(μ-acetato)-diaqua-di-copper(II).<br>**II. Estimation of prepared / commercial materials (ANY 4)**<br>i. Estimation of fertilizers: nitrogen in urea, nitrogen and sulfur in ammonium sulphate.<br>ii. Estimation of fertilizers: phosphorous in single superphosphates. | **48** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |

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| | iii. Estimation of metal content in the inorganic / metal organic pigment.<br>iv. Estimation of sodium borate to account for hydration.<br>v. Estimation of calcium in lime / cement / gypsum.<br>vi. Estimation of micronutrient metal in fertilizers by AES.<br>vii. Electrochemical reduction of metal salts (chromium / manganese / copper / molybdenum).<br>viii. Estimation of zinc in zinc(II)bis(L-prolinate).<br>ix. Estimation of copper tetrakis(μ-acetato)-diaqua-di-copper(II).<br>x. Cyclic voltametric study of tetrakis(μ-acetato)-diaqua-di-copper(II)<br>xi. UV-vis study of tetrakis(μ-acetato)-diaqua-di-copper(II).<br>xii. Estimation of enantiomeric excess of aldol addition products using chromatographic, optical techniques.<br>xiii. Estimation of structure purity of primary amides by NMR spectroscopy.<br>*NOTE: student is expected to recrystallize the prepared and commercial product, analyse prepared and commercial products by volumetric, gravimetric, instrumental techniques (such as IR, UV-Vis, AES, CHNS, PXRD, HPLC, optical rotation, Gouy's balance, etc.) and describe crystal structure or chemical composition.* | | | |
| **Module 5: (Practical)** | Field trip in Goa (Any two)<br>i. Fertilizer plant<br>ii. Cement industry<br>iii. Agrochemical industry<br>iv. Pesticide industry<br>v. Any other industry | **12** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |
| **Pedagogy:** | Theory: Mainly lectures and tutorials. Prelab excersise/Seminars / term papers /assignments / presentations / self- | | | |

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| | study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.<br>Practicals: Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. |
| **Texts:** | 1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>2. G. Buxbaum & G. Pfaff, Industrial Inorganic Pigments, 3rd completely revised Ed., Wiley VHC, 2005.<br>3. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972.<br>4. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd ed., Chapman & Hall, New York, 1974.<br>5. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th ed., Pearson, New Delhi, 2002.<br>6. K. H. Büchel, H.-H. Moretto & P. Woditsch, Industrial Inorganic Chemistry, 2nd completely revised Ed., Wiley VHC, 2000.<br>7. N. N. Greenwood & A. Earnshaw, Chemistry of the Elements, 3rd Ed., Pergamon Press, Exeter, 1998.<br>8. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, New Delhi, 2011.<br>9. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970. |
| **References/ Readings:** | 1. A. J. Elias, General Chemistry Experiments, Revised ed., University Press, Hyderabad, 2008.<br>2. A. R. West, Solid State Chemistry and Its Applications, 2nd Ed., John Wiley & Sons, 2014.<br>3. F. A. Cotton & G. Wilkinson, Advanced Inorganic Chemistry, 6th Ed., Wiley Eastern, 2007.<br>4. F. A. Cotton, G. Wilkinson & P. L. Gaus, Basic Inorganic Chemistry, 3rd Ed., John Wiley, 2007.<br>5. J. D. Lee, Concise Inorganic Chemistry, 5th Ed., Wiley, 2008.<br>6. J. E. Huheey, E.A. Keiter & R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4th Ed., Pearson, 1993.<br>7. M. Weller, T. Overton, J. Rourke & F. Armstrong, Inorganic Chemistry, International Ed., Oxford University Press, |

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| | 2018.<br>8. P. Atkins, J. De Paula & J. Keeler, Atkins' Physical Chemistry, International Ed., Oxford University Press, 2018.<br>9. S. De Meo, J. Chem. Ed., 80(2003)796-798. |
| **Web Resources:** | 1. https://doi.org/10.1016/j.tet.2012.03.085<br>2. https://doi.org/10.1039/B301117H |

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| **Title of the Course** | *p*-block elements and their compounds |
| **Course Code** | CHI-6403 |
| **Number of Credits** | 04 (2T+2P) |
| **Theory/Practical** | Theory and Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To study the different trends in physical and chemical properties of *p*-block elements.<br>2. To understand the variations in physical and chemical properties as well as structure and applications of compounds of *p*-block elements.<br>3. To provide hands- on experience on synthesis and crystallisation of inorganic compound and carry out different methods for estimation of elements and ions in inorganic compounds.<br>4. To learn characterization of compounds using different instruments. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the trends in physical properties in groups and periods | PSO1 |

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| | CO 2. compare the physical and chemical properties as well as structures of compounds of elements from different groups. | | PSO1, PSO2 | |
| | CO 3. develop skills in performing synthesis and operate analytical instrumental techniques for characterization of compounds. | | PSO1, PSO3, PSO4 | |
| | CO 4. interpret and evaluate experimental methodologies, accuracy of results, and data reliability to improve laboratory practices and scientific reporting. | | PSO1, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1: (Theory)** | **Chemistry of Group 13 Elements and their Compounds**<br>Introduction, physical properties.<br>Chemical reactions with oxygen, nitrogen, sulphur, halogens, HCl, NaOH, $NH_3$.<br>Synthesis of mono, di, tri-chlorides, and alums.<br>Synthesis, structure and applications of organo-compounds of B & Al.<br>Role of organo-aluminium in the synthesis of polythene and isoprene. | **05** | CO1, CO2 | K1, K2, K3, K4, K5 |
| **Module 2: (Theory)** | **Chemistry of Group 14 Elements and their Compounds**<br>Introduction, physical properties, allotropy, compounds of Gr.14: different types of oxides, hydrides, sulphides.<br>Cluster compounds of Ge, Sn and Pb.<br>Graphite, intercalation compounds of graphite with (i) oxygen, (ii) fluorine (iii) Group 1 elements and (iv) halides such as $FeCl_3$.<br>Graphene: Preparation, properties and applications. | **07** | CO1, CO2 | K1, K2, K3, K4, K5 |
| **Module 3: (Theory)** | **Chemistry of Group 15 Elements and their Compounds**<br>Introduction, allotropes, physical properties. | **05** | CO1, CO2 | K1, K2, K3, K4, |

