University of Mumbai

No. AAMS_UGS/ICC/2024-25/142

CIRCULAR:-

Attention of all the Principals of the Affiliated Colleges, Directors of the Recognized Institutions and the Head, University Departments is invited to this office Circular No. AAMS_UGS/ICC/2023-24/23 dated 08th September, 2023 relating to the NEP UG & PG Syllabus.

They are hereby informed that the recommendations made by the **Board of Studies in Chemistry** at its meeting held on 02nd September, 2024 and subsequently passed by the Board of Deans at its meeting held on 3rd September, 2024 **vide** item No. 6.15 (N) have been accepted by the Hon'ble Vice Chancellor as per the power confirmed upon him under section 12(7) of the Maharashtra Public Universities Act, 2016 and that in accordance therewith syllabus for **M.Sc.(Inorganic Chemistry) Sem – III & IV** is introduced as per appendix (NEP 2020) with effect from the academic year 2024-25.

(The Circular is available on the University's website www.mu.ac.in).

(Dr. Prasad Karande)
REGISTRAR

MUMBAI – 400 032
21st September, 2024

To

All the Principals of the Affiliated Colleges, Directors of the Recognized Institutions and the Head, University Departments.

BOD 6.15(N) 03/09/2024

Copy forwarded with Compliments for information to:-

1) The Chairman, Board of Deans,
2) The Dean, Faculty of Science,
3) The Chairman, **Board of Studies in Chemistry**
4) The Director, Board of Examinations and Evaluation,
5) The Director, Department of Students Development,
6) The Director, Department of Information & Communication Technology,
7) The Director, Centre for Distance and Online Education (CDOE) Vidyanagari,
8) The Deputy Registrar, Admission, Enrolment, Eligibility & Migration Department (AEM),

Copy forwarded for information and necessary action to :-	
1	The Deputy Registrar, (Admissions, Enrolment, Eligibility and Migration Dept)(AEM), dr@eligi.mu.ac.in
2	The Deputy Registrar, Result unit, Vidyanagari drresults@exam.mu.ac.in
3	The Deputy Registrar, Marks and Certificate Unit,. Vidyanagari dr.verification@mu.ac.in
4	The Deputy Registrar, Appointment Unit, Vidyanagari dr.appointment@exam.mu.ac.in
5	The Deputy Registrar, CAP Unit, Vidyanagari cap.exam@mu.ac.in
6	The Deputy Registrar, College Affiliations & Development Department (CAD), deputyregistrar.uni@gmail.com
7	The Deputy Registrar, PRO, Fort, (Publication Section), Pro@mu.ac.in
8	The Deputy Registrar, Executive Authorities Section (EA) eau120@fort.mu.ac.in He is requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to the above circular.
9	The Deputy Registrar, Research Administration & Promotion Cell (RAPC), rapc@mu.ac.in
10	The Deputy Registrar, Academic Appointments & Quality Assurance (AAQA) dy.registrar.tau.fort.mu.ac.in ar.tau@fort.mu.ac.in
11	The Deputy Registrar, College Teachers Approval Unit (CTA), concolsection@gmail.com
12	The Deputy Registrars, Finance & Accounts Section, fort draccounts@fort.mu.ac.in
13	The Deputy Registrar, Election Section, Fort drelection@election.mu.ac.in
14	The Assistant Registrar, Administrative Sub-Campus Thane, thanesubcampus@mu.ac.in
15	The Assistant Registrar, School of Engg. & Applied Sciences, Kalyan, ar.seask@mu.ac.in
16	The Assistant Registrar, Ratnagiri Sub-centre, Ratnagiri, ratnagirisubcentar@gmail.com
17	The Director, Centre for Distance and Online Education (CDOE), Vidyanagari, director@idol.mu.ac.in
18	Director, Innovation, Incubation and Linkages, Dr. Sachin Laddha pinkumanno@gmail.com
19	Director, Department of Lifelong Learning and Extension (DLLE), dlleuniversityofmumbai@gmail.com

Copy for information :-	
1	P.A to Hon'ble Vice-Chancellor, vice-chancellor@mu.ac.in
2	P.A to Pro-Vice-Chancellor pvc@fort.mu.ac.in
3	P.A to Registrar, registrar@fort.mu.ac.in
4	P.A to all Deans of all Faculties
5	P.A to Finance & Account Officers, (F & A.O), camu@accounts.mu.ac.in

To,

1	The Chairman, Board of Deans pvc@fort.mu.ac.in
2	**Faculty of Humanities,** **Dean** 1. Prof.Anil Singh Dranilsingh129@gmail.com **Associate Dean** 2. Dr.Suchitra Naik Naiksuchitra27@gmail.com 3.Prof.Manisha Karne mkarne@economics.mu.ac.in
	Faculty of Commerce & Management, **Dean** 1. Dr.Kavita Laghate kavitalaghate@jbims.mu.ac.in **Associate Dean** 2. Dr.Ravikant Balkrishna Sangurde Ravikant.s.@somaiya.edu 3. Prin.Kishori Bhagat kishoribhagat@rediffmail.com

	Faculty of Science & Technology **Dean** 1. Prof. Shivram Garje ssgarje@chem.mu.ac.in **Associate Dean** 2. Dr. Madhav R. Rajwade Madhavr64@gmail.com 3. Prin. Deven Shah sir.deven@gmail.com
	Faculty of Inter-Disciplinary Studies, **Dean** 1.Dr. Anil K. Singh aksingh@trcl.org.in **Associate Dean** 2.Prin.Chadrashekhar Ashok Chakradeo cachakradeo@gmail.com
3	Chairman, Board of Studies,
4	The Director, Board of Examinations and Evaluation, dboee@exam.mu.ac.in
5	The Director, Board of Students Development, dsd@mu.ac.in DSW direcotr@dsw.mu.ac.in
6	The Director, Department of Information & Communication Technology, director.dict@mu.ac.in

BOD – 3/9/2024
12 (7) of M.P.U.A. 2016
Item No. – 6.15 (N)

As Per NEP 2020

University of Mumbai

Title of the P.G. program

M.Sc. (Inorganic Chemistry)

Syllabus for Semester – Sem III & IV

(With effect from the academic year 2024-2025)

Ref: GR dated 16th May, 2023 for Credit Structure of PG

UNIVERSITY OF MUMBAI

Sr. No.	Heading	Particulars
1	Title of program O:_____	M. Sc. (Inorganic Chemistry)
2	Scheme of Examination R: _____	NEP 50% Internal 50% External, Semester End Examination Individual Passing in Internal and External Examination
3	Standards of Passing R: _____	40%
4	Credit Structure R : SP -15 B	Attached herewith
5	Semesters	Sem. III & IV
6	Program Academic Level	6.5
7	Pattern	Semester
8	Status	New
9	To be implemented from Academic Year	From the Academic Year 2024-25

Sign of the BOS Coordinator
Dr. Sunil Patil
BOS in Chemistry
Director, Students' Welfare,
University of Mumbai

Sign of the
Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science & Technology

Sign of the
Offg. Dean
Prof. Shivram S. Garje
Faculty of Science & Technology

Preamble

1) Introduction

This program is designed to provide a comprehensive and in-depth understanding of the fascinating world of Inorganic chemistry. Through a rigorous academic curriculum and hands-on research experience, we aim to nurture the intellectual curiosity and scientific acumen of our students, preparing them for successful careers in various sectors of the chemical sciences. The M.Sc. in Inorganic Chemistry course is structured to equip students with a strong theoretical foundation, practical skills, and critical thinking abilities necessary to address the challenges and opportunities in the diverse fields of chemistry. Our esteemed faculty members are experts in their respective fields, with a passion for both teaching and research. They are committed to providing a nurturing learning environment, encouraging open discussions, and fostering collaborative research endeavors. Through their mentorship, students will have the opportunity to engage in cutting-edge research projects, pushing the boundaries of scientific knowledge and contributing to the advancement of the chemical sciences.

We envision our M.Sc. in Inorganic Chemistry postgraduates act as catalysts for positive change, equipped to drive innovation, shape industries, and address societal challenges through their expertise in chemistry. Whether your passion lies in research, industry, education, or beyond, our program aims to provide the knowledge and skills necessary to excel in your chosen path.

2) Aims and Objectives

PO1: To equip students with a well-rounded and advanced education in the field of Inorganic chemistry. These goals focus on providing students with a deep understanding of chemical principles, fostering research and analytical skills, and preparing them for successful careers in various sectors of the chemical sciences.

PO2: To produce skilled and knowledgeable professionals who can contribute to scientific research, industrial innovation, and the betterment of society through their expertise in Inorganic chemistry.

PO3: To develop scientific temperament and inquisitiveness towards advanced inorganic chemistry field

PO4: To furnish knowledge of relevance and applications of various conventional theories

3) Learning Outcomes

PSO1: Recapitulation of classical theories will help the learner understand its significance in elucidation of chemical expressions

PSO2: Learners will be exposed to theoretical reaction mechanism underlying the instrumental methods so as to apply the knowledge in industry

PSO3: Learners will be educated about advanced emerging fields of chemistry involving significant role of metals in various processes

PSO4: Learners will develop research aptitude and research skills needed for scientific content developments, research methodology aspects to equip themselves with a comprehensive and advanced understanding of the field of chemistry. These learning outcomes reflect the knowledge, skills, and competencies that students are expected to gain upon successful completion of the program.

