AC – **07/07/2023**
Item No. – **6.11 (N)**

As Per NEP 2020

University of Mumbai

Title of the program

A- P.G. Diploma in Inorganic Chemistry
B- M.Sc. (Inorganic Chemistry) (Two Year) } **2023-24**
C- M.Sc. (Inorganic Chemistry) (One Year) - **2027-28**

Syllabus for the
Semester – Sem I & II

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

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.

5) Credit Structure of the M.Sc. (Physical Chemistry) (Sem I, II, III & IV)
(Table as per परिशिष्ट-1 with sign of HOD and Dean)

R _____

Post Graduate Program: M.Sc. (Inorganic Chemistry) परिशिष्ट-1

Year	Level	Sem	Major				RM	OJT/ FP	RP	Cum. Cr.	Degree
			Mandatory			Electives					
1	6.0	Sem I	3*4+ 2=14			4	4		-	22	PG Diploma (after 3 Years Degree)
			Physical Chemistry-I (CHEM 501)	TH	4	**Credits 4 (2+2)** **Course 1 :** Analytical Chemistry-I +chemistry practicals (Analytical Chemistry and physical Chemistry) (CHEM 50511) **(OR)** **Credits 4 (2+2)** **Course 2 :** Analytical Chemistry-II + Chemistry Practicals (Analytical Chemistry and Physical Chemistry) (CHEM 50512)	Research Methodology (CHEM 506)				
			Inorganic Chemistry-I(CHEM 502)	TH	4						
			Organic Chemistry-I (CHEM 503)	TH	4						
			Chemistry Practical-I (Inorganic Chemistry and Organic Chemistry) (PRCHEMIO 504)	PR	2						
		Sem II	3*4+ 2=14			4	-	4 CHEM	-	22	
			Physical Chemistry-II(CHEM 507)	TH	4	**Credits 4 (2+2)** **Course 1 :** Analytical Chemistry-III + Chemistry Practicals (Analytical Chemistry and Physical Chemistry) (CHEM 51011) **(OR)** **Credits 4 (2+2)** **Course 2 :** Analytical Chemistry-IV + Chemistry Practicals					
			Inorganic Chemistry-II (CHEM 508)	TH	4						
			Chemistry -II (CHEM 509)								
			Chemistry Practical-II (Inorganic Chemistry and Organic (PRCHEMIO 511)	PR	2						

						(Analytical Chemistry and Physical Chemistry) (CHEM 51012)						
Cum. Cr. For PG Diploma			28			8	4	4		44		
Exit Option: PG Diploma (44 credits) after Three Year UG Degree												
2	6.5	Sem III	3*4+ 2=14			4	-	-	4 (CHEM 626)	22	PG Degree after 3-yr UG or PG Degree after 4-yr UG	
			Chemistry of Inorganic Solids (CHEM 621)	TH	4	**Applied Chemistry** (Unit I and Unit II) + Practical (CHEM 62511) OR **Inorganic Materials** (Unit III and Unit IV) + Practical (CHEM 62512)						
			Bioinorganic & 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 (CHEM 631)	22		
			Properties of Inorganic Solids & Group Theory (CHEM 627)	TH	4	**Intellectual Property Rights & Cheminformatics** (CHEM 63011) **(OR)** Advanced Topics in Inorganic Chemistry (CHEM 63012)						
			Organometallics andChemistry of Main Group Chemistry (CHEM 628)	TH	4							
			Instrumental Methods in Inorganic Chemistry (CHEM 629)	TH	4							
Cum. Cr. For 1 Yr PG Degree			28			8	4	4		44		
Cum. Cr. For 2 YrPG Degree			54			16	4	4	10	88		

Sign of HOD

Prof. Shivram S. Garje
Head of Department,
Department of Chemistry,
University of Mumbai

HEAD
DEPARTMENT OF CHEMISTRY
UNIVERSITY OF MUMBAI

Sign of Dean,

Prof. Shivram S. Garje
Dean, Science and Technology
University of Mumbai

Syllabus
(M.Sc. Inorganic Chemistry
(Sem. I & II)

UNIVERSITY OF MUMBAI

Syllabus for M.Sc. (Inorganic Chemistry)
Semester I and II

Choice-Based Credit System
Under New Education Policy (NEP) 2020
(To be implemented from the academic year, 2023-2024)

PROGRAM OUTLINE 2023-2024

YEAR		COURSE CODE	COURSE TITLE	CREDITS
M.Sc. Sem-I	Mandatory Course-I	CHEM 501	Physical Chemistry-I	04
	Mandatory Course-II	CHEM 502	Inorganic Chemistry-I	04
	Mandatory Course-III	CHEM 503	Organic Chemistry-I	04
	Mandatory Course Practical	PRCHEMIO 504	Chemistry Practical-I (Inorganic Chemistry and Organic Chemistry)	02
	Elective 1	CHEM 50511	Analytical Chemistry-I and Chemistry Practical (Analytical+physical)	04
	Elective 2	CHEM 50512	Analytical Chemistry-II and Chemistry Practical(Analytical+physical)	04
	RM	CHEM 506	Research Methodology	04
M.Sc. Sem-II	Mandatory Course-I	CHEM 507	Physical Chemistry-II	04
	Mandatory Course-II	CHEM 508	Inorganic Chemistry-II	04
	Mandatory Course-III	CHEM 509	Organic Chemistry-II	04
	Mandatory Course Practical	PRCHEMIO 511	Chemistry Practical-II (Inorganic+Organic	02

			Chemistry)	
	Elective 1 Course I	CHEM 51011	Analytical Chemistry-III and Chemistry Practical (Analytical +physical)	04
	Elective 2	CHEM 51012	Analytical Chemistry-IV and Chemistry Practical (Analytical +physical)	04
	OJT/FP	CHEM 512	Industrial Training/Field Project	04

PROGRAMME SPECIFIC OUTCOME (PSOs)

1. To make the learners acquainted with advanced concepts in the branch of chemistry, scrutinize and accomplish a solution to problems encountered in the field of research and analysis.

2. To Apply the fundamental concepts of chemistry to accomplish goals assigned to them at the workplace in industry and academia to meet the global standards.

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

4. To instill the logical scientific approach along with analytical reasoning with respect to the novel techniques implemented in the industry.

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

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

7. To learn professional ethics and norms of scientific development.

Semester – I

	SEMESTER: I
PROGRAM(s): M.Sc.-I	**Major course 1**
Theory **Course:** **1aper-I**	**Course Code: (CHEM501)** **Course Title: - Physical Chemistry-I**

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

Learning Objectives:

1. To enable learners to have comprehensive knowledge and understanding of the advanced concepts in reaction kinetics, molecular dynamics and chemical thermodynamics.
2. To apply the basic knowledge of Physical chemistry to perform various tasks assigned to them at the workplace in industry and academia to meet the job requirements as per global standards.
3. Accomplish a solution to problems encountered in the field of research.

Course Outcomes:

1. The learners will apply the advanced thermodynamics, Maxwell equation and its applications to ideal gasses.
2. The learners evaluate the different theories of chemical kinetics and effect of temperature on reaction rates.
3. The learners will implement the applications of chemical thermodynamics to real gases, solutions, surfaces and their energetics.
4. The learners will understand the applications of operators and Schrodinger equation in the field of quantum Chemistry.
5. The learners will evaluate the resting membrane potential by using the concept of bio electrochemistry.
6. The learners will try to accomplish a solution to problems encountered in the field of research.

Semester – I

Paper I

Physical Chemistry-I

(CHEM 501)

Course code- CHEM 501	Unit	Course/Unit Title: Physical Chemistry-I	Credits 04/[60 L]
	1	**Thermodynamics-I**	**[15L]**
	1.1.	State function and exact differentials. Maxwell equations, Maxwell thermodynamic Relations; its significance and applications to ideal gases, Joule Thomson experiment, Joule Thomson coefficient, inversion temperature, Joule Thomson coefficient in terms of van der Waals constants.	**[8L]**
	1.2.	Third law of Thermodynamics, Entropy change for a phase transition, absolute entropies, determination of absolute entropies in terms of heat capacity, standard molar entropies and their dependence on molecular mass and molecular structure, residual entropy [Ref 2 and 1,10,11,12 17]	**[7L]**
	2	**Quantum Chemistry**	**[15L]**
	2.1.	Classical Mechanics, failure of classical mechanics: Need for Quantum Mechanics.	
	2.2	Particle waves and Schrödinger wave equation, wave functions, properties of wave functions, Normalization of wave functions, orthogonality of wave functions.	
	2.3	Operators and their algebra, linear and Hermitian operators, operators for the dynamic variables of a system such as, position, linear momentum, angular momentum, total energy, eigen functions, eigen values and eigen value equation, Schrödinger wave equation as the eigen value equation of the Hamiltonianoperator, average value and the expectation value of a dynamic variable of the system, Postulates of Quantum Mechanics, Schrodinger's Time independent wave equation from Schrodinger's time dependent wave equation.	

	2.4	Application of quantum mechanics to the following systems: a) Free particle, wave function and energy of a free particle. b) Particle in a one, two and three-dimensional box, separation of variables, Expression for the wave function of the system, expression for the energy of the system, concept of quantization, introduction of quantumnumber, degeneracy of the energy levels. c) Harmonic oscillator, approximate solution of the equation, Hermite polynomials, expression for wave function, expression for energy, use of the recursion formula. [Ref 7, 8 and 9]	
	3	**Chemical Kinetics and Molecular Dynamics-I**	**[15L]**
	3.1	Composite Reactions: Recapitulation: Rate laws, Differential rate equations Consecutive reactions, Steady state Approximation, rate determining steps, Microscopic Reversibility and Detailed Balanced Chain reactions-chain initiation processes. Some inorganic mechanisms: formation and decomposition of phosgene, decomposition of ozone, Reaction between Hydrogen and Bromine and some general examples Organic Decompositions: Decomposition of ethane, decomposition of acetaldehyde Gas phase combustion: Reaction between hydrogen and oxygen, Semenov – Hinshelwood and Thompson mechanism, Explosion limits and factors affecting explosion limits.	
	3.2	Polymerization reactions: Kinetics of stepwise polymerization, Calculation of degree of polymerization for stepwise reaction. Kinetics of free radical chain polymerization, Kinetic chain length and estimation of average no. of monomer units in the polymer produced by chain polymerization.	
	3.3 3.	Reaction in Gas Phase Unimolecular Reactions: Lindeman-Hinshelwood theory, Rice-Ramsperger-Kasssel (RRK) theory, Rice-Ramsperger-Kassel Marcus (RRKM) theory. [Ref. 2 and 15, 17, 18]	

	4.	**Electrochemistry**	**[15L]**
	4.1 3.	Debye-Hückel theory of activity coefficient, Debye-Hückel limiting law and its extension to higher concentration (derivations are expected).	
	4.2	Electrolytic conductance and ionic interaction, relaxation effect, Debye-Hückel- Onsager equation (derivation expected). Validity of this equation for aqueous and non- aqueous solution, deviations from Onsager equation, Debye-Falkenhagen effect (dispersion of conductance at high frequencies), Wien effect.	
	4.3	Batteries: Alkaline fuel cells, Phosphoric acid fuel cells, High temperature fuel cells [Solid –Oxide Fuel Cells (SOFC) and Molten Carbonate Fuel Cells	
	4.2	Bio-electrochemistry: Introduction, cells and membranes, membrane potentials, theory of membrane potentials, interfacial electron transfer in biological systems, adsorption of proteins onto metals from solution, electron transfer from modified metals to dissolved protein in solution, enzymes as electrodes, electrochemical enzyme-catalysed oxidation of styrene. Goldmann equation. (derivations are expected) [Ref: 14 and 16, 17, 18]	

