Academic Council dated 10th February, 2022 as per Item Number: 3.03

DOMBIVLI SHIKSHAN PRASARAK MANDAL'S,

K.V. PENDHARKAR COLLEGE OF ARTS, SCIENCE AND COMMERCE,

(AUTONOMOUS) DOMBIVLI (EAST), DIST. THANE

(Affiliated to University of Mumbai)

Faculty of Science

DEPARTMENT OF CHEMISTRY

(Programme: Master of Science, M.Sc.)

SYLLABUS FOR

M.Sc. Part-II (Inorganic Chemistry) (Semester III and IV)

Choice Based Credit System (CBCS)

(With effect from the Academic Year: 2022-2023)

Course Structure
M.Sc. II (Inorganic Chemistry)

Course Code	SEM III	Credit points	Couse code	SEM-IV	Credit points
PPSCHIII22-301	Paper-I (Chemistry of inorganic solids)	4	PPSCHIV22-401	Paper-I (Properties of inorganic solids and group theory)	4
PPSCHIII22-302	Paper-II (Bioinorganic, coordination and computational chemistry)	4	PPSCHIV22-402	Paper-II (Organometallics and main group chemistry)	4
PPSCHIII22-303	Paper-III (Spectral methods in inorganic chemistry)	4	PPSCHIV22-403	Paper-III (Instrumental methods in inorganic chemistry)	4
PPSCHIII22-304	Paper-IV (Applied chemistry)	4	PPSCHIV22-404	Paper-IV (Intellectual property rights and research methodology)	4
PPSCHIII22-P301	Paper-I-Analysis of ores/alloys	2	PPSCHIV22-P401	Paper-I-Analysis of ores	2
PPSCHIII22-P302	Paper-II-Solvent extraction	2	PPSCHIV22-P402	Paper-II-Co-ordination chemistry	2
PPSCHIII22-P303	Paper-III-Inorganic preparations	2	PPSCHIV22-P403	Paper-III-Analysis of the samples	2
PPSCHIII22-P304	Paper-IV-Analysis of the samples	2	PPSCHIV22-P404	Paper-IV-Project evaluation	2

Programme Outcomes:

1. Students will be able to think creatively (divergently and convergent) to propose novel ideas in explaining facts and figures or providing new solution to the problems in chemistry.
2. Students will build a scientific temper and will be able to learn the necessary skills to succeed in research or industrial field. In addition, they will acquire the skills in handling scientific instruments, planning and performing in laboratory experiments.
3. Students will gain a thorough Knowledge in the subject to be able to work in projects at different research as well as academic institutions.
4. Employ critical thinking and the scientific knowledge to design, carry out, record and analyze the

results of chemical reactions.

5. Understanding of good laboratory practices and safety.

Course Outcomes:

1. Learners able to analyze the various observations and chemical phenomena presented to them during the course.
2. Learners will get an opportunity to get hands on experience of the various concepts and processes in inorganic chemistry.
3. Learners can gain knowledge and skills of handling chemicals, reagents, apparatus, instruments and the care and safety aspects involved in such handling.
4. Impart skills to develop a research topic and design
5. Define a purpose statement, a research question or hypothesis, and a research objective.
6. Analyze the data and arrive at a valid conclusion.
7. Compile and present research findings.

Paper I- Chemistry of inorganic solids (PPSCHIII22-301)

Sr. No.	Units	Lectures	Credit points
1	Unit-I- Descriptive Crystal Chemistry	15	04
2	Unit-II- Imperfection in crystals and non-stoichiometry	15	
3	Unit-III- Methods of Preparations	15	
4	Unit-IV- Behavior of Inorganic Solids	15	

Learning objectives:

The learner to be imparted with:

1. Knowledge of various types of simple structures.
2. Understanding corner and edge sharing structures with suitable examples.
3. Different methods for the synthesis of inorganic materials.
4. Understand the behavior of inorganic solids.
5. Detailed study of various types of defects in crystals.

Learning outcomes:

On successful completion of this course students will be able to:

1. Explain and draw the different structures like perovskites, ilmenites, spinels etc.

2. Distinguish between stoichiometric and non-stoichiometric defects.
3. Learn various methods for the synthesis of inorganic materials, single crystals, thin films and solid solutions.
4. Understand the applications of diffusion in carburizing and non-carburizing processes.

	Topics	Lectures
Unit-I	**1.1 Descriptive Crystal Chemistry** **(a) Simple structures** Structures of AB type compounds (PbO and CuO), AB_2 type (β cristobalite, CaC_2 and Cs_2O), A_2B_3 type (Cr_2O_3 and Bi_2O_3), AB_3 (ReO_3, Li_3N), ABO_3 type, relation between ReO_3 and perovskite $BaTiO_3$ and its polymorphmic forms, Oxide bronzes, ilmenite structure, AB_2O_4 type, normal, inverse, and random spinel structures **(b) Linked Polyhedra** (i) Corner sharing: tetrahedral structure (Silicates) and octahedral structure (ReO3) and rotation of ReO_3 resulting in VF_3, RhF_3 and calcite type structures. (ii) Edge sharing: tetrahedral structures (SiS_2) and octahedral structures (BiI_3 and $AlCl_3$). pyrochlores, octahedral tunnel structures and lamellar structures	**15**
Unit-II	**1.2 Imperfection in crystals and non-stoichiometry** **(a) Point defects:** Point defects in metals and ionic Crystal – Frenkel defect and Schottky defect. Thermodynamics formation of these defects (mathematical derivation to find defect concentration); Defects in non-stoichiometric compounds, colour centres **(b) Line defects:** Edge and Screw Dislocations. Mechanical Properties and Reactivity of Solids. **(c) Surface Defects:** Grain Boundary and Stacking Fault. Dislocation and Grain Boundaries, Vacancies and Interstitial Space in Non-Stoichiometric Crystals, Defect Clusters, Interchangeable Atoms and Extended Atom Defects	**15**
Unit-III	**1.3 Methods of Preparations** **(a) Methods of Synthesis:** Chemical Method, High Pressure Method, Arc Technique and Skull Method (with examples) **(b) Different methods for single crystal growth:**	**15**

	(i) Crystal Growth from Melt–: Bridgman and Stockbargar, Czochralski and Vernuil methods (ii) Crystal growth from liquid solution: Flux growth and temperature gradient methods (iii) Crystal growth from vapor phase: – Epitaxial growth methods **(c) Thin film preparation:** Physical and Chemical methods **(d) Solid Solutions:** Formation of Substitutional, Interstitial and Complex Solid Solutions; Mechanistic Approach; Study of Solid solutions by X-ray Powder Diffraction and Density Measurement	
Unit-IV	**1.4 Behavior of Inorganic Solids** **(a) Diffusion in Solids**: Fick's Laws of Diffusion; Kirkendal Effect; Wagner mechanism, Diffusion and Ionic Conductivity; Applications of Diffusion in Carburizing and non-Carburizing Processes in Steel Making **(b) Solid state reactions:** General principles and factors influencing reactions of solids, Reactivity of solids **(c) Liquid Crystals:** Introduction and classification of thermotropic liquid crystals, Polymorphism in liquid crystal, Properties and applications of liquid crystals	**15**

Justification: No change in paper-I syllabus.

Learner's space:

1. Introduction and applications of liquid crystals.
2. Single crystal growth and thin film preparations.
3. Imperfections in crystal and non-stoichiometry.
4. Normal, inverse and random spinel structures.

Job oriented/Entrepreneurship development topics: Different types of spinel structures, pyrochlores, octahedral tunnel structures and lamellar structures, Types of defects, Methods for single crystal growth, thin film preparation and behavior of inorganic solids.

References:

1. L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
2. A. R. West, Solid State Chemistry and Its Applications, John Wiley & sons, 1987.
3. C.N.R. Rao and J. Gopalkrishnan New Directions in Solid State Chemistry, 2nd Ed., Cambridge University Press. 1997.
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5. D.W. Bruce and Dermont O Hare, Inorganic Chemistry, 2nd Ed. Wiley and sons, New York, 1966.
6. J.M. Hollas, Symmetry in Molecules, Chapman and Hall Ltd.,1972.
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9. R.N.Kutty and J.A.K.Tareen, Fundamentals of Crystal Chemistry, Universities Press (India) Ltd., 2001.
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11. D.K.Chakraborty, Solid State Chemistry, New Age International Publishers, 1996.
12. A. Earnshaw, Introduction to Magnetochemistry, Acad. Press, N.Y. (1966).