4) Any other point (if any)- Enhanced employability will be observed after successful completion of the program. Learner will be competent to express the knowledge gained through experiential learning. Capable of exploring the analytical skills while working in industries would be salient feature of the future chemist

R : SP -15 B

M.Sc. (Inorganic Chemistry) Parishishta - 1

MSc (Inorganic Chemistry) NEP Syllabus - Semester III & Semester IV											
Year	**Level**	**Sem**	**Major**				**RM**	**OJT /FP**	**RP**	**Cum. Cr.**	**Degree**
			Mandatory			**Elective**					
			3*4+ 2=14			**4**			**4**	**22**	
II	**6.5**	**Sem III**	**Chemistry of Inorganic Solids** (CHEM 621)	TH	4	**Applied Chemistry** + Practical (CHEM 62511) OR **Inorganic Materials** + Practical (CHEM 62512)	—	—	CHEM 626		PG Degree after 2-yr
			Bioinorganic and Coordination Chemistry (CHEM 622)	TH	4						
			Spectral Methods in Inorganic Chemistry (CHEM 623)	TH	4						
			Inorganic Chemistry Practical (CHEM 624)	PR	2						
		Sem IV	**3*4=12**			**4**			**6**	**22**	
			Properties of Inorganic Solids and Group Theory (CHEM 627)	TH	4	**Intellectual Property Rights & Cheminformatics** (CHEM 63011) **(OR) Advanced Topics in Inorganic Chemistry** (CHEM 63012)	—	—	CHEM 631		
			Organometallics and Main Group Chemistry (CHEM 628)	TH	4						
			Instrumental Methods in Inorganic Chemistry (CHEM 629)	TH	4						

Syllabus
M.Sc. (Inorganic Chemistry)
(Sem. III & IV)

UNIVERSITY OF MUMBAI

Syllabus for M.Sc. (Inorganic Chemistry)
Semester III and IV

Choice-Based Credit System
Under New Education Policy (NEP) 2020
(To be implemented from the academic year, 2024-2025)

PROGRAM OUTLINE 2024 – 2025

YEAR		COURSE CODE	COURSE TITLE	CREDITS
M.Sc. Sem - III	Mandatory Course – I	CHEM 621	Chemistry of Inorganic Solids	04
	Mandatory Course – II	CHEM 622	Bioinorganic and Coordination Chemistry	04
	Mandatory Course – III	CHEM 623	Spectral Methods in Inorganic Chemistry	04
	Mandatory Course Practical	CHEM 624	Inorganic Chemistry Practical	02
	Elective Course – I	CHEM 62511	Applied Chemistry + Practical	04
	Elective Course – II	CHEM 62512	Inorganic Materials + Practical	04
	RP	CHEM 626	Research Project	04
M.Sc. Sem - IV	Mandatory Course – I	CHEM 627	Properties of Inorganic Solids and Group Theory	04
	Mandatory Course – II	CHEM 628	Organometallics and Main Group Chemistry	04
	Mandatory Course – III	CHEM 629	Instrumental Methods in Inorganic Chemistry	04
	Elective Course – I	CHEM 63011	Intellectual Property Rights and Cheminformatics	04
	Elective Course – II	CHEM 63012	Advanced Topics in Inorganic Chemistry	04
	RP	CHEM 631	Research Project	06

PROGRAMME SPECIFIC OUTCOME (PSOs)

1. Gain knowledge of the advanced concepts in the branch of chemistry, scrutinize and accomplish a solution to problems encountered in the field of research and analysis.

2. Apply the basic knowledge of chemistry to perform various tasks assigned to them at the workplace in industry and academia to meet the global standards.

3. Deduce qualitative and quantitative information of chemical compounds using advanced spectroscopic methods which can further be analyzed using practical skills inculcated in them during the course.

4. Imbibe the attitude as well as aptitude of a scientific approach along with analytical reasoning with respect to the novel techniques actually implemented in the industry.

5. Use the subject knowledge, communication and ICT skills to become an effective team leader/team member in the interdisciplinary fields.

6. Understand, Manage and contribute to solve basic societal issues and environmental concerns ethically based on principles of scientific knowledge gained.

7. Exhibit professional work ethics and norms of scientific development

Semester – III

		SEMESTER: III			
PROGRAM: M.Sc.-II		**Mandatory course – I**			
Theory **Course Paper-I**		**Course Code: (CHEM621)** **Course Title: - Chemistry of Inorganic Solids**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. To educate about the different types of crystal structures in inorganic solids.
2. To develop a comprehensive understanding of imperfections in crystals and their relation to the properties and behaviour of inorganic materials.
3. To understand methods of synthesizing single crystals, solid state reactions and thin film preparation.
4. To appraise about polymorphism in liquid crystals and applications of liquid crystals.

Course Outcomes:

The learner will be able to

1. identify the diverse types of inorganic crystal structures and linked polyhedra.
2. understand the various types of crystal defects present in the inorganic compounds and study their effect on the mechanical and catalytic properties.
3. recognize different methods of single crystal growth, thin film preparation and understand the concepts in solid state reactions.
4. describe several forms of liquid crystals and their applications.

Semester – III
MANDATORY COURSE – I
COURSE TITLE: Chemistry of Inorganic Solids
COURSE CODE: CHEM 621 [CREDITS – 04]

(Numerical and word problems wherever possible)

UNIT	1.1	**Descriptive Crystal Chemistry (15L)**
I	1.1.1	**Simple Structures:** Structures of **AB** type of compounds (PbO and CuO), **AB_2** type (β-cristobalite and CaC_2) and **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 polymorphic forms, Oxide bronzes, ilmenite structure, **AB_2O_4** type, normal, inverse and random spinel structures.
	1.1.2	**Linked Polyhedra:**
	1.1.2.1	Corner sharing: tetrahedral structure (Silicates) and octahedral structure (ReO_3) and rotation of ReO_3 resulting in VF_3, RhF_3 and calcite type structures.
	1.1.2.2	Edge sharing: tetrahedral structures (SiS_2) and octahedral structures (BiI_3 and $AlCl_3$), pyrochlores, octahedral tunnel structures and lamellar structures.
II	1.2	**Imperfection in crystal and non-stoichiometry (15 L)**
	1.2.1	**Point defects:** Point defect in metal 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 centers.
	1.2.2	**Line defects:** Edge and Screw Dislocations. Mechanical Properties and Reactivity of Solids.
	1.2.3	**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.
III	1.3	**Methods of Preparations (15 L)**
	1.3.1	**Method of Synthesis:** Chemical Method, High Pressure Method, Arc Technique and Skull Method (with examples).
	1.3.2	**Different methods of Single Crystal Growth**:
	1.3.2.1	Single crystal growth from melt: Bridgman and Stockbargar, Czochralski and Vernuil methods.
	1.3.2.2	Crystal growth from liquid solution: Flux growth and temperature gradient methods.
	1.3.2.3	Crystal growth from vapour phase: Epitaxial growth methods.
	1.3.3	**Thin film preparation**: Physical and Chemical methods.

	1.3.4	**Solid solutions**: Formation of Substitutional**,** Interstitial and Complex Solid Solutions; Mechanistic Approach; Study of Solid solutions by X-ray Powder Diffraction and measurement.
IV	**1.4**	**Behaviour of Inorganic Solids (15 L)**
	1.4.1	**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.
	1.4.2	**Solid state reactions:** General principles and factors influencing reactions of solids, reactivity of solids.
	1.4.3	**Liquid Crystals:** Introduction and classification of thermotropic liquid crystals, Polymorphism in liquid crystals, properties and applications of liquid crystals.

REFERENCE BOOKS

	Unit I - Descriptive Crystal Chemistry
1	U. Muller, Inorganic structural chemistry, 2nd edition, Wiley 2007.
2	A. F. Wells, Structural inorganic chemistry, 5th edition, Clarendon press, Oxford 1984.
3	A. R. West, Solid state chemistry and its chemical applications, 2nd edition, Wiley 2014.
4	L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
5	H. V. Keer, Principles of Solid State, Wiley Eastern Ltd., 1993.
6	D.K.Chakraborty, Solid State Chemistry, New Age International publishers, 1996
7	C. N. R. Rao, University General Chemistry, An Introduction to Chemical Science, MacMillan India Limited, 1973
	Unit II - Imperfection in Crystal and Non-Stoichiometry
1	A. R. West, Solid state chemistry and its chemical applications, John Wiley & Sons, 1984.
2	H. V. Keer, Principles of the solid state, New Age International (P) Limited, Publisher, New Delhi, 2002.
3	L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
4	T.R.N Kutty and J.A.K Tareen, Fundamentals of Crystal Chemistry, Universities Press Ltd. (India), 2001
5.	V. Raghavan, Materials Science and Engineering, A First Course, Prentice-Hall of India Private Limited, New Delhi, 5th edition 2005
	Unit III - Methods of Preparations
1	A. R. West, Solid state chemistry and its chemical applications, John Wiley & Sons, 1984.
2	L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
3	C. N. R. Rao and J. Gopalakrishnan, New directions in solid state chemistry, Cambridge university press, 1986.

	Unit IV - Behaviour of Inorganic Solids
1	A. R. West, Solid state chemistry and its chemical applications, 2nd edition, Wiley 2014.
2	C. N. R. Rao and J. Gopalakrishnan, New directions in solid state chemistry, Cambridge university press, 1986.
	Common Books for Further Reading:
1	L. V. Azaroff, Introduction to Solids, Tata-McGraw Hill Book Co. New Delhi, 1977.
2	D. W. Bruce and Dermont O Hare, Inorganic Chemistry, 2nd Ed. John Wiley and Sons, New York, 1966.
3	J.M. Hollas, Symmetry in Molecules, Chapman and Hall Ltd., 1972.
4	N. B. Hanny Solid State Chemistry, Prentice Hall of India Pvt. Ltd. New Delhi, 1976
	……

	SEMESTER: III
PROGRAM: M.Sc.-II	**Mandatory course – II**
Theory **Course Paper-II**	**Course Code: (CHEM622)** **Course Title: - Bioinorganic and Coordination Chemistry**

Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA)** **(Marks- 50)**	**Semester End Examination** **(Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. To understand the role of elements in biological system.
2. To know the acid base concept, superacid and the calculations of acid base strength.
3. To comprehend the magnetic behavior of the complexes.
4. To know structure, bonding and stereochemistry of Coordination compounds.

Course Outcomes:

The learner will be able to

1. identify the role of elements in biological system.
2. classify the Lewis acids and bases based on frontier Molecular orbital and understand the concept of superacids and superbases.
3. differentiate the magnetic behavior and magnetic moment of transition metals and lanthanide complexes.
4. recognize the structure, bonding and stereochemistry of Coordination compounds.

Semester – III
MANDATORY COURSE – II
COURSE TITLE: Bioinorganic and Coordination Chemistry
COURSE CODE: CHEM 622 [CREDITS – 04]

(Numerical and word problems wherever possible)

UNIT	2.1	**Bioinorganic chemistry (15 L)**
I	**2.1.1**	Coordination geometry of the metal ion and functions.
	2.1.2	Zn in biological systems; carbonic anhydrase, proteolytic enzymes, e.g. carboxy peptidase, Zinc finger.
	2.1.3	Role of metal ion in biological electron transfer process; Iron Sulphur proteins.
	2.1.4	Less common ion in biology e.g. Mn (arginase; structure and reactivity, Ni (Urease; structure and reactivity)
	2.1.5	Biomineralization.
II	**2.2**	**Reactivity of chemical species (15L)**
	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	Oxoanions and Oxocations, Pauling rules to determine the strength of oxoacids; classification and Structural anomalies.
	2.2.3	Pourbaix Diagrams of iron in natural water
	2.2.4	Amphoteric behavior, Periodic trends in amphoteric properties of p-block and d-block elements
	2.2.5	Measures of hardness and softness of Acids and Bases, DragoWayland equation,
	2.2.6	Applications of acid-base Chemistry: Super acids and Super bases, heterogeneous acid-base reactions.
III	**2.3**	**Magnetic properties of complexes (15 L)**
	2.3.1	Origin of magnetism, classification of substances according to the magnetic properties: diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism and ferrimagnetism. Magnetic moment from magnetic susceptibility, Curie equation and Curie temperature, Curie-Weiss law, Neel temperature.
	2.3.2	Thermal energy and magnetic property, magnetic moment for different multiplet width, temperature independent paramagnetism, magnetic susceptibility and spin only formula, spin and orbital contribution to magnetic moment, spin cross-over.
	2.3.3	Magnetic properties of transition metal and lanthanide complexes, diamagnetic correction using Pascal constants and calculation of magnetic moment. Methods of determination of magnetic susceptibility.