References:

1. Peter Atkins and Julio de Paula, Atkin‟s *Physical Chemistry*, 7th Edn., Oxford University Press, 2002.
2. K.J. Laidler and J.H. Meiser, *Physical Chemistry*, 2nd Ed., CBS Publishers and Distributors, New Delhi, 1999.
3. Robert J. Silby and Robert A. Alberty, *Physical Chemistry*, 3rd Edn., John Wiley and Sons (Asia) Pte. Ltd., 2002.
4. Ira R. Levine, *Physical Chemistry*, 5th Edn., Tata McGraw-Hill New Delhi, 2002.
5. G.W. Castellan, *Physical Chemistry*, 3rd Edn., Narosa Publishing House, New Delhi, 1983.
6. S. Glasstone, *Text Book of Physical Chemistry*, 2nd Edn., McMillan and Co. Ltd., London, 1962
7. B.K. Sen, *Quantum Chemistry including Spectroscopy*, Kalyani Publishers, 2003.
8. A.K. Chandra, *Introductory Quantum Chemistry*, Tata McGraw – Hill, 1994.
9. R.K. Prasad, *Quantum Chemistry*, 2nd Edn., New Age International Publishers, 2000.
10. S. Glasstone, *Thermodynamics for Chemists*, Affiliated East-West Press, New Delhi, 1964.
11. W.G. Davis, *Introduction to Chemical Thermodynamics – A Non – Calculus Approach*, Saunders, Philadelphia, 19772.
12. Peter A. Rock, *Chemical Thermodynamics*, University Science Books, Oxford University Press, 1983.
13. Ira N. Levine, *Quantum Chemistry*, 5th Edn., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.
14. Thomas Engel and Philip Reid, Physical Chemistry, 3rd Edn., Pearson Education Limited 2013.
15. D.N. Bajpai, Advanced Physical Chemistry, S. Chand 1st Edn., 1992.

16. ***Bockris***, John O'M., ***Reddy***, Amulya K.N., Gamboa-Aldeco, Maria E., Modern Electrochemistry, 2A, Plenum Publishers, 1998.
17. Physical Chemistry by Gurtu and Gurtu.
18. Dr. Harichandra A Parbat and Dr. Damodar V Prabhu, Essence of Chemical Kinetics, Sara Publication, First Edition, Sept. 2022.
19. A Text book of Physical Chemistry by K L kapoor Vol 5 , 2nd Edn

PROGRAM(s): M.Sc.-I	SEMESTER: I Major course -II
Theory **Course: Paper I**	**Course Code: (CHEM502)** **Course Title: - Inorganic Chemistry-I**

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

Learning Objectives:

Inorganic Chemistry

1. To develop the ability to correlate fundamental theories of spatial orientations of molecules based on wave mechanics with advanced concepts in chemical bonding, symmetry of molecular systems and Structural aspects of inorganic solids.
2. To gain theoretical knowledge of cutting-edge topics such as solid-state lasers and contemporary methods of preparation of nanomaterials.
3. To learn about diverse tools available for characterization of coordination compounds in order to enhance competency while applying for practical purpose

Course Outcomes:

The learner will be able to:

1. apply basic knowledge of wave mechanics to derive the wave functions for different hybridization types and apply molecular orbital theory for diatomic and polyatomic species.
2. comprehend the important fundamental concept of Group Theory, which helps them in understanding the properties and bonding in polyatomic molecules.
3. grasp the electronic structure of solids based on wave mechanics and to know basic concepts of solid-state Lasers.
4. understand the various techniques for characterization of coordination compounds. and develops the skill in interpretation of the spectra.
5. get comprehensive idea about established instrumental techniques and significant characterization tools available to study inorganic complexes having wide applications in industries.

Semester – I
Inorganic Chemistry-I(CHEM502)
[60 L]

Unit – I

Chemical Bonding: [15 L]

1.1 Recapitulation of hybridization Derivation of wave functions for sp, sp^2, sp^3 orbital hybridization types considering only sigma bonding.

1.2 Discussion of involvement of d orbitals in various types of hybridizations. Concept of resonance, resonance energy derivation expected. Formal charge with examples.

1.3 Molecular Orbital Theory for diatomic species of First transition Series.

1.4 Molecular Orbital Theory for Polyatomic species considering σ bonding for SF_6, CO_2, B_2H_6, I_3^- molecular species.

1.5 Weak forces of attraction: Hydrogen bonding – concept, types, properties, methods of detection and importance. Van der Waal's forces, ion-dipole, dipole-dipole, London forces.

Unit - II

Molecular Symmetry and Group Theory: [15L]

1.1. Symmetry criterion of optical activity, symmetry restrictions on dipole moment. A systematic procedure for symmetry classification of molecules.

1.2. Concepts of Groups, Sub-groups, Classes of Symmetry operations, Group Multiplication Tables. Abelian and non-Abelian point groups.

2.3. a) Representation of Groups: Matrix representation of symmetry operations, reducible and irreducible representations. The Great Orthogonality Theorem and its application in construction of character tables for point groups C_{2v}, C_{3v} and C_2h, structure of character tables.

b) Determination of symmetry species for translations and rotations.

c) Mulliken's notations for irreducible representations.

d) Reduction of reducible representations using reduction formula.

2.4. Applications of Group Theory Symmetry adapted linear combinations (SALC), symmetry aspects of MO theory, sigma bonding in ABn (NH_3, CH_4) molecules.

Unit- III

Materials Chemistry and Nanomaterials: [15 L]

3.1 Solid State Chemistry

3.1.1. Electronic structure of solids and band theory, Fermi level, K Space and Brillouin Zones.

3.1.2. Structures of Compounds of the type: AB [nickel arsenide (NiAs)], AB_2 [fluorite (CaF_2) and anti-fluorite structures, rutile (TiO_2)

3.1.3. Solid state lasers: Introduction, types, working and applications.

3.2 Nanomaterials

3.2.1 Preparative methods, Chemical methods, solvothermal, combustion synthesis, microwave, coprecipitation, Langmuir-Blodgett(LB) method, biological methods, synthesis using microorganism.

3.2.2 Applications in the field of semiconductors, solar cells.

Unit- IV

Characterization of Coordination compounds [15L]

4.1. Methods of Characterisation: thermal studies, Conductivity measurements, electronic spectral and magnetic measurements, IR, NMR and ESR spectroscopic methods.

4.2. Introduction to Orgel & Tanabe Sugano Diagram, Terms, Splitting of terms in Octahedral environment, Calculation of electron parameters such as Δ, B' C, Nephelauxetic ratio with suitable examples.

4.3. Determination of formation constants of metal complexes (Overall and Stepwise): Comparative studies of Potentiometric and spectrophotometric method.

References:

Unit- I

1. B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone Publishers, 2013-2014.

2. W. W. Porterfield, Inorganic Chemistry-A Unified Approach, 2nd Ed., Academic Press, 1993.

3. B. W. Pfennig, Principles of Inorganic Chemistry, Wiley, 2015.

4. C. E. Housecroft and A. G. Sharpe, Inorganic Chemistry, Pearson Education Limited, 2nd Edition 2005.

5. J. Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry–Principles of Structure and Reactivity, 4th Ed., Harper Collins, 1993.

6. P. J. Durrant and B. Durrant, Introduction to Advanced Inorganic Chemistry, Oxford University Press, 1967.

7. R. L. Dekock and H.B.Gray, Chemical Structure and Bonding, The Benjamin Cummings Publishing Company, 1989.

8. G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004.

9. R. Sarkar, General and Inorganic Chemistry, Books & Allied (P) Ltd., 2001.

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11. J. N. Murrell, S. F. A. Kettle and J. M. Tedder, The Chemical Bond, Wiley, 1978.

12. G. A. Jeffrey, An Introduction to Hydrogen Bonding, Oxford University Press, Inc., 1997.

Unit- II

1. F. A. Cotton, Chemical Applications of Group Theory, 2nd Edition, Wiley Eastern Ltd., 1989.

2. H. H. Jaffe and M. Orchin, Symmetry in Chemistry, John Wiley & Sons, New York, 1996.

3. R. L. Carter, Molecular Symmetry and Group Theory, John Wiley & Sons, New York, 1998.

4. K. V. Reddy. Symmetry and Spectroscopy of Molecules, 2nd Edition, New Age International Publishers, New Delhi, 2009.

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6. P. K. Bhattacharya, Group Theory and its Chemical Applications, Himalaya Publishing House. 2014.

7. S. Swarnalakshmi, T. Saroja and R. M. Ezhilarasi, A Simple Approach to Group Theory in Chemistry, Universities Press, 2008.

Unit- III

1. Solid State Chemistry Introduction, Lesley E. Smart, Elaine A. Moore, ISBN 0- 203-49635-3, Taylor & Francis Group, LLC.

2. Nanomaterials & Nanochemistry, 2007, Catherine Brechignac, Philippe Houdy, Marcel Lahmani, ISBN 978-3-540-72992-1 Springer Berlin Heidelberg New York.

3. Nanomaterials Chemistry, Recent Developments and New Directions C.N.R. Rao, A. Muller, and A.K. Cheetham, ISBN 978-3-527-31664-9, 2007 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.

4. Nano-Surface Chemistry, 2001, Morton Rosoff, ISBN: 0-8247-0254-9, Marcel Dekker Inc. New York.

5. The Chemistry of Nanomaterials, CNR Rao, Muller Cheetham, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2004.

6. Semiconductor Nanomaterials, Challa S.S.R. Kumar, ISBN: 978-3-527-32166-7, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2010.

7. Peter Atkins and Julio de Paula, Atkin"s *Physical Chemistry*, 7th Edn., Oxford University Press, 2002.

8. An introduction to Lasers Theory and Applications by M.N. Avadhanulu. P.S.hemne, S. Chand publications.

9. Advances in solid state lasers development and Applications by M.Grishin.

10. Solid State Lasers _ A graduate Text by Walter Koechner, Michael Bass, Springer.

11. Rare earth materials – properties and applications by A,R.Jha, CRC Press.

Unit- IV

1. J. E. Huheey, E. A. Keiter and R. L. Keiter; Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education, 2006.

2. D. Banerjea ,Coordination Chemistry Tata McGraw Hill,1993.

3. Geary Coordination reviews 4. P.W. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong; Shriver & Atkins: Inorganic Chemistry, 4th ed. Oxford University Press, 2006.

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6. B. Douglas, D. McDaniel and J. Alexander. Concepts and Models of Inorganic Chemistry(3rd edn.), John Wiley & Sons (1994).

PROGRAM(s): M.Sc.-I	SEMESTER: I Major course -III
Course: III Theory	**Course Code: (CHEM 503)** **Course Title:- Organic Chemistry-I**

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

Learning Objectives:

1. To enable learners to have comprehensive knowledge and understanding of the advanced concepts in reaction Mechanism, stereochemistry, different reactions and reagents.
2. To apply the basic knowledge of Organic chemistry to perform various tasks assigned to themat the workplace in industry and academia to meet the job requirements as per global standards.
3. Accomplish a solution to problems encountered in the field of research.

