University of Mumbai

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Academic Authorities,
Meetings &Services (AAMS)
Room No. 128, M. G. Road, Fort,
Mumbai – 400 032.
Tel.022-68320033

Re- accredited with A ++ Grade (CGPA 3.65) by NAAC
Category- I University Status awarded by UGC

No. 2026/June/AAMS/C- 161/48209 Date: 5th June, 2026

CIRCULAR:-

Attention of all the Principals of the Affiliated Colleges, all Academic Heads of University Departments, the Directors of the Recognized Institutions/Centres, Director, Centre for Distance & Online Education, Director, Dharmaveer Anand Dighe Thane Sub-Campus, Co-ordinator, School of Engineering and Applied Sciences, Kalyan Sub-Campus, Director, Chitrakar Padmabhushan Dr.Dhananjay Keer Ratnagiri Sub-Campus, Director, Sindhudurg Sub-Campus, Principal, Vishwabhushan Bharatratna Dr. B. A. Ambedkar College, Ambadave, Ratnagiri and Principal, V.V. Dalvie College, Talere, Sindhudurg is invited to this office Circular No. AAMS/ICD/2025-26/ 37 of dated 27 May, 2025 relating to the NEP UG Syllabus.

They are hereby informed that the recommendations made by the **Board of Studies in Chemistry** at its meeting held on 28th March, 2026 and subsequently passed by the Board of Deans at its meeting held on 15th May, 2026 vide item No.1 (c) have been accepted by the Academic Council at its meeting held on 18th May, 2026 **vide** item No.6.3 (N). In accordance therewith syllabus of **B.Sc. (Chemistry) (Scheme - III) (Sem V & VI)** (NEP 2020) is introduced as per appendix with effect from the academic year 2026-27.

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

MUMBAI – 400 032
05th June, 2026

(Dr. Prasad Karande)
REGISTRAR

To

All the Principals of the Affiliated Colleges, all Academic Heads of Departments, the Directors of the Recognized Institutions/Centres, Director, Centre for Distance & Online Education, Director, Dharmaveer Anand Dighe Thane Sub-Campus, Co-ordinator, School of Engineering and Applied Sciences, Kalyan Sub-Campus, Director, Chitrakar Padmabhushan Dr.Dhananjay Keer Ratnagiri Sub-Campus, Director, Sindhudurg Sub-Campus, Principal, Vishwabhushan Bharatratna Dr. B. A. Ambedkar College, Ambadave, Ratnagiri and Principal, V.V. Dalvie College, Talere, Sindhudurg

AC./6.3 (N)/18/5/2026

Copy forwarded with Compliments for information to:-

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

AC – 18/05/2026
Item No. – 6.3 (N)

As Per NEP 2020

University of Mumbai

Syllabus for Major Vertical – 1, 4 & 6 (Scheme – III)		
Faulty of Science & Technology		
Board of Studies in Chemistry		
Name of the Programme – B.Sc. (Chemistry)		
U.G. Third Year Programme	**Exit Degree**	**B.Sc. (Chemistry)**
Semester		**V & VI**
From the Academic Year		**2026-27**

University of Mumbai

(As per NEP 2020)

Sr. No.	Heading	Particulars
1	Title of program O:____________________	B.Sc. (Chemistry)
2	Exit Degree	B.Sc. (Chemistry)
3	Scheme of Examination R: ___________	NEP 40% Internal 60% External, Semester End Examination Individual Passing in Internal and External Examination
4	Standards of Passing R: _____________	40%
5	Credit Structure R: SU- 525 E (III) R: SU- 525 F (III)	Attached herewith
6	Semesters	Sem. V & VI
7	Program Academic Level	5.5
8	Pattern	Semester
9	Status	New
10	To be implemented from Academic Year	2026-27

Sd/-
Sign of the BOS
Dr. Sunil Patil
Co-ordinator
BOS in Chemistry

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

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

B.Sc. (Chemistry)

Credit Structure (Sem. V & VI)

(B. Sc.)- Major & Minor

	R: SU- 525 E (III)										
Vertical		1	2		3	4	5	6			
Level	Semester	Major 1	Major 2 (Minor)	Major 3 (Minor)	OE	VSC, SEC (VSEC)	AEC, VEC, IKS	OJT, FP, CEP, CC,RP	Cum. Cr. / Sem.	Degree/ Cum. Cr.
		M1	M2	M3						
5.5	V	10+4 (**Mandatory + Elective**) Advanced Physical and Analytical Chemistry - Paper I (2) Advanced Analytical and Inorganic Chemistry – Paper II (2) Advanced Inorganic and Organic Chemistry – Paper III (2) Practicals in Advanced Chemistry – I (2) IKS in Chemistry (2) **Elective** Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals – I (2) Practicals in Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals – I (2	2	----	----	VSC (Practical) : 2 Techniques in Chemical Analysis and Synthesis (2)	----	CC:2 CEP:2	22	UG Degree 132
	R: SU- 525 F (III)										