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| | Preparation, properties and structure of (i) hydrides, (ii) halides, (iii) oxides, (iv) oxyacids, and (v) oxohalides of group 15 elements (except nitrogen).<br>Preparation, properties and structure of Phosphorous compounds: sulphides, oxosulphides, and organo-phosphorous compounds. | | | K5 |
| **Module 4:**<br>**(Theory)** | **Chemistry of Group 16 Elements and their Compounds**<br>Introduction, allotropes, physical properties.<br>Preparation, properties and structure of (i) hydrides, (ii) halides, (iii) oxohalides, (iv) oxides, and (v) oxyacids.<br>Polyatomic sulphur cations, anionic polysulphides, compounds with sulphur as a ligand. | **05** | CO1, CO2 | K1, K2, K3, K4 |
| **Module 5:**<br>**(Theory)** | **Chemistry of Group 17 Elements and their Compounds**<br>Introduction, physical properties.<br>Preparation, properties and structure of (i) oxides, (ii) oxyacids, (iii) halides, (iv) oxohalides, (v) halogenoxide fluorides and (vi) related compounds. | **05** | CO1, CO2 | K1, K2, K3, K4, K5 |
| **Module 6:**<br>**(Theory)** | **Chemistry of Group 18 Elements and their Compounds**<br>Introduction, physical properties.<br>Preparation, properties, structure and bonding of (i) organoxenon compounds, and (ii) compounds containing Xe-Xe bond.<br>Preparation, properties and structure of compounds of other noble gases. | **03** | CO1, CO2 | K1, K2, K3, K4, K5, K6 |
| **PRACTICAL (2 Credit)** | | | | |
| **Module 7:**<br>**(Practical)** | **Syntheses of Inorganic Compounds**<br>**a. Compounds of *p*- block metals (Any two)**<br>i. Aluminium(III) acetylacetonate<br>ii. Dipyridinium hexachloroplumbate (IV) | **36** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | iii. Potassium dihydrodioxalatotitanate(IV)<br>iv. Stannic iodide<br><br>**b. Compounds of other group metals containing *p*- block donors (Any two)**<br>i. $[Sr(H_2O)_7(4\text{-nba})](4\text{-nba})\cdot 2H_2O$<br>ii. $\{[Ba(H_2O)_5(4\text{-nba})](\mu_2\text{-}4\text{-nba})]\}_n$<br>iii. $[Co(H_2O)_4(4\text{-nba})_2]\cdot 2H_2O$<br>iv. $[Ni(H_2O)_4(4\text{-nba})_2]\cdot 2H_2O$ (4- nba is 4- nitrobenzoic acid)<br>v. Preparation of $[Co(H_2O)(pyz)(suc)]$ ; pyz = 1,4- pyrazine and suc = succinate by hydrothermal method.<br><br>**c. Preparation of metal carboxylates/ oxyhydroxides/ oxides (Any one)**<br>i. Magnesium/ calcium/ iron oxalates<br>ii. γ- FeO(OH) xerogels<br>iii. Silica gel<br>iv. Zeolites: Hydrothermal/ sol- gel methods.<br><br>**d. Preparation of organic ammonium tetrasulfidomolybdates (Any one)**<br>i. $(NH_4)_2[MoS_4]$<br>ii. $(pipH_2)[MoS_4]$ where $pipH_2$ = piperazine<br>iii. $(trenH_2)[MoS_4]\cdot H_2O$ where $trenH_2$= tris(2-aminoethyl)amine<br>NOTE: *Students are expected to recrystallize the product, carry out instrumental* | | | |

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| | *analysis (such as IR, UV- Vis and AES, elemental analysis and Gouy's balance) and describe crystal structure.* | | | |
| **Module 8: (Practical)** | **Analysis of metals/non- metals and ions in compounds by Colorimetry/Titrimetry/ Gravimetry**<br>**a. Colorimetric estimations (Any one)**<br>i. Determination of boron as bis(salicylate)borate (III) anion using ferroin.<br>ii. Determination of lead by dithiozone method.<br>iii. Determination of ammonia using Nessler's reagent.<br>iv. Determination of silica using ammonium molybdate.<br>**b. Titrimetric analysis (Any two)**<br>i. Determination of bismuth by direct titration with EDTA.<br>ii. Determination of sulphur in iron pyrites by titration with EDTA.<br>iii. Determination of potassium using titrimetry.<br>iv. Determination of chlorine in bleaching powder by iodometry.<br>v. Determination of aluminium by oxine using iodometry.<br>vi. Determination of chlorates by iodometry.<br>vii. Determination of borax using mannitol.<br>**c. Gravimetric estimations (Any one)**<br>i. Determination of lead as iodate.<br>ii. Determination of lead as chromate.<br>iii. Determination of bismuth as pyrogallate. | **24** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| **Pedagogy:** | Theory: Mainly lectures and tutorials. Prelab excersise/Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.<br>Practicals: Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. |
| **Texts:** | 1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>2. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972.<br>3. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, New Delhi, 2011.<br>4. J. Bassett, R. C. Denney, G. H. Jeffery, J. Mendham, Vogel's Text Book of Quantitative Inorganic Analysis, 4th ed., Longman, England, 1978.<br>5. J. D. Lee, Concise Inorganic Chemistry, 5th Ed. (reprint); Blackwell Science Wiley, New Delhi, 2015.<br>6. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, New Delhi, 2011.<br>7. J. Mendham, R.C. Denney, J.D. Barnes, M. J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6th ed., Pearson, New Delhi, 2002.<br>8. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd Ed. (reprinted); Elsevier, Kundli, India, 2014.<br>9. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford University Press, Oxford, 2009. |
| **References/Readings:** | 1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6th ed., Wiley India, New Delhi, 2003 (reprint 2012).<br>2. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd ed., Wiley India, New Delhi, 2008 (reprint).<br>3. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd ed., Pearson, New Delhi, 2004.<br>4. R. C. Mehrotra, R. Bohra, Metal carboxylates, Academic Press, London, 1983. |

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| **Web Resources:** | 1. A. Khaleque, M. M. Alam, M. Hoque, S. Mondal, J. B. Haider, B. Xu, M. A. H. Johir, A. K. Karmakar, J. L. Zhou, M. B. Ahmed, M. A. Moni, Env. Adv. 2 (2020) 100019. https://doi.org/10.1016/j.envadv.2020.100019<br>2. B. R. Srinivasan, S. N. Dhuri, C. Näther, W. Bensch, Inorg. Chim. Acta, 358 (2005) 279-287. https://doi.org/10.1016/j.ica.2004.09.009<br>3. J. Fan, Z. Zhao, Z. Ding, J. Liu, RSC Adv., 8 (2018) 7269-7279. https://doi.org/10.1039/C7RA12615H<br>4. L. Durães, O. Oliveira, L. Benedine, B. F. O. Costa, A. M. Beja, A. Portugal, J. Phys. & Chem. of Solids, 72 (2011) 678-684. https://doi.org/10.1016/j.jpcs.2011.02.020<br>5. S. L. Reddy, T. R. Reddy, G. S. Reddy, T. Endo, R. L. Frost, Spectrochim. Acta A, 123 (2014) 25- 29. https://doi.org/10.1016/j.saa.2013.12.024 |

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**SEMESTER IV**

**Generic Elective (GE) Courses**

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| **Title of the Course** | Selected Topics in Inorganic Chemistry |
| **Course Code** | CHI-6201 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | No |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses |
| **Course Objectives:** | 1. To introduce concepts of amorphous materials and glasses, including their structural characteristics, thermal behavior, and forming techniques.<br>2. To explore the classification and properties of refractory materials and solid lubricants.<br>3. To learn the concepts of oxidation-reduction processes in inorganic reactions.<br>4. To familiarize students with advanced characterization techniques, enabling them to interpret data from |

