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ताळगांव पठार
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(Accredited by NAAC)

GU/Acad –PG/BoS -NEP/2023/78/4 Date:24.05.2023

Ref: GU/Acad –PG/BoS -NEP/2022/339/11 dated 19.08.22

CIRCULAR

In supersession to the above referred Circular, the updated approved Syllabus with revised Course Codes of the **Master of Science in Chemistry Programme** is enclosed.

The approved Syllabus of the **Master of Science in Chemistry** Programme (Organic, Inorganic, Analytical and Physical, Pharmaceutical Chemistry) is attached.

The Dean/ Vice-Deans of the School of Chemical Sciences/ Principals of Affiliated Colleges offering the **Master of Science in Chemistry** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2023.05.24 17:31:44 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Deans, School of Chemical Sciences, Goa University.
3. The Principals of Affiliated Colleges offering the Master in Sciences in Chemistry Programme.

Copy to:

1. The Chairperson, Board of Studies in Chemistry PG.
2. The Programme Director, M. Sc. Chemistry, Goa University.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar, PG Examinations, Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

ANNEXURE-I

M.Sc. Chemistry (SEM I & II) Syllabus (80 Credit course) as per NEP 2020 for AY 2022-23

SEM I			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	CHO-500	Fundamentals of Organic Chemistry	4
2.	CHI-500	Fundamentals of Inorganic Chemistry	4
3.	CHP-500	General Physical Chemistry	4
4.	CHA-500	Techniques in Analytical Chemistry-I	4
5.	CHO-521	Practical Course in Organic Chemistry-I	2
6.	CHO-522	Practical Course in Organic Chemistry-II	2
7.	CHI-521	Practical Course in Inorganic Chemistry-I	2
8.	CHI-522	Practical Course in Inorganic Chemistry-II	2
9.	CHP-521	Practical Course in Physical Chemistry-I	2
10.	CHP-522	Practical Course in Physical Chemistry-II	2
11.	CHA-521	Practical Course in Analytical Chemistry-I	2
12.	CHA-522	Practical Course in Analytical Chemistry-II	2
SEM II (Inorganic Chemistry)			
1.	CHI-501	Chemistry of Coordination & Organometallic Compounds	4
2.	CHI-502	Chemistry of Materials	4
3.	CHI-503	Concepts in Molecular Symmetry and Spectroscopy	4
4.	CHI-504	Concepts in Inorganic Chemistry	4

SEM II (Analytical Chemistry)			
1.	**CHA-501**	Chemical Methods of Analysis	4
2.	**CHA-502**	Techniques in Analytical Chemistry-II	4
3.	**CHA-503**	Separation Techniques	4
4.	**CHA-504**	Instrumental Methods of Analysis	4
SEM II (Organic Chemistry)			
1.	**CHO-501**	Organic Spectroscopy	4
2.	**CHO-502**	Pericyclic and Organic Photochemical Reactions	4
3.	**CHO-503**	Synthetic Methodologies in Organic Chemistry	4
4.	**CHO-504**	Stereochemistry and Organic Transformations	4
SEM II (Physical Chemistry)			
1.	**CHP-501**	Quantum Chemistry and Statistical Thermodynamics	4
2.	**CHP-502**	Group Theory and Molecular Spectroscopy	4
3.	**CHP-503**	Chemical Kinetics and Thermodynamics	4
4.	**CHP-504**	Electrochemistry and Surface Studies	4

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHA-500 **Title of the course:** Techniques in Analytical Chemistry - I

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Learning various methods of data handling in analysis. 2. Understanding the significance of sampling and calibration techniques. 3. Understanding principles and applications of various types of techniques 4. Training the students to deduce structures based on IR, NMR, MS combined data.	
Content:	**1. Analytical Objectives and Data Handling** 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.	No. of Hours 5
	2. Sampling and Calibration Techniques Sampling and sample preparation, general steps in chemical analysis, calibration of glass wares. Finding the best straight line-least square regression, correlation coefficient; Calibration curves, standard addition technique and internal standards. Chemical concentrations.	5
	3. Classical methods of Analysis Gravimetry and Titrimetric methods, Principle, methodology, Advantages & Disadvantages over instrumental methods. Conditions for identifying a given reaction as method of Analysis, Classification of reactions in titrimetric analysis (Acid-Base, redox, complexometric and precipitation), Standard solutions and their preparation. Selection of Visual Indicators in titrimetric Analysis	6
	4. Introduction to Electroanalytical techniques Introduction to electrochemical cell, electrode potential, Classification of electroanalytical techniques, working principles, and their applications	4
	5. Introduction to Thermoanalytical techniques Principle, Instrumentation and applications of Thermo Gravimetric Analysis, Differential Thermal Analysis, and Differential Scanning Calorimetry. Numericals based on TGA.	5
	6. Introduction to Chromatographic Techniques a. Principles of chromatography, classification of	15

	chromatographic techniques based on mechanism of retention, configuration, mobile and stationary phase. Efficiency of separation- plate theory (theoretical plate concept) and rate theory (van Deemter equation). b. Principles and applications of Paper chromatography, thin layer chromatography, HPTLC, Size exclusion and Ion exchange chromatography. Counter-current chromatography for isolation of natural products. c. Gas and Liquid Chromatography: Introduction; Instrumental Modules; The Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, LCMS; Applicability-interpretation and numericals.	
	7. Introduction to Spectroscopic Techniques a. Interaction of Electromagnetic Radiation with Matter: Electromagnetic spectra, regions of spectrum, numericals. b. Ultraviolet and visible Spectroscopy: Electronic spectra and Molecular structure: types of electronic transition, Chromophore and auxochrome, absorption by isolated chromophore, conjugated chromophores, aromatic compounds, inorganic chelates. Calculating λmax for Conjugated Dienes, Trienes, polyenes, α,β-unsaturated carbonyl compounds, Numericals. 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. c. Infrared Spectroscopy: Infrared absorption and molecular structures, molecular vibrations, types of vibrations, IR spectra, overtones and bands-basis of NIR absorption. Spectra interpretation, Frequencies of functional group, Spectral Databases, Identification of unknown compounds. d. Spectrometric Instrumentation of UV-Vis and IR: Sources, monochromators, sample cells, detectors, instrumental wavelength and absorption calibration. e. Proton and Carbon NMR Spectroscopy: Theory of NMR, Instrumentation, Chemical shift, factors influencing chemical shift, solvents used in NMR, spin-spin splitting, coupling constant calculation, factors influencing coupling constant. f. Mass Spectrometry: Principle, Instrumentation and various	20

	fragmentation patterns. g. Conjoint spectrometry problems: Structural elucidation of organic molecules using IR, UV, NMR and MS. h. Raman Spectroscopy: Theory, Basic instrumentation and Structural analysis using Raman Spectra. (Note: Assignment based on all above spectrometric methods should be given to student. More weightage of lectures shall be given for solving IR and NMR data problems for structure elucidation)	
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.	
References / Readings:	1. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 2. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed.; Saunders College Publishing, 1990. 3. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th Ed.; McGraw- Hill Int., 1985. 4. W. Kemp, Organic Spectroscopy, 3rd Ed.; Palgrave, 1991. 5. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning, 2014. 6. F. J. Holler, D. A. Skoog, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Thomson Books, 2007. 7. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7th Ed.; HCBS Publishing, 2004. 8. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.; Tata McGraw- Hill, 2006. 9. R. M. Silverstein, F. X. Webster, Spectrometric identification of Organic Compounds, 6th Ed.; Wiley, 1998. 10. H. Gunzler, A. Williams, Handbook of Analytical Techniques, 1st Ed.; Wiley, 2001. 11. P. S. Kalsi, Spectroscopy of Organic Compounds, 2nd Ed.; New Age International, 2000. 12. E. Pretsch, P. Buhlmann, C. Affolter, Structural Determination of Organic Compounds, 2nd Ed.; Springer, 2005. 13. L. D. Field, S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4th Ed.; Wiley, 2007. 14. R. A. Day, A. L. Underwood, Quantitative Analysis, 6th Ed.; Prentice Hall, 2001. 15. B. K Sharma, Instrumental methods of chemical analysis, Goel Publishing House, Meerut, 2004. 16. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 6th Ed.; Wiley, 2009. 17. P. J. Larkin, Infrared and Raman Spectroscopy: principles and	

	spectral interpretation, 2th Ed.; Elsevier, 2018. 18. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, 2009.
Course outcomes:	1. Students will be able to analyse the role of statistical tools for determination of error and organised data management for systematic interpretation. 2. Student will be able to apply the sampling and calibration methods for obtaining reliable results. 3. Students will be able to understand basic principles and scope of different methods of Analysis 4. Students will be able to solve problems based on IR, NMR, MS combined spectral data.

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHA-521 **Title of the course:** Practical Course in Analytical Chemistry - I

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.	
Content:	*This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.* **Unit 1: Statistics** i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments Preparation of standard solutions and standardisation.	No of hours 9
	Unit 2: Colorimetry/ UV-Visible Spectrophotometry i. Estimation of Iron from Pharmaceutical sample (capsule) by thiocyanate method ii. Estimation of phosphoric acid in cola drinks by molybdenum blue method. iii. Estimation of KNO_3 by UV spectroscopy and $K_2Cr_2O_7$ by Visible spectroscopy iv. Simultaneous determination and Verification of law of additivity of absorbances ($K_2Cr_2O_7$ and $KMnO_4$).	8
	Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products. ii. Estimation of Pb in water sample by AES/AAS/ICP. iii. Estimation of Fe and Al in Iron ore sample by AES/AAS/ICP.	9
	Unit 4: Ion Exchange Chromatography and High Pressure Liquid Chromatography i. Separation and Estimation of chloride and bromide. ii. Separation of Anthracene and Naphthalene using reverse phase chromatography iii. Separation of Benzaldehyde and Benzyl alcohol using normal phase chromatography	10

	Unit 5: Volumetric Titrations i. Estimation of Ca in pharmaceutical tablet. ii. Estimation of Al and Mg in antacid tablet. iii. Estimation of CaO in cement.	10
	Unit 6: Solvent Extraction and spectrophotometry i. Extraction of Cu as copper dithiocarbamate (DTC) using solvent extraction and estimation by spectrophotometry. ii. Determination of Ni as Dimethylglyoxime complex by spectrophotometry. iii. Determination of Silver as ion association complex with 1,10-Phenanthroline and Bromopyrogallol red.	10
	Unit 7: Interpretation Exercises i. Thermal studies: TG/DTA and Isothermal weight loss studies of various hydrated solids like $CuSO_4 \cdot 5H_2O$, $Ca_2C_2O_4 \cdot H_2O$, $Fe_2C_2O_4 \cdot 2H_2O$. ii. X-ray powder diffractometry: Calculation of lattice parameters from X-ray powder pattern of cubic system such as $NiMn_2O_4$, $CoFe_2O_4$ etc. iii. IR spectra of Urea, benzoic acid, Copper sulphate pentahydrate etc.	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.	
References / Readings:	1. J. H. Kennedy, Analytical Chemistry Principles, Saunders College Publishing, 2nd Ed., 1990. 2. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia 2009. 4. A. J. Elias, Collection of interesting chemistry experiments, University press, 2002. 5. R.A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, 2001. 6. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, 2002.	
Course outcomes:	1. Students will be able to explain how to determine an unknown concentration of solution. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation. 4. Students will be able to interpret TG/X-Ray/IR spectra.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHA-522 **Title of the course:** Practical Course in Analytical Chemistry - II