	VI	14+4 **(Mandatory + Elective)** Advanced Physical and Analytical Chemistry - Paper IV (2) Advanced Analytical and Inorganic Chemistry – Paper V (2) Advanced Inorganic and Organic Chemistry – Paper VI (2) Practicals in Advanced Chemistry II (2) Practicals in Advanced Chemistry III (2) **Elective** Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals – II (2) Practicals in Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals – II (2)	----	----	----	----	----	OJT :4	22	
	Cum Cr.	52	18	8	10	8+2+2	6+4+2	8+6+4	132	
Exit option: Award of UG Degree in Major with 132 credits OR Continue with Major										

[Abbreviation - OE – Open Electives, VSC – Vocation Skill Course, SEC – Skill Enhancement Course, (VSEC), AEC – Ability Enhancement Course, VEC – Value Education Course, IKS – Indian Knowledge System, OJT – on Job Training, FP – Field Project, CEP – Community Engagement Project, CC – Co-Curricular, RP – Research Project]

[* 2 Credit IKS Major paper (Core Subject Specific Theory may be included in Sem III or V)]

Program Structure for Sem. V & VI
(NEP 2020)

Vertical No		Paper Title	Credits
Sem. V			
1.	Mandatory	1. Advanced Physical and Analytical Chemistry - Paper I	2
		2. Advanced Analytical and Inorganic Chemistry – Paper II	2
		3. Advanced Inorganic and Organic Chemistry – Paper III	2
		4. Practicals in Advanced Chemistry - I	2
		5. IKS in Chemistry	2
	Electives	1. Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals – I	2
		2. Practicals in Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals - I	2
2.	Minor (To be selected from other discipline)		4 (2+2)
4.	VSC (Practical)	Techniques in Chemical Analysis and Synthesis	2
6.	CEP (To be selected from CEP topic list)		2
		Credits	22
Sem. VI			
1.	Mandatory	1. Advanced Physical Chemistry – Paper IV	2
		2. Advanced Inorganic Chemistry – Paper V	2
		3. Advanced Organic Chemistry – Paper VI	2
		4. Advanced Analytical Chemistry – Paper VII	2
		5. Practicals in Advanced Chemistry - II	2
		6. Practicals in Advanced Chemistry - III	2
		7. Practicals in Advanced Chemistry - IV	2
	Electives	1. Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals – II	2
		2. Practicals in Drugs and Dyes / Heavy and Fine Chemicals/ Petrochemicals - II	2
6.	VI	OJT	4
		Credits	22
		Total Credits	44

Sem. - V

Sem. - V
Vertical – 1
Major
Mandatory
(2+2+2+2+2)

Syllabus
B.Sc. (Chemistry)
(Sem.- V)

Title of Paper: Advanced Physical and Analytical Chemistry - Paper I

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Advanced Physical & Analytical Chemistry I** introduces fundamental and applied concepts of physical chemistry and analytical chemistry with emphasis on molecular spectroscopy, thermodynamics of solutions, surface chemistry, polymer chemistry, and quality assurance in analytical processes. The course develops understanding of spectroscopic methods for molecular structure determination, thermodynamic relations governing colligative properties, adsorption phenomena, polymer characterization, and the role of quality control and sampling in reliable chemical analysis. The course emphasizes conceptual clarity, mathematical derivations, and numerical problem-solving relevant to academic, research, and industrial applications.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives** The course aims to: **COB1:** Introduce the fundamental principles of molecular spectroscopy, electromagnetic radiation, electromagnetic spectrum, and molecular energy levels. **COB2:** Develop understanding of rotational spectroscopy, including dipole moment, rigid rotor model, isotopic shift, applications, and numerical determination of bond length. **COB3:** Explain the principles of vibrational spectroscopy, including vibrational modes, Hooke's law, force constant, zero-point energy, IR spectra of simple molecules, and related numerical problems.	