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| | spectroscopic, microscopic, thermal, and diffraction methods to evaluate material properties. | | | |
| **Course Outcomes:** | Students will be able to | | **Mapped to PSO** | |
| | CO 1. explain the structural characteristics and thermal behavior of amorphous and glass materials | | PSO1 | |
| | CO 2. analyze the performance of various refractory materials and solid lubricants under extreme conditions. | | PSO2, PSO3 | |
| | CO 3. apply thermodynamic and electrochemical principles to analyze redox reactions, predict material stability, and interpret standard reduction potentials diagrams. | | PSO3, PSO4 | |
| | CO 4. interpret data to determine material composition, structure, and functional properties. | | PSO1, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Amorphous Materials**<br>Introduction to amorphous materials and types.<br>Types of glasses, Glass transition temperature, Composition of glasses, Viscosity, Glass forming methods, Commercial glasses, Chalcogenide glasses, Ceramic glasses, Metallic glasses. | **05** | CO1 | K1, K2 |
| **Module 2:** | **Refractories and Solid lubricants**<br>Classification of refractories, Properties of refractories.<br>Thermal expansion and contraction, Refractoriness, Spalting resistance, Thermal conductivities, Resistance to melts-slags and glasses.<br>Refractory materials: Aluminous type, silica type, basic type, insulating type, Special refractories, Oxide refractories, other refractories, ideal refractories.<br>Solid lubricants: Inorganic, organic, and nanomaterial lubricants. | **15** | CO2 | K1, K2, K3 |

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| **Module 3:** | **Oxidation and Reduction**<br>Reduction potentials: Redox half-reactions, Standard potentials and spontaneity, Trends in standard potentials, The electrochemical series, the Nernst equation.<br>Redox stability: The influence of pH, reactions with water-oxidation and reduction, the stability field of water, oxidation by atmospheric oxygen, disproportionation and comproportionation, the influence of complexation, the relation between solubility and standard potentials.<br>The diagrammatic presentation of potential data: Latimer diagrams, Frost diagrams, Pourbaix diagrams, natural waters.<br>Chemical extraction of the elements: Chemical reduction, chemical oxidation, electrochemical extraction. | **20** | CO3 | K1, K2, K3, K4, K5 |
| **Module 4:** | **Characterisation Techniques**<br>Diffraction methods: X-ray diffraction, Neutron diffraction, and Electron diffraction.<br>X-ray spectroscopic methods: X-ray fluorescence, absorption edge fine structure, X-ray absorption spectroscopy, electron spectroscopy for chemical analysis (XPS, UPS, Auger).<br>Atomic emission spectroscopy, inductively coupled plasma atomic emission spectroscopy. | **20** | CO4 | K1, K2, K3, K4, K5 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. A.R. West, Solid State Chemistry and Its Applications, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007).<br>2. B. D. Fahlman, Materials Chemistry, 2nd Ed.; Springer, The Netherlands, 2011.<br>3. D. K. Chakraborty, Solid State Chemistry, 2nd Ed.; New Age International Publisher, New Delhi, 2010.<br>4. G. Aruldas, Molecular Structure and Spectroscopy, 2ed Ed.; Prentice Hall India Learning Pvt. Ltd., India, 2015. | | | |

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| | 5. H. R. Allcock, Introduction to materials chemistry, 1st Ed.; John Wiley & Sons, New Jersey, 2011.<br>6. L. V. Azaroff, Introduction to Solids, 1st Ed. (33rd Reprint), Tata McGraw Hill, New Jersey, 2009.<br>7. R. H. Doremus, Glass Science, 2nd Ed.; Wiley, New York, 1973. |
| **References/ Readings:** | 1. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning, USA, 2014.<br>2. A. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Cengage learning, USA, 2007.<br>3. H. V. Keer, Principles of the Solid State, 1st Ed. (Reprint 2008); New Age International (P) Ltd., (Wiley Eastern Ltd.), New Delhi, 1993.<br>4. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong, Shriver & Atkins' Inorganic Chemistry, 5th Ed.; University Press, Oxford, 2010.<br>5. W. D. Callister, Materials Science and Engineering: An Introduction, 7th Ed.; John Wiley, New York, 2007. |

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| **Title of the Course** | Advanced Inorganic Chemistry |
| **Course Code** | CHI-6202 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To learn preparation, properties, and structure of important ring, cage, and chain compounds.<br>2. To know the applications of ring, chain, cage compounds, silicates and carbides.<br>3. To develop a comprehensive understanding of nitrogen and oxygen containing compounds.<br>4. To equip students with a comprehensive understanding of hydrogen as a sustainable energy carrier by exploring its production technologies, material requirements, and environmental implications. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. define the properties and reactivity of cage, ring, and chain compounds of *p*-block elements. | PSO1, PSO2 |

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| | CO 2. explain the synthesis, types, and uses of important compounds like silicones, silicates, borates, and carbides in industry and the environment. | | PSO1, PSO2 | |
| | CO 3. assess the suitability of various materials for hydrogen generation via gasification, electrolysis, thermochemical cycles, and photobiological methods, with emphasis on efficiency, stability, and sustainability. | | PSO2, PSO3, PSO4 | |
| | CO 4. interpret the chemistry of nitrogen and oxygen compounds-including hydrides, oxides, oxyacids, and coordination complexes-through structural, stereochemical, and ligand field perspectives. | | PSO1, PSO2, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Ring, cage and chain compounds of *p*-block elements**<br>Preparation, bonding and structure of higher boranes (except $B_2H_6$, $B_4H_{10}$), borane anions.<br>Synthesis, properties and structures of Carboranes and metallocarboranes.<br>Borazine: Synthesis, properties, structure, bonding and some of its derivatives.<br>Borates: classification, structures and examples.<br>Synthesis, properties and applications of silicones.<br>Silicates: classification with examples and applications.<br>Zeolites: introduction and applications.<br>Carbides: classification, preparation, properties and uses.<br>Synthesis of Metallocarbohedrenes.<br>Classification, preparation, properties, structures and uses of phosphazenes.<br>Compound of sulphur and nitrogen: Preparation, properties and structure of $(SN)_x$, $S_2N_2$ and $S_4N_4$. | **30** | CO1, CO2, CO4 | K1, K2, K3, K4, K5 |

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| **Module 2:** | **Compounds of Nitrogen and Oxygen:**<br>Hydrides of nitrogen: hydrazine, hydroxylamine.<br>Preparation, properties and structure of oxides of nitrogen, oxyacids and anions of nitrogen, dinitrogen and nitrogen compounds as ligands in coordination chemistry.<br>Compounds of oxygen: properties of dioxygen and ozone molecule, stereochemistry of oxygen compounds, oxygen fluorides, hydrogen peroxide, peroxo compounds, superoxides, ozonides, oxygen compounds as ligands in coordination chemistry. | **10** | CO1, CO4 | K1, K2, K3, K4, K5 |
| **Module 3:** | **Hydrogen economy**<br>Issues in hydrogen production using gasification.<br>Materials for water electrolysis cells.<br>Materials development for sulfur–iodine thermochemical hydrogen production.<br>Materials required for photobiological hydrogen production.<br>High temperature electrolysis.<br>Hydrogen separation and purification.<br>Hydrogen storage and challenges. | **20** | CO3 | K1, K2, K3, K4, K5 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd ed., Wiley India, New Delhi, 2008 (reprint).<br>2. J. D. Lee, Concise Inorganic Chemistry, 5th ed., Wiley India, New Delhi, 2008.<br>3. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th ed., Pearson, New Delhi, 2011.<br>4. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th ed., | | | |