IV	**2.4**	**Structure, Bonding and stereochemistry of Coordination compounds (15 L)**
	2.4.1	**Structure and bonding**
	2.4.1.1	Molecular orbital Theory for complexes with coordination number 4 & 5 for the central ion (sigma as well as pi bonding)
	2.4.1.2	Angular Overlap Model for octahedral and tetrahedral complexes for sigma and pi bonds.
	2.4.2	**Stereochemistry of coordination compounds**
	2.4.2.1	Chirality and fluxionality of coordination compounds with higher coordination numbers.
	2.4.2.2	Geometries of coordination compounds from Coordination number 6 to 9.

REFERENCE BOOKS

	Unit I - Bioinorganic Chemistry
1.	R. R. Crichton, Biological Inorganic Chemistry, A new introduction to molecular structure and function, 2nd Edition, Elsevier, 2012.
2.	I. Bertini, H. B. Gray, S. J. Lippard and J. S. Valentine, Bioinorganic chemistry, First South Indian Ed., Viva Books, New Delhi, 1998.
3	G. N. Mukherjee and A. Das, Elements of Bioinorganic chemistry, Dhuri and Sons, Calcutta, 1988.
4	J. A. Cowan, Inorganic biochemistry-An introduction, VCH Publication, 1993.
5	R. W. Hay, Bioinorganic chemistry, Ellis Harwood, England, 1984.
6	S. J. Lippard and J. M. Berg, Principles of bioinorganic chemistry, University Science Publications, Mill Valley, Caligronic, 1994.
7	Ivano Bertini, Harry Gray, Stephen Lippard, Joan Valentine, Bioinorganic Chemistry, Viva Books Private Limited, 1998
8.	Ajay Kumar, Organometallics and Bioinorganic Chemistry, Aaryush Education, 4th Edn, 2021.
	Unit II - Reactivity of Chemical Species
1	Gary Wulfsberg, Inorganic Chemistry; Viva Books PA Ltd., New Delhi; 2002
2	R. L. Madan and G. D. Tuli, Inorganic Chemistry,5th Ed., S. Chand, 2012.
3	H. Sosler, Chemistry in Non-aqueous solvents, New York Reinhold Publication, 1965.
4	P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5thEd., Oxford University Press, 2010.
5	B. Douglas, D. McDaniel and J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd Edition., John Wiley & Sons, Inc., 2001.
6	G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004.
7	B. W. Pfennig, Principles of Inorganic Chemistry, Wiley, 2015.
8	J. Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4th Ed., Harper Collins, 1993.
9	Ajay Kumar, Organometallics and Bioinorganic Chemistry, Aaryush Education, 4th Edn, 2021.

	Unit III - Magnetic properties of complexes
1	R. A. Dutta & A. Syamal, Elements of magnetochemistry, Affiliated East-West Press Pvt. Ltd. 2nd edition, 1993.
2	D. Banerjea, Coordination chemistry, 3rd edition, Asian Books Pvt. Ltd. 2009.
3	R. Gopalan and V. Ramalingam, Concise coordination chemistry, Vikas Publishing House Pvt. Ltd. 2007.
4	R. L. Carlin, Magnetochemistry, Springer Verlag, New York, 1986.
5.	Ajay Kumar, Organometallics and Bioinorganic Chemistry, Aaryush Education, 4th Edition, 2021.
	Unit IV - Structure, Bonding, and Stereochemistry of Coordination Compounds
1	C. J. Ballhausen and H. B. Gray, Molecular orbital Theory, McGraw-Hill, New York, 1965.
2	C, M, Day and Joel Selbin, Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 1985.
3	L. E. Orgel, An Introduction to Ligand Field Theory, Methuen & Co. Ltd., London, 1960.
4	B. Douglas, D. H. McDaniel and J. J. Alexander, Concepts and Models of Inorganic Chemistry, 2nd edition, John Wiley & sons, 1983.
5	F. A. Cotton and R. A. Walton, Multiple Bonds between Meal Atoms, 2nd edition, Claranden Press, Oxford, 1993.
6	D. Banerjea, Coordination chemistry, 3rd edition, Asian Books Pvt. Ltd. 2009.
7	J. R. Gispert, Coordination Chemistry, Wiley-VCH 2008.
8	R. Gopalan and V. Ramalingam, Concise coordination chemistry, Vikas Publishing House Pvt. Ltd. 2007.
9	G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004.
10	R. D. Wijesekera, Coordination Compounds Bonding, Structure and Nomenclature, Narosa Publication House, 2008.
11.	Ajay Kumar, Organometallics and Bioinorganic Chemistry, Aaryush Education, 4th Edition, 2021.
	Common Books for Further Reading:
1	James E. Huheey, Inorganic Chemistry, 3rd edition, Harper & Row, Publishers, Asia, Pte. Ltd., 1983.
2	J. D. Lee, Concise Inorganic Chemistry, 5th edition. Blackwell Science Ltd., 2002
3	B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone, 2014.
4	Asim K. Das, Fundamental Concepts of Inorganic Chemistry, Vol. I, II and III, CBS Publication, 2000.
5	P. L. Soni, Textbook of Inorganic Chemistry. Sultan Chand & Sons Publisher, 15th Edition 1984.
6	A. Earnshaw, Introduction to magnetochemistry, Academic Press, New Delhi, 1968
	…… …..

		SEMESTER: III			
PROGRAM: M.Sc.-II		**Mandatory course – III**			
Theory **Course Paper-III**		**Course Code: (CHEM623)** **Course Title: - Spectral Methods in Inorganic Chemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. To illustrate the principle and instrumentation of the X-ray Diffraction method for elucidation of crystal structure.
2. To study the significance of electron and neutron diffraction in identification of inorganic materials.
3. To acquaint the learners with the concept of inorganic spectroscopy and acquire the skills to solve problems of ESR spectroscopy.
4. To conceptualize the theoretical knowledge and develop the skills to solve the problems on Mossbauer spectroscopy.

Course Outcomes:

The learner will be able to

1. calculate miller indices, interplanar spacing, crystallite size etc. using X-ray Diffraction method.
2. elaborate on the instrumentation and application of electron and neutron diffraction techniques.
3. apply hyperfine splitting rule to deduce the number of ESR lines present in the inorganic compounds.
4. explain the principle and instrumentation of Mossbauer spectroscopy and its application in characterization of iron and tin compounds.

Semester – III

MANDATORY COURSE – III

COURSE TITLE: Spectral Methods in Inorganic Chemistry

COURSE CODE: CHEM 623 [CREDITS – 04]

(Numerical and word problems wherever possible)

UNIT	3.1	**Diffraction Methods – I (15L)**
I	**3.1.1**	Introduction to X-ray diffraction, generation of X-rays (K-shell knockout), Bragg condition, Miller indices, relationship between Miller indices and inter planar spacing.
	3.1.2	Methods of diffraction: Laue method, Debye-Scherrer method of X-ray structural analysis of crystals.
	3.1.3	Introduction to JCPDS and ICDD, index reflections, identification of unit-cells from systematic absences in diffraction pattern, use of powder X-ray diffraction, description of the procedure for an X-ray structure analysis, density and crystallite size determination.
II	**3.2**	**Diffraction Methods – II (15 L)**
	3.2.1	**Electron Diffraction**: Scattering of electrons, Scattering Intensity versus Scattering Angle, Weirl Measurement Technique, Elucidation of Structures of Simple gas phase molecules.
	3.2.2	**Neutron Diffraction**: Scattering of Neutrons: Scattering of neutrons by Solids and Liquids, Magnetic Scattering, Measurement Technique.
III	**3.3**	**Electron Spin Resonance Spectroscopy (15 L)**
	3.3.1	Electron behaviour, interaction between electron spin and magnetic field.
	3.3.2	Instrumentation: Source, Sample cavity. Magnet and Modulation coils, Microwave Bridge, sensitivity.
	3.3.3	Relaxation processes and Line width in ESR transitions:
	3.3.3.1	ESR relaxation and chemical bonding.
	3.3.3.2	Interaction between nuclear spin and electron spin (hyperfine coupling)
	3.3.3.3	Spin polarization for atoms and transition metal ions,
	3.3.3.4	Spin-orbit coupling and significance of g-tensors,
	3.3.3.5	Application to transition metal complexes (having one unpaired electron)
IV	**3.4**	**Mossbauer Spectroscopy (15 L)**
	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 proteins; Tin compounds - tin halides and tin oxides, organotin compounds.

REFERENCE BOOKS

	Unit I - Diffraction Methods-I – XRD
1	Fmiza Hammer, Inorganic spectroscopy and related topics, Sarup & Sons 2008.
2	G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis ELBS Publication. Fifth edition, 1996.
3	W.H. Zachariasen. Theory of X-Ray Diffraction in Crystals. John Wiley. New York. 1946.
4	B.D. Cullity, Elements of X-Ray Diffraction Procedures. John Wiley and Sons. New York, 1954.
5	Gurdeep R. Chatwal & Sham K. Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing House, 1st edition, 2005.
6	G. E. Bacon, X-ray and Neutron Diffraction, Pergamon Press, Oxford 1966.
	UNIT II - Diffraction Methods –II – Electron, Neutron
1	R. S. Drago, Physical methods for Chemists, 2nd edition, Saunders college publishing 1992.
2	R. S. Drago, Physical methods in Inorganic chemistry, Affiliated East-West Press Pvt. Ltd; New Delhi. 2012.
3	G. E. Bacon, X-ray and Neutron Diffraction, Pergamon Press, Oxford 1966.
4	G. E. Bacon, Neutron Scattering in Chemistry, Butterworths, London, 1977
	Unit III - Electron Spin Resonance Spectroscopy
1	D. N. Sathyanarayana, Introduction to magnetic resonance spectroscopy ESR, NMR, NQR, I. K. International Publishing house Pvt. Ltd., 2009.
2	K. Burger, Coordination chemistry: Experimental methods, London Butterworths, 1973.
3	Graham Smith; David Keeble. Introduction to Modern EPR Spectroscopy CRC Press, 2013.
4	M. Drescher an G. Jeschke, (Eds), EPR Spectroscopy: Applications in Chemistry and Biology, Springer-Verlag Berlin, Heidelberg 2012
5	Gurdeep R. Chatwal & Sham K. Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing House, 1st edition, 2005.
	UNIT IV - Mossbauer Spectroscopy
1	R. V. Parish, NMR, NQR, EPR and Mossbauer spectroscopy in Inorganic Chemistry, Ellis Horwood. 1990.
2	D. N. Sathyanarayana, Introduction to magnetic resonance spectroscopy ESR, NMR, NQR, I. K. International Publishing House Pvt. Ltd. 2009.
3	May and Leopold, An Introduction to Mossbauer Spectroscopy, Plenum, New York, 1971.
4	Colin N. Banwell and Elaine M. McCash, Fundamentals of Molecular Spectroscopy, Tata McGraw-Hill Publishing company Limited, New Delhi, 4th edition, 2003.
5	Gurdeep R. Chatwal & Sham K. Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing House, 1st edition, 2005.
6	R. A. Dutta & A. Syamal, Elements of magnetochemistry, Affiliated East-West Press Pvt. Ltd. 2nd edition, 1993.