ICT Backup:

1. https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/video-lectures/lecture-16/
2. https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/video-lectures/lecture-1/
3. https://www.youtube.com/user/MIT/search?query=chemistry
4. http://mit.uvt.rnu.tn/courses/materials-science-and-engineering/3-091sc-introduction-to-solid-state-chemistry-fall-2010/organic-materials/27-introduction-to-organic-chemistry/

Pedagogy:

Direct instructions, Flipped classrooms, Inquiry-based learning, Game-based learning, Videos, presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Udemy https://www.udemy.com/course/solid-state-chemistry/	11 lectures	50%	385/-

Paper-II-Bioinorganic, coordination and computational chemistry (PPSCHIII22-302)

Sr. No.	Units	Lectures	Credit points
1	Unit-I-Bioinorganic Chemistry	15	04
2	Unit-II- Reactivity of Chemical Species – I	15	
3	Unit-III- Structure, Bonding, and Stereochemistry of Coordination Compounds	15	
4	Unit-IV- Computational Chemistry	15	

Learning objectives:

The learner to be imparted with:

1. Knowledge of structure, bonding, and stereochemistry of coordination compounds.
2. Understanding coordination geometry of the metal ion and functions.
3. Pauling rules to determine the strength of oxoacids.
4. Periodic trends in amphoteric properties of d-block elements.
5. Variation principles and Ab initio methods.

Learning outcomes:

On successful completion of this course students will be able to:

1. Explain group characteristic of Lewis acids.
2. Understand role of metal ions in biological electron transfer processes.
3. To understand Huckel molecular orbital theory for alternant and nonalternant hydrocarbons.
4. Understand angular overlap model for octahedral and tetrahedral complexes.
5. To learn chirality and fluxionality of coordination compounds.

	Topics	Lectures
Unit-I	**2.1 Bioinorganic Chemistry** (i) Coordination geometry of the metal ion and functions (ii) Zn in biological systems: Carbonic anhydrase, protolytic enzymes, e.g., carboxy peptidase, Zinc finger (iii) Role of metal ions in biological electron transfer processes: iron sulphur proteins (iv) Less common ions in biology e.g., Mn (arginase; structure and reactivity), Ni (urease; structure and reactivity) (v) Biomineralization	**15**
Unit-II	**2.2 Reactivity of Chemical Species – I** 2.2.1 Recapitulation of the definition of Lewis acids and bases, Classification of Lewis acids and bases based on frontier Molecular orbital topology, Reactivity matrix of Lewis acids and bases 2.2.2 Group Characteristic of Lewis acids (Gp-1,13-17) 2.2.3 Pauling rules to determine the strength of oxoacids; classification and Structural anomalies 2.2.4 Periodic trends in amphoteric properties of d-block elements	**15**
Unit-III	**2.4 Structure, Bonding, and Stereochemistry of Coordination Compounds** **(a) Structure and Bonding** i) Molecular Orbital Theory for Complexes with Coordination Number 4 and 5 for the central ion (sigma as well as Pi bonding) ii) Angular Overlap Model for octahedral and tetrahedral complexes for sigma and pi bond **(b) Stereochemistry of Coordination Compounds** i) Chirality and Fluxionality of Coordination Compounds with Higher Coordination Numbers ii) Geometries of Coordination compounds from Coordination number 6 to 9	**15**
Unit-IV	**2.3 Computational Chemistry** 2.3.1 Huckel molecular orbital theory for alternant and nonalternant hydrocarbons 2.3.2 Variation principles	**15**

	2.3.3 Perturbation theory 2.3.4 Ab initio methods 2.3.5 Semiempirical methods 2.3.6 Density functional and molecular mechanics method	

Justification: The new direction in research in chemistry is computational chemistry hence PG students are introduced with computational chemistry.

Learner's space:

1. Less common ions in biology e.g., Mn and Ni
2. Molecular orbital theory for complexes with coordination number 4 and 5 for the central ion (sigma as well as Pi bonding).
3. Density functional and molecular mechanics method.

Job oriented/Entrepreneurship development topics: Role of metal ions in biological electron transfer processes, Pauling rules to determine the strength of oxoacids; classification and structural anomalies, Structure, bonding, and stereochemistry of coordination compounds and computational chemistry.

References:

1. Gary Wulfsberg, Inorganic Chemistry; Viva Books PA Ltd., New Delhi; 2002.
2. F.A. Cotton and Wilkinson, Advanced Inorganic Chemistry, 3rd edition.
3. James E. Huheey, Inorganic Chemistry, 3rd edition, Harper & Row, Publishers, Asia, Pte Ltd., 1983.
4. W.W.Porterfield, Inorganic Chemistry-An Unified Approach, Academic press(1993);
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11. H. Sisler, Chemistry in Non-aqueous Solvents: New York Reinhold Publ. 1965.

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13. C.M. Day and Joel Selbin, Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 1985.
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15. F.Basolo and R.G.Pearson, Mechanisms of Inorganic Reactions, Wiley, New York, 1967.
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18. G.W.Parshall and S.D.Ittel, Homogeneous Catalysis, 2nd edition, John Wiley & sons, Inc., New York, 1992.
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25. P.L. Soni, Vandana Soni, Ane Books Pvt., Ltd.
26. F. Jensen, Introduction to computational chemistry, 2nd edition, John Wiley & Sons Ltd.
27. C.J. Cramer, “Essentials of Computational Chemistry: Theories and Models”
28. D. Marx, J. Hutter, “Ab Initio Molecular Dynamics”.
29. Parr & Yang, “Density Functional Theory of Atoms & Molecules”.

ICT Backup:

1. https://ocw.mit.edu/courses/chemistry/
2. https://ocw.mit.edu/courses/captioned/
3. https://ocw.mit.edu/courses/captioned/#chemistry
4. https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/video-lectures/lecture-33/

Pedagogy:

Direct instructions, Flipped classrooms, Inquiry-based learning, Game-based learning, Videos, presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - NPTEL https://onlinecourses.nptel.ac.in/noc21_cy18/preview	4 weeks	30%	Free Certificate - Paid

Paper-III-Spectral Methods in Inorganic Chemistry (PPSCHIII22-303)

Sr. No.	Units	Lectures	Credit points
1	Unit-I- Diffraction Methods –I	15	04
2	Unit-II- Diffraction Methods –II	15	
3	Unit-III- Electron Spin Resonance Spectroscopy	15	
4	Unit-IV- Mossbauer Spectroscopy	15	

Learning objectives:

The learner to be imparted with:

1. X-ray, neutron and electron diffraction techniques.
2. Knowledge of instrumentation and applications of electron spin resonance spectroscopy.
3. Applications of low and high spin iron compounds.
4. Debye Scherrer method of X-Ray structural analysis of crystals.

Learning outcomes:

On successful completion of this course students will be able to:

1. Elucidation of structures of simple gas phase molecules using electron diffraction technique.
2. Explain X-ray diffraction technique.
3. Understand the electron spin resonance and Mossbauer spectroscopy.
4. Learn applications of iron, tin and iodine compounds.

	Topics	Lectures
Unit-I	**3.1 Diffraction Methods –I** X-Ray Diffraction: Bragg Condition; Miller PSCHI 303 Indices; Laue Method; Bragg Method; Debye Scherrer Method of X-Ray Structural Analysis of Crystals	**15**
Unit-II	**3.2 Diffraction Methods –II** **(a) Electron Diffraction:** Scattering of electrons, Scattering Intensity versus Scattering Angle, Weirl Measurement Technique, Elucidation of Structures of Simple gas Phase Molecules **(b) Neutron Diffraction:** Scattering of Neutrons: Scattering of neutrons by Solids and Liquids, Magnetic Scattering, Measurement Technique	**15**
Unit-III	**3.3 Electron Spin Resonance Spectroscopy** (a) Electron behavior, interaction between electron spin and magnetic field (b) Instrumentation: Source, Sample cavity. Magnet and Modulation coils, Microwave Bridge, Sensitivity. (c) Relaxation processes and Line width in ESR transitions: (i) ESR relaxation and chemical bonding (ii) Interaction between nuclear spin and electron spin (hyperfine coupling) (iii) Spin polarization for atoms and transition metal ions (iv) Spin-orbit coupling and significance of g tensors (v) Application to transition metal complexes (having one unpaired electron)	**15**
Unit-IV	**3.4 Mossbauer Spectroscopy** 3.4.1 Basic principle, recoil energy and Doppler shift 3.4.2 Instrumentation: sources and absorber; motion devices, detection, reference substances and calibration 3.4.3 Isomer shift, quadrupole interaction, magnetic interaction, electronegativity and chemical shift. 3.4.4 Applications: Iron compounds- low spin and high spin Fe(II) and Fe(III) compounds and complexes, effect of pi-bonding, mono and poly nuclear Iron complexes, spinel oxides and iron-sulphur	**15**

	proteins; Tin compounds- tin halides and tin oxides, organotin compounds; Iodine compounds- I_2 and alkali metal iodide compounds	

Justification: No change in paper-III syllabus.