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| | Oxford University Press, Oxford, 2009.<br>5. R. H. Jones and G. J. Thomas, Materials for Hydrogen Economy, 1st Edition, CRC Press, USA, 2008. |
| **References/ Readings:** | 1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6rd ed., Wiley India, New Delhi, 2003 (reprint 2012).<br>2. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd ed., Pearson, New Delhi, 2004. |

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| **Title of the Course** | Advanced Spectroscopic Techniques | |
| **Course Code** | CHI-6203 | |
| **Number of Credits** | 04 | |
| **Theory/Practical** | Theory | |
| **Level** | 500 | |
| **Effective from AY** | 2026-27 | |
| **New Course** | Yes | |
| **Bridge Course/ Value added Course** | No | |
| **Course for advanced learners** | No | |
| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To understand the principles, instrumentation, and data interpretation of advanced spectroscopic methods used in inorganic, bioinorganic, and materials chemistry.<br>2. To correlate spectroscopic data with molecular structure, bonding, oxidation states, and magnetic properties.<br>3. To learn advanced spectroscopic techniques for studying reactive intermediates, catalytic systems, and solid-state materials.<br>4. To develop analytical skills through data analysis, interpretation, and literature-based case studies. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the principles, selection rules, and instrumentation of advanced spectroscopic techniques (EPR, rRaman, XAS/EXAFS, CD/MCD). | PSO1, PSO2, PSO4 |

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| | CO 2. interpret spectroscopic data to deduce structural, electronic, and magnetic properties of coordination and bioinorganic systems. | | PSO1, PSO2, PSO4 | |
| | CO 3. apply theoretical and computational methods (spin Hamiltonian, EXAFS fitting, spectral simulation) for quantitative interpretation of spectra. | | PSO1, PSO2, PSO4 | |
| | CO 4. correlate data from multiple spectroscopic techniques to elucidate structures and reaction mechanisms of inorganic compounds. | | PSO1, PSO2, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Electron Paramagnetic Resonance (EPR) Spectroscopy**<br>Brief review of principles, g-factor, selection rules, isotropic and anisotropic systems, and qualitative spin Hamiltonian.<br>High-frequency (Q/W-band), pulsed and time-resolved EPR (TREPR); variable-temperature and high-field EPR; detection systems.<br>Principles and applications of ENDOR, ESEEM, HYSCORE; extraction of hyperfine and quadrupole information; correlation with NMR and Mössbauer data.<br>Anisotropic g and A tensors, D and E parameters, relaxation ($T_1$, $T_2$); introduction to spectral simulation using EasySpin.<br>Exchange coupling, spin delocalization, mixed-valence and spin-crossover systems; transient intermediates in catalysis. | **15** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5, K6 |
| **Module 2:** | **Resonance Raman (rRaman) Spectroscopy**<br>Raman vs. resonance Raman, enhancement mechanisms, vibronic coupling and Franck-Condon principle.<br>Lasers, detectors, filters, and sample handling, anti-Stokes/Stokes ratio; data collection parameters. | **15** | CO1, CO2, CO4 | K2, K3, K4, K5, K6 |

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| | Intensity patterns, depolarization ratio, selection rules, and isotope effects.<br>Applications in inorganic/bioinorganic chemistry:metal–oxo, peroxo, and superoxo species; metalloporphyrins, heme/non-heme enzymes. | | | |
| **Module 3:** | **X-ray Absorption Spectroscopy (XAS/EXAFS)**<br>Absorption edges, XANES and EXAFS regions, energy calibration, edge shifts and oxidation states.<br>Synchrotron radiation sources, detectors, sample environments, cryogenic systems.<br>Data processing and analysis: background subtraction, normalization, Fourier transform, and curve fitting using Athena/Artemis.<br>EXAFS equations and parameters: amplitude and phase functions, structural parameters (bond length, coordination number, disorder). | **15** | CO1, CO2, CO3, CO4 | K2, K3, K4, K5, K6 |
| **Module 4:** | **Circular Dichroism (CD) and Magnetic Circular Dichroism (MCD) Spectroscopy**<br>Optical activity, circular polarization, comparison of CD and MCD, selection rules.<br>Cotton effect, exciton coupling, Electronic CD (ECD) interpretation in metal complexes and chiral ligands; brief on Vibrational CD (VCD).<br>Magnetic Circular Dichroism (MCD): Theory and instrumentation, Zeeman effect, terms, temperature/field dependence.<br>Relationship between MCD and electronic absorption spectra; sign conventions; electronic transition assignments.<br>Applications and Case Studies: MCD/CD in transition metal and lanthanide complexes, metalloproteins, mixed-valence systems; integration with EPR, rRaman, XAS. | **15** | CO1, CO2, CO4 | K2, K3, K4, K5, K6 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |

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| **Texts:** | 1. A. Abragam, B. Bleaney, Electron Paramagnetic Resonance of Transition Ions, Oxford University Press, 3rd Ed, Oxford, 1970.<br>2. A. B. P. Lever, Inorganic Electronic Spectroscopy, Elsevier, 2nd Ed, Amsterdam, 1984.<br>3. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.,; Tata McGraw- Hill, New York, 2006.<br>4. C. N. R. Rao, Chemical Applications of Infrared and Raman Spectroscopy, Academic Press, 2nd Ed, New York, 1963.<br>5. J. A. Weil, J. R. Bolton, Electron Paramagnetic Resonance: Elementary Theory and Practical Applications, Wiley, 2nd Ed, New York, 2007.<br>6. J. Stohr, EXAFS Spectroscopy, Springer, 1st edition, Berlin, 1992.<br>7. N. Berova, K. Nakanishi, R. W. Woody, Circular Dichroism: Principles and Applications, Wiley-VCH, 2nd Ed, New York, 2000. |
| **References/ Readings:** | 1. EasySpin (ETH Zurich) and Demeter (Athena/Artemis) manuals for computational data analysis.<br>2. G. D. Christian, Analytical Chemistry, 6th ed., Wiley, New York, 2008.<br>3. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 6th Ed.; Wiley, New York, 2009.<br>4. P. J. Larkin, Infrared and Raman Spectroscopy: pPrinciples and Sspectral Iinterpretation, 2th Ed.; Elsevier, New York, 2018.<br>5. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th ed., Cengage learning, New York, 2022.<br>6. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th edn., Cengage learning, New York, 2017. |
| **Web Resources:** | 1. A. Tenderholt, B. Hedman, K. O. Hodgson, PySpline: A Modern, Cross-Platform Program for the Processing of Raw Averaged XAS Edge and EXAFS Data. AIP Conf. Proc. 882, 105, 2007.<br>https://www.slac.stanford.edu/econf/C060709 |