Course Outcomes:

After completing the course students will be able to:

1) predict the reactivity of organic compound from its structure.
2) Understand different methods used for determination and the fundamental concept in stereochemistry by applying varioussymmetry elements of organic molecule.
3) acquire the knowledge of chirality by taking examples of symmetrical and unsymmetrical molecule.
4) develop interest in stereochemistry by studying stereochemical features of different classes of organic compounds
5) identify the nomenclature of various stereochemical phenomena
6) organize the techniques of aromatic nucleophilic substitution reactions for synthesizing/transforming molecules.
7) understand the concept of aromaticity and to know the nature of bonds, electronic effects and other properties of molecules.
8) understand the preparation of important oxidizing reagent and predict the selectivity of the reagents in organic reactions.
9) explain the preparation and uses of important reducing reagents in various organic transformation reaction.

Syllabus-Course Code: (CHEM503)
Course Title:-Organic Chemistry-I

Physical Organic Chemistry:
(15L)

1.1. Thermodynamic and kinetic requirements of a reaction: rate and equilibrium constants, reaction coordinate diagram, transition state (activated complex), nature of activated complex, Hammond postulate, Reactivity *vs* selectivity, Curtin-Hammett Principle, Microscopic reversibility, Kinetic *vs* thermodynamic control of organic reactions.

1.2. Determining mechanism of a reaction: Product analysis, kinetic studies, use of isotopes (Kinetic isotope effect – primary and secondary kinetic isotope effect). Detection and trapping of intermediates, crossover experiments and stereochemical evidence.

Unit-II Stereochemistry:

(15 L)

2.1. Concept of Chirality: Recognition ofsymmetry elements.

2.2. Molecules with tri- and tetra-coordinate centers: Compounds with carbon, silicon, nitrogen, phosphorous and sulphur chiral centers, relative configurational stabilities.

2.3. Molecules with two or more chiral centers: Constitutionally unsymmetrical molecules: erythro-threo and syn-anti systems of nomenclature. Interconversion of Fischer, Sawhorse, Newman and Flying wedge projections. Constitutionally symmetrical molecules with odd and even number of chiral centers: enantiomeric and meso forms, concept of stereogenic, chirotopic, and pseudoasymmetriccentres. R-S nomenclature for chiral centres in acyclic and cyclic compounds.

2.4. Axial and planar chirality: Principles of axial and planar chirality. Stereochemical features and configurational descriptors (R,S) for the following classes of compounds: allenes, alkylidene cycloalkanes, spirans, biaryls (buttressing effect) (including BINOLs and BINAPs), ansa compounds, cyclophanes, trans-cyclooctenes.

2.5. Prochirality: Chiral and prochiralcentres; prochiral axis and prochiral plane. Homotopic, heterotopic (enantiotopic and diastereotopic) ligands and faces.Identification using substitution and symmetry criteria.Nomenclature of stereoheterotopic ligands and faces. Symbols for stereoheterotopic ligands in molecules with i) one or more prochiralcentres ii) a chiral as well as a prochiralcentre, iii) a prochiral axis iv) a prochiral plane v) pro-pseudoasymmetriccentre. Symbols for enantiotopic and diastereotopic face.

Unit III

Nucleophilic substitution reactions and Aromaticity (15L)

3.1. Nucleophilic substitution reactions: (9 L)

3.1.1 Aliphatic nucleophilic substitution: S_N1, S_N2, S_Ni reactions, mixed S_N1 and S_N2 and SET mechanisms. S_N reactions involving NGP - participation by aryl rings, σ and pi-bonds. Factors affecting these reactions: substrate, nucleophilicity, solvent, steric effect, hard-soft interaction, leaving group. Ambident nucleophiles. S_NcA, S_N1‟ and S_N2‟ reactions. S_N at sp^2(vinylic) carbon.

3.1.2 Aromatic nucleophilic substitution: S_NAr, S_N1, benzyne mechanisms. Ipso, cine, tele and vicarious substitution.

3.1.3 Ester hydrolysis: Classification, nomenclature and study of all eight mechanisms ofacid and base catalyzed hydrolysis with suitable examples.

3.2. Aromaticity: (6 L)

3.2.1. Huckel's (4n+2) and 4n rules, structural, thermochemical, and magnetic criteria for aromaticity, including NMR characteristics of aromatic systems. Delocalization and

aromaticity.

3.2.2. Aromatic and antiaromatic compounds up-to 18 carbon atoms. Homoaromatic compounds. Aromaticity of all benzenoid systems, heterocycles, metallocenes, azulenes, annulenes, aromatic ions and Fullerene (C_{60}).

Unit-IV

Oxidation and Reduction: (15L)

4.1. Oxidation: General mechanism, selectivity, and important applications of the following:

4.1.1. Dehydrogenation: Dehydrogenation of C-C bonds including aromatization of six membered rings using metal (Pt, Pd, Ni) and organic reagents (chloranil, DDQ).

4.1.2. Oxidation of alcohols to aldehydes and ketones: Chromium reagents such as $K_2Cr_2O_7/H_2SO_4$ (Jones reagent), CrO_3-pyridine (Collin's reagent), PCC (Corey's reagent) and PDC (Cornforth reagent), hypervalent iodine reagents (IBX, Dess-Martin periodinane). DMSO based reagents (Swern oxidation), Corey-Kim oxidation - advantages over Swern and limitations; and Pfitzner-Moffatt oxidation-DCC and DMSO and Oppenauer oxidation.

4.1.3. Oxidation involving C-C bonds cleavage: Glycols using HIO_4; cycloalkanones using CrO_3; carbon-carbon double bond using ozone, $KMnO_4$, CrO_3, $NaIO_4$ and OsO_4; aromatic rings using RuO_4 and $NaIO_4$.

4.1.4. Oxidation involving replacement of hydrogen by oxygen: oxidation of CH_2 to CO by SeO_2, oxidation of arylmethanes by CrO_2Cl_2 (Etard oxidation).

4.1.5. Oxidation of aldehydes and ketones: with H_2O_2 (Dakin reaction), with peroxy acid (Baeyer-Villiger oxidation)

4.2. Reduction: General mechanism, selectivity, and important applications of the following reducing reagents:

4.2.1. Reduction of CO to CH_2 in aldehydes and ketones-Clemmensen reduction, Wolff-Kishner reduction and Huang-Minlon modification.

4.2.2. Metal hydride reduction: Boron reagents ($NaBH_4$, $NaCNBH_3$, diborane, 9-BBN, $Na(OAc)_3BH$, aluminium reagents ($LiAlH_4$, DIBAL-H, Red Al, L and K- selectrides).

4.2.3. N_2H_2 (diimide reduction) and other non-metal based agents including organic reducing agents (Hantzschdihydropyridine).

4.2.4. Dissolving metal reductions: using Zn, Li, Na, and Mg under neutral and acidic conditions, Li/Na-liquid NH_3 mediated reduction of aromatic compounds (Birch reduction) and Alkynes.

Reference Books.

1. PhysicalOrganicChemistry,NeilIsaacs
2. ModernPhysicalOrganicChemistry,EricV.AnslynandDennisA.Dougherty
3. ComprehensiveOrganicchemistry,BartonandOllis,Vol1
4. OrganicChemistry,J.Claydens,N.Greeves,S.WarrenandP.Wothers,OxfordUniversityPress.
5. AdvancedOrganicChemistry,F.A.CareyandR.J.Sundberg,PartAandB,PlenumPress.
6. Stereochemistry: Conformation and mechamism, P.S. Kalsi, New Age International, New Delhi.
7. Stereochemistryofcarbon compounds, E.L Eliel, S.H Wilen and L.N Manden, Wiley.
8. Stereochemistry of Organic Compounds- Principles and Applications, D. Nasipuri.New International Publishers Ltd.
9. March'sAdvancedOrganicChemistry:Reactions,MechanismsandStructure,MichaelB. Smith, JerryMarch, Wiley.
10. AdvancedOrganicChemistry:Reactionsandmechanism,B.MillerandR.Prasad,PearsonEd ucation.
11. AdvancedOrganicChemistry:Reactionmechanisms,R.Bruckner,AcademicPress.

12. UnderstandingOrganicReactionMechanisms,AdamsJacobs,CambridgeUniversityPress.
13. WritingReactionMechanisminorganicchemistry,A.Miller,P.H.Solomons,AcademicPress.
14. AdvancedOrganicChemistry:Reactionsandmechanism,L.G.Wade,Jr.,MayaShankarSingh, PearsonEducation.
15. MechanisminOrganicChemistry,Petersykes,6theditiononwards.
16. ModernMethodsofOrganicSynthesis,W.CarruthersandIainColdham,CambridgeUniversityPress.
17. OrganicSynthesis,JagdambaSingh,L.D.S.Yadav,PragatiPrakashan.
18. Modern Methods of Organic Synthesis, W. Carruthers and Iain Coldham, Cambridge University Press.
19. Organic reactions and their Mechanisms, P.S. Kalsi, New Age International Publishers.
20. Organic Synthesis, Jagdamba Singh, L.D.S Yadav, PragatiPrakashan.
21. Principles ofOrganic Synthesis, R.O.C. Norman and J.M. Coxon, Nelson Thornes

Program (s) M.Sc. I	Semester I Major course - Practical				
Course Practical	Course Code – PRCHEMIO- 504				
	Course Title –Chemistry Practical – I (Inorganic and Organic Chemistry)				
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (Marks-25)	Semester End Assessment (Marks-25)
NA	04	NA	02	25	25

Learning Objectives:

Inorganic Chemistry

1. To apply basic concepts of separation and estimation of metals ions from constituent ores/alloys effectively using chemical analysis
2. To gain knowledge of employing instrumental techniques for quantitative analysis.

Course Outcome

1. The learner will be able to apply theoretical concepts of separation of metals and its characterization effectively for practical purpose
2. The learner will be equipped with knowledge of instrumental techniques, appropriate skillful handling of instruments, representation of data and interpretation of graphical results

Inorganic Chemistry Practical
Sem -I

Course Code: PRCHEMIO 504

Non Instrumental Experiments

Ores and Alloys

1) Analysis of Devarda's alloy
2) Analysis of Cu – Ni alloy
3) Analysis of Limestone
4) Analysis of Tin Solder alloy

Instrumental Experiments

1) Estimation of Fe (III) solution using Ce (IV) ions Potentiometrically
2) Estimation of Copper using Iodometric method Potentiometrically
3) Estimation of Na_2CO_3 in washing soda by pH- metry
4) Estimation of Cl^- ion in NaCl/KCl by Conductometry.

Reference:

1. Advanced experiments in Inorganic Chemistry., G. N. Mukherjee., 1st Edn., 2010., U.N.Dhur & Sons Pvt Ltd

2. The Synthesis and Characterization of Inorganic Compounds by William L. Jolly

3. Inorganic Chemistry Practical Under UGC Syllabus for M.Sc. in all India Universities By: Dr Deepak Pant

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PROGRAM(s): M.Sc.-I		**SEMESTER: I : Major course-Practical**			
Course: Practical		**Course Code:** PRCHEMOA504 **Course Title:- Chemistry Practical-I (OrganicChemistry)**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours perweek)	**Practical (Hours perweek)**	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA)(Marks-25)**	**Semester End Examination(Marks-25)**
NA	**04**	**NA**	**02**	**25**	**25**

Learning objectives:

1. Planning of synthesis, effect of reaction parameters including stoichiometry,and safetyaspects including MSDS should be learnt.
2. Purify the product by crystallization. Formation and purity of the productshould bechecked by TLC
3. Report mass and melting point ofthe purified product.
4. To gain knowledge and hands on experience in instrumental and non-instrumental analysis.
6. To introduce the concept of non-aqueous titrations. To study technique of ion exchange and efficiency of the ion exchanger.
7. To develop scientific temper and research-based skills.