Learner's space:

1. X-ray, electron and neutron diffraction techniques.
2. Interaction between electron spin and magnetic field.
3. Study of interaction of electromagnetic radiation with matter.
4. Basics of ESR and Mossbauer spectroscopy and applications.

Job oriented/Entrepreneurship development topics: X-ray, electron and neutron diffraction, ESR and Mossbauer spectroscopy.

References:

1. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis Fifth edition, (1996), ELBS Publication. Chapter 2, 3, 11.
2. W.H. Zachariasen. Theory of X-Ray Diffraction in Crystals. John Wiley. New York. 1946.
3. B.D. Cality, Elements of X-Ray Diffraction Procedures. John Wiley and Sons. New York, 1954.
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5. May and Leopold, An Introduction to Mossbauer Spectroscopy, Plenum, New York, 1971.
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24. Paul Gabbott Principles and Applications of Thermal Analysis Wiley-Blackwell; edition (2007)
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ICT Backup:

1. https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/video-lectures/lecture-1/
2. https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/video-lectures/lecture-7/

Pedagogy:

Direct instructions, Flipped classrooms, Inquiry-based learning, Game-based learning, Videos, presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform -NPTEL https://nptel.ac.in/courses/104/106/104106122/	12 weeks	40%	Free Certificate - Paid

Paper-IV-Applied Chemistry - (Elective 1)- (PPSCHIII22-304)

Sr. No.	Units	Lectures	Credit points
1	Unit-I-Safety in Chemistry Laboratories	15	04
2	Unit-II-Manufacture and Applications of Inorganic Compounds	15	
3	Unit-III-Metallurgy	15	
4	Unit-IV-Advances in Nanomaterials	15	

Learning objectives:

The learner to be imparted with:

1. Handling of hazardous materials in laboratories.
2. Synthesis and applications of nanomaterials.
3. Manufacture of Inorganic Compounds.
4. Metallurgy process of metals.

Learning outcomes:

On successful completion of this course students will be able to:

1. Explain the various types of toxins and their effects on humans.
2. Understand the unique properties of nanomaterials.
3. Understand the applications of inorganic compounds
4. Get the knowledge of physical and chemical properties metals.

	Topics	Lectures
Unit-I	**4.1 Safety in Chemistry Laboratories** 4.1.1 Handling of Hazardous Materials 4.1.2 Toxic Materials (Various types of toxins and their effects on humans) 4.1.3 Explosives and Inflammable Materials 4.1.4 Types of fire extinguishers (chemical reaction) 4.1.5 Bioactive materials 4.1.6 Safe working procedure and protective environment, protective apparel, emergency procedure, first aid, laboratory ventilation, safe storage, identification, verification and segregation	**15**

	of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals 4.1.7 Laboratory Wastes Disposal Management in Chemical Laboratories	
Unit-II	**4.2 Manufacture and Applications of Inorganic Compounds** 4.2.1 Study of industrial inorganic compounds (Lime, Chlorine and Caustic soda) 4.2.2 Ceramics and refractory materials 4.2.3 Fertilizers and micronutrients 4.2.4 Paints and Pigments **4.2.5 Inorganic Pharmaceuticals:** Gastrointestinal agents viz. i) antacids (aluminium hydroxide, milk of magnesia, sodium bicarbonate and ii) Cathartics (magnesium sulphate and sodium phosphate) Topical agents viz. protectives and adsorbents (talc, calamine) iii) antimicrobial agents (potassium permanganate, tincture iodine, boric acid) and astringents (potash alum)	**15**
Unit-III	**4.3 Metallurgy** 4.3.1 Occurrence, extraction and metallurgy of Zirconium, Hafnium, Niobium, Tantalum Platinum and Palladium metals 4.3.2 Physical and chemical properties and applications of these metals 4.3.3 Compounds of these metals, alloys and their uses	**15**
Unit-IV	**4.4 Advances in Nanomaterials:** 4.4.1 Types of nanomaterials, e.g., nanotubes, nanorods, solid spheres, core-shell, carbon nanofibers, nanoparticles, mesoporous materials; isolation of nano materials 4.4.2 Some important properties of nanomaterials: optical properties of metal and semiconductor nanoparticles, magnetic properties 4.4.3 Some special nanomaterials: Porous silicon: Preparation and mechanism of porous silicon formation, Factors affecting porous structure, properties of porous	**15**

	silicon; Aerogels: Types of aerogels, Properties and applications of aerogels 4.4.4 Synthesis of carbon nanomaterials from vegetable oils by CCVD technique 4.4.5 Applications of nanomaterials in electronics, energy, automobiles, sports and toys, textile, cosmetics, medicine, space and defense	

Justification: In Unit-I, safe working procedure and protective environment, disposal of chemicals in the sanitary sewer system etc. are added to the existing syllabus which is very important information to students while working in various type of industries. Unit-IV is newly introduced which discuss advances of nanomaterials. Students will get introduced to various nanomaterials, their synthesis and applications in various fields.

Learner's space

1. Safe working procedure and protective environment in chemistry laboratories.
2. Knowledge of topical agents, protectives, adsorbents etc.
3. Metallurgy of various metals.
4. Importance of nanomaterials.

Job oriented/ Entrepreneurship development topics: Safety in chemistry laboratories, Study of industrial inorganic compounds, Inorganic Pharmaceuticals, Metallurgy and Nanomaterials.

References:

1. G.M. Masters, Introduction to Environmental Engineering and Science, Prentice-Hall of India Pvt. Ltd. New Delhi, 1995.
2. Sulabha K. Kulkarni, Nanotechnology-Principles and Practices, Capital Publishing Co., 2007.
3. K. R. Mahadik and B. S. Kuchekar, Concise Inorganic Pharmaceutical Chemistry, Nirali Prakashan, Pune, 19.
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10. G B Sergeev, Nanochemistry, Elsevier 2006.
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ICT Backup:

1. https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/video-lectures/lecture-1/
2. https://www.youtube.com/user/MIT/search?query=chemistry

Pedagogy:

Direct instructions, Flipped classrooms, Inquiry-based learning, Game-based learning, Videos, presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Udemy https://www.udemy.com/course/chemical-safety-safely-working-with-chemicals-work-home/	11 sections, 36 lectures, 2hr. 51m in	30%	2240/-
2. Platform - Swayam https://onlinecourses.nptel.ac.in/noc22_mm21/preview	8 weeks	40%	Free

Paper-IV-Applied Chemistry - (Elective 2)- (PPSCHIII22-304)

Sr. No.	Units	Lectures	Credit points
1	Unit-I- Inorganic Materials	15	04
2	Unit-II- Nuclear Chemistry and Inorganic Pharmaceuticals	15	
3	Unit-III- Advances in Nanomaterials:	15	
4	Unit-IV- Some Selected Topics	15	

Learning objectives:

The learner to be imparted with:

1. Manufacture and applications of inorganic materials.
2. Knowledge of nuclear fuels and radiopharmaceuticals.
3. Some important properties of nanomaterials.
4. Some selected topics of inorganic chemistry.

Learning outcomes:

On successful completion of this course students will be able to:

1. Study preparation, properties and uses of industrially important chemicals.
2. Understand the types and synthesis of nanomaterials using various methods.
3. Get the knowledge of supramolecular and intercalation compounds.
4. Explain the various applications of inorganic materials.