	Common Books for Further Reading:
1	K. Veera Reddy, Symmetry and Spectroscopy of molecules, New Age International (P) Limited, Publisher, 2005
2	R. A. Scott and C. M. Lukehart, Applications of physical methods to inorganic and bioinorganic chemistry, John Wiley & Sons Ltd. 2007.
3	D. Harvey, Modern Analytical Chemistry, The McGraw-Hill Pub,1stEdition, 2000.
4	H.H. Willard, L.L. Merrit, J.A. Dean and F.A. Settle, Instrumental Methods of Analysis, C.B.S. Publishers and Distributors, New Delhi, 1986.
5	G.W. Ewing, Instrumental Methods, Of Analysis, 4th Ed. McGraw Hill Ltd., 1970.
6	N. N. Greenwood and T. C. Gibee, Mossabauer Spectroscopy, Chapman and Hall, 1971
7	V. I. Goldanski and R. H. Herber, Chemical Applications of Mossabauer Spectroscopy, Academic Press, 1968.
	……

		SEMESTER: III			
PROGRAM: M.Sc.-II		**Mandatory course – Practical**			
Course - Practical		**Course Code: (CHEM624)** **Course Title: - Inorganic Chemistry Practical**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 25)**	**Semester End Examination (Marks- 25)**
NA	**04**	**NA**	**02**	**50%**	**50%**

Learning Objectives:

1. To apply basic concepts of separation and estimation of metal ions from alloys.
2. To study the principle of solvent extraction in separation of various metals.
3. To familiarize with the principle and handling of various instruments like potentiometer, colorimeter, spectrophotometer etc.
4. To develop skills to synthesize and characterize the inorganic compounds by various spectral methods.

Course Outcomes:

The learner will be able to

1. apply theoretical concepts of separation of metals in alloys and its estimation by various quantitative techniques.
2. perform solvent extraction techniques for separation and estimation of metals.
3. make use of the concepts of coordination chemistry through different instrumental experiments.
4. synthesize the inorganic compounds and characterize by interpretation using spectroscopic techniques and thermal methods.

Semester – III
MANDATORY COURSE – Practical
COURSE TITLE: Inorganic Chemistry Practical
COURSE CODE: CHEM 624 [CREDITS – 02]

	Analysis of Alloys
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.
	Solvent Extraction
1	Separation of Co and Ni using n-butyl alcohol and estimation of Co
2	Separation of Cu and Fe using n-butyl acetate and estimation of Cu
	Coordination Chemistry
1	Determination of Stability constant of $[Zn(NH_3)_4]^{2+}$ by potentiometry
2	Determination of CFSE values of hexa-aqua complexes of Ti^{3+} and Cr^{3+}
3	Determination of Racah parameter for complex $[Ni(H_2O)_6]^{2+}$.
	Synthesis and interpretation of Inorganic compounds.
1	Synthesis of $[Mn(acac)_3]$ and its interpretation by IR and conductivity measurement. (Spectra will be provided)
2	Synthesis of CuO nanoparticles and its interpretation by UV-Visible and XRD techniques. (Spectra will be provided)
3	Synthesis of tris (acetyl acetonato) aluminium (III) complex and its interpretation by NMR. (Spectra will be provided)
4	Synthesis of calcium oxalate and its interpretation by TGA/DTA. (Spectra will be provided)

REFERENCE BOOKS

1	A. I. Vogel, Quantitative Inorganic Analysis, 5th Edn Longman Scientific and Technical, 1989.
2	J. D. Woolins, Inorganic Experiments. Hohn Wiley and Sons, 2010
3	Palmer, Inorganic Preparations, CUP, 1954
4	G. Raj, Advanced Practical Inorganic Chemistry. Goel Publication, 2010
5	J. E. House, Inorganic chemistry, Academic press, 2nd edition, 2013.
6	G. N. Mukherjee, Advanced Experiments in Inorganic Chemistry., U. N. Dhur & Sons Pvt. Ltd. 2010.
7	G. Christian, Analytical Chemistry, John Wiley, New York 4th edition 1986.
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		SEMESTER: III			
PROGRAM: M.Sc.-II		**Elective Course – I**			
Theory **Elective Course I**		**Course Code: (CHEM62511)** **Course Title: - Applied Chemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 25)**	**Semester End Examination (Marks- 25)**
02	**NA**	**--**	**02**	**50%**	**50%**

Learning Objectives:

1. To emphasize the necessity of safety in chemistry laboratories
2. To describe the different methods of metallurgical extraction of transition metals.

Course Outcomes:

The learner will be able to

1. understand the importance of safety in chemical laboratories, including handling hazardous materials, toxic waste, explosives, fire extinguishers, recycling and waste management.
2. outline the steps involved in extraction of metals.

Semester – III

ELECTIVE COURSE – I
COURSE TITLE: Applied Chemistry
COURSE CODE: CHEM 62511 [CREDITS – 02]

UNIT	1.1	**Safety in Chemistry Laboratories (15 L)**
I	**1.1.1**	Handling of Hazardous Materials
	1.1.2	Toxic Materials (Various types of toxins and their effects on humans)
	1.1.3	Explosives and Inflammable Materials
	1.1.4	Types of fire extinguishers (chemical reaction)
	1.1.5	Bioactive materials.
	1.1.6	Safety measures in recycling & recovery of metals with reference to silver, lead, cobalt, nickel and chromium
	1.1.7	Laboratory Wastes Disposal Management in Chemical Laboratories.
II	**1.2**	**Metallurgy (15 L)**
	1.2.1	Occurrence, extraction and metallurgy of Zirconium, Hafnium, Niobium, Tantalum Platinum and Palladium metals.
	1.2.2	Physical and chemical properties and applications of these metals
	1.2.3	Compounds of these metals, alloys and their uses.

REFERENCE BOOKS

	UNIT I -Safety in Chemistry Laboratories
1	Najat Rashid and Ramnik Sood, Manual of Laboratory Safety, Jaypee Brothers Medical Publishers (P) Ltd. 2013.
2.	K. Everett and E. W. Jenkins, A Safety Handbook for Science Teachers, The Pitman Press Bath, Great Britain, 3rd edition, 1980.
3	Hazardous Wastes (Management, Handling and Transboundary Movements) Rules, 2008, National Safety Council, Navi Mumbai.
	UNIT II -Metallurgy
1	R. Gopalan, Universities Press India Pvt. Ltd. Inorganic Chemistry for Undergraduates, 2009.
2	P. L. Soni, Textbook of Inorganic Chemistry. Sultan Chand & Sons Publisher, 15th Edition 1984.
3	Gurdeep Raj Chhatwal, Harish Mehra, Advanced Inorganic Chemistry, Goel Pub, 1976.
4	Satya Prakash, Advanced Chemistry of Rare Elements, 3rd Edn, S Chand, 1967.
5	J. D. Lee, 5th Edn., Concise Inorganic Chemistry, ELBS, 2010.
6	Jain & Jain, Engineering Chemistry (Chemistry of Engineering Materials), Dhanpat Rai & Sons, 9th edition, 1991.
	…….

		SEMESTER: III			
PROGRAM: M.Sc.-II		**Elective Course – II**			
Theory **Elective Course II**		**Course Code: (CHEM62512)** **Course Title: - Inorganic materials**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA)** **(Marks- 25)**	**Semester End Examination** **(Marks- 25)**
02	**NA**	**--**	**02**	**50%**	**50%**

Learning Objectives:

1. To acquire the skills to appraise various manufacturing processes of inorganic materials.
2. To explain the properties, classification and uses of industrially important compounds like glass, cement, paints, pigments etc.

Course Outcomes:

The learner will be able to

1. outline the various classes, properties and applications of industrially important inorganic compounds like cement, glass, paints, pigments etc.
2. summarize the manufacturing processes of inorganic compounds.

Semester – III
ELECTIVE COURSE – II
COURSE TITLE: Inorganic Materials
COURSE CODE: CHEM 62512 [CREDITS – 02]

UNIT	1.1	**Manufacture and Applications of Inorganic Compounds – I (15L)**
I	**1.1.1**	Lime, Chlorine and Caustic soda.
	1.1.2	Ceramics and refractory materials
	1.1.3	Cement
	1.1.4	Inorganic explosives (mercury fulminate, Lead azide)
II	**1.2**	**Manufacture and Applications of Inorganic Compounds – II (15 L)**
	1.2.1	Fertilizers and micronutrients.
	1.2.2	Glass
	1.2.3	Paints and Pigments

REFERENCE BOOKS

	Unit I & II - Manufacture and Applications of Inorganic Compounds
1	K. H. Buchel, H. H. Moretto, P Woditsch, Industrial Inorganic Chemistry, Wiley, 2003.
2	George Austin, Shreve's Chemical Process Industries 5th Edn, Mc Graw Hill, 1984.
3	Jain and Jain, Engineering Chemistry, Dhanpat Rai Publishing Company.
4	B. K. Sharma, Industrial Chemistry, Goel Publishing House, Meerut UP, 2011.
5	Jain & Jain, Engineering Chemistry (Chemistry of Engineering Materials), Dhanpat Rai & Sons, 9th edition, 1991.
6	F. M. Lea, The chemistry of cement and concrete, Edward Arnald, London, 3rd edition, 1970
	…….

	SEMESTER: III				
PROGRAM: M.Sc.-II	**Elective Course I Practical / Elective Course II Practical**				
Elective Course I and II Practical	**Course Code: CHEM62511 /CHEM 62512** **Course Title: - Inorganic Practical**				
Teaching Scheme					**Evaluation Scheme**
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 25)**	**Semester End Examination (Marks- 25)**
NA	**04**	**--**	**02**	**50%**	**50%**

Learning Objectives:

1. To apply basic concepts of separation and estimation of metal ions from ores.
2. To gain knowledge and hands on experience in synthesis of coordination compounds.
3. To understand and employ the concept of samples analysis by quantitative methods.