Course Outcomes:

1. After completion ofthis Course, the learner will be able to
2. Carry out one step preparation in laboratory with basic understanding ofstoichiometry
3. Evaluate the process and outcomes of an experiment quantitatively andqualitatively
4. Check purity of product using thin layer chromatography
5. handle and get familiar with SOP's of instruments like potentiometer,conductivity meter, colorimeter and spectrophotometer.
6. understand the concept of non-aqueous titrations and apply it in analysis ofsamples.
7. apply the theory of redox reactions to experimental systems.separate the component of interest from the matrix.
8. develop scientific temperament and research-based skills accomplish to address the challenges encountered in the field of research

Course Code:- CHEM 506 Theory	Unit	Course/ Unit Title: Research Methodology	04 Credits / 60 Lectures
I		**Literature Survey**	**15 L**
	1.1	Print: Primary, Secondary and Tertiary sources. Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, textbooks, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples.	**5 L**
	1.2	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.	**5 L**
	1.3	Information Technology and Library Resources: The Internet and World wide web, Internet resources for Chemistry, finding and citing published information.	**5 L**
II		**Data analysis**	**15 L**
		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.	
III		**Methods Of Scientific Research And Writing Scientific Papers**	**15 L**
		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.	
IV		**Chemical Safety & Ethical Handling Of Chemicals**	**15 L**
		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.	

M.SC SEM I Elective course

PROGRAM(s): M.Sc.-I				SEMESTER: I
Elective course 1 theory				Course Code: CHEM 50511 Course Title:-Analytical Chemistry-I
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Practical (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 25)	Semester End Examination (Marks- 25)
02	NA	02	25	25

Syllabus

Unit - I

1.1 Language of Analytical Chemistry [8 L]

1.1.1 Analytical perspective [3 L]

Analytical approach. common analytical problems. Terms involved in analytical chemistry - Analysis, Analyte, Matrix, Determination, Measurement, Techniques, Methods, Procedures and protocol.

1.1.2 An overview of analytical methods [3 L]

Analytical methods - Types, classification and selection. Quantitative method of Analysis- Calibration method, Method of Standard addition, Internal standard method. Performance Characteristics of analytical method- Accuracy, Precision, Selectivity, Sensitivity, Detection limit (LOD,LOQ,LOL) ,Dynamic range and Robustness and Ruggedness.

1.1.3 Errors [2 L]

Types of errors. Absolute error, Relative error, Constant error and Proportionate errors. Minimization of errors.

1.2 Quality in Analytical Chemistry [7L]

1.2.1 Total Quality Management- TQM [3L]

Definition, Principles, Importance and benefits. Philosophy of implementation of TQM -Process steps, Advantages and Limitations **i)** Kaizen -Six steps **ii)** Six Sigma approach **iii)** 5S and 5S audit check for laboratories.

1.2.2 Safety in laboratories [2L]

Basic concept of safety in laboratory- The Industrial Hygiene Principles. Personal protection equipment (PPE). Occupational Safety and Health Administration (OSHA).

1.2.3 Accreditations [2L]

Accreditation of laboratories, NABL**,** Indian Government standards (ISI, HALLMARK, AGMARK).- Meaning and significance.

Unit- II

2.1 Calculations based on Chemical Principles [15 L]

(The following topics are to be covered in the form of numerical problems only)

2.1.1 Concentration of a solution based on volume and mass units.

2.1.2 Calculations of ppm, ppb and dilution of the solutions, concept of mmol.

2.1.3 Stoichiometry of chemical reactions, concept of kg /mol, limiting reactant, theoretical and practical yield.

2.1.4 Solubility and solubility equilibria, effect of presence of common ion in solution.

2.1.5 Calculations of pH of acids, bases, acidic and basic buffers.

2.1.6 Concept of formation constants, stability and instability constants, stepwise formation constants.

2.1.7 Oxidation number, rules for assigning oxidation number, redox reaction in term of oxidation number, oxidizing and reducing agents, equivalent weight of oxidizing and reducing agents, stoichiometry of redox titration (Normality of a solution of an oxidizing / reducing agent and its relationship with molarity).

References

Unit I

1. Modern Analytical Chemistry ; David Harvey, McGraw-Hill,Higher Education,(2000)
2. Principles of Instrumental Analysis ; Skoog, Holler and Nieman, 5th Edition, Ch: 1
3. Fundamentals of Analytical Chemistry, Douglas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Edition, 2004, Ch: 5.

4. Undergraduate Instrumental Analysis ; J W Robinson, Marcel Dekker, 6th edition Ch:1.
5. ISO 9000 Quality Systems Handbook; David Hoyle. 4th edition (Chapter: 3 & 4) (Free download).
6. Quality in the Analytical Laboratory ; Elizabeth Pichard, Wiley India, Ch: 5, Ch: 6 &Ch: 7.
7. Quality Management; Donna C S Summers, Prentice-Hall of India, Ch:3.
8. Quality in Totality: A Manager‟s Guide To TQM and ISO 9000, Parag Diwan, Deep & Deep Publications, 1st Edition, 2000.
9. Quality Control and Total Quality Management - ; P.L. Jain-Tata McGraw-Hill (2006) Total Quality Management - Bester field - Pearson Education, Ch:5.
10. Industrial Hygiene and Chemical Safety, ; M H Fulekar, Ch:9, Ch:11 & Ch:15.
11. Safety and Hazards Management in Chemical Industries ; M N Vyas, Atlantic Publisher, Ch:4, Ch:5 & Ch:19.
12. World Health Organization (2009) Handbook: Good Laboratory Practice (GLP)
13. OECD Principles of Good Laboratory Practice (as revised in 1997)". OECD Environmental Health and Safety Publications. OECD. **1**. 1998
14. "A systematic approach for evaluating the quality of experimental toxicological and eco-toxicological data".; Klimisch, HJ; Andreae, M; Tillmann, U (1997). doi:10.1006/rtph.1996.1076. PMID 9056496.

Unit II

1.3000 solved problems in chemistry, Schaums Solved problem series, ; David E. Goldbers, Mc Graw Hill international Editions, Chapter 11,15,16,21,22 13, 1966

2. "Standard methods of Chemical Analysis"; W. W. Scott, Vol. I, Van Nostrand Company, Inc.,1939.

3."Spectrophotometric Determination of Traces of Metals"; E.B.Sandell and H.Onishi, ,Part II,4th Ed. ,A Wiley Interscience Publication, New York,1978

PROGRAM(s): M.Sc.-I				SEMESTER: I Elective II
Elective -course 2 Theory				Course Code: CHEM 50512 Course Title:-Analytical Chemistry-II
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Practical (Hours per week)	Credit	Continuous Assessment (CA) (Marks-25)	Semester End Examination (Marks- 25)
02	NA	02	25	25

Course Objectives:

1. To gain knowledge of the chromatography techniques and its applications.

2. To understand application of X-ray spectroscopy for qualitative and quantitative analysis.

3. To introduce radio analytical techniques.

4.To apply the surface analytical techniques for system.

5.To study advantages and applications of electroanalytical methods.

Course outcomes: -

After completion of this Course, the learner will be

1. able to compare the advantages/disadvantages of SEM, STM and TEM.

2. able to develop different techniques to separate the components of mixture.

3. conversant with basic principles and theories of mass spectrometry.

4. able to apply the electroanalytical methods to sample under consideration.

5. able to elaborate on electrogravimetry and coulometry techniques

Syllabus

Unit - I -Optical Methods [15 L]

1. 1 Infrared Absorption Spectroscopy [6 L]

1.1.1 Instrumentation: Sources, Sample handling, Transducers, Dispersive, non-dispersive instrument**.**

1.1.2 Applications of IR [Mid IR, Near IR, Far IR]: Qualitative with emphasis on "Finger print" and Quantitative analysis.

1.1.3 Advantages and Limitations of IR.

1.2 FT Technique [3]

1.2.1 Introduction of Fourier Transform**.**

1.2.2 Laser as a source of radiation, sample containers.

1.2.3 Detectors, Fiber optics.

1.2.4 FTIR and its advantages.

1.3 Molecular Ultraviolet and Visible Spectroscopy [6 L]

1.3.1 Factors affecting molecular absorption: pH, temperature, solvent and effect of substituents, types of transitions [emphasis on charge transfer absorption].

1.3.2 Applications of Ultraviolet and Visible spectroscopy:

i) On charge transfer absorption
ii) Simultaneous spectroscopy
iii) Derivative Spectroscopy

1.3.3 Dual spectrometry – Introduction, Principle, Instrumentation and Applications**.**

Unit - II Instrumental methods [15L]

Thermal Methods: [9 L]

2.1.1 Introduction: Types of thermal methods, comparison between TGA and DTA.

2.1.2 Differential Scanning Calorimetry-Principle, comparison of DTA and DSC.

2.1.3 Instrumentation, Block diagram, Nature of DSC Curve, Factors affecting DSC Curves.

2.14 Applications - Heat of reaction, Safety screening, Polymers, liquid crystals, Drug analysis.

2.2 Automation in chemical analysis: [6 L]

2.2.1 Need for automation, Objectives of automation.

2.2.2 An overview of automated instruments.

2.2.3 Process control analysis, flow injection analysis, discrete automated systems, automatic analysis based on multi-layered films, gas monitoring equipments.

2.2.4 Automatic titrators.

References

Unit I

1. Principles of Instrumental Analysis, ; D. A. Skoog, F. J. Holler, T. A. Nieman, 5th Edition, Harcourt Asia Publisher. Chapter 6, 7,8, 13, 14, 16,17
2. Instrumental Methods of Analysis,; H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, 6 th Edition, CBS Publisher. Chapter 2.
3. Introduction to Instrumental Analysis, ; R. D. Braun , McGraw Hill Publisher. Chapter 5, 8, 12
4. Instrumental Methods of Chemical Analysis, ; G. W. Ewing, 5 th Edition, McGraw Hill Publisher, Chapter 3.
5. The effect of temperature on ultraviolet absorption spectra and its relation to hydrogen bonding,; M. Ito, J. Mol. Spectrosc. 4 (1960) 106-124.
6. The effect of temperature on the visible absorption band of iodine in several solvents; A. J. Somnessa, Spectrochim. Acta. Part A: Molecular Spectroscopy, 33 (1977) 525-528.
7. Infrared Spectroscopy- Materials Science, Engineering and Technology. Z. M. Khoshhesab (2012). Prof. Theophanides Theophile (Ed.). ISBN: 978-953- 51-0537- 4, InTech,(open access)

Unit II

1. Introduction to instrumental methods of analysis; Robert D. Braun, Mc. Graw Hill (1987): Chapter 27,28
2. Thermal Analysis-theory and applications; R. T. Sane, Ghadge, Quest Publications
3. Instrumental methods of analysis; Willard, Merrit, Dean:7 th Edition, Chapter 25, 26
4. Instrumental Analysis, ; Skoog, Holler and Nieman, 5 th Edition, Chapter 31,33
5. Vogel's Quantitative Chemical Analysis,; 6 th Edition, Chapter 12
6. Analytical Chemistry - Open Learning: Thermal Methods; James W. Dodd, W. James and Kenneth H. Tonge

<table>
<tr><td colspan="4">PROGRAM(s): M.Sc.-I</td><td>SEMESTER: I</td></tr>
<tr><td colspan="4">Elective course 1 and 2 Practical</td><td>Course Code: PRCHEMAP 50511

Course Title:-Analytical Chemistry and Physical Chemistry-I</td></tr>
<tr><td colspan="4">Teaching Scheme</td><td>Evaluation Scheme</td></tr>
<tr><td>Lectures (Hours per week)</td><td>Practical (Hours per week)</td><td>Credit</td><td>Continuous Assessment (CA)

(Marks- 25)</td><td>Semester End Examination

(Marks- 25)</td></tr>
</table>

NA	**04**	**02**	**25**	**25**

Course Objectives :

1. To gain knowledge and hands on experience in instrumental and non-instrumental analysis.
2. To introduce the concept of non-aqueous titrations.
3. To study technique of ion exchange and efficiency of the ion exchanger.
4. To develop scientific temper and research-based skills.