	Topics	Lectures
Unit-I	**4.1 Inorganic Materials** (a) Classification, manufacture and applications of (i) Inorganic fibers, and (ii) Inorganic fillers. Study of (i) Condensed phosphates, and (ii) Coordination polymers (b) Preparation, properties and uses of industrially important chemicals – potassium permanganate, sodium thiosulphate, bleaching powder, hydrogen peroxide, potassium dichromate	**15**
Unit-II	**4.2 Nuclear Chemistry and Inorganic Pharmaceuticals**	**15**

	(a) Nuclear Chemistry: Introduction to of nuclear fuels and separation of fission products from spent fuel rods by PUREX process. Super heavy element, discovery, preparation, position in the periodic table **(b) Inorganic Pharmaceuticals:** Radiopharmaceuticals containing Tc and Bi, contrast agents for X-ray and NMR imaging. Gastrointestinal agents viz. (i) antacids (aluminium hydroxide, milk of magnesia, sodium bicarbonate and (ii) Cathartics (magnesium sulphate and sodium phosphate). Topical agents viz.(i) protectives and adsorbents (talc, calamine), (ii) antimicrobial agents (potassium permanganate, tincture iodine, boric acid) and astringents (potash alum)	
Unit-III	**4.3 Advances in Nanomaterials:** **(a) Types of nanomaterials,** e.g., nanotubes, nanorods, solid spheres, core-shell nanoparticles, mesoporous materials; isolation of nano materials **(b) Some important properties of nanomaterials:** optical properties of metal and semiconductor nanoparticles, magnetic properties. **(c) Some special nanomaterials:** Carbon nanotubes: Types, synthesis using various methods, growth mechanism, electronic structure; Porous silicon: Preparation and mechanism of porous silicon formation, Factors affecting porous structure, properties of porous silicon; Aerogels: Types of aerogels, Properties and applications of aerogels. **(d) Applications of nanomaterials in -** electronics, energy, automobiles, sports and toys, textile, cosmetics, medicine, space and defense. Environmental effects of nanotechnology.	**15**
Unit-IV	**4.4 Some Selected Topics** i) Isopoly and Hetropoly acids ii) Supramolecular chemistry iii) Inorganic pesticides, and iv) Intercalation compounds	**15**

Justification: No change in Paper-IV (Elective-2) syllabus.

Learner's space:

1. Preparation, properties and uses of industrially important chemicals.
2. Understand the applications of gastrointestinal agents.
3. Knowledge of inorganic pesticides.
4. Preparation and mechanism of porous silicon materials.

Job oriented/Entrepreneurship development topics: Preparation, properties and uses of industrially important chemicals, Radiopharmaceuticals containing Tc and Bi, contrast agents for X-ray and NMR imaging, Synthesis, properties & applications of nanomaterials.

References:

1. G.M.Masters, Introduction to Environmental Engineering and Science, Prentice-Hall of India Pvt. Ltd. New Delhi, 1995.
2. Sulabha K. Kulkarni, Nanotechnology-Principles and Practices, Capital Publishing Co., 2007.
3. K. R. Mahadik and B. S. Kuchekar, Concise Inorganic Pharmaceutical Chemistry, Nirali Prakashan, Pune, 19.
4. D. A. Skoog, D. M. West, and F. J. Holler, Fundamentals of Analytical Chemistry, 7th Edition, (printed in India in 2001), ISBN Publication.
5. B. Douglas, D.H. McDaniel and J.J.Alexander, Concepts and Models of Inorganic Chmistry, 2nd edition, John Wiley & Sons, 1983.

ICT Backup:

1. https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/video-lectures/
2. https://ocw.mit.edu/courses/chemistry/5-111sc-principles-of-chemical-science-fall-2014/
3. https://ocw.mit.edu/courses/civil-and-environmental-engineering/1-84j-atmospheric-chemistry-fall-2013/

Pedagogy:

Direct instructions, Flipped classrooms, Inquiry-based learning, Game-based learning, Videos, presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Udemy https://www.udemy.com/course/nanotechnology/	8 sections • 61 lectures • 4hr. 25min total length	40%	525/-
2. **Platform** – Udemy https://www.udemy.com/course/chemical-safety-safely-working-with-chemicals-work-home/	11 sections • 36 lectures • 2hr. 51min total length	40%	525/-

Laboratory work (Practicals) (Semester III)

Learning objectives:

The learner will be imparted with

1. Analysis of ores/alloys.
2. Separation & estimation of metal ions using solvent extraction technique.
3. Synthesis of inorganic complexes.
4. Analysis of the various samples.

Learning outcomes:

On completion of these experimentations, the learner will be able to

1. Learn the opening of alloys/ores and to estimate the amount of metal ions present in it.
2. Estimate the calcium content from calcium tablet by complexometric titration.
3. Estimate the iron content from iron tablet by colorimetry.
4. Learn the separation of two metal ions using suitable organic solvents.

	Practicals
Paper-I	**Analysis of ores/alloys (PPSCHIII22-P301)** 1. Analysis of Brass alloy: (i) Cu content by iodometric method (ii) Zn content by complexometric method 2. Analysis of Mangelium alloy: (i) Al content by gravimetric method as basic succinate (ii) Mg content by complexometric method

	3. Analysis of Bronze alloy: (i) Cu content by complexometric method (ii)Sn content by gravimetric method 4. Analysis of steel nickel alloy: (i) Ni content by homogeneous precipitation method
Paper-II	**Solvent Extraction (PPSCHIII22-P302)** 1. Separation of Mn and Fe using isoamyl alcohol and estimation of Mn. 2. Separation of Co and Ni using n-butyl alcohol and estimation of Co. 3. Separation of U and Fe using 8-hydroxyquinoline in chloroform and estimation of U. 4. Separation of Fe and Mo using isoamyl alcohol and estimation of Mo. 5. Separation of Cu and Fe using n-butyl acetate and estimation of Cu.
Paper-III	**Inorganic Preparations (PPSCHIII22-P303)** 1. Preparation of $V(oxinate)_3$ 2. Preparation of Sn (IV) Iodide 3. Preparation of $Co(\alpha\text{-nitroso-}\beta\text{-naphthol})_3$ 4. Preparation of $Ni(salicylaldoxime)_2$ 5. Hexaamine cobalt (III) chloride 6. Preparation of Trans-bis (glycinato) Cu (II)
Paper-IV	**Analysis of the following samples (PPSCHIII22-P304)** 1. Calcium tablet for its calcium content by complexometric titration. 2. Bleaching powder for its available chlorine content by iodometric method. 3. Iron tablet for its iron content colorimetry by 1,10-phenonthroline method. 4. Nycil powder for its Zn content complexometrically.

Justification: No change in Sem-III practicals.

Learner's space:

1. Able to analyze the metal ions present in alloy/ores by appropriate method.
2. They will learn method of separation such as solvent extraction.
3. Able to do analysis of various samples.
4. To synthesize inorganic complexes.

Job oriented/Entrepreneurship development topics: All the four papers of practicals will be helpful to students to develop their practical as well as research-oriented skills.

References:

1. I. Vogel, Quantitative Inorganic Analysis.
2. J. D. Woolins, Inorganic Experiments.
3. Palmer, Inorganic Preparations.
4. G. Raj, Advanced Practical Inorganic Chemistry.
5. J. E. House, Inorganic chemistry, Academic press, 2nd edition, (2013).

ICT Backup:

1. https://ocw.mit.edu/courses/chemistry/
2. https://www.futurelearn.com/courses/teaching-practical-science-chemistry
3. https://www.udemy.com/course/chemistry-practicals-activities-of-chemical-reactions/

Semester-IV

Paper I- Properties of Inorganic Solids and Group Theory (PPSCHIV22-401)

Sr. No.	Units	Lectures	Credit points
1	Unit-I-Electrical properties	15	04
2	Unit-II-Magnetic properties	15	
3	Unit-III-Thermal and optical properties	15	
4	Unit-IV-Applications of group theory to electronic structures	15	

Learning objectives:

The learner to be imparted with:

1. Properties of inorganic solids and group theory.
2. Introduction to magnetic properties.
3. Some important thermal and optical properties of inorganic solids.
4. Applications of group theory to electronic structures.

Learning outcomes:

On successful completion of this course students will be able to:

1. Explain the electrical properties of solids.

2. Understand the behavior of substances in the magnetic field.
3. Get the knowledge thermal expansion of metals.
4. Understand the construction of energy level diagrams.