Course Outcomes:

The learner will be able to

1. apply theoretical concepts of separation of metals in ores and its estimation by various quantitative techniques.
2. synthesize the coordination complex and utilize the knowledge in industry.
3. perform quantitative estimation of metal ions and understand the use of analytical instrument like Flame photometer.

Semester – III
ELECTIVE COURSE – Practical
COURSE TITLE: Elective Course I Practical/ Elective Course II Practical
COURSE CODE: CHEM 62511/ 62512 [CREDITS – 02]

	Analysis of Ores
1	Analysis of galena ore: (i) Pb content as $PbCrO_4$ by gravimetric method using 5% potassium chromate, (ii) Fe content by colorimetric method using 1, 10 - phenanthroline.
2	Analysis of Zinc blend ore: (i) Zn content by complexometric method, (ii) Fe content by colorimetric method (Thiocyanide method).
	Inorganic Preparations
1	Preparation of Co (α-nitroso-β-naphthol)$_3$
2	Preparation of Ni (salicylaldoxime)$_2$
3	Preparation of Trans-bis (glycinato) Cu (II)
	Analysis of the following Samples
1	Calcium tablet for its calcium content by complexometric titration.
2	Bleaching powder for its available chlorine content by iodometric method.
3	Nycil powder for its Zn content complexometrically.
4	Electral powder for Na content flame photometry.
5	Fasting salt for chloride content conductometrically.
6	Sea water for percentage salinity by Volhard's method.
7	Fertilizer for potassium content by flame photometry.

REFERENCE BOOKS

1	A. I. Vogel, Quantitative Inorganic Analysis, 5th Edn Longman Scientific and Technical, 1989.
2	J. D. Woolins, Inorganic Experiments. Hohn Wiley and Sons, 2010
3	Palmer, Inorganic Preparations, CUP, 1954
4	G. Raj, Advanced Practical Inorganic Chemistry. Goel Publication, 2010
5	J. E. House, Inorganic chemistry, Academic press, 2nd edition, 2013.
6	G. N. Mukherjee, Advanced Experiments in Inorganic Chemistry., U. N. Dhur & Sons Pvt. Ltd. 2010.

		SEMESTER: III			
PROGRAM: M.Sc.-II		**Research Project**			
		Course Code: (CHEM626) **Course Title: - Research Project**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA)** **(Marks- 50)**	**Semester End Examination** **(Marks- 50)**
NA	**08**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. To inculcate the research aptitude and scientific approach in learner.
2. To identify a research problem
3. To understand the importance of Literature survey
4. To develop skills in the application of theory to experimental work situations.
5. To employ theoretical knowledge to solve socially relevant challenges.

Course Outcomes:

The learner will be able to

1. develop scientific temperament and understand the basic principles relevant to the research.
2. select the research topics of interest and create a systematic research plan for a chosen research project.
3. analyze and evaluate scholarly literature successfully from journals and digital resources.
4. Learn several research methodologies efficiently.
5. design and execute original research projects for benefit of society.

Course Code: (CHEM626)

Course Title: - Research Project

Guidelines for the conducting the research project.

- Each student will perform project separately.
- Students should devote enough time to their project work (8 hours each week).
- Select a topic that is relevant to your interests and social relevance considering the constraints of available resources and time.
- Consult with faculty members or mentors to select a relevant research topic that has the potential to contribute to the discipline of chemistry.
- Literature survey for the research project is suggested to be from Journals indexed in globally recognized databases including recently published research papers.
- Participation in national and international conferences and other project competitions is encouraged.
- Project report must be written systematically and presented in bound form.
- Continuous evaluation of the research project will be done by the internal examiner or mentor. Student must do presentation of the research work in external exam.

Semester – IV

		SEMESTER: IV			
PROGRAM: M.Sc.-II		**Mandatory course – I**			
Theory **Course Paper-I**		**Course Code: (CHEM627)** **Course Title: - Properties of Inorganic Solids and Group Theory**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. The familiarize the students with the electrical, magnetic, thermal and optical properties of inorganic solids,
2. To gain theoretical knowledge of character tables and group theory, splitting of levels and terms in chemical environment and construction of energy level diagrams.

Course Outcomes:

The learner will be able to

1. study the conduction in solid electrolytes and other electrical properties such as Thomson, Seebeck, Hall effects etc.
2. explain the magnetic properties in metals, alloys, metal oxides, spinels, garnets etc and its applications.
3. understand the thermal properties in metals, ceramics & polymers and classify the optical properties in luminescence and phosphor materials.
4. review the applications of group theory in determination of electronic structures.

Semester – IV
MANDATORY COURSE – I
COURSE TITLE: Spectral Properties of Inorganic Solids and Group Theory
COURSE CODE: CHEM 627 [CREDITS – 04]

UNIT	1.1	**Electrical Properties (15 L)**
I	1.1.1	**Electrical properties of Solids:** Conductivity: Solid Electrolytes; Fast Ion Conductors; Mechanism of Conductivity; Hopping Conduction.
	1.1.2	**Other Electrical Properties:** Thomson and Seebeck Effects; Thermocouples and their Applications; Hall Effect; Dielectric, Ferroelectric, Piezoelectric and Pyrroelectric Materials and their Inter-relationships and Applications
II	1.2	**Magnetic Properties of solids (15 L)**
	1.2.1	Behaviour of substances in magnetic field, mechanism of ferromagnetic and antiferromagnetic ordering, superexchange, Hysteresis, Hard and soft magnets.
	1.2.2	Structures and magnetic properties of Metals and Alloys; Transition metal Oxides; Spinels; garnets; limenites; Perovskite and Magneto plumbites,
	1.2.3	Application in transformer cores, information storage, magnetic bubble memory devices and as permanent magnets
III	1.3	**Thermal and Optical Properties (15 L)**
	1.3.1	**Thermal Properties:** Introduction, Heat capacity and its temperature dependence, Thermal expansion of metals, ceramics and polymers and thermal stresses.
	1.3.2	**Optical Properties:** Colour centers and Birefringence, Luminescent and Phosphor materials, Coordinate model, Phosphor model, Anti stokes Phosphor, Ruby laser, neodymium laser.
IV	1.4	**Applications of group theory (15 L)**
	1.4.1	Recapitulation of Points groups and Character tables.
	1.4.2	Application of Group theory with respect to Molecular orbital Theory: Sigma and pi- molecular orbitals for AB_4 (tetrahedral) and AB_6 (octahedral) molecules;
	1.4.3	Application of Group theory in Infrared and Raman spectroscopy: 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.
	1.4.4	Application of Group theory in Ligand Field Theory: Electronic structures of free atoms and ions; Splitting of levels and terms in a chemical environment; Construction of energy level diagrams; Direct product; Correlation diagrams for d^2 ions in octahedral ligand field; Methods of Ascending and Descending Symmetry; Hole formalism.

REFERENCE BOOKS

	Unit I - Electrical Properties
1	A. R. West, Solid state chemistry and its chemical applications, John Wiley & Sons, 1984.
2	L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
3	R. C. Ropp, B.V. Warren, Solid State Chemistry, Elsevier Science 2003.
4	H. V. Keer, Principles of the Solid State, New Age International (P) Limited, 2002.
5	T. P. Orlando and K. A. Delin, Foundation of applied superconductivity, Addision - Wesley Inc., New York, 1991.
	UNIT II - Magnetic Properties of solids
1	A. R. West, Solid state chemistry and its chemical applications, John Wiley & Sons, 1984.
2	L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
3	H. V. Keer, Principles of the Solid State, New Age International (P) Limited, Publisher, 2002.
4	V. Raghavan, Materials Science and Engineering, A First Course, Prentice-Hall of India Private Limited, New Delhi, 5th edition, 2005.
	Unit III - Thermal and Optical Properties
1	A. R. West, Solid state chemistry and its chemical applications, John Wiley & Sons, 1984.
2	W. D. Callister, Jr., (adapted by R. Balasubramaniam), Callister's Materials science and engineering, Wiley-India 2010.
3	Paul Gabbott Principles and Applications of Thermal Analysis Wiley-Blackwell ; edition 2007.
4	H. Kambe and P.D.Garn. Thermal Analysis, Kondansha Ltd. Toyo,1974.
5	R. S. Drago, Physical Methods in Inorganic Chemistry, John Wiley Pub.,1975
	UNIT IV - Applications of Group Theory
1	Gary Wulfsberg, Inorganic chemistry, Viva Books Pvt. Ltd., 2002.
2	J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, Inorganic chemistry- Principles of structure and reactivity, 4th edition, Pearson, 2006.
3	D. F. Shriver and P. W. Atkins, Inorganic chemistry, 3rd edition, Oxford University Press 1999.
4	R. L. Carter, Molecular symmetry and group theory, John Wiley & Sons, New York, 1998.
5	S. F. A. Kettle, Symmetry and structure-Readable Group Theory for Chemists, 3rd Ed., John Wiley & Sons, Inc., 2000.
6	K. V. Reddy, Symmetry and Spectroscopy of molecules, New Age International (P) Ltd. 2nd Edition, 2009.

7	A. S. Kunju and G. Krishnan, Group theory and its application in chemistry, PHL Learning Pvt. Ltd., 2012.
8	F. A. Cotton, Chemical applications of group theory, Wiley Eastern Ltd., 1989.
	Common Books for Further Reading:
1	C.N.R. Rao and J. Gopalkrishnan New Directions in Solid State Chemistry, 2nd Ed., Cambridge University Press. 1997.
2	L. V. Azaroff, Introduction to Solids, Tata-McGraw Hill Book Co New Delhi, 1977.
3	J.M. Hollas, Symmetry in Molecules, Chapman and Hall Ltd., 1972.
4	Ulrich Muller, Inorganic structural Chemistry,2nd edition, Wiley and Sons, Chichester, 1993
5	G.W. Ewing, Instrumental Methods, Of Analysis, 4th Ed. McGraw Hill Ltd., 1970.
6	N. D. Hanny, Solid state chemistry, Prentice Hall, Englewood Cliffs, New Jersy, 1967.
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		SEMESTER: IV			
PROGRAM: M.Sc.-II		**Mandatory course – II**			
Theory **Course Paper-I**		**Course Code: (CHEM628)** **Course Title: - Organometallics and Main Group Chemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA)** **(Marks- 50)**	**Semester End Examination** **(Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. To educate learner on bonding, electron count, correlation with structures, isolobal relation in metal clusters.
2. To instruct the learner on the distinctions between homogeneous and heterogenous catalysis, as well as the mechanism in different organic reactions.
3. To have the learner evaluate the bonding in boranes, carboranes, cluster compounds, and electron precise compounds, specifically in relation to inorganic cage and cluster compounds.
4. To appraise the learner about different compounds silicates, polysilicates and aluminosilicates, phosphazenes, phosphazene polymers polyanionic and polycationic compounds.