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.	
Content:	*This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.*	No of hours
	Unit 1: Statistics i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments iii. Preparation of standard solutions and standardisation.	9
	Unit 2: Titrimetric Analysis i. Standardisation and estimation of Chloride using precipitation titration (Mohr's method) ii. Analysis of commercial caustic soda by neutralisation titrimetric method iii. Determination of sulphates by complexometric titrations using EDTA.	8
	Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products using flame photometer. ii. Estimation of chromium in water sample by AES/AAS/ICP. iii. Estimation of nickel, molybdenum in Hastelloy C-22 using AES/AAS/ICP.	10
	Unit 4: Natural product isolation and Ion Exchange Chromatography i. Isolation of cinnamaldehyde from cinnamon ii. Isolation of Caffeine from tea powder iii. Separation and estimation of Cadmium and Zinc	9
	Unit 5: UV-Visible Spectrophotometry and High-Pressure Liquid Chromatography i. Estimation of KNO_3 and $K_2Cr_2O_7$ using UV- Visible	10

	spectroscopy ii. Separation of Benzaldehyde and benzoic acid using reverse phase HPLC. iii. Quantification of naphthalene in a sample using reverse phase HPLC.	
	Unit 6: Solvent Extraction and spectrophotometry i. Spectrophotometric determination of aspirin/phenacetin/ caffeine in APC tablet using solvent extraction ii. Colorimetric determination of iron with salicylic acid. iii. Determination of copper in brass sample by colorimetry.	10
	Unit 7: Data Interpretation Exercises i. NMR/Mass spectra ii. HPLC and GC chromatograph iii. XRD powder pattern of cubic systems iv. Thermogram of coordination compounds	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.	
References / Readings:	1. J. H. Kennedy, Analytical Chemistry Principles, Saunders College Publishing, 2nd Ed., 1990. 2. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia 2009. 4. J. Elias, Collection of interesting chemistry experiments, University press, 2002. 5. R.A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, 2001. 6. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, 2002.	
Course outcomes:	1. Students will be able to standardize a material to determine an unknown concentration. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation. 4. Students will be able to interpret TG/X-Ray/IR spectra.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHI-500**Title of the course:** Fundamentals of Inorganic Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University	
Course Objective:	1. To introduce atomic structure, molecular structure, bonding, and symmetry. 2. To provide fundamental knowledge of solid state chemistry, coordination chemistry, organometallic chemistry, and bioinorganic chemistry. 3. To provide fundamental aspects of transition & inner transition elements & their compounds. 4. To introduce air and water pollution, and its treatments, to follow directive of the Supreme Court in 1993 to introduce environmental education at all levels.	
Content	**1. Atomic structure, molecular structure and bonding** 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. 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	No of hours 10
	2. Molecular Symmetry a. Symmetry elements and symmetry operations. b. Equivalent symmetry elements and equivalent atoms, symmetry point groups with examples, point groups of higher symmetry. c. Systematic procedure for symmetry classification of molecules and illustrative examples, dipole moment, optical activity and point groups	4
	3. Solid state chemistry a. Structures of solids: crystal structures, lattices and unit cells,	10

	fractional atomic coordinates and projections, close packing of spheres, holes in closed-packed structures. b. Structures of metals & alloys: polytypism, nonclosed-packed structures, polymorphism of metals, atomic radii of metals, alloys, substitutional and interstitial solid solutions, intermetallic compounds. 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 the Born–Haber cycle, The calculation of lattice enthalpies. (numerical expected)	
	4. Chemistry of transition & inner transition elements a. Transition elements**:** IUPAC definition of transition elements, occurrence, physical and chemical properties, noble character, metal halides, oxides & oxido complexes, examples of metal-metal bonded clusters, difference between 1^{st} row and other two rows. b. Inner transition elements: Lanthanides, occurrence, properties, oxidation states, electronic structure, colour and spectra, magnetic properties, lanthanide contraction, compounds of lanthanides. Actinoid chemistry: general trends and properties, electronic spectra, thorium and uranium.	10
	5. Coordination and Organometallic Chemistry a. Coordination chemistry: Introduction, representative ligands, nomenclature. Constitution and geometry: low coordination numbers, intermediate coordination numbers, higher coordination numbers, polymetallic compounds. Isomerism & chirality in square planar and octahedral complexes, ligand chirality. Thermodynamics of complex formation: formation constants, chelate and macrocyclic effects, steric effects and electron delocalization. Electronic properties of metal complexes: CFT applied to octahedral and tetrahedral complexes, magnetic moments, CFSE. Electronic spectroscopy: basic concepts, interpretation of spectra of d^1 & d^9 ions (Orgel diagram for octahedral and tetrahedral complexes). b. Organometallic Chemistry: Introduction to organometallic chemistry, nomenclature, stability and inert gas rules (neutral atom and donor pair electron count methods). Ligands: CO & phosphines, homoleptic carbonyls its synthesis and properties, oxidation-reduction of carbonyls, metal carbonyl basicity, reactions of CO ligand, spectroscopic properties of metal carbonyls. Oxidative addition and reductive elimination.	12
	6. Basic Bioinorganic Chemistry a. Macronutrients/micronutrients. Role of elements in biology.	4

	Metal ion transport role. b. Definition of metallobiomolecules, metalloporphyrins, structure of porphine and heme group, examples of metalloenzymes of Cu and Zn.	
	7. Environmental Chemistry 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) (a) sources (b) physiological and environmental effect (c) monitoring, (d) various remedial & technological measures to curb pollution. Air quality standards. 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.	10
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.	
References / Readings:	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, 2011. 3. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, 2008 (reprint). 4. J. D. Lee, Concise Inorganic Chemistry, 5th Ed.; Wiley, 2008. 5. F. A. Cotton, Chemical applications of group theory, 3rd Ed.; Wiley Eastern, 2012 (reprint). 6. L. Pauling, The Nature of The Chemical Bond, 3rd Ed.; Cornell University Press, 1960. 7. M. C. Day, J. Selbin, Theoretical Inorganic Chemistry, 2ed Ed.; Van Nostrand-Reinhold, 1969. 8. H. V. Keer, Principles of Solid state Chemistry, 1st Ed.; New Age Intl. Ltd, 1993, (reprint 2008). 9. A. R. West, Solid State Chemistry and Its Applications, 1st Ed.; John Wiley & Sons, Singapore, 1984 (reprint 2007). 10. D. K. Chakrabarty, Solid State Chemistry, 2ed Ed.; New Age Intl. Publishers, 2010. 11. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley Eastern, 2001. 12. A. V. Salker, Environmental Chemistry: Pollution and Remedial Perspective, 1st Ed.; Narosa Publication, 2017.	

	13. A.K. De, Environmental Chemistry, 3rd Ed.; New Age Intl. Publishers, 2005. 14. A. C. Stern, R. W. Boubel, D. Bruce turner, D. L. Fox, Fundamentals of Air Pollution, 1st Ed.; Academic Press, 1984. 15. R. A. Horne, Chemistry of Our Environment, 1st Ed.; John Wiley, 1978. 16. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 17. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004
Course outcomes:	1. Students will be able to predict geometry and shape of different molecules, and the point group symbols. 2. Students will be able to explain the fundamentals of atomic and molecular structure, solid state chemistry, coordination chemistry, organometallic chemistry, and bioinorganic chemistry. 3. Students should be able to describe and explain the properties and usefulness of transition & inner transition metals. 4. Students will able to explain different air and water pollutants and will be in a position to apply knowledge to treat these pollutants.

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHI-521 **Title of the course:** Practical course in Inorganic Chemistry-I

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Students shall acquire skills in synthetic inorganic chemistry. 2. Students will learn to prepare coordination compounds. 3. Students will learn to prepare useful potash alum from scrap aluminum. 4. Students will learn how to grow single crystals. 5. Students will acquire skills in determination of chromium, oxalate, and aluminum by redox titrations. 6. Students will be trained to fix the formula of compounds and find lattice water molecules by complexometric, redox & iodometric titrations. 7. Students shall acquire skills in determination of metal content at very low concentrations (ppm) using colorimetry / spectrophotometry.	
Content	*Minimum 13 experiments from the list shall be conducted.* **1. Preparations / Synthesis of Inorganic Compounds: (Any Five)** i. Preparation of hexaamminenickel(II) chloride. ii. Preparation of Trisethylenediaminecobalt(III) chloride. iii. Preparation of potassium trioxalatoaluminate trihydrate. iv. Preparation of potassium hexathiocyanato-*κN*-chromate tetrahydrate. v. Preparation of potassium trioxalatochromate trihydrate. vi. Preparation of potash alum from scrap aluminum.	No of hours 25
	2. Estimations / Determinations: (Any Eight) i. Estimation of nickel in $[Ni(NH_3)_6]Cl_2$ by complexometry or Gravimetry. ii. Estimation of cobalt in $[Co(en)_3]Cl_3$ by complexometry. iii. Estimation of oxalate in $K_3[Al(C_2O_4)_3]\cdot xH_2O$ or $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ iv. Estimation of nitrite by redox titration. v. Estimation of calcium from calcite ore. vi. Iodometric determination of Copper in gun metal alloy/Devarda's alloy. vii. Determination of chromium in chrome alum and $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ and to determine degree of hydration. viii. Colorimetric/Spectrophotometric determination of nickel or	35

	chromium. ix. Estimation of manganese by colorimetric / spectrophotometry 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 should be interactive in nature to enable peer group learning.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed, Pearson, 2011. 8. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrnad Reinhold London, 1972.	
Course outcomes:	1. Students will be in a position to synthesis coordination compounds with different metals and ligands. 2. Students will be able to grow single crystal. 3. Students will be able to prepare potash alum compound from waste scrap Al source. 4. Students will be able to determine metal content in the synthesised inorganic compounds. 5. Students will be able to fix the formula of compounds. 6. Students will be able to use and explain the diverse methods available for estimation of the metals including colorimeters and spectrometers.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHI-522**Title of the course:** Practical course in Inorganic Chemistry-II

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Students shall acquire skills in synthetic inorganic chemistry. 2. Students will learn to prepare coordination compounds. 3. Students will learn how to grow single crystals. 4. Students will acquire skills in determination of metal present by gravimetric and titrimetric method. 5. Students shall acquire skills in determining the metal content at very low concentrations (ppm) using colorimetry / spectrophotometry.	
Content	*Minimum 13 experiments from the list shall be conducted.* **1. Preparations / Estimation of Inorganic Compounds: (Any Nine)** i. Preparation of hexaamminecobalt(III) nitrate. ii. Estimation of cobalt in hexaamminecobalt(III) nitrate by volumetric titration. iii. Preparation of Potassium Trioxalatoferrate(III) Trihydrate iv. Estimation of iron and oxalate by redox titration v. Synthesis of metal nanoparticles (Cu, Ag, Au, Ni) and determining the absorption maxima by UV-visible spectrophotometer. vi. Estimation of amount of calcium in given sample by gravimetric method. vii. Estimation of amount of nickel in given sample by gravimetric method. viii. Estimation amount of zinc present in given sample by gravimetric method. ix. Estimation of iron by colorimetric / spectrophotometry method. x. Estimation of barium by complexometric titration method. xi. Estimation of manganese in presence of iron by complexometric titration method.	No of hours 40
	2. Semi-micro qualitative analysis of cation and anion in a given inorganic mixture: (Any four mixture) Mixture containing total six cations and/or anions. **Cations :** Pb^{2+}, Cu^{2+}, Cd^{2+}, Sn^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+},	20