Course Outcomes:

After completion of this Course, the learner will be able to

1. handle and get familiar with SOP's of instruments like potentiometer, conductivity meter, colorimeter and spectrophotometer.
2. understand the concept of non-aqueous titrations and apply it in analysis of samples.
3. apply the theory of redox reactions to experimental systems.
4. separate the component of interest from the matrix.
5. develop scientific temperament and research-based skills accomplish to encountered in the field of research

Elective -I and II Practical

Semester I

Instrumental Experiments

1. To determine percentage purity of sodium carbonate in washing soda pH metrically.
2. To determine amount of Ti(III) and Fe(II) in a mixture bytitration with Ce(IV) potentiometrically.
3. To determine the percentage purity of a sample (glycine/sodium benzoate/primary amine) by titration with perchloric acid in a non-aqueous medium using glass calomel system potentiometrically.
4. To determine the amount of nitrite present in the given water sample colorimetrically.

Non-Instrumental Experiments

1. To carry out assay of the sodium chloride injection by Volhard's method.
2. To determine (a) the ion exchange capacity (b) exchange efficiency of the given cation exchange resin.
3. To determine amount of Cr(III) and Fe(II) individually in a mixture of the two bytitration with EDTA.
4. To determine number of nitro groups in the given compound using $TiCl_3$.

References:

1. Quantitative Inorganic Analysis including Elementary Instrumental Analysis by ; A. I. Vogels, 3rd Ed. ELBS (1964)

2. Vogel's textbook of quantitative chemical analysis, Mendham, Denny, Barnes, Thomas, Pearson education, Sixth Ed.

3. Standard methods of chemical analysis ; F. J. Welcher, 1975

4.Standard methods of chemical analysis :Instrumental methods of Analysis ; F. J. Welcher ,vol . 3,1966

5. Standard methods of Chemical Analysis, W.W.Scott, Vol I ,Van Nostrand Company, Inc,. 1939

6. Spectrophotometric determination of traces of Metals, E.B.Sandell and H.Onishi, Part II 4th Ed. A.Wiley Interscience publication, NewYork,1978.

Semester – II

Semester – II

Physical Chemistry

PROGRAM(s): M.Sc.-I	SEMESTER: II Major course 1
Theory **Course:1-**	**Course Code: CHEM 507** **Course Title:- Physical Chemistry-II**

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

Learning Objectives:

1. To gain knowledge of the advanced concepts in quantum mechanics, applications of HMO theory,chemical kinetics and molecular dynamics.
2. To understand the advanced concepts in chemical thermodynamics and photochemistry.
3. To develop the skill to solve the problems encountered in the field of quantum andelectrochemistry.

Course outcomes: -

1. To learn the concept of quantum chemistry and able to solve problems related to 1D box, 2D box, 3Dbox and to explain the role of operators in quantum chemistry.
2. To understand the use of Schrodinger wave equation in one and two electron systems along withapplications of HMO.
3. To develop the skill to solve the problems based on chemical thermodynamics, molecular dynamicsand quantum Chemistry.
4. To apply the concept of Jablonski mechanism in photochemical reactions.
5. Learners will get knowledge of advanced chemical kinetics and molecular dynamics.

Syllabus

Course Code:- CHEM-507	Unit	Course/ Unit Title: Physical Chemistry-II	04 Credits / 60 Lectures
		Chemical Thermodynamics II	
	1.1.	Fugacity of real gases, Determination of fugacity of real gases using graphical method and from equation of state. Equilibrium constant for real gases in terms of fugacity. Gibbs energy of mixing, entropy and enthalpy of mixing.	
	1.2	**Real solutions:** Chemical potential in non ideal solutions excess functions of non ideal solutions calculation of partial molar volume and partial molar enthalpy, Gibbs Duhem Margules equation.	
	1.3	**Thermodynamics of surfaces**, Pressure difference across curved surface (Laplace equation), vapour pressure of droplets (Kelvin equation), Gibbs adsorption isotherm, BET isotherm (derivations expected).	
	1.4	Bioenergetics : standard free energy change in biochemical reactions, exergonic, endergonic. Hydrolysis of ATP, synthesis of ATP from ADP. [Ref 2 and 1,10,11,12]	
	2	**Quantum Chemistry II**	
	2.1	gid rotor, spherical coordinates Schrödinger wave equation in spherical coordinates, separation of the variables, the phi equation, wavefunction, quantum number, the theta equation, wave function, quantization of rotational energy, spherical harmonics.	

	2.2	Hydrogen atom, the two particle problem, separation of the energy as translational and potential, separation of variables, the Radial (R), Zenith (theta) and Azimuthal (Phi) equations, solution of the equation, introduction of the four quantum numbers and their interdependence on the basis of the solutions of the three equations, total wave function, expression for the energy, probability density function, distances and energies in atomic units, radial and	
		angular plots, points of maximum probability.	
	2.3.	Application of the Schrödinger equation to two electron system, limitations of the equation, need for the approximate solutions, methods of obtaining the approximate solution of the Schrödinger wave equation	
	2.4.	Hückel Molecular Orbitals theory for ethylene, 1,3-butadiene, cyclobutadiene and benzene. ***(Derivation expected)*** [Ref 7, 8 and 9]	
	3	**Chemical Kinetics and Molecular Dynamics-II**	
	3.1.	**Elementary Reactions in Solution:-** Solvent Effects on reaction rates, Reactions between ions- influence of solvent Dielectric constant, influence of ionic strength, Linear free energy relationships Enzyme action	
	3.2**.**	**Kinetics of reactions catalyzed by enzymes** -Michaelis-Menten analysis, Lineweaver-Burk and Eadie Analyses	
	3.3.	**Inhibition of Enzyme action**: Competitive, Noncompetitive and Uncompetitive Inhibition. Effect ofpH, Enzyme activation by metal ions, Regulatory enzymes	
	3.4.	**Kinetics of reactions in the Solid State:-** Factors affecting reactions in solids **Rate laws for reactions in solid**: The parabolic rate law, The first order rate law, the contracting sphere rate law, Contracting area rate law, some examples of kinetic studies. (Ref: 7 and 2, 22)	

		Photochemistry	
	4.1	Absorption of light, laws of photochemistry, electronic structure of molecules, molecular orbital, electronically excited singlet states, designation based on multiplicity rule, construction of Jablonski diagram, electronic transition,	
		Frank Condon principle, selection rules, intensity of absorption bands, nature of electronic spectra and primary process, photo-dissociation, pre-dissociation.	
	4.2	Photo physical phenomena: physical pathways of excited molecular system (radiative and non-radiative), prompt fluorescence, delayed fluorescence,and phosphorescence, fluorescence quenching: concentration quenching, collisional quenching, quenching by excimer and exciplex emission, fluorescence resonance energy transfer between photo-excited donor and acceptor systems.	
	4.3.	Stern-Volmer relation, critical energy transfer distances, energy transfer efficiency, examples and applications in chemical analysis. Photochemical reactions, photo-oxidation, photoreduction, photo-dimerization, photoisomerization and photosensitized reactions. Photochemistry of environment: Greenhouse effect.	

References:

1. Peter Atkins and Julio de Paula, Atkin‟s *Physical Chemistry*, 7th Edn., Oxford University Press, 2002.
2. K.J. Laidler and J.H. Meiser, *Physical Chemistry*, 2nd Ed., CBS Publishers and Distributors, New Delhi, 1999.
3. Robert J. Silby and Robert A. Alberty, *Physical Chemistry*, 3rd Edn., John Wiley and Sons (Asia) Pte. Ltd., 2002.
4. Ira R. Levine, *Physical Chemistry*, 5th Edn., Tata McGraw-Hill New Delhi, 2002.
5. G.W. Castellan, *Physical Chemistry*, 3rd Edn., Narosa Publishing House, New Delhi, 1983.
6. S. Glasstone, *Text Book of Physical Chemistry*, 2nd Edn., McMillan and Co. Ltd., London, 1962.
7. Principles of Chemical Kinetics, 2nd Ed., James E. House, ELSEVIER, 2007.
8. B.K. Sen, *Quantum Chemistry including Spectroscopy*, Kalyani Publishers, 2003.
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19. Principles of physical Chemistry , Marrown and Prutton 5th edition
20. Essentials of Physical Chemistry , Arun Bahl, B. S Bahl, G. D.Tulli , S Chand and Co. Ltd , 2012 Edition.
21. Introduction of Solids L.V Azaroff , Tata McGraw Hill .
22. Dr. Harichandra A Parbat and Dr. Damodar V Prabhu, Essence of Chemical Kinetics, Sara Publication, First Edition, Sept. 2022.
23. A Text book of physical Chemistry ; Applications of thermodynamics vol III, Mac Millan Publishers India Ltd, 2011
24. New directions in solid state Chemistry, C.N.R. Rao and J Gopalkrishnan , Cambridge University Press.

Theory **Course: II**	**Course Code: (CHEM508) Major course2** **Course Title: - Inorganic Chemistry-II**				
Teaching Scheme					**Evaluation Scheme**
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks-50)**	**Semester End Examination (Marks- 50)**
04	**NA**	–	**04**	**50**	**50**

Learning Objectives:

Inorganic Chemistry

1. The course aims at the detailed mechanistic study of various inorganic complexes involving different methods for kinetic study of inorganic complex.
2. The course aims at the detailed interception of synthesis, structure & bonding in organometallic compounds.
3. To gain environmental consciousness through study of toxicity of metals and consequences of heavy metal pollution
4. To have extensive knowledge of significance of biological oxygen carriers and mechanism of enzyme catalytic reactions in biological systems.

Course Outcomes:

The learner will be able:

1. To elucidate on the rate, mechanism of inorganic reactions and methods of determination of rate of reactions.
2. To compare the stability of complexes, elaborate different methods of preparation of organometallic compounds and analyze the structure and bonding.
3. To understand the toxicity of heavy metals, specific case studies and adverse effect on human beings.
4. To infer role of biological oxygen carriers, copper containing enzymes and nitrogen fixing enzymes in biological systems.

Semester – II

Inorganic Chemistry-II

(CHEM508)
[60 L]

Unit- I

Inorganic Reaction Mechanism: [15 L]

1.1 Rate of reactions, factors affecting the rate of reactions, techniques for determination of rate of reaction (Direct chemical analysis, spectrophotometric method, electrochemical and flow methods).
1.2 Ligand substitution reactions of:
a) Octahedral complexes without breaking of metal-ligand bond (Use of isotopic labelling method)
b) Square planar complexes, trans-effect, its theories and applications. Mechanism and factors affecting these substitution reactions.
1.3 Redox reactions: inner and outer sphere mechanisms, complimentary and non-complimentary reactions.