Course Outcomes:

The learner will be able to

1. elaborate on the bonding, correlation of Total Electron Count with structures of metal clusters and isolobal analogy.
2. differentiate between homogenous and heterogenous catalysis and understand the mechanism in various organic reactions
3. explain the various aspects of inorganic cage and cluster compounds.
4. summarize the key aspects of inorganic ring and chain compounds

Semester – IV
MANDATORY COURSE – II
COURSE TITLE: Organometallics and Main Group Chemistry
COURSE CODE: CHEM 628 [CREDITS – 04]

UNIT	2.1	**Organometallics and main group Chemistry (15L)**
I	**2.1.1**	**Metal-Metal Bonding and Metal Clusters**
	2.1.1.1	Dinuclear, trinuclear and tetranuclear clusters. Quadruple bonding in metal cluster,
	2.1.1.2	Multinuclear Carbonyl Clusters: Low Nuclearity Carbonyl Clusters (LNCC) and High Nuclearity Carbony Clusters (HNCC)
	2.1.2	**Electron Count and Structures of Clusters:** Total Electron Count (TEC), Polyhedral electron count (PEC), Wade's Rule, Correlation of PEC with structure
	2.1.3	Isolobal analogy and its applications
II	**2.2**	**Applications of Organometallic Compounds (15 L)**
	2.2.1	Catalysis - Homogenous and Heterogenous Catalysis: Comparison, Basic reaction steps.
	2.2.2	Organometallics as Catalysts in Organic Reactions: (i) Hydrosilation, (ii) Hydroboration. (iii) Water gas Shifts Reaction (iv) Wacker process (Oxidation of alkenes) (v) Monsanto Acetic Acid Process (Alcohol carbonylation)
	2.2.3	Coupling reactions: (i) Heck's reaction (ii) Suzuki reaction
III	**2.3**	**Inorganic Cluster and Cage Compounds (15 L)**
	2.3.1	Introduction, Bonding in boranes, Heteroboranes, Carboranes, Metalloboranes.
	2.3.2	Cluster compounds
	2.3.3	electron precise compounds and their relation to clusters
IV	**2.4**	**Inorganic ring and chain compounds (15 L)**
	2.4.1	Silicates, polysilicates and aluminosilicates
	2.4.2	Phosphazenes, phosphazene polymers
	2.4.3	Polyanionic and polycationic compounds

REFERENCE BOOKS

	Unit I- Organometallic Chemistry
1	F. A. Cotton, G. Wilkinson, C. Murillo and M. Bochmann, Advanced Inorganic Chemistry, John Wiley, New York, 6th edition, 1999.
2	F.A. Cotton and R.A.Walton, Multiple Bonds between Metal Atoms, claranden Press, Oxford, 2nd edition, 1993
3	Gary Miessler and Donald Tarr, Inorganic Chemistry, Pearson Education, 3rd Ed. 2004.
4	Shriver and Atkin's, Inorganic Chemistry, 5th Edition, 2010.
5	Puri, Sharma and Kalia, Principles of Inorganic Chemistry, Milestone Publishers, 31st Edition, 2010.
6	Gurudeep Raj, Advanced Inorganic Chemistry, Vol- II, Krishna Prakashan Media Pvt. Ltd, 2014
7	R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, Wiley-Interscience, New York, 2014.
8	Ajay Kumar, Organometallic and Bioinorganic Chemistry AAyush Education, 2014
9	B. D. Gupta, E.J. Elias, Basic Organometallic Chemistry, Universities Press, 2009
	UNIT II- Applications of Organometallic Compounds
1	R. C. Mehrotra and A. Singh, Organometallic Chemistry – A Unified Approach, 2nd edition, New Age International Pvt. Ltd., 2000.
2	R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, Wiley-Interscience, New York, 2014.
3	Gary O. Spessard and Gary L. Miessler, Organometallic Chemistry, Oxford University Press 3rdedn., 2015.
4	G. W. Parshall and S. D. Ittel, Homogeneous Catalysis, John Wiley & Sons. Inc. New York, 2nd edition, 1992.
5	F. Basolo and R. G. Pearson, Mechanism of Inorganic Reactions, Wiley, New York, 1967.
6	Christoph Elschenbroich, Organometallics, Wiley-VCH, 3rd edition, 2005.
7	Jahn Hartwig, Organotransition chemistry-From bonding to catalysis, University science books, California 2010.
8	William L. Jolly, Morden Inorganic Chemistry, McGraw Hill, Inc. 2nd edition 1991
	Unit III – Inorganic cluster and cage compounds
1	H.G. Heal, The Inorganic Heterocyclic Chemistry of Sulphur, Nitrogen and Phosphorous, Academic Press, NewYork,1980
2	N.H. Ring, Inorganic Polymers, Academic Press, New York, 1978.
3	F.A. Cotton and R.A.Walton, Multiple Bonds between Metal Atoms, 2nd edition, Claranden Press, Oxford,1993.
4	William L. Jolly, Morden Inorganic Chemistry, McGraw Hill, Inc. 2nd edition 1991

	UNIT IV – Inorganic ring and chain compounds
1	James E. Huheey, Inorganic Chemistry-Principles of structure and reactivity, Harper & Row Publishers, 4th edition. 1993.
2	B. Douglas, D.H. McDaniel and J. J. Alexander, Concepts and Models of Inorganic Chemistry, John Wiley & Sons, 2nd edition, 1983.
3	Gary Wulfsberg, Inorganic Chemistry; Viva Books PA Ltd., New Delhi; 2002.
4	D. F. Shriver, P. W. Atkins and C.H. Langford, Inorganic Chemistry, Oxford University Press, 3rd edition, 1999
5	F. A. Cotton, G. Wilkinson, C. Murillo and M. Bochmann, Advanced Inorganic Chemistry, John Wiley, 6th edition, New York,1999.
6	T. Chivers, I. Manners, Inorganic Rings and Polymers of the p-Block Elements, from Fundamentals to Applications, RSC Publishing, 2009.
	Common Books for Further Reading:
1	David Thompson, Insights into speciality Inorganic Chemicals, The Royal Society of Chemistry, 1995.
2	N. H. Ring, Inorganic Polymers, Academic Press, New York, 1978.
	…….

		SEMESTER: IV			
PROGRAM: M.Sc.-II		**Mandatory course – III**			
Theory **Course Paper-I**		**Course Code: (CHEM629)** **Course Title: - Instrumental Methods in Inorganic Chemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA)** **(Marks- 50)**	**Semester End Examination** **(Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. The acquaint the learner with the concepts of inorganic spectroscopy such as IR, Raman, NMR.
2. To study the different microscopic techniques for surface analysis of solids.
3. To study the optical methods of various polymeric and inorganic compounds along with basic aspects of cyclic voltammetry.
4. to gain knowledge about principles, experimental setup of various thermos-analytical techniques.

Course Outcomes:

The learner will be able to

1. interpret IR, Raman and NMR spectra of inorganic compounds.
2. gain knowledge about fundamentals and applications of various microscopic techniques in surface analysis.
3. study optical activity of inorganic complexes using CD, ORD techniques and the applications of cyclic voltammetry.
4. apply fundamentals of thermal techniques like TGA, DTA, DSC to interpret stability and thermodynamic parameters of inorganic compounds.

Semester – IV
MANDATORY COURSE – III
COURSE TITLE: Instrumental Methods in Inorganic Chemistry
COURSE CODE: CHEM 629 [CREDITS – 04]

(Numerical and word problems wherever possible)

UNIT	3.1	Spectroscopy (15 L)
I	3.1.1	**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 $C_2O_4^{2-}$.
	3.1.2	**Raman spectroscopy:** Raman spectroscopy for diatomic molecules. Determination of molecular structures like diatomic and triatomic molecules
	3.1.3	**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.
II	3.2	**Microscopy of Surface Chemistry (15 L)**
	3.2.1	Introduction to surface spectroscopy, Microscopy, problems of surface analysis, distinction of surface species, sputter etching and depth profile and chemical imaging.
	3.2.2	Auger Emission Spectroscopy (AES), Electron Spectroscopy for Chemical Analysis. XPS /ESCA, Instrumentation and applications of Scanning Electron Microscopy (SEM), Atomic force microscopy (AFM) and transmission electron microscopy (TEM).
III	3.3	**Optical methods of analysis and Cyclic Voltammetry (15 L)**
	3.3.1	Circular dichroism (CD) and optical rotatory dispersion (ORD): Introduction, principle, Cotton effect, Faraday and Kerr effects, instrumentation, and applications in determining absolute configuration of metal complexes.
	3.3.2	Basic aspects of electrochemistry, electron transfer reactions at electrode surface, potential and electrochemical cells; Voltammetry techniques: linear volatammetry, cyclic voltammetry, reversible, irreversible, and quasi-reversible processes, instrumentation, electrolytes and applications with reference to ferrocene and transition metal complexes.
IV	3.4	**Thermal Methods (15L)**
	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).

REFERENCE BOOKS

	Unit I – Spectroscopy (IR, RAMAN, NMR)
1	R. S. Drago, Physical methods for Chemists, Saunders College publishing, 2nd edition, 1992.
2	R. S. Drago, Physical methods in Inorganic chemistry, Affiliated East-West Press Pvt. Ltd; New Delhi, 1977
3	Fmiza Hammer, Inorganic spectroscopy and related topics, Sarup & Sons 2008.
4	D. N. Sathyanarayana, Introduction to magnetic resonance spectroscopy ESR, NMR, NQR, I. K. International Publishing House Pvt. Ltd. 2009.
5	K. Burger, Coordination chemistry: Experimental methods, London Butterworths, 1973.
6	C. E. Housecroft and A. G. Sharpe, Inorganic Chemistry, Pearson Education Ltd. 2nd edition 2005.
7	C.N.R. Rao, Chemical Applications of Infrared Spectroscopy, Academic Press, N.Y.1963
8	P.J. Hore, Nuclear Magnetic Resonance, Oxford University Press, Oxford,2003.
9	Reverts John D, Nuclear Magnetic Resonance, McGraw Hill, NewYork,1959.
10.	Alan K. Brisdon, Inorganic Spectroscopic Methods, Oxford University Press, 2005
11.	Colin N. Banwell and Elaine M. McCash, Fundamentals of Molecular Spectroscopy, Tata McGraw-Hill Publishing Company Limited, New Delhi, 4th ed, 2003.
12.	Gurdeep R. Chatwal & Sham K. Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing House, 1st edition, 2005.
	UNIT II – Microscopy of Surface Chemistry
1	D. A. Skoog and F. J. Holler and T. A. Nieman, Principles of instrumental analysis, Harcourt Asia PTE Ltd. 5th edition, 1998.
2	R. A. Scott and C. M. Lukehart, Applications of physical methods to inorganic and bioinorganic chemistry, John Wiley & Sons Ltd. 2007.
3	Sulabha K. Kulkarni, Nanotechnology: Principles and practices, Capital Publishing Company, 2007.
4	G. Lawes, Scanning electron Microscopy and x-ray microanalysis, John Wiley and Sons, New York, 1987.
	Unit III - Optical Methods of Analysis and Cyclic Voltammetry
1	R. A. Scottand, C.M. Lukehart, Applications of physical methods to inorganic and bioinorganic chemistry, John Wiley & Sons Ltd. 2007.
2	D. A. Skoog and F.J. Holler and S. R. Crouch, Instrumental analysis, Harcourt Asia PTE Ltd. 5th edition, 1998.