	Mn^{2+}, Ni^{2+}, Co^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}, $(NH_4)^+$, K^+ **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.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed, Pearson, 2011. 8. G. Marr & B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold Company, London, 1972.	
Course outcomes:	1. Students will be in a position to synthesize coordination compounds with different metals and ligands. 2. Students will be able to grow single crystal. 3. Students will be able to determine metal content in the given sample. 4. Students will be in position to apply diverse methods available for estimation of the metals and can use colorimeters and spectrometers. 5. Students will able to detect cations and anions in the given salt.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHO-500 **Title of the course:** Fundamentals of Organic Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To study the various concepts based on molecular orbital theory. 2. To understand the concepts of topicity, prostereoisomerism and chemo-, regio- and stereoselectivity in organic reactions. 3. To understand the mechanistic aspects of various type of reactions in organic synthesis.	
Content	**1.Molecular orbitals and delocalized chemical bonding** a. Qualitative description of molecular orbitals of simple acyclic and monocyclic systems, frontier molecular orbitals. b.Conjugation, cross conjugation, resonance, hyperconjugation and tautomerism (types and examples). c. Aromaticity: Origin of Huckel's rule, examples of aromatic, non-aromatic and antiaromatic compounds; concept of Mobius aromaticity.	No of hours 08
	2.Structure & Reactivity 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. b. Concept of superacids and superbases. c. Electrophilicity&nucleophilicity, examples of ambident nucleophiles & electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution)	08
	3.Stereochemistry 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 centres. b. Conformational analysis of open chain compounds (Butane, 2, 3-butane diol, 2,3-dibromobutane etc.). *Erythro*and *threo*nomenclature. c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and Cram's rule /diastereotopic ligands and faces. d. Introduction to chemoselective, regioselective and	14

	stereoselective reactions. e. Stereochemistry of *cis*- and *trans*-decalins, conformation and reactivity of cyclohexane and substituted cyclohexanes, cyclohexene / cyclohexanone. conformational isomerism and analysis in acyclic and simple cyclic systems –substituted ethanes, cyclopentane, cyclohexane cycloheptane, cyclooctane and decalins, 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.	
	4.Reaction Mechanism a. Brief revision of carbocations, carbanions, free radicals, carbenes, Arynes and nitrenes with reference to generation, structure, stability and reactivity; b. Types of mechanisms, types of reactions, thermodynamic and kinetic control. c. The Hammond postulate and principle of microscopic reversibility, d. Methods of determining reaction mechanisms like- i. Identification of products, ii. Determination of the presence of intermediates (isolation, detection, trappingandaddition of suspected intermediate, iii. Isotopic labelling, iv. Stereochemical evidence, v. Kinetic evidence and vi. Isotope effect (at least two reactions to exemplify each method be studied)	08
	5.Aliphatic Nucleophilic substitution a. Brief revision of nucleophilic substitutions with respect to Mechanism, various factors affecting such reactions; 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)	08
	6.Elimination reactions a. The E2, E1 and E1cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule. b. Effects of changes in the substrate, base, leaving group and medium on	08

	i. Overall reactivity, ii. E1 vs. E2 vs. E1cB iii. Elimination vs substitution, Mechanism and orientation in pyrolytic *syn* elimination (various examples involving cyclic and acyclic substrates to be studied).	
	7. Selective reagents for Organic transformation a. Oxidation of organic compounds, PCC, PDC and MnO_2, ozonolysis, peracids. b. Reduction of organic compounds: $NaBH_4$, LAH, DIBAL reduction and reduction with borane and dialkylboranes. Clemmensen reduction, Birch reduction and Wolff-Kishner reduction	06
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.	
References / Readings	1. W. Caruthers, I. Coldham, Modern Methods of Organic Synthesis, Cambridge University Press, 4th Ed., 2016. 2. M. B. Smith, Organic Synthesis, McGraw–HILL, New York, International Edition, 1994. 3. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press, 2nd Ed., 2012. 4. R. Bruckner, Advanced Organic Chemistry – Reaction Mechanisms, San Diego, CA: Harcourt /Academic Press, San Diego, 2002. 5. J. Fuhrhop, G. Penxlin, Organic Synthesis – Concepts, Methods, Starting Materials, VCH Publishers Inc., New York, 1994. 6. H. O. House, Modern Synthetic Reactions, W. A. Benjamin, 2nd Ed.,1965 7. M. Nogradi, Stereoselective Synthesis, VCH Publishers, Inc., Revised and Enlarged Edition, 1994. 8. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, Springer India Private Limited, 5th Ed, 2007. 9. T. Laue, A. Plagens, Named Organic Reactions, John Wiley and Sons, Inc., 2005.	
Course outcomes:	1. Students will be in a position to evaluate the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds. 2. Students will be able to apply various concepts in stereochemistry to understand stereochemical outcome in a reaction. 3. Students shall be in a position to understand/propose plausible mechanism of organic reactions. 4. Students will understand and apply various reagents for desired organic transformations.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHO-521 **Title of the course:** Practical Course in Organic Chemistry-I

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.	
Content	*Minimum 13 experiments from the list shall be conducted.* **1. Introduction to laboratory equipments, apparatus and safety** a. Use of common laboratory equipments like fume hoods, vacuum pumps, weighing balance etc. to be explained to the students. b. Introduction to various types of quick fit joints and apparatus to the students. c. Discussion of Safety Techniques: i Disposal of chemicals ii Usage of protective equipment's iii First aid iv Fire extinguishers, types of fire v Hazards of chemicals and risk assessment	No of hours 04
	2. **Laboratory Techniques** a. Simple distillation (any one): i. Toluene-dichloromethane mixture using water condenser. ii. Nitrobenzene and aniline using air condenser. b. Steam distillation (anyone): i. Separation of *o*- and *p*- nitrophenols. ii. Naphthalene from its suspension in water, iii. Clove oil from cloves. c. Crystallisation: Concept of induction of crystallization (any one) i. Crystallisation of phthalic acid from hot water using fluted filter paper and stemless funnel. ii. Acetanilide from boiling water iii. Naphthalene from ethanol. iv. Decolorisation and crystallization of brown sugar (sucrose) with animal charcoal using gravity filtration. d. Sublimation: Simple or vacuum sublimation of camphor, naphthalene, anthracene or succinic acid (any one). e. Vacuum distillation (any one): o-dichlorobenzene, diphenyl	24

	ether. Also use of nomograph should be explained. f. Thin layer Chromatography (any one): i. Separation of *o* and *p*-nitroanilines. ii. Separation of analgesic drugs iii. Separation of *o* and *p*-nitrophenols,	
	3. Organic synthesis (Any Seven experiments) a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol & acetone. b. Aromatic electrophilic substitution (anyone): i. Preparation of *p*-bromoacetanilide. ii. Bromination of acetophenone to phenacyl bromide iii. Nitration of napththalene to 1-nitronaphthalene iv. Nitration of benzaldehyde to 3-nitrobenzaldehdye. c. Oxidation (any one) i. Benzoic acid from toluene. ii. Cyclohexanone from cyclohexanol. iii Isoborneol to camphor using Jones reagent. d. Reduction (any one) i. Reduction of *o*-nitroaniline to *o*-phenylenediamine using Sn/HCl ii. Reduction of *p*-nitro benzaldehyde to *p*-nitrobenzyl alcohol using $NaBH_4$. e. Bromination of an alcohol using CBr_4/ triphenylphosphine. f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. g. Aldol condensation: Dibenzal acetone from benzaldehyde h. Acetoacetic ester condensation: Preparation of ethyl *n*-butylacetoacetate or ethyl acetoacetate. i. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate. j. Friedel Craft's reaction (any one): i. using toluene and succinic anhydride ii. Resorcinol to resacetophenone, benzene and maleic anhydride to *β*-benzoylacrylic acid k. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation. l. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, MnO_2. m. Preparation of cuprous chloride.	24
	4. Isolation from natural sources (Any two) i. Caffeine from tea powder. ii. Piperine from pepper. iii. Cinnamaldehyde from cinnamon iv. Lemongrass oil from lemongrass	8
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. Each of the experiments should be done individually by the students.	
References / Readings	1. A.I. Vogel, A., R. Tatchell, B. S. Furniss, A.J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5thEd., Prentice Hall; 2011. 2. D. Pasto, C. Johnson and M. Miller, Experiments and Techniques in Organic Chemistry, 1stEd., Prentice Hall, 1991. 3. L.F. Fieser, K.L. Williamson,Organic Experiments, 7thedition D. C. Heath, 1992. 4. K.L. Williamson, K.M. Masters, Macroscale and Microscale Organic Experiments, 6thEdition, Cengage Learning, 2010 5. R.K. Bansal, Laboratory Manual in Organic Chemistry, New Age International, 5thEdition, 2016. 6. S. Delvin, Green Chemistry, Sarup& Sons, 2005. 7. O.R. Rodig, C.E. Bell Jr. and A.K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, Saunders College Publishing, 3rdedition, 2009. 8. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014.	
Course outcomes	1. Students will be in a position to understand stoichiometric requirements during organic syntheses. 2. Students will be in a position to understand Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 3. Students will be in a position to apply the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC) etc. 4. Students will get hands-on experience on isolation of some important natural products.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHO-522 **Title of the course:** Practical Course in Organic Chemistry-II

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.	
Content	*Minimum 13 experiments from the list shall be conducted.* **1. Introduction to laboratory equipments, apparatus and safety** a. Common Hazards in Chemical Laboratory, Risk assessment b. Accidents and Emergency procedures	No of hours 04
	2. **Laboratory Techniques (Any Two)** a. Simple distillation i. Simple distillation of thionyl chloride under anhydrous condition ii. Simple distillation under Nitrogen atmosphere b. Fractional distillation i. Chloroform-dichloromethane mixture using water condenser. ii. Toluene and cyclohexane by fractionating column. c. Vacuum distillation under inert atmosphere Dry Distillation of DMF, *o*-dichlorobenzene, $POCl_3$ d. Thin layer Chromatography i. Purification and isolation of mixture of acids by using Preparative TLC. ii. Purification and isolation of mixture of phenols by using Preparative TLC. iii. Purification and isolation of pharmaceutical drugs using Preparative TLC.	08
	3. Organic Synthesis (Any Four) a. *p*-Iodonitrobenzene by Sandmeyer reaction b. Pinacol- Pinacolone rearrangement c. Hydrogenation of Maleic acid (Hydrogen balloon) d. Preparation of nitrostyrene from aldehyde e. Preparation of α,β-dibromocinnamic acid f. Reduction of nitro compounds g. Synthesis of Urea from ammonium cyanate	16

	4. Solvent Free Organic synthesis (Any Two) a. Reduction using ball milling technique b. Oxidation of 2° alcohol using $KMnO_4$/Alumina by grinding technique. c. Synthesis of (±)-Binol from β-naphthol d. Hunsdiecker reaction of cinnamic acid derivatives e. Beckmann rearrangement of oxime derivatives	08
	5. Two-step Organic Synthesis (Any Two) a. Benzamide-Benzoic acid-Ethyl Benzoate b. Phthalic anhydride – Phthalimide – Anthranilic acid. c. Methyl benzoate- *m*-nitrobenzoate- *m*-nitrobenzoic acid d. Chlorobenzene – 2, 4 – dinitrochlorobenzene – 2,4-dinitrophenol e. Acetanilide – *p*–Bromo acetanilide – *p*–Bromoaniline f. Acetophenone – Oxime – Acetanilide	16
	6. Separation, Isolation and Identification of Organic compounds (Any One) a. Separation, purification and identification of compounds of binary mixture (Solid-Solid, Solid-liquid and Liquid-liquid) using the TLC and column chromatography, chemical tests. IR spectra to be used for functional group identification.	08
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.	
References / Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Prentice Hall; 2011. 2. K. Tanaka, Solvent-free Organic Synthesis, Wiley-VCH, 2nd Ed., 2009 3. L. F. Fieser, K. L. Williamson "Organic Experiments" 7th edition D. C. Heath, 1992. 4. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th Edition, Cengage Learning, 2010 5. R. K. Bansal, Laboratory Manual in Organic Chemistry, New Age International, 5th Edition, 2016. 6. S. Delvin, Green Chemistry, Sarup& Sons, 2005. 7. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, Saunders College Publishing, 3rdedition, 2009. 8. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014.	
Course outcomes	1. Students will be in a position to adopt Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 2. Students will be in a position to understand and calculate stoichiometric requirements during organic syntheses.	

	3. Students will be in a position to perform common laboratory techniques including reflux, distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC). 4. Students will get hands-on experience on isolation of some important natural products.