1.4 Isomerization and racemization reactions.

Unit-II

Organometallic Chemistry of Transition metals: [15 L]

2.1. Eighteen electron rule and electron counting with examples, sixteen electron Square Planar complexes.

2.2. Preparation and properties of the following compounds

(a) Alkyl and aryl derivatives of Pd and Pt complexes

(b) Carbenes and carbynes of Cr, Mo and W

(c) Alkene derivatives of Pd and Pt

(d) Alkyne derivatives of Pd and Pt

(e) Allyl derivatives of nickel

(f) Sandwich compounds of Fe, Cr and Half Sandwich compounds of Cr, Mo.

2.3 Structure and bonding on the basis of VBT and MOT in the following organometallic compounds: Zeise‟s salt, bis(triphenylphosphine)diphenylacetylene platinum (0) $[Pt(PPh_3)_2(HC{\equiv}CPh)_2]$, diallylnickel(diallylnickel(II), ferrocene and bis(arene)chromium(0), tricarbonyl (η^2-butadiene) iron(0).

Unit- III

Environmental Chemistry: [15 L]

3.1. Conception of Heavy Metals: Critical discussion on heavy metals

3.2. Toxicity of metallic species: a) Mercury, lead, cadmium, arsenic, copper and chromium, with respect to their sources, distribution, speciation, biochemical effects and toxicology, control and treatment.

b) Itai-itai disease for Cadmium toxicity,

c) Arsenic Poisoning in the Indo-Bangladesh region.

3.3. Interaction of radiation in context with the environment: Sources and biological implication of radioactive materials. Effect of low-level radiation on cells- Its applications in diagnosis and treatment, Effect of radiation on cell proliferation and cancer.

Unit- IV

Bioinorganic Chemistry: [15 L]

4.1. Biological oxygen carriers; hemoglobin, hemerythrene and hemocyanine- structure of metal active center and differences in mechanism of oxygen binding, Differences between hemoglobin and myoglobin: Cooperativity of oxygen binding in hemoglobin and Hill equation, pH dependence of oxygen affinity in hemoglobin and myoglobin and its implications.

4.2. Activation of oxygen in biological system with examples of mono-oxygenases

4.3. Copper containing enzymes- superoxide dismutase,

References

Unit- I

1. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5th Ed., Oxford University Press, 2010.

2. D. Banerjea, Coordination Chemistry, Tata McGraw Hill, 1993.

3. W. H. Malik, G. D.Tuli and R. D. Madan, Selected Topics in Inorganic Chemistry, 8th Ed., S. Chand & Company ltd.

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6. Gurdeep Raj, Advanced Inorganic Chemistry-Vol.II, 12th Edition, Goel publishing house,

7. B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone Publishers, 2013-2014.

8. F. Basalo and R. G. Pearson, Mechanism of Inorganic Reactions, 2nd Ed., Wiley, 1967.

9. R. Gopalan and V. Ramlingam, Concise Coordination chemistry, Vikas Publishing house Pvt Ltd., 2001.

10. Robert B. Jordan, Reaction Mechanisms of Inorganic and Organometallic Systems, 3rd Ed., Oxford University Press 2008.

Unit -II

1. D. Banerjea, Coordination chemistry. Tata McGrew Hill, New Delhi,1993.

2. R.C Mehrotra and A.Singh, Organometallic Chemistry- A unified Approach, 2nded, New Age International Pvt Ltd, 2000.

3. R.H Crabtree, The Organometallic Chemistry of the Transition Metals, 5th edition, Wiley International Pvt, Ltd 2000.

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5. Organometallic Chemistry by G.S Sodhi. Ane Books Pvt Ltd.

Unit-III

1. Environmental Chemistry 5th edition, Colin Baird Michael Cann, W. H. Freeman and Company, New York, 2012.

2. Environmental Chemistry 7th edition, Stanley E. Manahan, CRC Press Publishers,

3. Environmental Contaminants, Daniel A. Vallero, ISBN: 0-12-710057-1, Elsevier Inc., 2004.

4. Environmental Science 13th edition, G. Tyler Miller Jr. and Scott E. Spoolman, ISBN-10: 0-495-56016-2, Brooks/Cole, Cengage Learning, 2010.

5. Fundamentals of Environmental and Toxicological Chemistry 4th edition, Stanley E. Manahan, ISBN: 978-1-4665-5317-0, CRC Press Taylor & Francis Group, 2013.

6. Living in the Environment 17th edition, G. Tyler Miller Jr. and Scott E. Spoolman, ISBN-10: 0-538-49414-X, Brooks Cole, Cengage Learning, 2011

7. Poisoning and Toxicology Handbook, Jerrold B. Leikin, Frank P. Paloucek, ISBN: 1-4200-4479-6, Informa Healthcare USA, Inc.

8. Casarett and Doull's Toxicology- The Basic Science of Poisons 6th edition, McGraw-Hill, 2001.

Unit -IV

1. R. W. Hay, *Bioinorganic Chemistry,* Ellis Harwood, England, 1984.

2. I. Bertini, H.B.Gray, S. J. Lippard and J.S. Valentine, Bioinorganic Chemistry, First South Indian Edition, Viva Books, New Delhi, 1998.

3. J. A. Cowan, *Inorganic Biochemistry-An introduction,* VCH Publication, 1993.

4. S. J. Lippard and J. M. Berg, *Principles of Bioinorganic Chemistry,* University Science Publications, Mill Valley, Caligronic, 1994.

5. G.N. Mukherjee and A. Das, Elements of Bioinorganic Chemistry, Dhuri & Sons, Calcutta, 1988.

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7. E.Frienden, J.Chem. Educ., 1985, 62.

8. Robert R.Crechton, Biological Inorganic Chemistry – An Introduction, Elsevier

9. J. R. Frausto da Silva and R. J. P. Williams *The Biological Chemistry of the Elements,* Clarendon Press, Oxford, 1991.

10. JM. D. Yudkin and R. E. Offord *A Guidebook to Biochemistry,* Cambridge University Press, 1980.

PROGRAM(s): M.Sc.-I		SEMESTER: II Major course III			
Theory **Course: Paper-III**		**Course Code: (CHEM 509)** **Course Title:- Organic Chemistry-II**			
Teaching Scheme					**Evaluation Scheme**
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA)** **(Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**–**	**04**	**50**	**50**

Learning Objectives:

1. To enable learners to have comprehensive knowledge and understanding of the advanced concepts in reaction Mechanism, molecular orbital theory, different rearrangement reactions and spectroscopic techniques.
2. To apply the basic knowledge of Organic chemistry to perform various tasks assigned to them atthe workplace in industry and academia to meet the job requirements as per global standards.
3. Accomplish a solution to problems encountered in the field of research.

Course Learning Outcomes.

After completing the course students will be able to:

1) Recognise the type of mechanism & intermediates involved in the given organic reaction and to prove mechanism for the reaction.
2) Identify the ways to modify aliphatic and aromatic compounds via Nucleophilc substitution reactions.
3) Predict the mechanism and stereochemistry ofimportant organic reactions.
4) Understand and write the mechanism of rearrangement reactions withstereochemistry and its applications.
5) Understand the HOMO-LUMO concept and it significance in organic chemistry.
6) Understand the basic principle and concepts in UV and IR spectroscopy
7) Understand the basic concepts of ^{1}H, ^{13}C NMR, and mass spectroscopy.
8) Understand how ^{1}H, ^{13}C NMR and Mass spectroscopy are important for thestructure determination of organic compounds.

Syllabus

Course Code:(CHEM 509)

CourseTitle:-Organic Chemistry-II

Unit-I

1.1. Alkylation of Nucleophilic Carbon Intermediates: (7 L)

1.1.1. Generation of carbanion, kinetic and thermodynamic enolate formation, Regioselectivity in enolate formation, alkylation of enolates.

1.1.2. Generation and alkylation of dianion, medium effects in the alkylation of enolates, oxygen versus carbon as the site of alkylation.

1.1.3. Alkylation of aldehydes, ketones, esters, amides and nitriles.

1.1.4. Nitrogen analogs of enols and enolates- Enamines and Imines anions, alkylation of enamines and imines.

1.1.5. Alkylation of carbon nucleophiles by conjugate addition (Michael reaction).

1.2. Reaction of carbon nucleophiles with carbonyl groups: (8 L)

1.2.1. Mechanism of Acid and base catalyzed Aldol condensation, Mixed Aldol condensation with aromatic aldehydes, regiochemistry in mixed reactions of aliphatic aldehydes and ketones, intramolecular Aldol reaction and Robinson annulation.

1.2.2. Addition reactions with amines and iminium ions; Mannich reaction.

1.2.3. Amine catalyzed condensation reaction: Knoevenagel reaction.

1.2.4. Acylation of carbanions.

Unit-II

2.1. Introduction to Molecular Orbital Theory for Organic Chemistry: (7L)

2.1.1. Molecular orbitals: Formation of σ- and π-MOs by using LCAO method. Formation of π MOs of ethylene, butadiene, 1, 3, 5-hexatriene, allyl cation, anion and radical. Concept of nodal planes and energies of π-MOs

2.1.2. Introduction to FMOs: HOMO and LUMO and significance of HOMO-LUMO gap in absorption spectra as well as chemical reactions. MOs of formaldehyde: The effect of electronegativity perturbation and orbital polarization in formaldehyde. HOMO and LUMO (π and π* orbitals) of formaldehyde. A briefdescription of MOs of nucleophiles and electrophiles. Concept of 'donor-acceptor' interactions in nucleophilic addition reactions on formaldehyde. Connection of this HOMO-LUMO interaction with 'curved arrows' used in reaction mechanisms.The concept of hardness and softness and its application to electrophiles and nucleophiles.Examples of hard and soft nucleophiles/ electrophiles.Identification of hard and soft reactive sites on the basis of MOs.

2.1.3. Application of FMO concepts in (a) SN2 reaction, (b) Lewis acid base adducts (BF3- NH3 complex), (c) ethylene dimerization to Cyclobutane, (d) Diels-Alder cycloaddition, (e) regioselective reaction of allyl cation with allyl anion (f) addition of hydride to formaldehyde.

2.2. Applications of UV and IR spectroscopy: (8L)

2.2.1. Ultraviolet spectroscopy: Recapitulation, UV spectra of dienes, conjugated polyenes (cyclic and acyclic), carbonyl and unsaturated carbonyl compounds, substituted aromatic compounds. Factors affecting the position and intensity of UV bands – effect of conjugation, steric factor, pH, and solvent polarity. Calculation of absorption maxima for above classes of compounds by Woodward-Fieser rules (using Woodward-Fieser tables for values for substituents).

2.2.2. Infrared spectroscopy: Fundamental, overtone and combination bands, vibrational coupling, factors affecting vibrational frequency (atomic weight, conjugation, ring size, solvent and hydrogen bonding). Characteristic vibrational frequencies for alkanes, alkenes, alkynes, aromatics, alcohols, ethers, phenols, amines, nitriles and nitro compounds. Detailed study of vibrational frequencies of carbonyl compounds, aldehydes, ketones, esters, amides, acids, acid halides, anhydrides, lactones, lactams and conjugated carbonyl compounds.