3	D. T. Sawyer, A. Sobkowak, J. L. Roberts Jr. Electrochemistry for Chemists, John Wiley, Inc. New York, 2nd edition, 1995.
4	P. Zanello, Inorganic electrochemistry, Theory, Practice and Application, Publisher RSC, 2003.
5	D. A. Skoog, D. M. West, Holler and Crouch, Fundamental of Analytical Chemistry, Saunders College Publishing, New York, 8thedition, 2005.
6	Joseph Wang, Electroanalytical chemistry, John Wiley & Sons, Inc. 2006
7	Kh. Brainina and E. Neyman, Electroanalytical stripping methods: Wiley Interscience,1994.
8	J. Mohan, Organic Spectroscopy: Principles and Applications, CRC press, 2001.
9	D. A. Skoog, F. J. Holler, and T. A. Nieman, Principles of Instrumental Analysis, Philadelphia: Saunders College Publishing, 5th edition, 1998.
10	A. J. Bard and L. R. Faulkner, Electrochemical Methods, Wiley, New York, 1980.
11	A. M. Bond, Modern Polarographic Methods in Analytical Chemistry, Marcel Dekker, New York, 1980.
12	Asim K. Das and M. Das, Fundamental Concepts of Inorganic Chemistry, CBS Pub., Volumes-VII, 2000.
13	Gurdeep R. Chatwal & Sham K. Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing House, 1st edition, 2005.
	UNIT IV - Thermal Methods
1	W. W. Wendlandt, Thermal analysis, John Wiley, New York, 3rd edition 1986.
2	P. D. Garn, Thermoanalytical methods of investigation, Academic press, N. Y., 1963.
3	A. Blazek, Thermal analysis, Van Norstrand Reinhold Co., London, 1973.
4	T. Daniel, Thermal analysis, Kogan page Ltd., London, 1973.
5	C. J. Keattch and D. Dollimore, An introduction to thermal analysis, Heyden, London, 1975.
6	M. D. Judd and M. I. Pope, Differential thermal analysis, Heydon, London, 1977.
7	G. W. H. Hohne, W. F. Hemminger and H. Flammerscheim, Differential scanning calorimetry-An introduction for practioners, Springer-verlag, Berlin, 1996.
8	K. Burger, Coordination chemistry: Experimental methods, London Butterworths, 1973.
9	G. W. H. Hohne, W. F. Hemminger and H. Flammers cheim, Differential scanning calorimetry-An introduction for practioners, Springer-verlag, Berlin Heidelberg, 2003.
10	R. A. Scott and C. M. Lukehart, Applications of physical methods to inorganic and bioinorganic chemistry, John Wiley & Sons Ltd.,2007.
11	D. A. Skoog and F. J. Holler and S. R. Crouch, Instrumental analysis, Harcourt Asia PTE Ltd. 5th edition, 1998.
12	Gurdeep R. Chatwal & Sham K. Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing House, 1st edition, 2005.
	Common Books for Further Reading:
1	B. E. Hall, Introduction to electron microscopy, McGraw Hill, 2nd edition, 1966.
	……

		SEMESTER: IV			
PROGRAM: M.Sc.-II		**Elective course – I**			
Theory **Elective Course I**		**Course Code: (CHEM63011)** **Course Title: - Intellectual Property Rights and Chemoinformatics**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. To introduce learners to Intellectual Property, Patents, Industrial Designs, Copyrights, Trademarks and Geographical Indications
2. To understand about the Trade Secrets with perspective to IP infringement issue and law of enforcement agencies
3. To give an understanding of the economic value of Intellectual property and different international agreements
4. To introduce learners to cheminformatics and gain knowledge of representation of molecules chemical reaction and also explore chemical structures
5. To give them an insight of different methods of structure elucidation.
6. To enhance their knowledge about tools for drug designing

Course Outcomes:

The learner will be able to

1. use the knowledge of patents for their research which will be more patent oriented.
2. describe the knowledge of industrial design, copyright, trademarks and geographical indications
3. explain the scope, risk and legal aspects of trade secret protection
4. describe the role of judiciary and law of enforcement agencies in IP Infringement issue.
5. utilize the knowledge of the economic value of intellectual property in their future research.
6. describe different international agreements under World Trade organization and Paris convention WIPO AND TRIPS
7. explain the use and prospects of cheminformatics.
8. apply the knowledge of molecular modeling and structure elucidation to establish the structure

Semester – IV
ELECTIVE COURSE – I
COURSE TITLE: Intellectual Property Rights and Chemoinformatics
COURSE CODE: CHEM 63011 [CREDITS – 04]

UNIT	1.1	Fundamentals of Intellectual Property (15 L)
I	1.1.1	**Introduction to Intellectual Property:** Historical Perspective, Different types of IP, Importance of protecting IP.
	1.1.2	**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.
	1.1.3	**Industrial Designs:** Definition, How to obtain, features, International design registration.
	1.1.4	**Copyrights:** Introduction, How to obtain, Differences from Patents.
	1.1.5	**Trade Marks:** Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, trade names etc.
	1.1.6	**Geographical Indications:** Definition, rules for registration, prevention of illegal exploitation, importance to India.
II	1.2	**Intellectual Property organizations and enforcement method (15 L)**
	1.2.1	**Trade Secrets:** Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.
	1.2.2	**IP Infringement issue and enforcement:** Role of Judiciary, Role of law enforcement agencies – Police, Customs etc.
	1.2.3	**Economic Value of Intellectual Property:** Intangible assests and their valuation, Intellectual Property in the Indian context – Various Laws in India Licensing and Technology transfer.
	1.2.4	**Different International agreements (15 L)**
	1.2.4.1	**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
	1.2.4.2.	Paris Convention, WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity.
	1.3	**Chemoinformatics (15L)**
		Introduction to Chemoinformatics: History and evolution of cheminformatics, Use of Cheminformatics, Prospects of cheminformatics, Molecular modeling and structure elucidation.

III	**1.3.2**	**Representation of molecules and chemical reactions:** Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification.
	1.3.3	**Searching Chemical Structures:** Full structure search, sub-structure search, basic ideas, similarity search, three-dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.
IV	**1.4**	**Applications of Chemoinformatics (15L)**
	1.4.1	Prediction of Properties of Compound, Linear Free Energy Relations, Quantitative Structure – Property Relations, Descriptor Analysis, Model Building, Modeling Toxicity, Structure – Spectra correlations, Prediction NMR, IR and Mass spectra, Computer Assisted Structure elucidations, Computer assisted Synthesis Design, Introduction to drug design, Target Identification and Validation, Lead Finding and Optimization, analysis of HTS data, Virtual Screening, Design of Combinatorial Libraries, Ligand-based and Structure based Drug design, Application of Cheminformatics in Drug Design.

REFERENCE BOOKS

1	Rupinder Tewari and Mamta Bhardwaj, Intellectual Property – A Ptemer for Academia, Publication Bureau, Punjab University, 2021.
2	Aoron Schwabach, Intellectual Property – A Reference Handbook, ABC CLIO, Inc, 2007.
3	David Bainbridge, Intellectual Property, 8th edn, Pearson Education Limited 2010.
4	Ramesh Shahabadkar and Sai Satyanarayana Reddy, Intellectual Property Rights, Notion Press, Chennai 2019.
5	Stephan Elias and Richard Stim, Patent, Copyright & Trademark, 7th edn, Delta Printing Solutions, Inc, 2004
6	Andrew R. Leach and Valerie J. Gillet, An Introduction to Chemoinformatics, Springer, 2007.
7	S. P. Gupta, QSAR and Molecular Modeling, Anamaya Publishers, 2011.
8	J. Gasteiger and T. Engel, Chemoinformatics A Textbook, Wiley VCH 2003
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		SEMESTER: IV			
PROGRAM: M.Sc.-II		**Elective course – II**			
Theory **Elective Course II**		**Course Code: (CHEM63012)** **Course Title: - Advanced Topics in Inorganic Chemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**--**	**04**	**50%**	**50%**

Learning Objectives:

1. To explain the properties and uses of industrially important chemicals.
2. To study the nuclear processes and super heavy elements.
3. To analyze the role of inorganic metal ions in medicinal chemistry.
4. To study the properties and applications of nanomaterials in various sectors.
5. To gain knowledge about isopoly & heteropoly acids, supramolecular chemistry, inorganic pesticides and intercalation compounds.

Course Outcomes:

The learner will be able to

1. outline the properties and applications of industrially important inorganic chemicals.
2. understand the rnuclear processes its applications.
3. know the role of metal ions in pharmaceuticals.
4. apply various physical and chemical methods in the synthesis of nanomaterials and its application in industrial sectors.
5. understand the concepts of some selected topics in inorganic chemistry like isopoly & heteropoly acids, supramolecular chemistry, inorganic pesticides and intercalation compounds.