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHP-500 **Title of the course:** General Physical Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Introduction of various concepts on thermodynamics. 2. Introduction of electro chemistry and kinetics. 3. Learning quantum chemistry.	
Content	**1. Mathematical Preparations** a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. Complex numbers and complex functions. b. Linear equations, vectors, matrices and determinants. c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting. d. Introduction to series, convergence and divergence, power series, Fourier series e. Probability (permutations and combinations).	No of hours 12
	2. Quantum Chemistry a. Operators, Functions, Eigen value equations, Postulates. b. Schrodinger 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). c. Hydrogen like atoms, Schrodinger equation and its solutions, atomic orbital wave functions and interpretation. 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
	3. Thermodynamics a. Thermodynamic properties: Gas laws, Real gasses, Boyle temperature, Critical temperature, State and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy and their relations and significances. Maxwell relations. Thermodynamic equations of state b. Joule-Thomson effect. Joule-Thomson coefficient for van der	12

	Waals' gas. Joule-Thomson effect and production of low temperature, adiabatic demagnetization, Joule-Thompson coefficient, inversion temperature. 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. 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. 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.	
	4. Electrochemistry a. EMF series, The cell potential: The Nernst equation, Cells at equilibrium. Determination of thermodynamic functions. 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. c. Electroplating and electroless plating, electrosynthesis. d. Concepts of acid-base aqueous and non-aqueous solvents, hard and soft acid-base concept and applications.	8
	5. Chemical Kinetics a. General introduction to various types of order of reaction including fractional order, Molecularity of the reaction. 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. c. Collision Theory and Maxwell Boltzmann distribution of energies of colliding molecules (derivation not required). The concept of collisional cross section and reactive cross section and its significance. d. Comparative study of transition state and collision state theory (derivation not required). e. Reaction Mechanisms: elementary reactions, Consecutive elementary reactions, steady state approximation, the rate determining step and pre-equilibria f. Free radical reactions, Complex reactions such as acetaldehyde decomposition and reaction between H_2 and Br_2, Homogeneous reactions and acid-base catalysis.	8

	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.	
References / Readings	1. P. W. Atkins and J. D. Paula, Physical Chemistry, 8th Ed., Oxford University Press, New Delhi. 2007 2. G. M. Barrow, Physical Chemistry, 5th Ed., Tata McGraw Hill, New Delhi. 2016 3. J. E. House, Principles of Chemical Kinetics, 2nd Ed., Academic Press, Elsevier Burlington, USA, 2007 4. I. N. Levine, Quantum Chemistry, 7th Ed., Prentice-Hall, New Delhi. 1999	
Course outcomes:	1. Students should be in a position to understand and explain various concepts in physical chemistry. 2. Students should be in a position to apply these concepts during the lab course in physical chemistry. 3. Students will understand concepts of electrochemistry. 4. Students will be able to apply fundamentals of chemical kinetics for understanding reaction mechanisms.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHP-521 **Title of the course:** Practical course in Physical Chemistry-I

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills	
Content	Minimum 13 Experiments to be performed per Semester Non-instrumental Experiments (any 7) 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. 2. To determine the order of reaction between potassium persulphate and potassium iodide by graphical, fractional change and differential methods. 3. To study the three-component system such as acetic acid, chloroform; and water and obtain tie line. 4. To determine the molecular weight of polyvinyl alcohol by viscosity measurement. 5. To study the electro-kinetics of rapid reaction between SO_4^{2-} and I^- in an aqueous solution. 6. To determine the buffer capacity of acidic buffer solution. 7. To determine the partial molal volume of ethanol-water mixture at a given temperature. 8. To measure energy content of various types of plastics using bomb calorimetry 9. To determine number average molecular weight of a polymer sample with an indirect titration method. 10. To investigate basic hydrolysis of ethyl acetate at four different temperatures and find out energy of activation	No of hours 30
	Instrumental Experiments (any 6)	

	11. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometer. 12. To determine the dissociation constants of a tribasic acid (Phosphoric acid obtain derivative plot to get equivalence point. 13. To determine formal redox potential of Fe^{2+}/Fe^{3+} and Ce^{3+}/Ce^{4+} system obtain derivative plot to get equivalence point. 14. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate) 15. To determine Avogadro's number by improved electroplating. 16. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids 17. To verify the Kohlrausch's law for weak electrolyte by conductometry 18. To determine the transport numbers of Cu^{2+} and SO_4^{2-} ions in $CuSO_4$ solution by Hittorf's method.	30
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /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.	
References / Readings	1. A. Finlay & J.A. Kitchener, Practical Physical Chemistry, Longman. 2. F. Daniels & J.H. Mathews, Experimental Physical Chemistry, Longman. 3. A. M. James, Practical Physical Chemistry, Longman. 4. D.P. Shoemaker & C.W. Garland, Experimental Physical Chemistry, McGraw-Hill.	
Course outcomes:	1. Students will able to explain various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work. 3. Students will be able to use spectrophotometric titrations for appropriate analysis. 4. Students will be able to determine molecular weight of some polymers.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHP-522 **Title of the course:** Practical course in Physical Chemistry-II

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test.	
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills	
Content	Minimum 13 experiments to be conducted per Semester **Non-instrumental Experiments (any 8)** 1. To determine the radius of a molecule by viscosity measurements. 2. To determine ΔG, ΔH and ΔS of silver benzoate by solubility product method 3. To investigate the adsorption of oxalic acid by activated charcoal and test the validity of Freundlich and Langmuir's isotherms. 4. To determine the molecular weight of a given polymer by turbidimetry 5. To study the rate of reaction between ethyl bromoacetate and sodium thiosulphate kinetically. 6. To determine the percentage composition of a given mixture of two liquids by stalagmometer method. 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. 8. To study the kinetics of the reaction between Potassium per sulphate ($K_2S_2O_8$), and Potassium iodide (KI), and to determine a) Energy of activation b) Entropy of activation and c) Free energy change. 9. To determine the order of reaction for hydrolysis of ethyl acetate by graphical, fractional change and differential methods. 10. To determine the molecular weight of polystyrene by	No of hours 35

	viscosity measurement.	
	Instrumental Experiments (any 5) 11. To determine the relative strength of chloroacetic acid and acetic acid by conductometry. 12. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry. 13. To determine the composition of a mixture of acetic acid, dichloroacetic acid and hydrochloric acid by conductometric titration. 14. To determine the dissociation constants of monobasic acid and dibasic acid and obtain derivative plot to get equivalence point. 15. To determine the redox potential of Fe^{2+}/Fe^{3+} system by titrating it with standard $K_2Cr_2O_7$ solution. 16. To study the electrodeposition of metal.	25
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /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.	
References / Readings	1. A. Finlay & J.A. Kitchener, Practical Physical Chemistry, Longman. 2. F. Daniels & J.H. Mathews, Experimental Physical Chemistry, Longman. 3. A. M. James, F. E. Prichard, Practical Physical Chemistry, Longman. 4. D.P. Shoemaker & C.W. Garland, Experimental Physical Chemistry, McGraw-Hill.	
Course outcomes:	1. Students will gain knowledge of various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work. 3. Students will be able to use spectrophotometric titrations for appropriate analysis. 4. Students will be able to determine molecular weight of some polymers.	

Name of the Programme: M.Sc. Part-I (Inorganic Chemistry)

Course Code: CHI-501**Title of the course:** Chemistry of Coordination & Organometallic Compounds

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To make understand fundamentals of coordination and organometallic chemistry. 2. To gain the knowledge on structural aspects of compounds. 3. To make understand bonding using various models. 4. To correlate spectroscopic and magnetic properties with bonding models. 5. To develop a skill of interpretation of magnetic and spectroscopic properties. 6. To understand fundamental concepts of inorganic chemistry reaction mechanisms. 7. To provide knowledge on applications of organometallic compounds in homogenous catalysis.	
Content:	**1. Electronic structure of coordination compounds** Basic introduction to bonding theories: a. Valence Bond theory & its utility, limitations of VBT. b. Crystal field theory and its uses in: i) Octahedral compounds; ii) tetrahedral compounds; iii) square-planar compounds and other geometries; iv) tetragonally distorted compounds (Jahn-Teller Effect); v) octahedral vs tetrahedral; vi) Evidences showing covalency to the M-L bonds. c. Molecular orbital theory (MOT): σ & π-bonding in octahedral, tetrahedral, square planar compounds.	No of hours 12
	2. Spectra and magnetic studies of coordination compounds a.(i) Electronic spectra of atoms, (ii) Electronic spectra of complexes; Orgel diagrams, correlation diagrams, T-S diagrams examples and problem solving, (iii) Charge-transfer bands; (iv) Selection rules and intensities, (v) Luminescence. b. Vibrational spectra of coordination compounds. c. Magnetic studies: cooperative magnetism, basic concepts of magnetic properties: diamagnetism, paramagnetism,	12

	ferromagnetism, antiferromagnetism, temperature dependent magnetism, Curie law, Curie Weiss Law; spin cross over phenomenon.	
	3. Inorganic reaction mechanisms a. The thermodynamics of complex formation: Formation constants; Trends in successive formation constants; The chelate and macrocyclic effects; Steric effects and electron delocalization. b. Ligand substitution reactions and mechanisms: Rates of ligand substitution; The classification of mechanisms; Ligand substitution in square-planar complexes: The nucleophilicity of the entering group; The shape of the transition state. Ligand substitution in octahedral complexes: Rate laws and their interpretation; The activation of octahedral complexes; Base hydrolysis; Stereochemistry; Isomerization reactions. C. Redox reactions: The classification of redox reactions; The inner-sphere mechanism; The outer-sphere mechanism. d. Photochemical reactions: Prompt and delayed reactions; d–d and charge-transfer reactions; Transitions in metal–metal bonded systems.	12
	4. Organometallic chemistry of d-block elements a. Stable electron configurations; Electron count preference; Electron counting and oxidation states. b. Ligands: Carbon monoxide, Phosphines, Hydrides and dihydrogen complexes, η^1-Alkyl, -alkenyl, -alkynyl, and -aryl ligands, η^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. c. Compounds: *d*-Block carbonyls, Metallocenes, Metal–metal bonding and metal clusters. d. Reactions: Ligand substitution, 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. e. 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	24

	catalyzed C-C bond forming reactions, methanol carbonylation (Monsanto acetic acid process).	
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.	
References / Readings:	1. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong 2010, Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press, 2010. 2. J. E. Huheey, E. A. Keiter& R. L. Keiter, Inorganic Chemistry:Principles of structure and reactivity, 4th Ed.;Pearson, 2014. 3. J. D. Lee, Concise Inorganic Chemistry, 5thEd, Chapman and Hall, 1996. 4. F. A. Cotton, G. Wilkinson & P. L. Gaus, Basic Inorganic Chemistry, 3rd Ed.; John Wiley, 1995. 5. F. A. Cotton & G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed. (4th & 5th Eds. preferred);Wiley Eastern, New-Delhi, 1984. 6. D. Banerjee, Coordination Chemistry, 1st Ed.;Tata McGraw–Hill, New Delhi, 1994. 7. N. N. Greenwood & A. Earnshaw, Chemistry of the Elements, Pergamon Press, Exeter, 1984. 8. G. Rodgers, Introduction to coordination, solid state, and descriptiveInorganic chemistry, 1st Ed.; McGraw–Hill,1994. 9. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 10. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004	
Course outcomes:	1. Students will be able to understand the electronic structure of coordination and organometallic compounds. 2. Students will be well equipped with knowledge of CFT and MOT 3. Students will be in position to understand the magnetic and electronic properties. 4. Students will be able to acquire skill on interpretation of electronic and IR spectra of inorganic compounds 5. Students will be able understand concepts of inorganic reactions & mechanisms. 6. Students will be aware of applications of organometallic compounds in industrial processes.	