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3. D. G. Karmalkar, H. Lim, M. Sundararajan, Y.-M. Lee, M. S. Seo, D. Y. Bae, X. Lu, B. Hedman, K. O. Hodgson, W. S. Kim, E. Lee, E. I. Solomon, S. Fukuzumi, W Nam, Synthesis, Structure, and Redox Reactivity of Ni Complexes Bearing a Redox and Acid−Base Non-innocent Ligand with $Ni^{II}$, $Ni^{III}$, and $Ni^{IV}$ Formal Oxidation States. J. Am. Chem. Soc., 147, 3981, 2025. https://doi.org/10.1021/jacs.4c11751.
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5. J. J. Rehr & R. C. Albers, Theoretical Approaches to X-ray Absorption Fine Structure, Rev. Mod. Phys., 72, 621, 2000. https://doi.org/10.1103/RevModPhys.72.621
6. N. J. Wolford, A. Radovica, M. L. Neidig, C-Term Magnetic Circular Dichroism (MCD) Spectroscopy in Paramagnetic Transition Metal and F-element Organometallic Chemistry, Dalton Trans., 50, 416, 2021. https://doi.org/10.1039/D0DT03730C
7. N. Lehnert, Elucidating Second Coordination Sphere Effects in Heme Proteins Using Low-Temperature Magnetic Circular Dichroism Spectroscopy. J. Inorg. Biochem, 110, 83, 2012. https://doi.org/10.1016/j.jinorgbio.2012.02.033
8. N. Lehnert, S. George, E. I. Solomon, Recent Advances in Bioinorganic Spectroscopy, Curr. Opin. Chem. Biol. 5, 176, 2001. https://doi.org/10.1016/S1367-5931(00)00188-5
9. P. J. Riggs-Gelasco, J. C. Price, R. B. Guyer, J. H. Brehm, E. W. Barr, J. M. Bollinger, C. Krebs, EXAFS Spectroscopic Evidence for an Fe=O Unit in the Fe(IV) Intermediate Observed during Oxygen Activation by Taurine:α-Ketoglutarate Dioxygenase, J. Am. Chem. Soc. 126, 8108, 2004. https://doi.org/10.1021/ja048255q

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| **Title of the Course** | Framework Materials and Polyoxometalates |
| **Course Code** | CHI-6204 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Theory |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To enable understanding of different terminologies used in framework Chemistry.<br>2. To familiarize the concept of coordination polymers and metal- organic frameworks and assess synthetic routes, factors and applications of framework materials.<br>3. To comprehend the parallels between transition metal clusters and Zintl compounds.<br>4. To assimilate the knowledge on terms and methodologies in polyoxometalates. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. comprehend various terminologies in framework materials, metal clusters and polyoxometalates. | PSO1, PSO2 |

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| | CO 2. perform syntheses and apply factors affecting formation of the compounds. | | PSO2, PSO4 | |
| | CO 3. analyze and assess the properties of the compounds using characterization techniques. | | PSO3, PSO4 | |
| | CO 4. design compounds suitable for applications in catalysis, magnetism, environment and healthcare. | | PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Coordination Networks: From CPs to MOFs**<br>Framework materials/porous materials: Sorbents, zeolites, clathrates.<br>Coordination polymers (CPs) and Metal organic frameworks (MOFs): Definition, nomenclature, history (Prussian blue and Hofmann complex), classification and pre-requisites.<br>Terminologies: Reticular synthesis, secondary building units, linkers, struts, nodes, synthon and tecton.<br>Types of linkers: Neutral and anionic, flexible and rigid based on carboxylates and organic nitrogen compounds including quinoline based ligands. | **20** | CO1, CO2 | K1, K2, K3 |
| **Module 2:** | **Synthesis and applications of coordination networks**<br>Method of synthesis: Slow evaporation, hydro/solvothermal, microwave, mechanochemical, electrochemical and sonochemical.<br>Factors affecting the synthesis, structure stability, surface area, porosity.<br>Characterization techniques of discrete and dimensional compounds by infrared, thermogravimetry, single crystal and powder X- ray diffraction, X- ray photoelectron spectroscopy, vibrating sample magnetometry, Gouy's balance, electron spin resonance, adsorption measurements, cyclic voltammetry and fluorescence.<br>Applications of the discrete and dimensional compounds in the field of catalysis, gas | **15** | CO2, CO3, CO4 | K2, K3, K4, K5, K6 |

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| | storage, magnetism, medicine and fluorescent sensors for nitro aromatic compounds (NACs) and heavy metal pollutants. | | | |
| **Module 3:** | **Selected topics in metal- carbon frameworks and clusters**<br>Parallels between main group elements and organometallic chemistry: Metal- metal bonds in Re, Os and Mo.<br>Cluster compounds: Carbonyl compounds, transition metal halides, Zintl compounds and pincer ligands. | **10** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Module 4:** | **Chemistry of Polyoxometalates (POMs)**<br>Introduction and history: An overview on heptamolybdates, octatamolybdates and paratungstates.<br>Classification of POM clusters based on the structure and nuclearity for molybdenum, tungsten and vanadium: Anderson, Lindqvist, Keggin and Wells- Dawson anions.<br>Synthesis of POMs by 'one pot' methodology using ambient, reflux and hydrothermal conditions including heptamolybdates containing *s*- block cations, reactions with organic amines and crown ethers.<br>Application of POM clusters in catalysis (water splitting, ester hydrolysis and oxidation), energy storage and conversion and as Single- Molecule Magnets (SMMs). | **15** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5 |
| **Pedagogy:** | Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6th ed., Wiley India, New Delhi, 2003 (Reprint 2012).<br>2. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 5th ed., Pearson, United States of America, 2014.<br>3. M. T. Pope, A. Müller, Polyxometalate Chemistry From Topology via Self-Assembly to Applications, Kluver Academic Publishers, Netherlands, 2001. | | | |