	Topics	Lectures
Unit-I	**1.1 Electrical Properties** (**a) Electrical properties of solids:** (i) Conductivity: Solid Electrolytes; Fast Ion Conductors; Mechanism of Conductivity; Hopping Conduction. **(b) Other Electrical Properties:** Thomson and Seeback Effects; Thermocouples and their applications; Hall Effect; Dielectric, Ferroelectric, Piezoelectric and Pyroelectric Materials and their Inter-relationships and Applications	**15**
Unit-II	**1.2 Magnetic Properties** (a) Behavior of substances in magnetic field, mechanism of ferromagnetic and antiferromagnetic ordering, super exchange, Hysteresis, Hard and soft magnets, structures and magnetic Properties of Metals and Alloys; Transition metal Oxides; Spinels; garnets, Ilmenites; Perovskite and Magneto plumbites, Application in transformer cores information storage, magnetic bubble memory devices and as permanent magnets.	**15**
Unit-III	**1.3 Thermal and Optical Properties** **(a) Thermal Properties:** Introduction, Heat Capacity and its Temperature Dependance; Thermal Expansion of Metals; Ceramics and Polymers and Thermal Stresses. **(b) Optical properties:** Color Centres and Birefringence; Luminescent and Phosphor Materials; Coordinate Model; Phosphor Model; Anti Stokes Phosphor; Ruby Laser; Neodymium Laser	**15**
Unit-IV	**1.4 Applications of group theory to electronic structures** (a) Recapitulation of points groups and character tables (b) Transformation properties of atomic orbitals (c) Sigma and pi- molecular orbitals for AB_4 (tetrahedral) and AB_6 (octahedral) molecules (d) **Ligand Field Theory:** Electronic structures of free atoms and ions; Splitting of levels and terms in a chemical environment;	**15**

	Construction of energy level diagrams; Direct product; Correlation diagrams for d^2 ions in octahedral and tetrahedral ligand field; Methods of Ascending and Descending Symmetry; Hole formalism.	

Justification: No change in paper-I syllabus.

Learner's space:

1. Study of electrical and magnetic properties of solids.
2. Understanding luminescent and phosphor materials.
3. Applications of group theory to electronic structures.
4. Knowledge of thermal and optical properties of solids.

Job oriented skill development topics: Electrical, thermal and optical properties of solids, behavior of substances in magnetic field and transformation properties of atomic orbitals.

References:

1. L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
2. A.R.West, Solid State Chemistry and Its Applications, John Wiley & sons, 1987.
3. C.N.R. Rao and J. Gopalkrishnan, New Directions in Solid State Chemistry, 2nd Ed., Cambridge University Press. 1997.
4. L.V. Azaroff, Introduction to solids, Tata-McGraw Hill Book Ce. New Dehli, 1977.
5. D.W. Bruce and Dermont O Hare, Inorganic Chemistry, 2nd Ed. Wiley and sons, New York, 1966.
6. J.M. Hollas, Symmetry in Molecules, Chapman and Hall Ltd., 1972.
7. Reboert L carter, Molecular Symmetry and Group Hohm Wiley and Sons, New York, 1988.
8. Ulrich Muller, Inorganic structural Chemistry, 2nd edition, John Wiley and Sons, Chichester, 1993.
9. R.N.Kutty and J.A.K.Tareen, Fundamentals of Crystal Chemistry, Universities Press (India) Ltd., 2001.
10. H.V.Keer, Principles of the Solid state, Wiley Eastern Ltd., 1993.
11. Gary L.Miessler and Donald A.Tarr, Inorganic Chemistry, 3rd edition, Pearson Education, Inc., 2004.
12. D.K.Chakraborty, Solid State Chemistry, New Age International Publishers, 1996.
13. A. Earnshaw, Introduction to Magnetochemistry, Acad. Press, N.Y. (1966).

ICT Backup:

1. https://ocw.mit.edu/courses/materials-science-and-engineering/3-054-cellular-solids-structure-properties-and-applications-spring-2015/video-lectures/lecture-9-foams-thermal-properties/
2. https://ocw.mit.edu/courses/materials-science-and-engineering/3-021j-introduction-to-modeling-and-simulation-spring-2012/part-ii-lectures-videos-and-notes/lecture-8/
3. https://ocw.mit.edu/courses/physics/8-04-quantum-physics-i-spring-2013/lecture-videos/lecture-22/
4. https://www.youtube.com/watch?v=uAS3c2zAD70
5. https://ocw.mit.edu/courses/chemistry/5-61-physical-chemistry-fall-2017/lecture-videos/modern-electronic-structure-theory-basis-sets/

Pedagogy:

Direct instructions, Flipped classrooms, Inquiry-based learning, Game-based learning, Videos, presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Udemy https://www.udemy.com/course/solid-state-chemistry/	1 section, 11 lectures, 1hr. 59 min	30%	1280/-
2. Platform- edx https://www.edx.org/course/introduction-to-solid-state-chemistry?index=product&queryID=21fe5f8357f9271a10d178063fcd87a5&position=1	15 weeks	40%	Free

Paper-II-Organometallics and main group chemistry (PPSCHIV22-402)

Sr. No.	Units	Lectures	Credit points
1	Unit-I- Organometallic chemistry	15	04
2	Unit-II- Applications of organometallic compounds	15	

3	Unit-III- Inorganic cluster and cage compounds	15	
4	Unit-IV- Inorganic ring and chain compounds	15	

Learning objectives:

The learner to be imparted with:

1. Electron count and structures of clusters.
2. Introduction to organometallics as catalysts in organic reactions.
3. Bonding in boranes.
4. Knowledge of inorganic ring and chain compounds.

Learning Outcomes:

On successful completion of this course students will be able to:

1. Explain the metal-metal bonding in organometallic compounds.
2. Applications of organometallic compounds.
3. Understand silicates, polysilicates and aluminosilicates.
4. Get the knowledge of electron precise compounds and their relation to clusters.

	Topics	**Lectures**
Unit-I	**2.1 Organometallic chemistry** (a) Metal-metal bonding and metal clusters (b) Electron count and structures of clusters (c) Isolobal analogy (d) Organo palladium and Organo platinum complexes (preparations, properties and applications)	**15**
Unit-II	**2.2 Applications of Organometallic Compounds** (a) Catalysis-Homogenous and Heterogenous Catalysis: Comparison, Fundamental Reaction Steps (b) Organometallics as Catalysts in Organic Reactions: i) Hydrosilation, ii) Hydroboration, iii) Water gas Shifts Reaction, iv) Wacker process (Oxidation of alkenes) and v) Alcohol carbonylation (c) Coupling reactions: i) Heck's reaction and ii) Suzuki reaction	**15**
Unit-III	**2.3 Inorganic cluster and cage compounds**	**15**

	i) Introduction, ii) Bonding in boranes, iii) Heteroboranes, iv) Carboranes, v) cluster compounds and vi) electron precise compounds and their relation to clusters	
Unit-IV	**2.4 Inorganic ring and chain compounds** (a) Silicates, polysilicates and aluminosilicates (b) Phosphazenes, phosphazene polymers (c) Polyanionic and polycationic compounds	**15**

Justification: No change in paper-II syllabus.

Learner's space:

1. Applications of organometallic chemistry.
2. Electron precise compounds and their relation to clusters.
3. Inorganic ring and chain compounds.
4. Alcohol carbonylation and coupling reactions.

Job oriented skill development topics: Chemistry of Organo palladium and Organo platinum complexes, Homogenous and heterogenous catalysis and silicates, polysilicates and aluminosilicates.

References:

1. Gary Wulfsberg, Inorganic Chemistry; Viva Books PA Ltd., New Delhi; 2002.
2. F.A. Cotton and Wilkinson, Advanced Inorganic Chemistry, 3rd edition.
3. James E. Huheey, Inorganic Chemistry, 3rd edition, Harper &Row, Publishers, Asia, Pte Ltd., 1983.
4. W.W.Porterfield, Inorganic Chemistry-An Unified Approach, Academic press (1993).
5. D.F.Shriver, P.W.Atkins and C.H. Langford, Inorganic Chemistry,3rd edition Oxford University Press, 1999.
6. Asim K.Das, Fundamental Concepts of Inorganic Chemistry,(Volumes-I,II and III) CBS Pub. (2000).
7. N.N.Greenwood and A.Earnshaw, Chemistry of Elements, Pergamon, 1984.
8. J.M.Hollas, Symmetry in Chemistry, Chapmanad Hall Ltd., NY, 1972.
9. F.A.Cotton, Chemical Applications of Group Theory, 2nd edition, Wiley Eastern Ltd., New Delhi, 1976.
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11. H. Sisler, Chemistry in Non-aqueous Solvents: New York Reinhold Publ. 1965.