Name of the Programme: M. Sc -I (Inorganic Chemistry)

Course Code: CHI-502 **Title of the course:** Chemistry of Materials

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1.To provide information about different types of materials. 2.To provide knowledge about different types of synthesis. 3.To be familiar with different solid state properties of materials.	
Content:	**1. Introduction to Materials Chemistry** Basic knowledge about properties, structure and applications of materials.	No of hours 1
	2. 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	6
	3. Crystal defects & Non-stoichiometry in Solids a. Types of defects: Point defects, Dislocations: Line defects and Plane defects. b. Oxygen deficient oxides; Metal deficient oxides and classification of non-stoichiometry.	6
	4. Materials preparation techniques a. Broad Classification of methods: Ceramic method, and Different wet chemical methods. b.Types of Materials: Powdered bulk materials, Single crystal and Thin films, Amorphous materials, and Nanomaterials. c. Preparation methods for different materials with their advantages and disadvantages: 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. 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, electrochemical reduction method. iii. Amorphous Materials: Synthesis & applications.	16

	Nanomaterials: Synthesis, properties: structural, optical and magnetic and applications.	
	5. Reactivity of Solid Materials Tarnish reactions, decomposition reaction, solid-solid reactions, addition reactions, double decomposition reaction, electron transfer reaction, solid-gas reactions, sintering, factors influencing reactivity of solids.	4
	6. Phase Transformations in Solids 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's classification.	6
	7. Electrical Properties Electrical conductivity, free electron theory, Fermi energy, insulators, semiconductors and conductors, band theory of semiconductor, Brilliouin zones, Hall effect, Peltier effect, Seebeck effect, photo conductivity and ionic conductivity, Superconductivity, BCS theory, Meissner effect, high temperature superconductor.	7
	8. 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.	5
	9. Optical and dielectric properties Luminescence and phosphorescence, piezoelectric, ferroelectric materials and applications, thermal conductivity, phonon interaction, thermal expansion coefficient.	4
	10. Magnetic properties Introduction to magnetism, behavior of substance in a magnetic field, magnetic moments, diamagnetism, paramagnetism, experimental determinations of susceptibility, ferromagnetism, anti-ferromagnetism and ferrimagnetism, magnetization of ferromagnetic substance.	5
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.	
References / Readings:	1. A.R. West, Solid State Chemistry and Its Applications, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007). 2. L.V. Azaroff, Introduction to Solids, 1st Ed., Tata McGraw Hill, 2009,	

	(33rd Reprint). 3. N. B. Hannay, Treatise on Solid State Chemistry Vol.4 Reactivity of Solids, 1st Ed.; Plenum Press, 1976. 4. D. K. Chakraborty, Solid State Chemistry, 2nd Ed.; New Age International Publisher, 2010. 5. H. V. Keer, Principles of the Solid State, 1st Ed., New Age International (P) Ltd., (Wiley Eastern Ltd,), 1993, (Reprint 2008). 6. C. N. R. Rao & K. J. Rao, Phase Transitions in Solid, 1st Ed.; McGraw Hill, 1977. 7. W. D. Callister, Materials Science and Engineering:An Introduction, 7th Ed.; John Wiley, 2007. 8. B. D. Fahlman, Materials Chemistry, 2nd Ed.; Springer, 2011. 9. H. R. Allcock, Introduction to materials chemistry, 1st Ed.; John Wiley & Sons, 2011. 10. C. N. R Rao & Gopalkrishnan, New directions in solid state chemistry, 2nd Ed.; Cambridge University Press, 1997. 11. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017. 12. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004.
Course outcomes:	1. Students will be able to explain different methods of material synthesis. 2. Students can explaineffect of size variations on solid state properties of materials. 3. Students can explain different types of defects and phase transformations in materials. 4. Students will be in position to describe magnetic, electrical, dielectric, optical, and semiconductor properties of materials.

Name of the Programme: M. Sc -I (Inorganic Chemistry)

Course Code: CHI-503 **Title of the course:** Concepts in Molecular Symmetry and Spectroscopy

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To train the students to understand the concepts of molecular symmetry and their applications in chemistry 2. To train the students to understand different spectroscopic techniques viz. magnetic resonance, vibrational & Mössbauer spectroscopy with emphasis on spectral interpretation.	
Content	**1. Molecular symmetry** a. Symmetry elements and symmetry operations, symmetry planes and symmetry reflections, inversion center, proper axes and proper rotations, improper axis and improper rotations. b. 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. c. 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. d. Some properties of matrices and vectors, the great orthogonality theorem, reducible and irreducible representations, irreducible representations and their characters, character tables. Bases for irreducible representations, direct product. Symmetry Adapted Linear Combinations and its applications. Cage and cluster compounds, metal sandwich compounds. e. Crystal symmetry, space groups.	No of hours 30
	2. Spectroscopy a. Magnetic Resonance Spectroscopy; interaction between electron spin and magnetic field, interaction between nuclear spin and magnetic field, Resonance condition, instrumental requirements, b. Presentation of ESR (electron spin resonance) and NMR (nuclear magnetic resonance) spectra, line widths of ESR and	30

	NMR spectra, hyperfine coupling in isotropic systems (e.g. H atom, methyl radical etc.), anisotropic system, number of expected ESR signals for one electron paramagnetic species, zero field splitting and Kramer's degeneracy, Spin energy levels of octahedral Mn(II) complexes, nuclear quadrupole interaction, spin Hamiltonian, ESR spectra of some transition metal compounds, Electron delocalization, NMR spectral interpretation of a few nuclei like ^{19}F, ^{29}Si, ^{31}P. c. 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. d. Vibrational spectroscopy: Infrared spectroscopy and Raman spectroscopy, principle, their use in determination of molecular structure.	
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.	
References / Readings	1. F. A. Cotton, Chemical Applications of Group theory, 3rd Ed.; John Wiley,1990 2. J. E. Huheey, E. A. Keiter, R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4thEd.; Pearson, 1993. 3. G. R. Desiraju, J. J. Vittal, A. Ramanan, Crystal Engineering, IISC Press, world Scientific, 2011. 4. R. L. Dutta, A. Syamal, Elements of Magnetochemistry, 2nd Ed.; Affiliated East-West Press, New Delhi, 1993. 5. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.; Tata McGraw Hill, New Delhi, 1994. 6. G. Aruldhas, Molecular structure and spectroscopy, Prentice Hall of India, 2001 7. P. Atkins, J. De Paula, J. Keeler, Atkins' Physical Chemistry, International Ed.; Oxford University Press, 2018. 8. M. Weller, T. Overton, J. Rourke, F. Armstrong, Inorganic Chemistry, International Ed.;Oxford University Press, 2018. 9. E. A. V. Ebsworth, D. W. H. Rankin, S. Cradock, Structural Methods in Inorganic Chemistry, ELBS, 1988. 10. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part A: Theory and Applications in Inorganic Chemistry, 6thEd.; Wiley, 2009. 11. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part B: Applications in Coordination,	

	Organometallic and Bioinorganic Chemistry, 6th Ed.; Wiley, 2009. 12. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 13. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004
Course outcomes:	1. Students will be able to explain symmetry aspects of simple molecules and their applications in chemistry. 2. Students will be able to explain IR, Raman, ESR, NMR, Mössbauer spectra of simple molecules to determine molecular geometry. 3. Students will understand fundamental difference between various spectroscopic techniques. 4. Students will be able to explain the space groups.

Name of the Programme: M. Sc -I (Inorganic Chemistry)

Course Code: CHI-504 **Title of the course:** Concepts in Inorganic Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To gain knowledge in selected topics in inorganic chemistry and study the applications of inorganic compounds in selected areas. 2. To learn in details about the s-block elements and their compounds. 3. To understand the concepts in acid-base reactions in the Inorganic chemistry. 4. To gain knowledge about atomic stability and nuclear reactions. 5. To study the importance of metal ions in the field of medicinal chemistry.	
Content	**1. s-Block elements and their compounds** a. 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. b. 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. c. 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.	No of hours 17
	2. Inorganic medicinal chemistry a. Anticancer agents; Platinum and Ruthenium complexes as anticancer drugs, Cancerchemotherapy, phototherapy, radiotherapy using borane compounds. b. Chelation therapy. c. Gadolinium and technetium complexes as MRI contrast agents, X-ray contrast agents. d. Anti-arthritis drugs.	16

	e. Anti-bacterial agents (Ag, Hg, Zn and boron compounds). f. Antiseptic and anti-biotic. g. Deodorants and anti-perspirants.	
	3. Chemistry of radioactive elements a. Atomic nucleus; Classification of nuclides and nuclear stability. b. Review of Nuclear models. c. Radioactivity, Decay processes and decay energy, half-life of radioactive elements. d. Nuclear reactions; Nuclear fission and fusion processes. e. Nuclear Reactors; Nuclear reactor components and functions, Q values for nuclear reactions. f. Detection and measurement of activity; Radiation detection principles. g. Physical and Chemical separation techniques of radioactive elements. h. Radio-analytical techniques, Activation analysis. i. Nuclear waste management. j. Applications of radioactivity.	15
	4. Acids and Bases a. 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. b. Lewis acidity; Examples of Lewis acids and bases, Group characteristics of Lewis acids. c. 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. d. Applications of acid–base chemistry, Superacids and superbases, Heterogeneous acid–base reactions.	12
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.	
References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.;Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.;Pearson, 2011.	

	3. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.;Wiley, 2008. 4. J. D. Lee, Concise Inorganic Chemistry, 5thEd.;Wiley, 2008. 5. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley, 1984. 6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, Pergamon Press, 1st Ed.; 1984. 7. A. G. Sykes, Advances in Inorganic Chemistry, UK Ed.;Academic Press Ltd., 1991. 8. H. J. Arnikar, Essentials of Nuclear Chemistry, 4th Revised Ed.; New Age Intl.Publishers, 2011. 9. G. Friedlander, J. W. Kennedy, E. S. Macias, J. M. Miller, Nuclear & Radiochemistry, 3rd Ed.; John Willey & Sons, 1981. 10. K.A. Strohfeldt, Essentials of Inorganic Chemistry, Ist Ed.; John Willey & Sons, 2015. 11. G.R. Choppin, J-O. Linjenzin, Radiochemistry and Nuclear Chemistry, 2nd Ed.; Butterworth-Heinemann Ltd, 1995. 12. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 13. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004
Course outcomes:	1. Students will be able to explain the chemistry of s-block elements. 2. Students will be able to explain fundamentals of inorganic medicinal chemistry. 3. Students will be able to solve numerical problems related to some concepts in acid-base and nuclear chemistry. 4. Students will be able to analyse reactions and processes in field of nuclear chemistry.

M.Sc. Organic/Inorganic/Analytical/Physical Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV) based on NEP 2020

SEM III & IV			
Research Specific Elective (RSE) Courses			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	CHO-600	Practical Course in Organic Chemistry-III	4
2.	CHO-601	Practical Course in Organic Chemistry-IV	4
3.	CHO-602	Retrosynthesis and Heterocyclic Chemistry	4
4.	CHO-603	Chemistry of Natural Products	4
5.	CHI-600	Practical Course in Inorganic Chemistry-III	4
6.	CHI-601	Practical Course in Inorganic Chemistry-IV	4
7.	CHI-602	Principles and applications in catalysis	4
8.	CHI-603	Selected Topics in Inorganic Chemistry	4
9.	CHA-600	Practical Course in Analytical Chemistry-III	4
10.	CHA-601	Practical Course in Analytical Chemistry-IV	4
11.	CHA-602	Advanced Mass Spectrometry	4
12.	CHA-603	Selected Topics in Analytical Chemistry	4
13.	CHP-600	Practical Course in Physical Chemistry-III	4
14.	CHP-601	Practical Course in Physical Chemistry-IV	4
15.	CHP-602	Heterogeneous Catalysis: Fundamentals and Applications	4
16.	CHP-603	Applied Electrochemistry	4
17.	CHC-600	Research Methodology and instrumental techniques-I	4
18.	CHC-601	Research Methodology and instrumental techniques-II	4
19.	CHC-651	Discipline Specific Dissertation	16
Generic Elective (GE) Courses			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	CHO-621	Polymer Chemistry: Concepts, Synthesis and Processing of Polymers	4
2.	CHO-622	Concepts in Medicinal Chemistry	4
3.	CHO-623	Concepts in Green Chemistry	4
4.	CHO-624	Chemistry of Life	4
5.	CHO-625	Organometallic Chemistry and Rearrangement Reactions	4
6.	CHI-621	Bioinorganic Chemistry	4
7.	CHI-622	Chemistry of p-block elements & their compounds	4

8.	**CHI-623**	Environmental Chemistry	4
9.	**CHI-624**	Inorganic Chemistry: Industrial Perspective	4
10.	**CHA-621**	Fundamentals of Crystallography	4
11.	**CHA-622**	Advanced NMR and combined Spectroscopy	4
12.	**CHA-623**	Bioanalytical Techniques	4
13.	**CHA-624**	Calibration and Validation in Analytical Chemistry	4
14.	**CHP-621**	Solid State Chemistry: Concepts and Applications	4
15.	**CHP-622**	Nanoscience: Concepts and Applications	4
16.	**CHP-623**	Physical aspects of Polymer Chemistry	4
17.	**CHP-624**	Colloids and Surface Chemistry	4
		Dissertation	
1.	**CHC-651**	Discipline Specific Dissertation	16