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| | 4. M. T. Pope, Heteropoly & isopolyoxometalates, Springer, New York, 1983.<br>5. N. N. Greenwood, A. Earnshaw, Chemistry of the elements, 2nd ed., Elsevier, India, 2014.<br>6. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th ed.,Oxford University Press, Oxford, 2009.<br>7. R. C. Mehrotra, R. Bohra, Metal carboxylates, Academic Press, London, 1983.<br>8. R. H. Crabtree, The Organometallic Chemistry Of The Transition Metals, 4th ed., John Wiley & Sons, New Jersey, USA, 2005.<br>9. S. R. Batten, S. M. Neville, D. R. Turner, Coordination Polymers: Design, Analysis, and Application, Royal Society of Chemistry, Cambridge, 2008. |
| **References/ Readings:** | 1. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds Part A: Theory and Applications in Inorganic Chemistry, 6th ed., John Wiley & Sons, New Jersey, USA, 2009.<br>2. M. Hutin, M.H. Rosnes, D. L. Long, L. Cronin, Comprehensive Inorganic Chemistry II, Elsevier, Glasgow, 2013. |
| **Web Resources:** | 1. B. R. Srinivasan, S. C. Sawant, Indian J. Chem., 43 (2004) 1066.http://nopr.niscair.res.in/handle/123456789/18144?mode=simple<br>2. C. Dey, T. Kundu, B. P. Biswal, A. Mallick, R. Banerjee, Acta Cryst. B.,70 (2014) 3-10.doi: 10.1107/S2052520613029557<br>3. D. D. Narulkar, A. R. Patil, C. C. Naik, S. N. Dhuri, Inorg. Chim. Acta, 427(2015)248-258. doi:10.1016/j.ica.2015.01.009<br>4. D. L. Long, R.T. Sunashima, L. Cronin, Angew. Chem. Int. Ed., 49 (2010) 1736-1758. doi:10.1002/anie.200902483<br>5. http://nopr.niscair.res.in/handle/123456789/39730<br>6. L. V. Nadal, L. Cronin, Nature Reviews, 2 (2017) 1-15. doi:10.32628/IJSRST24114140<br>7. N. Stock, S. Biswas, Chem. Rev., 112 (2012) 933-969. doi:10.1021/cr200304e<br>8. O. M. Yaghi, M. O'Keeffe, N. W. Ockwig, H. K. Chae, M. Eddaoudi, J. Kim, Nature, 423 (2003) 705- 714. |

doi:10.1038/nature01650

9. P. M. Forster, N. Stock, A. K. Cheetham, Angew. Chemie- Int. Ed., 44 (2005) 7608-7611. doi:10.1002/anie.200501766
10. S. Kitagawa, R. Kitaura, S. I. Noro, Angew. Chemie- Int. Ed., 43 (2004) 2334-2375. doi:10.1002/anie.200300610
11. S. R. Batten, N. R. Champness, X. -M. Chen, J. Garcia- Martinez, S. Kitagawa, L. Ohrstom, M. O'Keeffe, M. Paik Suh, J. Reedijk, Pure Appl. Chem., 85 (2013) 1715- 1724. doi:10.1351/PAC-REC-12-11-20
12. S. S. Nagarkar, B. Joarder, A. K. Chaudhari, S. Mukherjee, S. K. Ghosh, Angew. Chemie- Int. Ed., 52 (2013) 2881-2885. doi: 10.1002/anie.201208885

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| **Title of the Course** | Inorganic Chemistry Practical – V |
| **Course Code** | CHI-6205 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To learn the synthesis of various inorganic materials using different preparative methods.<br>2. To understand quantitative determination of metal using different laboratory and instrumental techniques.<br>3. To acquire knowledge for analysing elements from a mixture of two or more elements<br>4. To learn different characterization techniques and select proper technique or procedure for analysis of elements. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain various methods for synthesis of inorganic materials. | PSO1, PSO2, PSO4 |

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| | CO 2. evaluate suitable method for material synthesis based on their properties and characterized the prepared materials using suitable techniques. | | PSO1, PSO2, PSO4 | |
| | CO 3. analyze different elements using various laboratory and instrumental techniques. | | PSO1, PSO3, PSO4 | |
| | CO 4. apply knowledge to design procedures for synthesis of inorganic materials and analysis of elements. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Preparation of Materials (Any 10 experiments)**<br>i. Preparation of silver nanoparticles by colloidal route and spectrophotometry analysis.<br>ii. Preparation of copper nanoparticles by colloidal route and spectrophotometry analysis<br>iii. Preparation of ZnO nanomaterials by co-precipitation/sol-gel method and XRD analysis.<br>iv. Preparation of NiO nanomaterials by co-precipitation/sol-gel method and XRD analysis<br>v. Preparation of CdS nanomaterials by precipitation/precursor method and XRD analysis.<br>vi. Preparation of ZnS nanomaterials precipitation/precursor method and XRD analysis.<br>vii. Preparation of silver supported $SiO_2$ by wet impregnation method.<br>viii. Preparation of ZnO supported $SiO_2$ by wet impregnation method.<br>ix. Preparation of NiO supported $Al_2O_3$ by wet impregnation method<br>x. Preparation of silver nanoparticles using green reducing agents.<br>xi. Preparation of NiO-$MnO_2$ using co-precipitation/precursor method.<br>xii. Preparation of CuO-ZnO using co-precipitation/hydrothermal method. | **60** | CO1, CO2, CO3 | K1, K2, K3, K5, K6 |

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| | xiii. Preparation of CoB nanomaterials by reduction/co-precipitation/sol-gel method and XRD analysis.<br>xiv. Preparation of $MnO_2$, $Mn_2O_3$, and $Mn_3O_4$ by coprecipitation method.<br>xv. Preparation of zinc ferrite by co-precipitation/sol-gel/microwave method and XRD analysis.<br>xvi. Preparation of nickel ferrite by co-precipitation/sol-gel/microwave method and XRD analysis. | | | |
| **Module 2:** | **Inorganic Analysis (Any 10 experiments)**<br>i. Analysis of soda ash by acidimetry.<br>ii. Analysis of talcum powder for Mg(II) by complexometric titration.<br>iii. Analysis of cobalt in Vit B12 tablets (colorimetrically/gravimetry).<br>iv. Analysis of borax (titrimetry).<br>v. Determination of the strength of commercial phosphoric acid by pH titration.<br>vi. Percentage purity of ZnO in commercial samples by complexometric titration.<br>vii. Percentage purity of NiO in commercial samples by complexometric titration.<br>viii. Percentage purity of Epsom Salt by complexometric titration.<br>ix. Analysis of lime stone (estimation of calcium and magnesium by titrimetry.<br>x. Analysis of wood's metal (separation of metal ions and analysis by gravimetry/titrimetry).<br>xi. Analysis of Monel metal (Cu and Ni by gravimetrically/spectrophotometrically).<br>xii. Analysis of magnalium (Mg and Al by volumetrically/gravimetrically)<br>xiii. Estimation of Si and Ca from Plaster of Paris sample.<br>xiv. Estimation of Mn content by spectrophotometry from a given sample.<br>xv. Estimation of iron and zinc from zinc ferrite (by gravimetry/titrimetry).<br>xvi. Estimation of iron and nickel from nickel ferrite (by gravimetry/titrimetry). | **60** | CO2, CO3, CO4 | K1, K2, K3, K4, K5 |

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| | xvii. XRD and TG/DTA analysis of $MnO_2$, $Mn_2O_3$, and $Mn_3O_4$. | | | |
| **Pedagogy:** | Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. A. R. West, Solid State Chemistry and Its Applications, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007).<br>2. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, New Delhi, 2011.<br>3. J. Bassett, R. C. Denney, G. H. Jeffery, J. Mendham, Vogel's Text Book of Quantitative Inorganic Analysis, 4th ed., Longman, England, 1978.<br>4. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th ed., Pearson, New Delhi, 2002.<br>5. S. K. Kulkarni, Nanotechnology principles and practices, 3rd ed., Capital Publishing Company, New Delhi, 2014. | | | |
| **References/ Readings:** | 1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6th ed., Wiley India, New Delhi, 2003 (reprint 2012).<br>2. N. N. Greenwood, A. Earnshaw, Chemistry of the elements, 2nd ed., Elsevier, India, 2014.<br>3. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th ed., Oxford University Press, Oxford, 2009. | | | |