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13. C.M. Day and Joel Selbin, Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 1985.
14. L.E.Orgel, An Introduction to Ligand Field Theory , Methuen & Co. Ltd., London, 1960.
15. F.Basolo and R.G.Pearson, Mechanisms of Inorganic Reactions, Wiley, New York, 1967.
16. J.D.Lee, Concise Inorganic Chemistry, 5th ed., Blackwell Science Ltd., 2005.
17. R.H. Crabtree, The Organometallic Chemistry of the Transition Metals, Wiley-Interscience, New York, 1988.
18. G.W.Parshall and S.D.Ittel, Homogeneous Catalysis, 2nd edition, John Wiley & sons, Inc., New York, 1992.
19. Gary O. Spessard and Gary L.Miessler, Organometallic Chemistry, Prentice-Hall, (1997).
20. R.C.Mehrotra and A.Singh, Organometallic Chemistry-A Unified Approach, 2nd ed., New Age International Pvt. Ltd., 2000.
21. B.Douglas, D.H. McDaniel and J.J.Alexander, Concepts and Models of Inorganic Chemistry, 2nd edition, John Wiley & Sons, 1983.
22. James E.Huheey, Inoganic Chemistry-Principles of structure and reactivity, edn Harper & Row Publishers (1972).
23. F. A. Cotton, G. Wilkinson, C. Murillo and M. Bochmann, Advanced Inorganic Chemistry, 6th ed., John Wiley, New York,1999.
24. F.A. Cotton and R.A.Walton, Multiple Bonds between Metal Atoms, 2nd edition, claranden Press, Oxford, 1993.
25. P.L. Soni, Vandana Soni, Ane Books Pvt., Ltd.

ICT Backup:

1. https://www.youtube.com/watch?v=8XF6xWaGxHY&list=PLYXnZUqtB3K-dWnJR4u1bGchK7bVFtatA
2. https://www.youtube.com/watch?v=8pqCeN7GoMc
3. https://www.youtube.com/watch?v=X033TBYwo2U
4. https://nptel.ac.in/courses/104/101/104101091/

Pedagogy: Inquiry-based learning, Game-based learning, Direct instructions, Flipped classrooms, Videos, Presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Swayam https://onlinecourses.nptel.ac.in/noc22_cy05/preview	12 weeks	50%	Free
2. Platform – Swayam https://onlinecourses.nptel.ac.in/noc22_cy01/preview	4 weeks	45%	Free

Paper-III- Instrumental methods in Inorganic Chemistry (PPSCHIV22-403)

Sr. No.	Units	Lectures	Credit points
1	Unit-I-Spectroscopy	15	04
2	Unit-II-Microscopy of Surface Chemistry-I	15	
3	Unit-III-Microscopy of Surface Chemistry-II	15	
4	Unit-IV-Thermal Methods	15	

Learning objectives:

The learner to be imparted with:

1. Fundamental of Infrared and Raman spectroscopy.
2. Introduction to surface spectroscopy.
3. Important topics on electron microscopy (SEM) and (TEM).
4. Basic principle, instrumentation and applications to other thermal methods.

Learning Outcomes:

On successful completion of this course students will be able to:

1. Explain the instrumental methods in inorganic chemistry.
2. Understand the depth profile and chemical imaging of samples.
3. Understand the instrumentation of electron microscopy.
4. Get the knowledge of thermal stability of polymeric materials.

	Topics	Lectures
Unit-I	**3.1 Spectroscopy** **(a) Infrared spectroscopy:** Fundamental modes of vibrations, selection rules, IR absorption bands of metal - donor atom, effect of complexation on the IR spectrum of ligands formations on the IR of ligands like NH_3, CN^-, CO, olefins (C=C) and $C_2O_4^{2-}$ **(b) Raman spectroscopy:** Raman spectroscopy for diatomic molecules. Determination of molecular structures like diatomic and triatomic molecules **(c) Applications of Group theory in Infrared and Raman spectroscopy** (c) Molecular Vibrations: Introduction; The Symmetry of Normal Vibrations; Determining the Symmetry Types of the Normal Modes; symmetry-based Selection Rules of IR and Raman; Interpretation of IR and Raman Spectra for molecules such as H_2O, BF_3, N_2F_2, NH_3 and CH_4 **(d) Nuclear Magnetic Resonance Spectroscopy:** Introduction to basic principles and instrumentation. Use of ^1H, ^{19}F, ^{31}P, ^{11}B NMR spectra in structural elucidation of inorganic compounds; Spectra of paramagnetic materials: Contact shift, application of contact shift, lanthanide shift reagent	**15**
Unit-II	**3.2 Microscopy of Surface Chemistry-I** Introduction to surface spectroscopy, Microscopy, problems of surface analysis, distinction of surface species, sputter etching and depth profile and chemical imaging, instrumentations, Ion Scattering Spectra (ISS), Secondary Ion Mass Spectroscopy (SIMS), Auger Emission Spectroscopy (AES)	**15**
Unit-III	**3.3 Microscopy of Surface Chemistry-II** ESCA, Scanning Electron Microscopy (SEM), Atomic force microscopy (AFM) and transmission electron microscopy (TEM): Instrumentation and applications	**15**

Unit-IV	**3.4 Thermal Methods** 3.4.1 Application of TGA in Thermal characterization of polymers, quantitative analysis of mixture of oxalates, moisture content in coal, study of oxidation state of alloys etc. 3.4.2 Application of DSC and DTA in determination of thermodynamic parameters such as heat capacity and standard enthalpy of formation of the compounds, investigation of phase transitions, thermal stability of polymeric materials, purity of pharmaceuticals samples, M.P. and B.P. of organic compounds etc. 3.4.3 Basic principle, instrumentation and applications to other thermal methods like Thermomechanical analysis (TMA) and evolved gas analysis (EGA)	**15**

Justification: No change in paper-III syllabus.

Learner's space:

1. Applications of IR, Raman and NMR spectroscopy.
2. Introduction to surface spectroscopy.
3. Instrumentation and applications of SEM and TEM.
4. Basic principle, instrumentation and applications of thermal methods.

Job oriented skill development topics: Raman spectroscopy for determination of molecular structures like diatomic and triatomic molecules, Use of ^{1}H, ^{19}F, ^{31}P, ^{11}B NMR spectra in structural elucidation of inorganic compounds, distinction of surface species, sputter etching and depth profile and chemical imaging, thermal stability of polymeric materials, purity of pharmaceuticals samples, Melting point and boiling point of organic compounds.

References:

1. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis Fifth edition, (1996), ELBS Publication. Chapter 2, 3, 11.
2. W.H. Zachariasen. Theory of X-Ray Diffraction in Crystals. John Wiley. New York. 1946.
3. B.D. Cality,, Elements of X-Ray Diffraction Procedures. John Wiley and Sons. New York, 1954.
4. R. Reaching, Electron Diffraction, Methuen and Co. London. 1936
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10. G.W. Ewing, Instrumental Methods, Of Analysis, 4th Ed. McGraw Hill Ltd., 1970.
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13. G.T. Seaborg, Man-made Transuranic Elements Preitce- Hall, 1963.
14. M.T.R. Series, The Superheavy Elements.
15. Haissilsky, Nuclear Chemistry and its Application, 1962.
16. S. Glasstone, Sourcebook of Aomic Energy, East-West Publisher,1969.
17. D.Harvey, Modern Analytical Chemistry, The McGraw-Hill Pub,1st Edition (2000).
18. John H. Block, E.B. Roche, T.P.Soine and Charles O.Wilson, Inorganic Medicinal and Pharmaceutical Chemistry, Lea and Febiger, 1974.
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20. M. Drescher an G. Jeschke, (Eds), EPR Spetroscopy: Applications in Chemistry and Biology, Springer-Verlag Berlin, Heidelberg, 2012.
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22. C.N.R. Rao, Chemical Applications of Infrared Spectroscopy Academic Press, N.Y (1963).
23. K. Veera Reddy, Symmetry and Spectroscopy,
24. Paul Gabbott Principles and Applications of Thermal Analysis, Wiley-Blackwell ; edition (2007).
25. Richard Vernon Parish, NMR, NQR, EPR, and Mössbauer spectroscopy in inorganic chemistry, Publisher, E. Horwood, (1990).