M.Sc. Inorganic Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III INORGANIC CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHI-600**	Practical Course in Inorganic Chemistry-III	4
2	**CHI-601**	Practical Course in Inorganic Chemistry-IV	4
3	**CHC-600**	Research Methodology and instrumental techniques-I	4
4	**CHC-601**	Research Methodology and instrumental techniques-II	4
5	**CHI-621**	Bioinorganic Chemistry	4
6	**CHI-622**	Chemistry of p-block elements & their compounds	4
7	**CHI-623**	Environmental Chemistry	4
8	**CHI-624**	Inorganic Chemistry: Industrial Perspective	4
SEM-IV INORGANIC CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHI-602**	Principles and applications in catalysis	4
2	**CHI-603**	Selected topics in Inorganic Chemistry	4
3	**CHC-651**	Discipline Specific Dissertation	16

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-600 **Title of the course:** Practical Course in Inorganic Chemistry-III

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Should have studied Inorganic chemistry practical course at M.Sc. Part-I.	
Course Objective:	1. To introduce practical knowledge in Inorganic Chemistry. 2. To learn techniques of crystallization and synthesis of coordination compounds. 3. To learn characterization of compounds using different instruments. 4. To provide experience of synthesis and characterization of materials. 5. To introduce analysis of ores for metal content.	
Content	*Minimum 23 experiments from the entire list shall be conducted* **Unit – 1 Experiments in coordination chemistry: complex synthesis, metal analysis (Any Five)** a. Purification (distillation/recrystallisation) of ligands like acacH, en, carboxylic acids etc. b. Preparation of manganic tris(acetylacetonate) and estimation of manganese. c. Preparation of tris(thiourea)copper(I) sulfate and estimation of copper. d. Preparation of isomers; cis and trans-dichloro(ethylenediamine)cobalt(III) chloride and estimation of cobalt. e. Preparation and resolution of tris(ethylenediamine)cobalt(III) ion and estimation of cobalt. f. Preparation of cis and trans-potassium dioxalatodiaquochromate(III) and estimation of chromium. g. Preparation of nitro and nitrito-pentaaminecobalt(III) chlorides and estimation of cobalt. h. Preparation cobalt(III) porphyrin complex and estimation of cobalt. i. IR spectral characterization of free ligands and coordinated ligands. *NOTE: In complex synthesis, the student is expected to recrystallise the product, record IR spectra and carry out metal analysis. Spectral analysis can be carried over.*	No of hours 30
	Unit –2 Experiments in Solid state chemistry (Any Eight) a. Preparation of spinel oxides by precursor method.	36

	b. Estimation of metals in precursors and oxides. c. Characterization of precursors by thermal analysis. d. Characterization of precursors and oxides by infrared analysis. e. X-ray diffraction studies of metal oxides. f. Direct current electrical resistivity of semiconductor (Ge/Si) by Four Probe method. g. Curie temperature determination of dielectric material (PZT) by measurement of dielectric constant v/s temperature. h. Measurement of saturation magnetization, Ms, Mr and Hc of ferromagnetic materials. i. Determination of Curie temperature of magnetic oxides by A.C. susceptibility studies. j. Preparation of CuO/SiO_2 or NiO/SiO_2 by wet impregnation method.	
	Unit – 3 Instrumental methods / spectral analysis / ion exchange (Any Six) a. Determination of stability constant of Fe(III) – salicylic acid compound (Job's Method). b. Determination of stability constant of Fe(III) – thiocyanate compound. c. Determination of stability constant of Fe(II) – 1,10-phenanthroline compound. d. Determination of instability constant for the reaction between Ag^+ and NH_3. e. Determination of instability constant for the reaction between Ag^+ and en. f. Determination of instability constant for the reaction between Cu^{2+} and NH_3. g. Determination of instability constant for the reaction between Cu^{2+} and en. h. Ion exchange chromatography: Separation of Mg^{2+} and Co^{2+} by anion exchange column. Separation of transition metal cations by anion exchange column.	30
	Unit – 4 Ore / Alloy / commercial sample separation and analysis using Titrimetry / Gravimetry / spectroscopy method (Any Four) a. Analysis of Goan Iron ore: Hematite / magnetite b. Analysis of Devardas alloy c. Analysis of solder (Pb and Sn) d. Analysis of Pyrolusite e. Analysis of Nickel-Aluminium alloy f. Analysis of Brass alloy g. Analysis of Bauxite	24

	h. Analysis of Magnesite	
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed.; Pearson, 2011. 8. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrnad Reinhold London, 1972.	
Course Outcome:	1. Students will be in a position to purify ligands and will apply knowledge to synthesize coordination compounds. 2. Students will be able to study properties of coordination compounds using different instruments. 3. Students will apply knowledge to synthesize solid state material and can study their properties. 4. Students will be in position to separate metal ions by ion exchange chromatography. 5. Students apply knowledge to separate and analyze metals present in ores and alloys.	

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-601 **Title of the course:** Practical Course in Inorganic Chemistry-IV

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Should have studied Inorganic chemistry practical course at M.Sc. Part-I.	
Course Objective:	1. To introduce to practical knowledge in Inorganic Chemistry. 2. To learn techniques of crystallization and synthesis of coordination compounds. 3. To learn characterization of compounds using different instruments. 4. To provide experience of synthesis and characterization of materials. 5. To introduce analysis of ores for metal content.	
Content	*Minimum 20 experiments from the entire list shall be conducted* **Unit–1 Preparation of ligands (including distillation / recrystallization) / metal-ligand compounds / inorganic compounds (Any 6)** a. Preparation of Schiff's base and characterization by IR. Ex. Condensation of simple aldehydes with diammines (ethylene diammine, 1,3-propanediammine) b. Preparation of substituted benzoic acids and characterization. c. Preparation of acetylacetonate complexes of Co(II) and Co(III) and estimation of cobalt. d. Preparation of ammonium dichromate and ammonium heptamolybdate. e. Preparation of aluminium(III)tris(acetylacetonate) and estimation of aluminium. f. Preparation of potassium dihydroxodioxalatotitanate(IV) and estimation of titanium. g. Preparation of manganic acetate and estimation of manganese h. Preparation of chromium(II) acetate hydrate and estimation of chromium. i. Preparation of $K_2ON(SO_3)_2$ (Fremy's salt). *Note: Wherever possible IR and other spectral studies should be undertaken for prepared compounds*.	No of hours 36
	Unit –2: Syntheses, characterization and solid state study of ABO_3/AB_2O_4 oxides (Any 6) a. Preparation of Perovskite/Spinel oxide by oxalate precursor method. b. Characterization of precursor using CHN Analyser and estimation of metals in the precursors and oxides by gravimetric and	36

	volumetric analysis. c. Characterization of precursor and Perovskite/Spinel oxide by FTIR. d. Thermal analysis (TG/DTA) of prepared precursors. e. Isothermal Mass Loss Studies. f. X-ray diffraction studies of Perovskite/Spinel oxide prepared. g. Electrical resistivity measurement of the prepared oxide by Two probe / Four Probe method. h. Dielectric studies of prepared oxide: Dielectric constant and dielectric loss V/s I) Frequency and II) Temperature. i. Magnetic Characterization of prepared Spinel oxide by i) Hysteresis loop data (Ms, Mr, Hc) and ii) A.C Susceptibility. *Note: Wherever possible IR and other spectral studies should be undertaken.*	
	Unit – 3: Instrumental experiments/separation of metal ions by ion exchange resins (Any 6) a. Determination of stability constant of Fe(III)-Sulfosalicylic acid compound in the solution. b. UV-visible spectroscopy study of transition metal complexes. c. Potentiometric determination of cobalt/ nickel /zinc by EDTA. d. Conductance measurements: preparation and electrical conductivity measurements of some cobalt complexes. e. Determination of magnetic susceptibility of Mn(II), Cu(II) etc. salts/complexes. f. Colorimetric estimation of Hg/Cd g. Separation of transition metal cations by cation – exchange chromatography h. IR and NMR studies of Inorganic compounds. Ex. $VO(acac)_2$ i. Cyclic voltammetry experiment (ferrocene/hexacyanatoferrate).	36
	Unit – 4: Ore analysis/ Alloy analysis using Titrimetry / Gravimetry / spectroscopy method (Any 2) a. Analysis of Malanchite b. Analysis of Ilmenite c. Analysis of Nickel Steel alloy d. Analysis of Rolled Gold e. Analysis of Gun Metal f. Analysis of magnalium g. Analysis of Bronze	12
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed.; Chapman & Hall, 1974.	

	3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed.; Pearson, 2011. 8. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrnad Reinhold London, 1972.
Course Outcome:	1. Students will be in a position to explain general aspects involved in purification of ligands and will apply knowledge to synthesize ligands and coordination compounds. 2. Students will be able to characterize coordination compounds usinf instrumental techniques. 3. Students will be in a position to prepare solid state materials and study their properties. 4. Students will apply knowledge to separate metal ions by ion exchange chromatography. 5. Students will be able to analyze metals in ores and alloys

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-602 **Title of the course:** Principles and applications in catalysis

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. Part-I.	
Course Objective:	1. To understand the fundamentals concepts of chemical reactions over the catalysts. 2. To understand energy saving and making green processes in chemical reactions. 3. To understand fundamentals and basic concepts of chemical reactions for developing higher productivity and viability. 4. To provide knowledge on applications of heterogeneous, homogenous and other catalytic processes. 5. To make aware of catalytic approaches in environmental pollution control processes.	
Content	**1. Origin and development of catalysts** a. Introduction to heterogeneous, homogeneous and bio-catalysis, importance of catalysis in chemical reactions and its industrial applications. b. Concepts of Atom Economy, Turnover number and Turnover frequency.	No of hours 5
	2. Heterogeneous Catalysis a. Introduction to heterogeneous catalysis, energy profile diagram and diffusion of gas, general mechanisms such as Langmuir-Hinshelwood and Rideal-Eiley. b. 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. c. 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, activity and life of the catalysts, active centers, promoters and poisons, catalyst deactivations. d. 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	23

	the catalysts. e. 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. f. Theories of Catalysis: Boundary layer theory, catalysis by semiconductors, Wolkenstein theory, Balanding's approach, electronic factors in catalysis by metals, molecular orbital approach.	
	3. Homogeneous Catalysis a. Homogeneous catalytic reactions, merits and demerits, intermediate stages in homogenous catalysis, energy profile diagram, activation energy, general scheme for calculating kinetics of the reactions. b. Decomposition of hydrogen peroxide, acid-base catalysis. c. Homogeneous catalytic reactions: Hydrogenation, hydroformylation, isomerization, Monsanto acetic acid process, Carboxylation reactions, Wacker reaction, coupling reactions and asymmetric oxidations.	12
	4. 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.	3
	5. Catalytic polymerizations Homogeneous and heterogeneous catalysis in polymerizations reactions (few examples), Ziegler – Natta catalyst in polymerizations reactions.	5
	6. Bio-catalysis Nomenclature and classification of enzymes, metal ions and metalloenzymes, general properties, enzymatic reactions such as redox and decomposition, action of enzymes, mechanistic pathways of few enzymatic reaction, factors affecting enzymes and enzyme applications.	3
	7. Phase transfer catalysis Mechanism of PTC, types of phase transfer catalysis with selected examples, advantages and disadvantage.	3
	8. Catalyst for energy and environment Catalytic gasification, electricity from gas turbine, steam reforming, electro-catalysis, fuel cells for energy production like methanol, molten carbonate and solid oxide fuel cells, catalysts for environmental pollution in emission control and selective catalytic	6

	reduction.	
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.	
References / Readings	1. A.V. Salker, Catalysis: Principles and Basic Concepts, Scientific International, 2019. 2. P. H. Emmett, Catalysis, Vol I, Reinhold,1955. 3. D. K. Chakraborty, Adsorption and Catalysis by Solids, New Age International (P) Ltd., 2008. 4. J. M. Thomas, W.J. Thomas, Heterogeneous Catalysis, VCH publication, 1997. 5. A. Clark, The Theory of Adsorption and Catalysis, Academic Press, 1970. 6. E. R. Rideal, Concept in Catalysis, Academic Press, 1968. 7. G. M. Panchenov, V. P. Lebedev, Chemical Kinetics and Catalysis, Mir publication, 1976. 8. S. J. Thomson, G. Webb, Heterogeneous Catalysis, Oliver and Boyd Publications, 1968. 9. R. A. Van Santen, J. W. Niemantsvedict, Chemical Kinetics and Catalysis, Plenum Press, 1995 10. M. Beller, A. Renken, R. van Santen, Catalysis, Wiley VCH, 2012.	
Course Outcome:	1. Students will be able to explain concepts and general properties of different types of catalysts. 2. Students will be able to explain the catalytic reaction mechanisms and green catalytic processes. 3. Students will be in position to prepare and characterized catalysts. 4. Students will apply knowledge to develop reaction specific catalysts using basic concepts. 5. Students will apply knowledge to develop catalysts for useful chemical reactions and environmental pollution control processes.	