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|---|---|
| **Title of the Course** | Inorganic Chemistry Practical – VI |
| **Course Code** | CHI-6206 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To know purification of starting materials by crystallization, separation.<br>2. To learn synthesis of metal compounds.<br>3. To learn characterization of compounds by volumetric / gravimetric methods.<br>4. To provide hand-on experience in electroanalytical and spectroscopic techniques for compound characterization. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the importance of purification of starting materials. | PSO1, PSO2, PSO3, PSO4 |
| | CO 2. synthesize metal compounds. | PSO1, PSO2, PSO3, |

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| | | | PSO4 | |
| | CO 3. apply knowledge of volumetric and gravimetric analysis for estimation of metal content. | | PSO1, PSO2, PSO3, PSO4 | |
| | CO 4. analyze the electroanalytical and spectroscopic properties of metal compounds. | | PSO1, PSO2, PSO3, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Purification of ligands and Preparation of metal compounds (Any Six)**<br>i. Purification (distillation/recrystallisation) of ligands like amines and carboxylic acids.<br>ii. Preparation of *N*,*N*-Dipicolyl amine.<br>iii. Purification of *N*,*N*-Dipicolyl amine by column chromatography.<br>iv. Preparation of Dichlorobis(*o*-chloroaniline)cobalt(III)<br>v. Preparation of Dichlorobis(*m*-chloroaniline)cobalt(III)<br>vi. Preparation of Dichlorobis(*p*-chloroaniline)cobalt(III)<br>vii. Preparation of $MnCl_2$(L-proline)·$H_2O$ Solution method<br>viii. Preparation of $MnCl_2$(L-proline)·$H_2O$ by Mechanochemical grinding.<br>ix. Preparation of catena-[(m-chloro)-bis(1H-imidazole)-chloro-copper(II)]<br>x. Preparation of Manganese(II) ammonium phosphate monohydrate<br>xi. Preparation of Manganese(III) orthophosphate monohydrate<br>xii. Preparation of $Zn_4O(CH_3COO)_6$<br>xiii. Preparation of Iron(dipicolylamine)$Cl_3$<br>*NOTE: student is expected to recrystallize the product, carry out estimations like volumetric, gravimetric, instrumental analysis (such as IR, UV-Vis, AES, CHNS, optical rotation, Gouy's balance) and describe crystal structure.* | **36** | CO1, CO2 | K1, K2, K3, K4, K5, K6 |

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| **Module 2:** | **Estimation of metals by volumetric / gravimetric methods (Any Six)**<br>i. Estimation of Manganese in Manganese(II) ammonium phosphate monohydrate.<br>ii. Estimation of Manganese in Manganese(III) orthophosphate monohydrate.<br>iii. Estimation of phosphate in Manganese(II) ammonium phosphate monohydrate.<br>iv. Estimation of phosphate in Manganese(III) orthophosphate monohydrate.<br>v. Estimation of cobalt in Dichlorobis(*o*-chloroaniline)cobalt(III), Dichlorobis(*m*-chloroaniline)cobalt(III) and Dichlorobis(*p*-chloroaniline)cobalt(III).<br>vi. Estimation of Manganese in $MnCl_2$(L-proline)·$H_2O$.<br>vii. Estimation of copper in catena-[(m-chloro)-bis(1H-imidazole)-chloro-copper(II)].<br>viii. Estimation of copper in tetrakis($\mu$-acetato)-diaqua-di-copper(II)<br>ix. Estimation of zinc in $Zn_4O(CH_3COO)_6$.<br>x. Estimation of iron in iron(dipicolylamine)$Cl_3$ | **36** | CO3 | K1, K2, K3, K4, K5, K6 |
| **Module 3:** | **Electroanalytical studies of metal compounds (Any Four)**<br>i. Cyclic voltametric study of ferrocene.<br>ii. Cyclic voltametric study of $K_3[Fe(CN)_6]$.<br>iii. Cyclic voltametric study of iron(dipicolylamine)$Cl_3$<br>iv. Cyclic voltammetry study of catena-[(*m*-chloro)-bis(1H-imidazole)-chloro-copper(II)]<br>v. Cyclic voltammetry study of Dichlorobis(*o*-chloroalinine)cobalt(III) or Dichlorobis(*m*-chloroalinine)cobalt(III) or Dichlorobis(*p*-chloroalinine)cobalt(III)<br>vi. Cyclic voltammetry study of $MnCl_2$(L-proline)·$H_2O$ | **24** | CO4 | K1, K2, K3, K4, K5, K6 |
| **Module 4:** | **Spectroscopic analysis of metal compounds (Any Four)**<br>i. UV-vis study of $Cu(acac)_2$ | **24** | CO4 | K1, K2, K3, K4, K5, K6 |

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| | ii. UV-vis study of Iron(dipicolylamine)$Cl_3$<br>iii. UV-vis study of catena-[(m-chloro)-bis(1H-imidazole)-chloro-copper(II)]<br>iv. UV-vis study of Dichlorobis(*o*-chloroalinine)cobalt(III)<br>v. UV-vis study of Dichlorobis(*m*-chloroalinine)cobalt(III)<br>vi. UV-vis study of Dichlorobis(*p*-chloroalinine)cobalt(III)<br>vii. UV-vis study of $MnCl_2$(L-proline)·$H_2O$ | | | |
| **Pedagogy:** | Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd ed., Chapman & Hall, New York, 1974.<br>3. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, New Delhi, 2011.<br>4. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th ed., Pearson, New Delhi, 2002.<br>5. S. De Meo, J. Chem. Ed., 80(2003)796-798.<br>6. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970. | | | |
| **References/ Readings:** | 1. A. J. Elias, General Chemistry Experiments, Revised ed., University Press, Hyderabad, 2008.<br>2. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972. | | | |

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| **Title of the Course** | Inorganic Chemistry Practical – VII |
| **Course Code** | CHI-6207 |
| **Number of Credits** | 04 |
| **Theory/Practical** | Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | 1. To acquire practical knowledge in identification of cations and anions in compounds.<br>2. To learn techniques of crystallization, separation and purification of synthesized metal compounds.<br>3. To learn characterization of compounds by chemical and instrumental methods.<br>4. To gain hands-on experience in data analysis. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. identify cations and anions in compounds. | PSO1, PSO4 |
| | CO 2. explain techniques related to synthesis of metal compounds. | PSO1, PSO2, PSO3, PSO4 |