Unit III

Reactions and Rearrangements: (15L)

Mechanisms, stereochemistry (if applicable) and applications of the following:

3.1. Reactions:Baylis-Hillman reaction, McMurry Coupling, Corey-Fuchs reaction, Nef reaction, Passerini reaction.

3.2. Concerted rearrangements: Hofmann, Curtius, Lossen, Schmidt, Wolff, Boulton-Katritzky.

3.3. Cationic rearrangements:Tiffeneau-Demjanov, Pummerer, Dienone-phenol, Rupe, Wagner-Meerwein.

3.4. Anionic rearrangements: Brook, Neber, Von Richter, Wittig, Gabriel–Colman, Baker-Venkataraman.

Unit-IV

1H and 13C NMR spectroscopy and Mass spectrometry (15L)

4.1. Proton magnetic resonance spectroscopy: Principle, Chemical shift, Factors affecting on chemical shift (Electronegativity, H-bonding, Anisotropy effects). Chemical and magnetic equivalence, Chemical shift values and correlation for protons bonded to carbon and other nuclei as in alcohols, phenols, enols,

carboxylic acids, amines, amides. Spin-spin coupling, Coupling constant (J), Factors affecting J, geminal, vicinal,Karplusequation, long range coupling (allylic and aromatic).

4.2. 13C NMR spectroscopy: Theory and comparison with proton NMR, proton coupled and decoupled spectra, off-resonance decoupling. Factors influencing carbon shifts, correlation of chemical shifts of aliphatic, olefin, alkyne, aromatic and carbonyl carbons.

4.3. Mass spectrometry: Basic Principle, Molecular ion peak, base peak, isotopic abundance, metastable ions. Nitrogen rule, Determination of molecular formula of organic compounds based on isotopic abundance and HRMS.Fragmentation pattern in various classes of organic compounds (including compounds containing hetero atoms), McLafferty rearrangement, Retro-Diels-Alder reaction, ortho effect.

4.4. Structure determination involving individual or combined use of the above spectral techniques.

References:

1. OrganicChemistry,J.Claydens,N.Greeves,S.WarrenandP.Wothers,OxfordUniversit yPress.
2. AdvancedOrganicChemistry,F.A.CareyandR.J.Sundberg,PartA,pageno.713- 769,andB, PlenumPress.
3. March'sAdvancedOrganicChemistry:Reactions,MechanismsandStructure,Michael, B.Smith,JerryMarch,Wiley.
4. OrganicChemistry,R.T.Morrison,R.N.BoydandS.K.Bhattacharjee,PearsonPublicati on(7thEdition)
5. AdvancedOrganicChemistry:Reactionsandmechanism,B.MillerandR.Prasad,Pearso nEducation.
6. AdvancedOrganicChemistry:Reactionmechanisms,R.Bruckner,AcademicPress.
7. UnderstandingOrganicReactionMechanisms,AdamsJacobs,CambridgeUniversityPr ess.
8. WritingReactionMechanisminorganicchemistry,A.Miller, P.H.Solomons,AcademicPress.
9. PrinciplesofOrganicSynthesis,R.O.C.NormanandJ.MCoxon,NelsonThornes.
10. AdvancedOrganicChemistry:Reactionsandmechanism,L.G.Wade,Jr.,MayaShankar Singh,Pearson Education.
11. MechanisminOrganicChemistry,PeterSykes,6th
12. MolecularOrbitalandOrganicchemicalreactions,IanFlemingReferenceEdition,Wiley
13. IntroductiontoSpectroscopy,DonaldL.Pavia,GaryM.Lampman,GeorgeS.Kriz,Thom sonBrooks.
14. SpectrometricIdentificationofOrganicCompounds,R.Silverstein,G.CBasslerand T.C.Morrill,John WileyandSons.
15. OrganicSpectroscopy,WilliamKemp,W.H.Freeman&Company.
16. OrganicSpectroscopy-PrinciplesandApplications,Jagmohan,NarosaPublication.
17. OrganicSpectroscopy,V.R.Dani,TataMcGrawHillPublishingCo.

18. SpectroscopyofOrganicCompounds,P.S.Kalsi,NewAgeInternationalLtd.
19. OrganicReactionMechanisms,V.K.Ahluwalia,R.K.Parashar,AlphaScienceInternati onal,2011.
20. NameReactions,JieJackLi,Springer
21. Organic Reaction Mechanisms, V.K. Ahluwalia, R.K Parasher, Alpha Science International, 2011.
22. Reactions, Rearrangements and Reagents by S.N. Sanyal.
23. Name Reactions, Jie Jack Li, Springer.
24. Name reactions and Reagents in Organic Synthesis, Bradford P. Mundy, M.G. Ellerd and F.G. Favaloro, John Wiley & Sons.
25. Organic reactions and their Mechanisms, P.S. Kalsi, New Age International Publishers.
26. Elementary Organic Spectroscopy By- Y R Sharma, (S. Chand Publications)

Program(s) M.Sc. I	Semester II Major course IV
Course :Practical	Course Code – PRCHEMIO- 511
	Course Title – Chemistry Practical – II(Inorganic and Organic Chemistry)

Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours perweek)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment(Marks -25)**	**Semester End Assessment (Marks-25)**
NA	**04**	**NA**	**02**	**25**	**25**

Learning Objectives:

Inorganic Chemistry

1. To understand the metal ligand interaction in coordination compounds
2. To gain knowledge and hands on experience in synthesis of coordination compounds.
3. To gain knowledge of employing instrumental techniques for quantitative analysis.
4. To develop the practical skills of handling of instruments, interpretation of graphical representation.

Course Outcome:

1. The learner will be able to synthesize the coordination complexes schematically and can utilize the knowledge while working in industry.
2. The learner will be equipped with knowledge of instrumental techniques, appropriate skillful handling of instruments, representation of data.

Non-Instrumental Experiments: Inorganic Preparations (Synthesis and Characterization)

1) Bis-(tetramethylammonium) tetrachloro Cuprate (II) $(Me_4N)_2[CuCl_4]$

2) Bis-(tetramethylammonium) tetrachloro Nickelate (II) $(Me_4N)_2[NiCl_4]$

3) Bis (ethylenediammine) Copper (II) Sulphate $[Cu(en)_2]SO_4$

4) Hexaamine Ni(II) Sulphate $[Ni(NH_3)_6]SO_4$

5) Potassium trioxalato Chromate(III) trihydrate $K_3[Cr(C_2O_4)_3].3H_2O$

6) Tetrammine monocarbanato Cobalt (III) Nitrate $[Co(NH_3)_4CO_3]NO_3$

Instrumental Experiments:

1) Determination of equilibrium constant by Slope intercept method for Fe^{+3}/ SCN^- system

2) Determination of Electrolytic nature of inorganic compounds by Conductance measurement.

References:

1. Advanced experiments in Inorganic Chemistry., G. N. Mukherjee., 1st Edn., 2010., U.N.Dhur & Sons Pvt Ltd

2. The Synthesis and Characterization of Inorganic Compounds by William L. Jolly

3. Inorganic Chemistry Practical Under UGC Syllabus for M.Sc. in all India Universities By: Dr Deepak Pant

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Organic Chemistry Practicals

Separation of Binary mixture using micro-scale technique

1. Separation of binary mixture using physical and chemical methods.
2. Characterization of one of the components with the help of chemical analysis and confirmation of the structure with the help of derivative preparation and its physical constant.
3. Purification and determination of mass and physical constant of the second component.

The following types are expected:

(i) Water soluble/water insoluble solid and water insoluble solid,
(i) Non-volatile liquid-Non-volatile liquid (chemical separation)
(i) Water-insoluble solid-Non-volatile liquid.

(Minimum two mixtures from each type and a total of eight mixtures are expected.)

M.Sc. SEM II Elective course

PROGRAM(s): M.Sc.-I				SEMESTER: II
Elective course 1 Theory				Course Code: CHEM 51011 Course Title:-Analytical Chemistry III
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Practical (Hours perweek)	Credit	Continuous Assessment (CA) (Marks-50)	Semester End Examination (Marks- 50)
04	NA	02	25	25

Course Objectives:

1. To gain knowledge of the chromatography techniques and its applications.

2. To understand application of X-ray spectroscopy for qualitative and quantitative analysis.

3. To introduce radio analytical techniques.

4.To apply the surface analytical techniques for system.

5.To studyadvantages and applications of electroanalytical methods.

Course outcomes: -

After completion of this Course, the learner will be

1. able to compare the advantages/disadvantages of SEM, STM and TEM.

2. able to develop different techniques to separate the components of mixture.

3. conversant with basic principles and theories of mass spectrometry.

4. able to apply the electroanalytical methods to sample under consideration.

5. able to elaborate on electrogravimetry and coulometry techniques.

Semester II

Analytical Chemistry Elective Course I

Unit I -Chromatography [15 L]

1.1 Basic concepts and theories of chromatography: **[5 L]**

1.1.1 Introduction and Classification of chromatographic methods.

1.1.2 Concept of plate and rate theories in chromatography, efficiency, resolution selectivity and separation capability.

1.1.3 Van Deemter equation and broadening of chromatographic peaks. Optimization of chromatographic conditions**.**

1.2 Gas Chromatography: **[5 L]**

1.2.1 Instrumentation –sample injection systems (split/split less), column types (solid/ liquid stationary phases), column switching techniques, temperature programming.

1.2.2 Requirements of an ideal detector and types of detectors in GLC and GSC.

1.2.3 Applications -Qualitative and quantitative analysis**.**

1.3 High Performance Liquid Chromatography (HPLC):[5 L]

1.3.1 Normal phase and reversed phase with special reference to types of commercially available columns (Use of C8 and C18 columns).

1.3.2 Diode array type and fluorescence detector.

1.3.3 Applications of HPLC.

Unit II - Instrumental methods - II [15L]

2.1 X-ray spectroscopy: **[6 L]**

Principle, instrumentation, applications, advantages and limitations of

2.1.1 X-rayabsorption spectroscopy. (XAS)

2.1.2 X-ray fluorescence spectroscopy (XRF)

2.1.3 X-raydiffraction spectroscopy. (XRD)

2.2 Mass spectrometry: **[6 L]**

2.2.1 Instrumentation -

i) Ion sources - electron impact, field ionization, field absorption, chemical ionization and fast atom bombardment sources.

ii) Mass analyzers: Quadrupole, time of flight and ion trap.

2.2.2 Applications

2.3 Radio analytical Methods –[3 L]

2.3.1 Neutron Activation Analysis(NAA)- Introduction, Principle, Theory and Applications.

2.3.2 Advantages and Limitations of NAA.

…….

References:

Unit I

1. Instrumental Analysis, Skoog, Holler and Crouch, 7th edition
2. HPLC Practical and Industrial Applications; E.B.Sandell and H.Onishi 2 nd Ed., CRC Press

Unit II

1. Essentials of Nuclear Chemistry; H J Arnikar, New Age Publishers (2005)
2. Fundamentals of Radiochemistry; D. D. Sood A. V. R. Reddy and N. Ramamoorthy, , IANCAS 4th edition, 2010
3. Principles of Instrumental Analysis - Skoog, Holler and Nieman, 5th Edition, Ch: 12, 20

PROGRAM(s): M.Sc.-I				**SEMESTER: II**
Elective course 2 Theory				**Course Code: CHEM 51012** **Course Title:-Analytical Chemistry IV**
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Practical (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 25**	**Semester End Examination** **(Marks- 25)**
04	**NA**	**02**	**25**	**25**

Course Objectives:

1. To apply the surface analytical techniques for system.
2. To studyadvantages and applications of electroanalytical methods.

Course outcomes: -

After completion of this Course, the learner will be

1. able to compare the advantages/disadvantages of SEM, STM and TEM.
2. able to develop different techniques to separate the components of mixture.

3. able to elaborate on electrogravimetry and coulometry techniques.