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-603 **Title of the course:** Selected Topics in Inorganic Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Part-I	
Course Objective:	1. To study the amorphous and glass materials. 2. To learn the properties of refractories and solid lubricants and their applications. 3. To understand the concepts of Inorganic electrochemistry. 4. To study the important instrumental techniques for characterization of Inorganic materials.	
Content	**1. Amorphous and Glass Materials** a. Introduction to amorphous materials b. Glasses c. Glass transition temperature d. Composition of glasses e. Viscosity f. Glass forming methods g. Commercial glasses h. Chalcogenide glasses i. Ceramic glasses j. Metallic glasses	No of hours 7
	2. Refractories and Solid lubricants a. Classification of refractories b. Properties of refractories: Thermal expansion and contraction, Refractoriness, Spalting resistance, Thermal conductivities c. Resistance to melts-slags and glasses d. Refractory materials: Aluminous type, silica type, basic type, insulating type e. Special refractories: Oxide refractories, other refractories, ideal refractories f. Solid lubricants: Inorganic, organic, and nanomaterial lubricants	13
	3. Fundamentals of Inorganic Electrochemistry a. Basic aspects of electrochemistry, electron transfer reactions at electrode surface, potential and electrochemical cells, b. Voltammetric techniques, linear voltammetry, cyclic voltammetry; reversible, irreversible, and quasi-reversible processes; applications of cyclic voltammetry with reference to ferrocenes, transition metal complexes.	5
	4. Characterisation Techniques a. Diffraction methods (XRD, Neutron and Electron)	35

	b. X-ray spectroscopies (XRF, AEFS, EXAFS) c. Thermal analysis d. SEM, FESEM e. TEM (HR-TEM and Imaging) f. FTIR g. X-ray Absorption spectroscopy h. Electron spectroscopy (XPS, UPS, Auger) i. Atomic emission spectroscopy j. UV-Visible spectroscopy (DRS)	
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.	
References / Readings	1. A.R. West, Solid State Chemistry and Its Applications, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007). 2. L.V. Azaroff, Introduction to Solids, 1st Ed. (33rd Reprint), Tata McGraw Hill, 2009. 3. D. K. Chakraborty, Solid State Chemistry, 2nd Ed.; New Age International Publisher, 2010. 4. H. V. Keer, Principles of the Solid State, 1st Ed. (Reprint 2008); New Age International (P) Ltd., (Wiley Eastern Ltd.), 1993. 5. W. D. Callister, Materials Science and Engineering:An Introduction, 7th Ed.; John Wiley, 2007. 6. B. D. Fahlman, Materials Chemistry, 2nd Ed.; Springer, 2011. 7. H. R. Allcock, Introduction to materials chemistry, 1st Ed.; John Wiley & Sons, 2011. 8. R. H. Doremus, Glass Science, 2nd Ed.; Wiley, 1973. 9. P. N. Ross, Handbook of Fuel Cells, 7th Ed.; Wiley, 2003. 10. D. T. Sawyer, A. Sobkowak, J. L. Roberts Jr., Electrochemistry for chemists, 2nd Ed.; John Wiley, Inc., 1995. 11. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong, Shriver & Atkins' Inorganic Chemistry, 5th Ed.; Oxford University Press, 2010. 12. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning, 2014. 13. A. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Cengage learning, 2007. 14. G. Aruldas, Molecular Structure and Spectroscopy, 2ed Ed.; PHI Learning Pvt. Ltd., 2015.	
Course Outcome:	1. Students will be able to explain different amorphous and glass materials and their properties. 2. Students will be able to differentiate between the types of refractories and solid lubricants. 3. Students will be able to analyse a cyclic voltammogrames of inorganic	

	compounds. 4. Students will apply knowledge to characterize inorganic materials by using instrumental techniques.

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-621 **Title of the course:** Bioinorganic Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students have studied chemistry/biochemistry courses at M.Sc. Part-I.	
Course Objective:	1. To understand the role of inorganic elements especially metal ions in biology. 2. To introduce metallobiolecules, metalloproteins & metalloenymes. 3. To understand the role of small molecule model compounds. 4. To introduce the concept of Biomimetic chemistry.	
Content	**1. Essential elements in biology** Periodicity of elements, distribution of elements in biosphere, bio-availability, bio-stability, building blocks of the biosphere; carbohydrates, nucleic acids and proteins, biological importance of water, and brief review of the chemistry of biopolymers. Metallobiomolecules: classification, metalloproteins (enzymes), metal activated proteins (enzymes), metal functions in metalloproteins, Principles of coordination chemistry related to bioinorganic research, physical methods in bioinorganic chemistry.	No of hours 12
	2. Alkali and alkaline earth metals in biology Introduction, biological importance of the alkali and the alkaline earth cations, Cation transport through membranes (ion pumps). Photosynthesis, Hill reaction, Chlorin macrocycle and chlorophyll, Absorption of light by chlorophyll, role of metals in photosynthesis, in vitro photosynthesis.	12
	3. Non-redox metalloenzymes Zinc metalloenzymes like carboxypeptidase, carbonic anhydrase and alcohol dehydrogenase, Bio-functions of zinc enzymes, active site structure and model complexes.	12
	4. Biochemistry of a few transition metals Role of Fe, Mo, Cu and Ni. Oxygen carriers and oxygen transport proteins, iron porphyrins (Haemoglobin and myoglobin). Haemocyanins and Haemerythrins, Synthetic models for oxygen binding haemproteins. Cytochrome C, catalase, peroxidase, and superoxide dismutase, blue copper proteins, vitamin B_{12} coenzymes, nitrogen fixation and iron-sulfur proteins, biological nitrogen fixation, nitrogenase and dinitrogen complexes, iron-sulfur proteins, synthetic analogues for Fe-S proteins, core extrusion reactions. Metal transport and storage: A brief review of iron transport. transferrin, ferritin, hemosiderin, siderophores, iron biomineralization	12
	5. Biomimetic Inorganic Chemistry Fundamentals of biomimetic chemistry, metal – oxygen intermediates, techniques used to probe the active sites of oxygen carriers, redox chemistry	12

	of free molecular dioxygen, spectroscopy of Fe-O-Fe moiety, geometry and electronic structure of coordinated dioxygen, other ligands for biological oxygen carriers, reactions of metal-oxygen compounds, oxygenases, Cytochrome P-450, synthetic procedures of simple ligands, isolation of S-containing amino acidor extraction of chlorophyll from green leaves, recrystallization of carboxylic acids. Non-Heme and heme ligands.	
Pedagogy	Mainly lectures / tutorials / assignments /group discussion / self-study /presentations or a combination of some of these could also be used to some extent.	
Reference / Readings	1. S. J. Lippard & J. M. Berg, Principles of Bioinorganic chemistry, Panima Publishing Corporation 2. B. I. Britini, H. B. Gray, S. J. Lippard & J. S. Valentine, Bioiorganic chemistry, University Science books, Mill Valey, CA, 1994. 3. D. E. Fenton, Biocoordination Chemistry, Oxford Chemistry Printers, 25 Oxford University Press, 1995 4. E. E. Conn, P.K. Stumpf, G. Bruening & R. H. Doi, Outlines of Bioinorganic Chemistry, 5th Ed.; Wiley Eastern, 1983. 5. F.A. Cotton, G. Wilkinson, P.L. Gaus, Basic Inorganic Chemistry, 3rd Ed. (Chapter 31); WileyIndia, 2007. 6. M. Weller, T. Overton, J. Rourke & F. Armstrong Inorganic Chemistry, Int. Ed. (Chapter 25); Oxford University Press, 2018. 7. P Atkins, T Overton, J Rourke, M Weller & F Armstrong, Shriver & Atkins' Inorganic Chemistry, 5th Ed. (Chapter 27); Oxford University Press, 2010. 8. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 5th Ed. (Chapter 19); Addison Wesley Publishing. 9. R. W. Hay, Bioinorganic chemistry, Ellis Horwood Chichester, 1984. 10. M.N. Hughes, The Inorganic Chemistry of Biological processes, 2nd Ed.; Wiley (Interscience), 1984. 11. R. R. Crichton, Biological Inorganic Chemistry, Elsevier, 2012. 12. R. Breslow, Biomimetic Chemistry: Biology as an Inspiration, The Journal of Biological Chemistry, vol. 284, no. 3, pp. 1337–1342, 2009. 13. C. Housecroft, A. G. Sharpe, Inorganic Chemistry, 4th Ed; Pearson Publishing, 2012.	
Course Outcome:	1. Students will be in a position to clarify the significance of essential elements in biology. 2. Students will be able to explain the role played by metal ions in vital processes like i) oxygen storage and transport and ii) electron transfer. 3. Students will be able to explain basic concepts in Biomimetic chemistry. 4. The students will be able use different techniques in Bioinorganic Chemistry.	

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-622 **Title of the course:** Chemistry of p-block elements & their compounds

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry/biochemistry courses at M.Sc. Part-I.	
Course Objective:	1. To study the different trends in physical and chemical properties of p-block elements. 2. To understand the variations in physical and chemical properties of compounds of p-block elements. 3. To study the preparation and structure of some important compounds of p-block elements. 4. To study the applications of some of their compounds.	
Content	**1. General trends of different properties in groups and periods in periodic table**	No of hours 4
	2. Chemistry of Group 13 Elements and their Compounds a. Introduction, physical properties, chemical reactions with oxygen, nitrogen, sulphur, halogens, HCl, NaOH, NH_3, mono-di-tri-chlorides, alums, organo-compounds of B and Al, difference between boron and other Gr. 13 elements, diagonal relationship. b. Preparation, bonding and structure of diborane, higher boranes, borane anions, carboranes and metallocarboranes. c. Borazine: Synthesis, properties, structure, bonding and some of its derivatives. d. Borates: Classification, structure and examples.	13
	3. Chemistry of Group 14 Elements and their Compounds a. Introduction, physical properties, allotropy, compounds of Gr.14: different types of oxides, di, tetra & catenated halides, hydrides, sulphides, cyanides. b. Coordination compounds, organosilicon compounds, silicones, cluster compounds of Ge, Sn and Pb. c. Silicates: classification with examples and applications, zeolite. d. Carbon dating, graphene, metallocarbohedrenes, freons. e. Intercalation compounds of graphite with oxygen and fluorine, heavier Group 1 elements, different halides including $FeCl_3$. f. Carbides: classification, preparation, properties and uses.	13
	4. Chemistry of Group 15 Elements and their Compounds a. Introduction, allotropes, physical properties, Preparation,	9

	properties and structure of: Hydrides, halides, oxides, oxyacids, oxohalides. b. Preparation, properties and structure of Phosphorous: sulphides, oxosulphides, organophosphorous compounds. c. Classification, preparation, properties and structures of phosphazenes.	
	5. Chemistry of Group 16 Elements and their Compounds a. Introduction, allotropes, physical properties, Preparation, properties and structure of: Hydrides, halides, oxohalides, oxides, oxyacids, classification of oxides. b. Compound of sulphur and nitrogen: Preparation, properties and structure of $(SN)_x$, S_2N_2 and S_4N_4. c. Polyatomic sulphur cations, anionic polysulphides, compounds with sulphur as a ligand.	9
	6. Chemistry of Group 17 Elements and their Compounds a. Introduction, physical properties; preparation, properties and structure of: oxides, oxyacids, halides, oxohalides, hydrogenoxide fluorides and related compounds. b. Preparation, properties and structure of: interhalogen compounds, polyhalide anions, polyhalonium cations, halogen cations.	8
	7. Chemistry of Group 18 Elements and their Compounds a. Introduction, physical properties; preparation, properties, structure and bonding of xenon compounds (fluorides and oxides); organoxenon compounds, compound containing Xe-Xe bond. b. Preparation, properties and structure of compounds of other noble gases.	4
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.	
References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, 2011. 3. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd Ed. (reprinted); Elsevier, 2014. 4. J. D. Lee, Concise Inorganic Chemistry, 5th Ed. (reprint); Blackwell Science Wiley, 2015. 5. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, 2008. 6. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley, 1984.	