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| | CO 3. apply chemical and instrumental methods for compound characterization. | | PSO1, PSO3, PSO4 | |
| | CO 4. estimate the metal content in ores, minerals and alloys. | | PSO1, PSO3 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| **Module 1:** | **Preparation and estimation of compounds (Any Seven)**<br>i. Preparation of $[Co(bpy)_2(CO_3)](4\text{-nba})\cdot 5H_2O$<br>ii. Preparation of $[Co(bpy)_2(CO_3)]_2$ (nip)$\cdot 11H_2O$<br>iii. Estimation of cobalt in $[Co(bpy)_2(CO_3)](4\text{-nba})\cdot 5H_2O$ and $[Co(bpy)_2(CO_3)]_2$ (nip)$\cdot 11H_2O$<br>iv. Preparation of $[(H_2O)_4Li(\mu\text{-}H_2O)_2](4\text{-nba})_2$ and $[Na(4\text{-nba})(H_2O)_3]_n$<br>v. Preparation of $[Mg(H_2O)_6(4\text{-nba})_2]\cdot 2H_2O$ and its ligand displacement reaction with imidazole (Im) to yield $[Mg(H_2O)_2(Im)_2(4\text{-nba})_2]$<br>vi. Estimation of magnesium in $[Mg(H_2O)_6(4\text{-nba})_2]\cdot 2H_2O$ and $[Mg(H_2O)_2(Im)_2(4\text{-nba})_2]$<br>vii. Preparation of $[Ca(H_2O)_4(4\text{-nba})_2]$ and its ligand displacement reaction with Im to yield $[Ca(Im)(H_2O)_3(4\text{-nba})_2]$<br>viii. Estimation of calcium in $[Ca(H_2O)_4(4\text{-nba})_2]$ and $[Ca(Im)(H_2O)_3(4\text{-nba})_2]$.<br>ix. Estimation of iron as 8- hydroxyquinolateiron(II).<br>x. Determination of potassium as sodium hexanitritocobaltate(III) and tetraphenylboron. | **42** | CO1 | K1, K2, K3, K4 |
| **Module 2:** | **Experiments in Solid state chemistry (Any Nine)**<br>i. Preparation of manganese(II) oxalate dihydrate by precursor method.<br>ii. Estimation of manganese(II) and oxalate in manganese oxalate dihydrate. | **54** | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |

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| | iii. Characterization of manganese(II) oxalate dihydrate by IR and thermal analysis.<br>iv. Preparation of nickel zinc oxalate hexahydrate by precursor method.<br>v. Estimation of nickel and zinc in nickel zinc oxalate hexahydrate.<br>vi. Characterization of nickel zinc oxalate hexahydrate by IR and thermal analysis.<br>vii. Preparation of cobalt zinc iron oxalate hexahydrate by precursor method.<br>viii. Isothermal studies of manganese(II) oxalate dihydrate and nickel zinc oxalate hexahydrate.<br>ix. X-ray diffraction studies of spinel oxides such as gamma-$Fe_3O_4$, $CoFe_2O_4$, $Co_{0.5}Ni_{0.5}Fe_2O_4$, $Co_{0.5}Zn_{0.5}Fe_2O_4$.<br>x. Raman studies of spinel oxides such as gamma-$Fe_3O_4$, $CoFe_2O_4$, $Co_{0.5}Ni_{0.5}Fe_2O_4$, $Co_{0.5}Zn_{0.5}Fe_2O_4$.<br>xi. XPS studies of spinel oxides such as gamma-$Fe_3O_4$, $CoFe_2O_4$, $Co_{0.5}Ni_{0.5}Fe_2O_4$, $Co_{0.5}Zn_{0.5}Fe_2O_4$. | | | |
| **Module 3:** | **Ore analysis/ Alloy analysis using Titrimetry / Gravimetry / spectroscopy method (Any Four)**<br>i. Analysis of magnesium percentage in Magnesite.<br>ii. Analysis of magnesium & calcium percentage in Dolomite.<br>iii. Analysis of iron percentage in gamma-FeO(OH).<br>iv. Analysis of lead percentage in galena.<br>v. Analysis of iron percentage in iron sulphide | **24** | CO2, CO3, CO4 | K2, K3, K4, K5 |
| **Pedagogy:** | Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning. | | | |
| **Texts:** | 1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963.<br>2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd ed., | | | |

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| | Chapman & Hall, New York, 1974.<br>3. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, New Delhi, 2011<br>4. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th ed., Pearson, New Delhi, 2002.<br>5. S. De Meo, J. Chem. Ed., 80(2003)796-798.<br>6. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970. |
| **References/ Readings:** | 1. A. J. Elias, General Chemistry Experiments, Revised ed., University Press, Hyderabad, 2008.<br>2. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972. |

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**DISSERTATION (40 Credits)**

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| **Title of the Course** | Discipline Specific Dissertation (DSD) |
| **Course Code** | CHI-6501 |
| **Number of Credits** | 40 |
| **Theory/Practical** | Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | To develop the skills of preparing and conducting independent research. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the principles and techniques used in chemical analysis and experimentation. | PSO1, PSO3 |
| | CO 2. use appropriate chemical tools and methods to solve experimental problems. | PSO1, PSO2, PSO4 |
| | CO 3. analyze and interpret experimental data to draw meaningful conclusions. | PSO1, PSO3, PSO4 |
| | CO 4. design independent research projects using appropriate chemical methodologies. | PSO2, PSO4 |

| Content: | | No of hours | Mapped to CO | Cognitive Level |
|---|---|---|---|---|
| | As per OA-35A | 1200 | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |
| **Pedagogy:** | Dissertation carried out individually by each student throughout the academic year. | | | |
| **Texts:** | As required for the development of review and methodology. | | | |
| **References/ Readings:** | As required for the development of review and methodology. | | | |
| **Web Resources:** | As required for the development of review and methodology. | | | |

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**DISSERTATION (20 Credits)**

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| **Title of the Course** | Discipline Specific Dissertation (DSD) |
| **Course Code** | CHI-6502 |
| **Number of Credits** | 20 |
| **Theory/Practical** | Practical |
| **Level** | 500 |
| **Effective from AY** | 2026-27 |
| **New Course** | Yes |
| **Bridge Course/ Value added Course** | No |
| **Course for advanced learners** | No |

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| **Pre-requisites for the Course:** | Level 400 courses | |
| **Course Objectives:** | To develop the skills of preparing and conducting independent research. | |
| **Course Outcomes:** | Students will be able to | **Mapped to PSO** |
| | CO 1. explain the principles and techniques used in chemical analysis and experimentation. | PSO1, PSO3 |
| | CO 2. use appropriate chemical tools and methods to solve experimental problems. | PSO1, PSO2, PSO4 |
| | CO 3. analyze and interpret experimental data to draw meaningful conclusions. | PSO1, PSO3, PSO4 |

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|---|---|---|---|---|
| | CO 4. design independent research projects using appropriate chemical methodologies. | | PSO2, PSO4 | |
| **Content:** | | **No of hours** | **Mapped to CO** | **Cognitive Level** |
| | As per OA-35A | 600 | CO1, CO2, CO3, CO4 | K1, K2, K3, K4, K5, K6 |
| **Pedagogy:** | Dissertation carried out individually by each student throughout the academic year. | | | |
| **Texts:** | As required for the development of review and methodology. | | | |
| **References/ Readings:** | As required for the development of review and methodology. | | | |
| **Web Resources:** | As required for the development of review and methodology. | | | |

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