Semester – IV
ELECTIVE COURSE – II
COURSE TITLE: Advanced Topics in Inorganic Chemistry
COURSE CODE: CHEM 63012 [CREDITS – 04]

UNIT	1.1	1.1 Inorganic Materials (15 L)
I	1.1.1	Classification, manufacture and applications of (i) Inorganic fibers and (ii) Inorganic fillers. Study of (i) Condensed phosphates, and (ii) Coordination polymers.
	1.1.2	**Preparation, properties and uses of industrially important chemicals** – potassium permanganate, sodium thiosulphate, bleaching powder, hydrogen peroxide, potassium dichromate
II	1.2	**Nuclear Chemistry and Inorganic Pharmaceuticals (15 L)**
	1.2.1	**Nuclear Chemistry:** Introduction to nuclear fuels and separation of fission products from spent fuel rods by PUREX process. Super heavy element, discovery, preparation, position in the periodic table.
	1.2.2	**Inorganic Pharmaceuticals:**
	1.2.2.1	Radiopharmaceuticals containing Tc and Bi, contrast agents for X-ray and NMR imaging.
	1.2.2.2	Gastrointestinal agents: antacids (aluminium hydroxide, milk of magnesia, sodium bicarbonate
	1.2.2.3	Cathartics (magnesium sulphate and sodium phosphate).
	1.2.2.4	Topical agents viz.(i) protectives and adsorbents (talc, calamine) (ii) antimicrobial agents (potassium permanganate, tincture iodine, boric acid) and astringents (potash alum).
III	1.3	**Advances in Nanomaterials (15L)**
	1.3.1	Types of nanorods, solid spheres, core-shell nanoparticles, mesoporous materials; isolation of nano materials
	1.3.2	**Some important properties of nanomaterials:** optical properties of metal and semiconductor nanoparticles, magnetic properties.
	1.3.3	**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.
	1.3.4	**Applications of nanomaterials** in electronics, energy, automobiles, sports and toys, textile, cosmetics, medicine, space and defense. Environmental effects of nanotechnology
IV	1.4	**Some Selected Topics (15 L)**
	1.4.1	Isopoly and Heteropoly acids
	1.4.2	Supramolecular chemistry
	1.4.3	Inorganic pesticides
	1.4.4	Intercalation compounds

REFERENCE BOOKS

	UNIT I - Inorganic Materials
1	K. H. Buchel, H. H. Moretto, P Woditsch, Industrial Inorganic Chemistry, Wiley, 2003.
2	J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, Inorganic chemistry- Principles of structure and reactivity, 4th edition, Pearson 2006.
3	P. L. Soni, Textbook of Inorganic Chemistry. Sultan Chand & Sons Publisher, 15th Edition .1984.
	UNIT II - Nuclear Chemistry and Inorganic Pharmaceuticals
1	H. J. Arniker, Essentials of nuclear chemistry, 4th edition; NAIL publishers 2011.
2	G.Friedlander, J.W.Kennedy, E.S.Macias and J.M.Miller; Nuclear and Radiochemistry; 1981.
3	G.T.Seaberg, Man-made Transuranic Elements Prentice-Hall, 1963.
4	M.T.R.Series,The Superheavy Elements.
5	Haissilsky, Nuclear Chemistry and its Applications, 1962.
6	A.V.R.Reddy, D.D.Sood, Nuclear Chemistry, IANCAS Publishers
7	Ed. Nicholas P. Farrell, Uses of Inorganic Chemistry in Medicine.
8	K.A.Strohfeldt, Essentials of Inorganic Chemistry, Wiley publications,
9	J. H. Block, E. B. Roche, T. O. Soine and C. O. Wilson, Inorganic medicinal and pharmaceutical chemistry, Lea and Febiger, 1974.
10	K. R. Mahadik and B. S. Kuchekar, Concise Inorganic Pharmaceutical Chemistry, Nirali Prakashan, Pune,
	UNIT III - Advances in Nanomaterials
1	S. Kulkarni, Nanotechnology: Principles and Practices, CRC Press, 4th edition, 2010
2	T. Pradeep, Nano: The essential, McGraw-hill Publication
3	M. A. Shah and T. Ahmad, Principles of Nanoscience and Nanotechnology, Alpha Science.
4	Sulabha K. Kulkarni, Nanotechnology-Principles and Practices, Capital Publishing Co., 2007.
	UNIT IV -Some Selected Topics
1	Mandeep Dalal, A Textbook of Inorganic Chemistry, Vol I, Dalal Institute, 2000.
2	N.N. Greenwood and Earnshaw, Chemistry of Elements, Oxford, Britian, , 1998.
3	J. R. Gispert, Coordination Chemistry, Wiley-VCH .2008.
4	J. M. Lehn, Supramolecular Chemistry: Concepts and Perspectives, VCH, 38 Weinheim, 1995.
5	P. S. Kalsi and J. P Kalsi, Bioorganic, Bioinorganic and Supramolecular Chemistry, New Age International Publishers, 2007.
6	D. F. Shriver and P. W. Atkins, Inorganic chemistry, 3rd edition, Oxford University Press ,1999.
7	S. M. Khopkar, Analytical chemistry of macrocyclic and supramolecular compounds, Narosa publishing House, 2002.
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		SEMESTER: IV			
PROGRAM: M.Sc.-II		**Research Project**			
		Course Code: (CHEM631) **Course Title: - Research Project**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA)** **(Marks- 75)**	**Semester End Examination** **(Marks- 75)**
NA	**12**	**--**	**06**	**50%**	**50%**

Learning Objectives:

1. To become aware of safe working procedure and ethical handling of chemicals.
2. acquire new understanding and expertise in a particular field of research.
3. To understand the use of mathematical and statistical tools to analyse the data, writing and presenting scientific papers.
4. To learn to work independently and as part of a team.

Course Outcomes:

The learner will be able to

1. practice safety and ethical guidelines in conducting research.
2. have the aptitude to create or execute the novel approach or methods discovered during investigation.
3. characterize, interpret and present a report on the research performed.
4. have insights, ideas in identifying resources and collaborating on interdepartmental/ interfaculty research activities.

Course Code: (CHEM631)

Course Title: - Research Project

Guidelines for the conducting the research project.

- Students are to work on research project individually and should be the continuity of the research project selected in the semester III.
- Research Project is of 6 credits which equals to project working hours of 180
- The title of the research project should be descriptive, appropriate and concise as possible.
- A detailed description of Chemicals, equipment, experimental procedures should be mentioned in the project report.
- The project report should be well-structured, should present an accurate and complete account of the research performed with data, discussion and conclusions
- The publications of earlier work should be cited
- Record of attendance and continuous performance of the student is monitored by the mentor.
- At the end of the semester, the student has to present the project report in a bound form for external evaluation.
- Participation in national and international conferences and other project competitions is encouraged.

MODALITIES OF ASSESSMENT - THEORY EXAMINATION

I)MANDATORY COURSE FOR SEMESTER III AND IV AND ELECTIVE COURSE FOR SEMESTER IV

A) CONTINUOUS ASSESSMENT: 50% (50 Marks per paper)

Sr. No	Evaluation Type	Marks
1	Written Objective/ Short Answer Examination	**25**
2	Assignment/ Industrial visit report / Presentation	**25**
	Total	**50**

B) SEMESTER END THEORY EXAMINATION: 50% (50 Marks per paper)

1. **Duration** - These examinations shall be of **TWO HOURS** duration.
2. **Theory question paper pattern**

i) There shall be 04 questions each of 10 marks on each unit and one mix question for 10 marks. (The mix question will have two questions of two marks each from each of the four units).

ii) All questions shall be compulsory with internal choice within the question

Paper Pattern:

Question	Options	Marks	Questions Based on
Q.1	2 out of 4	10	Unit I
Q.2	2 out of 4	10	Unit II
Q.3	2 out of 4	10	Unit III
Q.4	2 out of 4	10	Unit IV
Q.5	5 out of 8	10	Units (I+II+III+IV)
	Total	**50**	

II) ELECTIVE COURSE FOR SEMESTER III

A) CONTINUOUS ASSESSMENT: 50% (25 Marks per paper)

Sr. No	Evaluation Type	Marks
1	Written Objective/ Short Answer Examination	**15**
2	Assignment/ Industrial visit report / Presentation	**10**
	Total	**25**

B) SEMESTER END THEORY EXAMINATION: 50% (50 Marks per paper)

1. **Duration** - These examinations shall be of **ONE HOUR** duration.
2. **Theory question paper pattern**

i) There shall be 02 questions each of 08 marks on each unit and one mix question for 09 marks (The mix question will have three questions of three marks each from each of the two units).

ii) All questions shall be compulsory with internal choice within the question

Paper Pattern:

Question	Options	Marks	Questions Based on
Q.1	2 out of 4	08	Unit I
Q.2	2 out of 4	08	Unit II
Q.3	3 out of 6	09	Units (I+II)
	Total	**25**	

MODALITIES OF ASSESSMENT – PRACTICAL EXAMINATION

SEMESTER III

A) CONTINUOUS ASSESSMENT OF PRACTICALS - 50%

Particulars	Continuous Assessment (CA)
Assessment during practicals (Interaction / Performance) Skill, accuracy, precision of measurement, Record of observation, calculations, graph, result and conclusion. Timely submission of journal	**20**
Overall performance (attendance, punctuality, interaction during Practical session throughout semester)	**05**
Total	**25**

B) SEMESTER END PRACTICAL EXAMINATION - 50%

Particulars	Semester end Practical examination
Laboratory work/ Experimental performance	**15**
Viva	**05**
Journal	**05**
Total	**25**

PRACTICAL BOOK/JOURNAL

- The students are required to perform 75% of the Practical for the journal to be duly certified.
- The students are required to present a duly certified journal for appearing at the practical examination, failing which they will not be allowed to appear for the examination

MODALITIES OF ASSESSMENT FOR RESEARCH PROJECT

SEMESTER III

A) CONTINUOUS ASSESSMENT: 50% (50 Marks)

Sr. No	Criteria for evaluation	Marks
1.	Selection of research topic	**10**
2.	Literature Survey	**15**
3.	Scheme/ Outline of project	**10**
4.	Methodology	**15**
	Total	**50**

B) SEMESTER END EXTERNAL EXAMINATION: 50% (50 Marks)

Sr. No	Criteria for evaluation	Marks
1.	Presentation	**30**
2.	Report Writing	**20**
	Total	**50**

SEMESTER IV

A) CONTINUOUS ASSESSMENT: 50% (75 Marks)

Sr. No	Criteria for evaluation	Marks
1.	Experimental work	**30**
2.	Characterization & Interpretation	**25**
3.	Conclusion	**20**
	Total	**75**

B) SEMESTER END EXTERNAL EXAMINATION: 50% (75 Marks)

Sr. No	Criteria for evaluation	Marks
1.	Presentation	**50**
2.	Report Writing	**25**
	Total	**75**

Letter Grades and Grade Points:

Semester GPA/ Programme CGPA Semester/ Programme	% of Marks	Alpha-Sign/ Letter Grade Result	Grading Point
9.00 - 10.00	90.0 - 100	O (Outstanding)	10
8.00 - < 9.00	80.0 - < 90.0	A+ (Excellent)	9
7.00 - < 8.00	70.0 - < 80.0	A (Very Good)	8
6.00 - < 7.00	60.0 - < 70.0	B+ (Good)	7
5.50 - < 6.00	55.0 - < 60.0	B (Above Average)	6
5.00 - < 5.50	50.0 - < 55.0	C (Average)	5
4.00 - < 5.00	40.0 - < 50.0	P (Pass)	4
Below 4.00	Below 40.0	F (Fail)	0
Ab (Absent)	-	Ab (Absent)	0

Sign of the BOS Coordinator
Dr. Sunil Patil
BOS in Chemistry
Director, Students' Welfare, University of Mumbai

Sign of the Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science & Technology

Sign of the Offg. Dean
Prof. Shivram S. Garje
Faculty of Science & Technology