	7. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004.
Course Outcome:	1. Students will be able to explain the trends in physical properties in groups and periods in the periodic table. 2. Students will be able to explain the chemistry of p-block elements as this course will give sufficient information about p-block elements and their compounds in particular. 3. Students will be able to prepare some important compounds of p-block elements. 4. Students will apply the knowledge of chemical properties of compounds to solve day to day problems.

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-623 **Title of the course:** Environmental Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry/ biochemistry courses at M.Sc.Part-I.	
Course Objective:	1. To introduce to fundamentals of environmental chemistry. 2. To provide important knowledge of environmental chemistry in day-to-day life. 3. To give the basic knowledge of environmental pollution. 4. To make aware of the harmful effects of environmental pollutants and control measures.	
Content	**1. Structure and properties of atmosphere:** Introduction, Temperature profile of the atmosphere, Lapse rate, Temperature inversion.	No of hours 4
	2. Biogeochemical cycles Introduction, Biogeochemical cycles of Oxygen, Carbon, Sulphur, Nitrogen, Phosphorus, and Hydrogen.	8
	3. Soil Pollution Introduction, Air and water in the soil, 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.	6
	4. Air pollution Types of emissions, Air pollution dispersion models, Types of emission sources, Estimation of Dispersion parameters, Types of Plumes, global warming Particulate matter: Introduction, Particle size range, Health Hazards, Analysis of particulate matter, Control devices, Inorganic Particulates, Radioactive particulates, Organic particulates and other contaminants.	12
	5. Water pollution and Conditioning a. Introduction. b. Hard water and water softening by chemical methods. c. Carbonate hardness removal by lime, Magnesium hardness removal by lime, and non-carbonated hardness removal by soda ash. d. Calcium carbonate solubility. e. Re-carbonation and acid process. f. Barium-lime cold process. g. Ion exchange process.	8
	6. Plastic pollution a. Microplastics b. Global occurrence, distribution, and the fate of plastic in the	10

	environment. c. Weathering and degradation of plastics. d. Microplastics, types of microplastics, nanoplastics. e. Analysis and identification of microplastics. f. Impact on the terrestrial and marine environment (estuarine, open ocean, coral reefs). g. Inputs of microplastics into the oceans. h. Transfer of microplastics into the food chain: bioaccumulation and Biomagnification. i. Microplastic ingestion, toxicity, and impact on human health.	
	7. Selected industrial effluent treatment. a. Industrial effluent treatment, b. Effects of Industrial effluents on surface water and land, c. Manufacture process and treatment of fertilizers and pesticides, d. Electroplating process and treatment of the waste, e. Waste from the cement industry, Waste from the sugarcane and paper industry.	8
	8. Waste Management and Case studies a. Waste Management (sources and types of solid wastes, disposal techniques, collection methods, waste management approach). b. Case study (Bhopal gas tragedy, use of DDT).	4
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.	
References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, 2011. 3. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd Ed. (reprinted); Elsevier, 2014. 4. J. D. Lee, Concise Inorganic Chemistry, 5th Ed. (reprint); Blackwell Science Wiley, 2015. 5. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, 2008. 6. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley, 1984. 7. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004. 8. R. C. Hale, M. E. Seeley, M. J. La Guardia, L. Mai, E. Y. Zeng, A global perspective on microplastics, 2020, Journal of Geophysical Research: Oceans, Wiley, 125 (1), e2018JC014719. 9. S. Sharma, S. Chatterjee, Microplastic pollution, a threat to marine ecosystem and human health: a short review. 2017, Environmental Science and Pollution Research, Springer, 24, 21530–21547.	

	10. L. Andrady, Microplastics in the marine environment, 2011, Marine pollution bulletin, 62(8), 1596-1605. 11. R. C. Thompson, C. J. Moore, F. S. Vom Saal, S. H. Swan, Plastics, the environment and human health: current consensus and future trends. 2009, Philosophical transactions of the royal society B: biological sciences, Royal Society, 364 (1526), 2153-2166.
Course Outcome:	1. Students will be in a position to know the basic environmental chemical processes. 2. Students will be able to explain the origin and harmful effects of toxic chemicals in the environment. 3. Students will be aware of the analysis of some pollutants. 4. Students will be in a position to give examples of case studies.

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-624 **Title of the course:** Inorganic Chemistry: Industrial Perspective

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied M.Sc. Part-I chemistry courses.	
Course Objectives:	1. To discuss the economic importance of inorganic materials. 2. To teach the concepts in chemistry useful for inorganic industries. 3. To learn syntheses involved in industrial production. 4. To recognize applications of industrial inorganic materials in several other sectors.	
Content	**1. Economic importance of Inorganic materials in industry** a. Chemical industries & their economic importance b. Commodity, fine and speciality chemicals c. Water: potable water, fresh water from sea water & / or brackish water d. Hydrogen: water electrolysis, petrochemical processes and coal gasification e. Peroxide and inorganic peroxo compounds: hydrogen peroxide, sodium peroxide, sodium perborate, sodium carbonate perhydrate, alkali peroxodisulfate f. Nitrogen / phosphorous / sulphur /halogens and their compounds: ammonia, hydrazine, hydroxylamine, phosphoric acid & its salts, organophosphorus compounds, sulphuric acid, other important sulphur compounds, compounds of fluorine, chloroalkali electrolysis, hydrochloric acid, chlorine-oxygen compounds, compounds of bromine and compounds of iodine	No of hours 15
	2. Minerals in fertilizer industry a. Nitrogen-containing fertilizers: ammonium sulphate, ammonium nitrate and urea b. Phosphorous-containing fertilizers: superphosphates, triple superphosphates, ammonium phosphates and nitrophosphates c. Potassium-containing fertilizers: potassium chloride, potassium sulphate and potassium nitrate	10
	3. Metals / silicon and their compounds in industry a. Alkali metals: lithium, sodium and potassium b. Alkaline-earth metals: beryllium, magnesium, calcium, strontium and barium c. Others metals: aluminium, chromium, manganese and iron d. Silicon: silicon & its inorganic compounds andorgano-silicon	15

	compounds	
	4. Inorganic solids and their applications a. Silicates: glass, alkali silicates, zeolites b. Inorganic fibers: asbestos, textile glass, optical, carbon, metal and ceramic reinforcing fibers c. Ceramics: clay, electro, magneto and nonoxide ceramics d. Construction materials: lime, cement, gypsum, coarse ceramic and expanded products e. Enamels: enamel frit and its raw material as metal oxides / carbonates / nitrates / fluorides f. Metal carbides: titanium, zirconium, hafnium, vanadium, niobium tantalum, chromium, molybdenum, tungsten, thorium and uranium carbides g. Inorganic carbon: diamond, natural graphite, synthetic carbon & synthetic graphite, pyrolytic carbon & pyrolytic graphite and activated carbon h. Fillers: natural and synthetic fillers i. Inorganic pigments: white, coloured, black and speciality pigments	20
Pedagogy	Mainly lectures / tutorials / assignments / self-study/ industrial visits/ field trips in and around Goa or combination of some of these could also be used to some extent.	
Reference /Readings	1. K.H. Büchel, H.-H. Moretto& P. Woditsch, Industrial Inorganic Chemistry, 2nd completely revised Ed., Wiley VHC, 2000. 2. G. Buxbaum& G. Pfaff, Industrial Inorganic Pigments, 3rd Ed., Wiley VHC, 2005. 3. N.N. Greenwood & A. Earnshaw, Chemistry of the Elements, 3rd Ed., Pergamon Press, Exeter, 1998. 4. F.A. Cotton, G. Wilkinson & P. L. Gaus, Basic Inorganic Chemistry, 3rd Ed., John Wiley, 2007. 5. F.A. Cotton & G. Wilkinson, Advanced Inorganic Chemistry, 6th Ed., Wiley Eastern, 2007. 6. J.E. Huheey, E.A. Keiter, R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4th Ed., Pearson, 1993. 7. J.D. Lee, Concise Inorganic Chemistry, 5th Ed., Wiley, 2008. 8. M. Weller, T. Overton, J. Rourke & F. Armstrong, Inorganic Chemistry, International Ed., Oxford University Press, 2018. 9. P. Atkins, J. De Paula & J. Keeler, Atkins' Physical Chemistry, International Ed., Oxford University Press, 2018. 10. A.R. West, Solid State Chemistry and Its Applications, 2nd Ed., John Wiley & Sons,2014.	
Course Outcomes:	1. Students will be able to discuss the economic importance of inorganic materials. 2. Students will be able to understand concepts in chemistry useful for	

	inorganic industries. 3. Students will be able to describe syntheses involved in industrial production. 4. Students will be able to explain applications of industrial inorganic materials in several other sectors.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-600 **Title of the course:** Research Methodology and instrumental techniques-I

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.	
Content	**1. Introduction to Research Methodology** Research- meaning, objectives, motivation, types and methodology. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	No of hours 5
	2. Scientific conduct and ethics Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. Intellectual honesty and research integrity. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). Redundant publications: duplicate and overlapping publications. Selective reporting and misrepresentation of data.	5
	3. Academic writing Publication ethics: definition, introduction and importance Conflicts of interest Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa Violation of publication ethics, authorship and contributorship Identification of publication misconduct, complaints and appeals Predatory publishers and journals	5

	4. Data bases and research metrics Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
	5. Safety aspects in Chemistry Good laboratory practices. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	6. Softwares in Chemistry Data plotting Structure Drawing Reference management software	7
	7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: Elemental analysis: CHNS analysis and AES Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) Nuclear magnetic resonance (^{1}H, ^{13}C) Chromatographic techniques: HPLC, GC, Hyphenated Techniques: LC-MS & GC-MS, Diffraction methods: XRD Thermal analysis: DSC Microscopy: SEM, TEM Methods for determination of magnetic & dielectric properties. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. 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. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National	

	Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-601 **Title of the course:** Research Methodology and instrumental techniques-II

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I.	
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.	
Content	**1. Research Methodology, Scientific conduct, ethics & academic writing** Research- meaning, objectives, motivation, types and methodology. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. Intellectual honesty and research integrity. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). Redundant publications: duplicate and overlapping publications. Selective reporting and misrepresentation of data. Publication ethics: definition, introduction and importance Conflicts of interest Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa Violation of publication ethics, authorship and contributorship Identification of publication misconduct, complaints and appeals Predatory publishers and journals	No of hours 15
	2. Softwares in chemistry, Data bases and Research metrics	10

	Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc Molecular Docking software	
	3. Safety practices in Chemical research Introduction to lab safety. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	4. Instrumental methods UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) Electrochemical Impedance Spectroscopy (EIS) Resonance Raman and isotope labelling studies. Infrared (IR) spectroscopy applications ^{1}H, ^{13}C- NMR spectroscopy and applications Selected chromatographic techniques such as HPLC, GC. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS Diffraction methods: High temperature XRD Thermal analysis: TG/DTA/DSC Microscopy: Fe-SEM, HR-TEM Methods for determination Ms, Mr, Hc, Tc, ε^{l} and Tanδ. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. 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. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,́ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989. 19. Leach, Molecular Modelling, Principles and applications, Longman, 1998. 20. W. Nam et al, Dioxygen activation by Metalloenzymes & models, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-651 **Title of the course:** Discipline Specific Dissertation

Number of Credits: 16

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Content	As per OA-35	*No of Hours* 480
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.	
References / Readings:	As required for the development of review and methodology.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	