ICT Backup:

1. https://www.youtube.com/watch?v=KRoWMB3AR3s
2. https://www.youtube.com/watch?v=f2j567E1Zqo
3. https://www.youtube.com/watch?v=7jOSbtR8mTs
4. https://www.youtube.com/watch?v=WTmj_9VT5oE
5. https://www.youtube.com/watch?v=kITvP4Irigg
6. https://www.youtube.com/watch?v=vRHfYWg9GXM

Pedagogy:

Direct instructions, Flipped classrooms, Inquiry-based learning, Game-based learning, Videos, presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Swayam https://onlinecourses.nptel.ac.in/noc22_cy23/preview	12 weeks	25%	Free
2. Platform – Udemy https://www.udemy.com/course/materials-characterization-techniques/	12 sections,14 lectures, 1hr. 27 min	45%	3499/-

Paper-IV-Intellectual Property Rights & Research Methodology (Elective-1) (PPSCHIV22-404)

Sr. No.	Units	Lectures	Credit points
1	Unit-I-Introduction to Intellectual Property-I	15	04
2	Unit-II-Introduction to Intellectual Property-II	15	
3	Unit-III-Introduction to Research Methodology	15	
4	Unit-IV-Methods of scientific research and writing scientific papers	15	

Learning objectives:

The learner to be imparted with:

1. Fundamental of different types of intellectual property (IP) and importance of
2. protecting IP.
3. Role of judiciary and role of law enforcement agencies.
4. Understanding primary, secondary and tertiary sources.

5. Knowledge about methods of scientific research and writing scientific papers.

Learning outcomes:

On successful completion of this course students will be able to:

1. Introduction to chemical abstracts and knowledge of research methodology.
2. Understand the intellectual property in the Indian context, various laws in India licensing and technology transfer.
3. Write literature surveys and reviews, organize a poster display, giving an oral presentation.
4. Learn writing ethics to avoid plagiarism.

	Topics	Lectures
Unit-I	**Introduction to Intellectual Property-I** **4.1 (a) Introduction to Intellectual Property:** Historical Perspective, Different types of IP, Importance of protecting IP **(b) Patents:** Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Health care-balancing promoting innovation with public health, Software patents and their importance for India **(c) Industrial Designs:** Definition, How to obtain, features, International design registration **(d) Copyrights:** Introduction, How to obtain, Differences from Patents **(e) Trade Marks:** Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, trade names etc. **(f) Geographical Indications:** Definition, rules for registration, prevention of illegal exploitation, importance to India	**15**
Unit-II	**Introduction to Intellectual Property-II** **4.2 (a) Trade Secrets:** Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection **(b) IP Infringement issue and enforcement:**	**15**

	Role of Judiciary, Role of law enforcement agencies – Police, Customs etc. **(c) Economic Value of Intellectual Property:** Intangible assets and their valuation, Intellectual Property in the Indian context – Various Laws in India Licensing and Technology transfer **(d) Different International agreements:** **World Trade Organization (WTO):** i) General Agreement on Tariffs and Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement ii) General Agreement on Trade Related Services (GATS) Madrid Protocol iii) Berne Convention iv) Budapest Treaty **Paris Convention** WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity	
Unit-III	**4.3 – Introduction to Research Methodology** **(a) Print:** Primary, Secondary and Tertiary sources **(b) Journals:** Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples **(c) Digital:** Web sources, E-journals, Journal access, TOC alerts, Hot articles, Citation Index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and communities, Blogs, preprint servers, Search engines, Scirus, Google Scholar, ChemIndustry, Wiki-databases, ChemSpider, Science Direct, SciFinder, Scopus **(d) Information Technology and Library Resources:** The Internet and World wide web, Internet resources for Chemistry, finding and citing published information	**15**

Unit-IV	**4.4 Methods of scientific research and writing scientific papers** Reporting practical and project work, writing literature surveys and reviews, organizing a poster display, giving an oral presentation. **Writing Scientific Papers:** Justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work, writing ethics, avoiding plagiarism	**15**

Justification: In the proposed syllabus, two units of research methodology are introduced which includes primary, secondary and tertiary sources available for research, methods of scientific research and writing scientific papers which will be useful to students who pursue research carrier after M.Sc.

Learner's space:

1. Importance of protecting Intellectual Property (IP).
2. IP in the Indian context - Various Laws in India licensing and technology transfer.
3. Information regarding web sources, E-journals, journal access, TOC alerts, hot articles, citation Index, impact factor, H-index etc.
4. Publications of scientific work, writing ethics, avoiding plagiarism.

Job oriented/Entrepreneurship development topics: Different types of Intellectual Properties (IP), Importance of protecting IP, Role of Judiciary, Role of law enforcement agencies- Police, Customs etc. and Methods of scientific research and writing scientific papers

References:

1. Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J., & Jones, A., (2011), Practical skills in Chemistry, 2nd Ed., Prentice Hall, Harlow.
2. Hibbert, D. B. & Gooding, J. J. (2006) Data Analysis for Chemistry Oxford University Press.
3. Topping, J., (1984) Errors of observation and their treatment 4th Ed., Chapman Hill, London.
4. Harris, D. C. (2007) Quantitative Chemical Analysis 6th Ed., Freeman Chapters 3-5.
5. Fundamentals of Research Methodology and Statistics,. Yogesh Kumar Singh,. New Age International (P) Limited, Publishers, 2006.
6. Research Methodology Methods and Techniques, C.R. Kothari,. New Age International (P) Limited, Publishers, 2004.
7. Research Methodology a step-by-step guide for beginners, 3rd edition, Ranjit Kumar,. SAGE Publications India Pvt Ltd, 2011

8. Research Methods The Basics Nicholas Walliman,. Routledge, Taylor & Francis, 2011.

ICT Backup:

1. https://www.youtube.com/watch?v=eWOOVlwkrEc
2. https://www.youtube.com/watch?v=qKXB5nuZ7Cs
3. https://www.youtube.com/watch?v=RQOJgEA5e1k
4. https://www.youtube.com/watch?v=GSeeyJVD0JU
5. https://www.youtube.com/watch?v=nv7MOoHMM2k

Pedagogy: Inquiry-based learning, Game-based learning, Direct instructions, Flipped classrooms, Videos, Presentations, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Swayam https://onlinecourses.nptel.ac.in/noc22_ge08/preview	12 weeks	40%	Free
2. Platform – Swayam https://onlinecourses.swayam2.ac.in/aic21_ge02/preview	16 weeks	50%	Free
3. Platform - edx https://www.edx.org/course/intellectual-property-rights-a-management-perspect?index=product&queryID=050c74f84c7a909016f8465153ff5a0f&position=1	6 weeks	40%	Free

Paper-IV-Research Methodology (Elective-2) (PPSCHIV22-404)

Sr. No.	Units	Lectures	Credit points
1	Unit-I-Introduction to Research methodology	15	04
2	Unit-II-Data analysis	15	
3	Unit-III- Methods of scientific research and writing scientific papers	15	
4	Unit-IV- Chemical Safety & Ethical Handling of Chemicals	15	

Learning objectives:

The learner to be imparted with:

1. Knowledge of journal abbreviations, abstracts, current titles and reviews.
2. Understanding web sources, e-journals, journal access, TOC alerts, hot articles, citation index, impact factor and H-index.
3. Basics of internet resources for chemistry.
4. Identify basic aspects of multiple linear regression analysis.

Learning outcomes:

On successful completion of this course students will be able to:

1. Explain subject index, substance index, author index, formula index and other indices with examples.
2. Understand the internet and world wide web.
3. Understand scientific methods and design of experiments.
4. Understand justification for scientific contributions.

	Topics	Lectures
Unit-I	**Introduction to Research Methodology** **4.1 (a) Print:** Primary, Secondary and Tertiary sources **(b) Journals:** Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples **(c) Digital:** Web sources, E-journals, Journal access, TOC alerts, Hot articles, Citation Index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and communities, Blogs, preprint servers, Search engines, Scirus, Google Scholar, ChemIndustry, Wiki-databases, ChemSpider, Science Direct, SciFinder, Scopus **(d) Information Technology and Library Resources:** The Internet and World wide web, Internet resources for Chemistry, finding and citing published information	**15**
Unit-II	**4.2 Data Analysis** **The Investigative Approach:** Making and recording Measurements, SI units and their use, Scientific methods and design of experiments **Analysis and Presentation of Data:** Descriptive statistics, choosing and using statistical tests, Chemometrics, Analysis of Variance (ANOVA), Correlation and regression, curve fitting, fitting of linear equations, simple linear cases, weighted linear case, analysis of residuals, general polynomial fitting, linearizing transformations, exponential function fit, r and its abuse, basic aspects of multiple linear regression analysis	**15**

Unit-III	**4.3 Methods of scientific research and writing scientific papers** Reporting practical and project work, writing literature surveys and reviews, organizing a poster display, giving an oral presentation **Writing Scientific Papers:** Justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work, writing ethics, avoiding plagiarism	**15**
Unit-IV	**4.4 Chemical Safety & Ethical Handling of Chemicals** Safe working procedure and protective environment, protective apparel, emergency procedure, first aid, laboratory ventilation, safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric pressure, safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals	**15**

Justification: No change in Paper-IV (Elective-2).