Syllabus Elective 2 Analytical chemistry

Unit I- Instrumental methods - [15L]

1.1 Surface Analytical Techniques – [9 L]

Principle, Instrumentation and Applications of:

1.1.1 Scanning Electron Microscopy (SEM)

1.1.2 Scanning Tunneling Microscopy (STM)

1.2 Transmission Electron Microscopy (TEM)Atomic Spectroscopy [6 L]

1.2.1 Atomic Spectroscopy based on plasma sources – Introduction, Principle, Instrumentation and Applications.

1.2.2 Advantages and Limitations of AAS

Unit II -Electroanalytical Methods [15L]

2.1 Ion selective potentiometry and Polarography: [10 L]

(Numericals are Expected)

2.1.1 Ion selective electrodes: Applications of - solid state, precipitate, liquid –liquid, enzyme, gas sensing, bio-catalytic membrane and enzyme-based biosensors electrodes.

2.1.2 Polarography**:** Ilkovic equation, Cottrell equation, effect of complex formation on the polarographic waves.

2.2 Electrogravimetry: **[2 L]**

2.2.1 Introduction, Principle and Instrumentation.

2.2.2 Factors affecting the nature of the deposit.

2.2.3 Applications**.**

2.3 Coulometry: [3 L]

2.3.1 Introduction, Principle and Instrumentation.

2.3.2 Coulometry at controlled potential and controlled current.

Referencs:

Unit I

1. Instrumental Analysis; Douglas A. Skoog - F. James Holler - Crouch, Publisher: Cengage; Edition, (2003), ISBN-10: 8131505421, ISBN-13: 978-8131505427
2. Physical Principles of Electron Microscopy, An Introduction to TEM, SEM, and AEM ; Ray F. Egerton, ISBN: 978-0- 387-25800- 3 (Print) 978-0- 387-26016- 7 (Online)
3. Modern techniques of surface science; D.P. Woodruff and T.A. Delchar, Cambridge Univ. Press, 1994.
4. Introduction to Scanning Tunneling Microscopy ; C. J. Chen, Oxford University Press, New York, 1993.
5. Transmission Electron Microscopy: A text book for Material Science; David B Williams and C., Barry Carter, Springer, 2009
6. Modern Spectroscopy,; J.M. Hollas, , John Wiley, New York, 3rd Edition (1996),
7. Principles of Instrumental Analysis; Skoog, Holler, Nieman, Harcourt College Publishers, 5th ed., 1998.
8. Instrumental Analysis; Douglas A. Skoog - F. James Holler - Crouch, Publisher: Cengage; Edition (2003), ISBN10: 8131505421, ISBN-13: 978-8131505427

Unit II

1. Principles of Instrumental Analysis – ; Skoog, Holler, Nieman, Harcourt College Publishers, 5th Edition, 1998. Chapters - 23, 24, 25.
2. Analytical Chemistry Principles – ; John H Kennnedy, Saunders College Publishing, 2nd edition, (1990).
3. Modern Analytical Chemistry; David Harvey; McGraw Hill Higher education publishers, (2000).
4. Vogel‟s Text book of quantitative chemical analysis; Pearson Education Limited, 6th edition, (2007).
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Elective Analytical and Physical Chemistry Practical
Semester II

PROGRAM(s): M.Sc.-I			SEMESTER: II
Elective course 1 and 2			Course Code: PRCHEMAP 51011 Course Title:- Analytical Chemistry and Physical Chemistry
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Practical (Hours per week)	Credit	Semester End Examination (Marks- 50)
NA	04	02	50

Course Objectives:

1. To gain knowledge and hands on experience in instrumental and non-instrumental analysis.
2. To introduce the concept of simultaneous determination in spectrophotometry.
3. To study technique of ion exchange and breakthrough capacity.
4. To develop scientific temper and research-based skills.

Course Outcomes: After completion of this Course, the learner will be able to

1. handle and get familiar with SOP's of instruments like potentiometer, conductivity meter, colorimeter and spectrophotometer.
2. understand the concept of complexometric titrations and factors enhancing selectivity of EDTA as a titrant.
3. apply the theory of FES to fertilizers analysis.
4. develop scientific temperament and research-based skills accomplish to encountered in the field of research

Elective course II Practical
Semester II

Instrumental Experiments

1. To determine the amount of Fe(II) and Fe(III) in a mixture using 1,10-phenanthroline spectrophotometrically.
2. Simultaneous determination of Cr(VI) and Mn(VII) in a mixture spectrophotometrically.
3. To determine the percentage composition of HCl and H_2SO_4 on weight basis in a mixture of two by

conductometric titration with NaOH and $BaCl_2$. To determine amount of potassium in the given sample of fertilizers using flame photometer by standard addition method.

Non-Instrumental Experiments

4. To determine the lead and tin content of a solder alloy by titration with EDTA.
5. To determine amount of Cu(II) present in the given solution containing a mixture of Cu(II) and Fe(II).
6. To determine the break through capacity of a cation exchange resin.
7. Estimation of a mixture of Hydrochloric acid and boric acid by acid base titration.

References

1. Quantitative Inorganic Analysis including Elementary Instrumental Analysis by ; A. I. Vogels, 3rd Ed. ELBS (1964)
2. Vogel's textbook of quantitative chemical analysis, Mendham, Denny, Barnes, Thomas, Pearson education, Sixth Ed.
3. Standard methods of chemical analysis ; F. J. Welcher, 1975
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5. "Standard methods of Chemical Analysis"; W. W. Scott, Vol. I, Van Nostrand Company, Inc.,1939.
6.,"Spectrophotometric Determination of Traces of Metals"; E.B.Sandell and H.Onishi, ,Part II,4th Ed. ,A Wiley Interscience Publication, New York,1978

PROGRAM(s): M.Sc-I		SEMESTER: II			
Course: Industrial Training/ Field Projects		Course Code: CHEM 512			
Teaching Scheme					Evaluation Scheme
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks-50)	Semester End Examination (Marks-50)
NA	08	–	04	50	50

Learning Objectives:

To provide students the opportunity to test their interest in a particular career before permanent commitments are made.

To develop skills in the application of theory to practical work situations. To develop skills and techniques directly applicable to their careers.

Course Outcomes:

At the end of the Course,

Understand the Organizational Structure of a company.

Develop work habits and attitudes necessary for job success (technical competence, professional attitude, organization skills etc.)

Develop written communication and technical report writing skills.

Structure of Assessment

Theory Examination Pattern:

A. Internal Assessment- 50%- 50 Marks per paper

Sr.No.	Evaluation Type	Marks
1	Written Objective/Short Answer Examination	25
2	Assignment/ Case study/ field visit report/ presentation/ project	25
	Total	50

B. External Examination- 50%-

50 Marks per paper Semester End Theory Examination:
Duration - These examinations shall be of two hours duration.

Theory question paper pattern:

1.There shall be total 05 questions each of 10 marks from all units.
2.All questions shall be compulsory with internal choice within the questions.

Paper Pattern: External Theory

Question	Options	Marks
Q.1	**2 out of 4**	**10**
Q.2	**2 out of 4**	**10**
Q.3	**2 out of 4**	**10**
Q.4	**2 out of 4**	**10**
Q.5	**5 out of 8**	**10**
	TOTAL	**50**

25 Marks per paper Semester
End Theory Examination:

1. Duration - These examinations shall be of **one hour** duration.

2. Theory question paper pattern:

   a. There shall be 02 questions each of 08 marks on each unit and one mix question for 09 marks

   b. All questions shall be compulsory with internal choice within the questions.

Question	Options	Marks
Q.1	2 out of 4	08
Q.2	2 out of 4	08
Q.3	3 out of 6	09
	TOTAL	25

Semester End Practical Examination

Particulars	Continuous assessment (CA)	Semester end external examination
Laboratorywork	15	15
Viva	05	05
Journal	05	05
Total	25	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.

Letter Grades and Grade Points

Semester GPA/ Program CGPA/Semester	% Marks	Letter Grade Result
9.00-10.00	90.0-100.0	O (Outstanding)
8.00<9.00	80.0<90.0	A+ (Excellent)
7.00<8.00	70.0<80.0	A (Very Good)
6.00<7.00	60.0<70.0	B+ (Good)
5.50<6.00	55.0<60.0	B (Above Average)
5.00<5.50	50.0<55.0	C (Average)
4.00<5.00	40.0<50.0	P (Pass)
Below 4.00		F (Fail)
Ab (Absent)		Absent

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DEPARTMENT OF CHEMISTRY
UNIVERSITY OF MUMBAI

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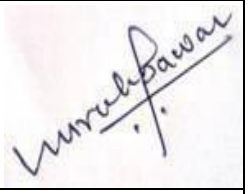
Dr. Suresh Damodar Pawar	Department of Chemistry University of Mumbai, Santacruz (E), Mumbai – 400098Email: sureshpawar@chemistry.mu.ac.in Mobile No.: 9869420362	
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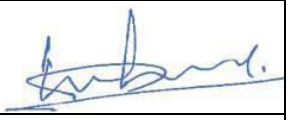
Dr. Santosh Waman Kulkarni	K.M. Agrawal College, Kalyan. Email – kulkarnisantosh17055@gmail.com Mobile – 9930897130	
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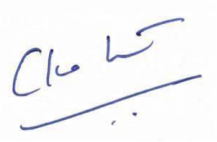
Dr. Chitralekha Kotian,	Royal College of Arts, Science and Commerce, Bhaktivedanta Swami Marg, Shrishti Complex, Mira Road,Thane Email: chitralekharewa1998@gmail.com Mobile: 9820362978	
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Appendix B

Justification for M.Sc. (Inorganic Chemistry)

1.	The necessity for starting the course:	M.Sc. (Inorganic Chemistry) course is necessary for those who seek to deepen their knowledge, specialize in a particular area, and pursue advanced careers in research, industry, academia, or other chemistry-related fields. It offers numerous opportunities for personal and professional growth, enabling you to make a positive impact on the world through scientific exploration and discovery.
2.	Whether the UGC has recommended the course:	Yes
3.	Whether all the courses have commenced from the academic year 2023-24	The course has already commenced from the academic year from 1967 and in the academic year 2022-23 it is restructured under NEP 2020
4.	The courses started by the University are self-financed, whether adequate number of eligible permanent faculties are available?:	This course is not self-financed. There are adequate PG recognized teachers available in the colleges
5.	To give details regarding the duration of the Course and is it possible to compress the course?:	The duration of the program is two years (4 semesters). It is not possible to compress the course. Under NEP 2020 students have option of exit at the end of first year with PG Diploma in Inorganic Chemistry.
6.	The intake capacity of each course and no. of admissions given in the current academic year:	The intake capacity of the program is variable as per college intake capacity. Number of admission for the academic year 2022-23 is variable as per college intake capacity.
7.	Opportunities of Employability / Employment available after undertaking these courses:	M.Sc. (Inorganic Chemistry) students have a wide range of employment opportunities across various sectors. The skills and knowledge acquired during their master's program make them well-equipped for diverse roles. Some of the common areas where M.Sc. (Inorganic Chemistry) students can find employment include; Research and Development (R&D), Pharmaceutical Industry, Chemical Manufacturing, Environmental and Analytical Chemistry, Quality Assurance and Control, Materials Science and Nanotechnology, Teaching and Academia, Healthcare and Clinical Research etc. The

		key to employability for M.Sc. (Inorganic Chemistry) students are to build a strong resume through internships, research projects, and networking. Additionally, staying updated with the latest advancements in the field and continuously improving their skills can enhance their competitiveness in the job market.

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