Learner's space:

1. Information regarding web sources, E-journals, journal access, TOC alerts, hot articles, citation Index, impact factor, H-index etc.
2. Publications of scientific work, writing ethics, avoiding plagiarism.
3. Recycling and reuse of laboratory chemicals.
4. Basic aspects of multiple linear regression analysis.

Job oriented/Entrepreneurship development topics: Scientific methods and design of experiments, Methods of scientific research and writing scientific papers, Chemical safety & ethical handling of chemicals.

References:

1. Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J., & Jones, A., (2011), *Practical skills in Chemistry*, 2nd Ed., Prentice Hall, Harlow.
2. Hibbert, D. B. & Gooding, J. J. (2006) *Data Analysis for Chemistry* Oxford University Press.
3. Topping, J., (1984) *Errors of Observation and their Treatment* 4th Ed., Chapman Hill, London.
4. Harris, D. C. (2007) *Quantative Chemical Analysis* 6th Ed., Freeman Chapters 3-5.
5. Levie, R. De. (2001) *How to use Excel in Analytical Chemistry and in general scientific data analysis* Cambridge University Press.
6. Chemical Safety matters – IUPAC-IPCS, (1992) Cambridge University Press.
7. OSU Safety manual 1.01.

ICT Backup:

1. https://www.youtube.com/watch?v=GSeeyJVD0JU
2. https://www.youtube.com/watch?v=nv7MOoHMM2k
3. https://www.youtube.com/watch?v=PDjS20kic54
4. https://www.youtube.com/watch?v=9IJscfF_irU

Pedagogy: Presentations, Inquiry-based learning, Game-based learning, Direct instructions, Flipped classrooms, Videos, Group discussions etc.

MOOC:

Platform and link	Course duration	Similarity index	Tentative cost
1. Platform - Swayam https://onlinecourses.nptel.ac.in/noc22_ge08/preview	12 weeks	40%	Free
2. Platform – Swayam https://onlinecourses.swayam2.ac.in/aic21_ge02/preview	16 weeks	50%	Free

Laboratory work (Practicals) (Semester IV)

Learning objectives:

The learner to be imparted with

1. Analysis of ores.
2. Determination of stability constant of various complexes by potentiometry and slope ratio method.
3. Analysis of soil for mixed oxide content by gravimetric method.
4. Analysis of the various samples.

Learning outcomes:

On completion of these experimentations, the learner will be able to

1. Learn the opening of ores and to estimate the amount of metal ions present in it.
2. Estimate the potassium content from fertilizer by flame photometry.
3. Estimate the chlorine content from fasting salt by conductometrically.
4. Determine CFSE values of hexa-aqua complexes of Ti^{3+} and Cr^{3+}.

	Practicals
Paper-I	**Analysis of ores (PPSCHIV22-P401)** **1. Analysis of galena ore:** i) Pb content as $PbCrO_4$ by gravimetric method using 5% potassium chromate ii) Fe content by colorimetrically using 1, 10- phenonthroline **2. Analysis of Zinc blend ore:** i) Zn content by complexometric method ii) Fe content by colorimetric method (Azide method) **3. Analysis of Pyrolusite ore:** i) Mn content by complexometric method ii) Acid insoluble residue by gravimetric method
Paper-II	**Coordination Chemistry (PPSCHIV22-P402)** 1. Determination of Stability constant of $[Zn(NH_3)4]^{2+}$ by potentiometry. 2. Determination of Stability constant of $[Ag(en)]^{+}$ by potentiometry. 3. Determination of Stability constant of $[Fe(SCN)]^{2+}$ by slope ratio method. 4. Determination of CFSE values of hexa-aqua complexes of Ti^{3+} and $Cr^{3+.}$ 5. Determination of Racah parameters for complex $[Ni(H_2O)6]^{2+}$ and $[Ni(en)_3]^{2+}$

Paper-III	**Analysis of the following samples (PPSCHIV22-P403)** 1. Electral powder for Na/K content flame photometrically. 2. Fasting salt for chloride content conductometrically. 3. Sea water for percentage salinity by Volhard's method. 4. Soil for mixed oxide content by gravimetric method. 5. Fertilizer for potassium content by flame photometry.
Paper-IV	**Project evaluation (PPSCHIV22-P404)**

Justification: No change in Sem-IV practicals.

Learner's space:

1. Able to analyze the metal ions present in ores by suitable method.
2. Able to do analysis of various samples.
3. To determine the stability constant of inorganic complexes.

Job oriented/Entrepreneurship development topics: All the four papers of practicals including project evaluation will be helpful to students to develop their practical as well as research-oriented skills.

References:

1. Vogel, Quantitative Inorganic Analysis.
2. J. D. Woolins, Inorganic Experiments.
3. Palmer, Inorganic Preparations.
4. G. Raj, Advanced Practical Inorganic Chemistry.
5. J. E. House, Inorganic chemistry, Academic press, 2nd edition, (2013).

ICT Backup:

1. https://ocw.mit.edu/courses/chemistry/
2. https://www.futurelearn.com/courses/teaching-practical-science-chemistry
3. https://www.udemy.com/course/chemistry-practicals-activities-of-chemical-reactions/

Syllabus of following universities referred:

1. Savitribai Phule Pune University, Pune
2. Shivaji University, Kolhapur
3. University of Kolkata, Kolkata

4. Banaras Hindu University, Varanasi
5. Harvard University, Massachusetts, USA

EVALUATION SCHEME:

EXAMINATION PATTERN

External Exam: 60 marks

Internal Exam: 40 marks

External Exam Paper Pattern:

Total marks: 60

Duration: 2 hr. 30 mins

1.	**EXTERNAL ASSESSMENT FOR THEORY (Semester End Examination)**		**60 Marks**
	N.B. 1. All questions are compulsory 2. All questions carry equal marks.		
	Q.1	Based on Unit-I, II, III and IV A) Multiple choice questions B) Fill in the blanks C) Short questions (one or two line)	 06 03 03
	Q.2 A) OR B) P) OR Q)	Unit-I	 06/07 06/05
	Q.3 A) OR B) P) OR Q)	Unit-II	 06/07 06/05

	Q.4 A) OR B) P) OR Q)	Unit-III	06/07 06/05
	Q.5 A) OR B) P) OR Q)	Unit-IV	06/07 06/05

Internal Exam Pattern: 40 marks

2.	**INTERNAL ASSESSMENT**	**40 Marks**
2.1	One class test (Objectives/ Multiple Choice)	15 Marks
2.2	Assignment/ Project/ Presentation/Book or research paper Review	20 Marks
2.3	Active participation, Overall performance	05 Marks

Evaluation Pattern for M.Sc. (PRACTICALS)

3.	**EXTERNAL ASSESSMENT FOR PRACTICALS**	**200 Marks**
	Sem-III Practicals for paper-I, II, III and IV (Each paper carries 50 marks. Distribution of marks is shown below.) **Sem-IV** Practicals for paper-I, II and III For each paper, one experiment to be performed by the candidate One experiment from each paper Viva Journal	 **40** **05** **05**

	Sem-IV, Paper-IV – Project evaluation	
	Dissertation	**25**
	Presentation	**15**
	Viva	**10**
	TOTAL MARKS	**50 X 4 =200**

Practical examination of each paper for 50 marks will be held for three and half hours.

Students will have to perform the necessary experiments in each semester and all experiments should be reported in journal.

Passing Standard:

1. The student will have to secure a minimum of 40% marks in internal assessment as well as semester end examination per theory paper, for all the theory papers.
2. The college will conduct all the semester examinations of 50 marks per practical paper at the end of each semester. The student will have to secure a minimum of 40% marks in the examination per practical paper, for all the above practical papers.