	COB4: Provide knowledge of chemical thermodynamics, particularly colligative properties and their application in determining molar mass using elevation in boiling point and depression in freezing point. **COB5:** Introduce the concepts of surface chemistry and polymer chemistry, including adsorption phenomena, adsorption isotherms, classification of polymers, and determination of molecular mass using viscosity method. **COB6:** Develop understanding of quality assurance in analytical chemistry and sampling techniques, including GLP, GMP, certified reference materials, and methods of sampling solids and liquids.
8	**Course Outcomes:** **At the end of the course, students will be able to:** **CO1:** Explain the basic concepts of electromagnetic radiation, molecular energy levels, and spectroscopic transitions. **CO2:** Apply principles of rotational spectroscopy to determine molecular parameters such as bond length and interpret rotational spectra. **CO3:** Apply concepts of vibrational spectroscopy to calculate vibrational frequency, force constant, and interpret IR spectra of simple molecules. **CO4:** Apply thermodynamic relations to determine molar mass of non-volatile solutes using elevation in boiling point and depression in freezing point methods. **CO5:** Explain adsorption phenomena, apply Langmuir and BET isotherms, classify polymers, and determine molecular weight using viscosity method. **CO6:** Explain principles of quality control, GLP, GMP, and apply appropriate sampling methods for analysis of solids and liquids.
9	**Modules**:
	Module 1
	1.1. Molecular Spectroscopy (10 Hours) 1.1.1 Introduction: Definition of Spectroscopy, Electromagnetic radiation, Inter-conversion of units, Electromagnetic Spectrum, Molecular energy levels 1.1.2. Rotational Spectroscopy: Dipole moment and Polarisation of bond, Permanent dipole moment and induced dipole moment. Definition and conditions of rotational spectra, Bond length of simple diatomic molecule (rigid rotor). Rotational spectrum of a diatomic molecule, Isotopic shift in rotational spectra, limitations of rotational spectra, applications of rotational spectra. (Numerical expected) 1.1.3. Vibrational Spectrum: Definition and conditions of vibrational spectra, modes of vibrations, Hookes law, vibrational frequency, force constant, zero-point energy, vibrational spectra of simple harmonic oscillator. Infrared spectra of simple molecules like H_2O and CO_2, Applications of vibrational spectroscopy. (Numerical expected)

1.2. Chemical Thermodynamics: (5 Hours)
1.2.1. Colligative Properties:
Vapour pressure and relative lowering of vapour pressure, (Numerical Expected)
1.2.2. Solution of Solid in Liquid:
1.2.2.1. Elevation in boiling point of a solution:
Thermodynamic derivation relating elevation in boiling point of the solution and molar mass of non-volatile solute. (Numerical Expected)
1.2.2.2. Depression in freezing point of a solution:
Thermodynamic derivation relating the depression in the freezing point of a solution and molar mass of the non-volatile solute, Rast Method. (Numerical expected)

Module 2

2.1. Surface Chemistry: (4 Hours)
2.1.1. Adsorption: Physical and Chemical Adsorption, types of adsorption isotherms, Langmuir's adsorption isotherm (Postulates and derivations expected). B.E.T. equation for multilayer adsorption, (derivation not expected), Determination of surface area of an adsorbent using B.E.T. equation. ((Numerical expected)

2.2. Polymer chemistry: (3 Hours)
2.2.1. Recapitulations: Basic terms of polymer
2.2.2. Classification of polymer: Classification based on Source, Thermal response, physical properties
2.2.3. Method of determination molar masses of polymer: Viscosity method using Ostwald Viscometer (derivation and numerical expected),
2.2.4. Light Emitting Polymer: Introduction, Characteristics, Method of preparation and applications.

2.3 Quality in Analytical Chemistry (3 Hours)
2.3.1 Concepts of Quality, Quality Control and Quality Assurance
2.3.2 Introduction to Good laboratory Practices(GLP) and Good manufacturing Practices (GMP)
2.3.3 Chemical Standards and Certified Reference Materials: Importance in chemical analysis
2.3.4 Quality of material: Various grades of laboratory reagents

2.4 Sampling (5 Hours)
2.4.1 Importance of sampling, Terms involved in sampling, Types of sampling, Difficulties encountered in sampling
2.4.2 Sampling of solids: Sample size, bulk ratio, size to weight ratio, multistage and sequential sampling, size reduction methods.
2.4.3 Sampling of compact solids: equipment's and methods of sampling of compact solids
2.4.4 Sampling of particulate solids: methods and equipment's used for sampling of particulate solids.
2.4.5 Sampling of liquids: Homogeneous and heterogeneous, Static and flowing liquids

10	**Reference Books:** **Module 1and 2 : Physical Chemistry** 1 K L Kapoor, A Textbook of Physical Chemistry - Dynamics of Chemical Reactions, Statistical Thermodynamics, Macromolecules and Irreversible Processes by, McGraw Hill Education. Volume 5 , 3rd Edition, 2014 2 Fred W Bilmeyer, Textbook of Polymer Science, John Wiley & Sons (Asia) Ple. Ltd., Singapore, 2007. 3 Colin N Banwell and Elaine M McCash, Fundamental of Molecular Spectroscopy, Tata McGraw Hill Publishing Co. Ltd. New Delhi, 4th Edn. 2008. 4 B.R. Puri, L.R. Sharma, M.S. Pathania, Principles of Physical Chemistry, Vishal Publishing Company, 2008. 5 Ira Levine, Physical Chemistry, Tata McGraw Hill Publishing Co.Ltd. 5th Edition, 2002 6 P.W. Atkins, The Elements of Physical Chemistry, Oxford University Press Oxford. 2nd Edition, 2003 7 P.C. Rakshit, Physical Chemistry, Sarat Book Distributors, Kolkata. 6th Edition, 2001, 8 R.J. Silbey, & R.A. Alberty, Physical Chemistry, John Wiley & Sons, Inc, 3rd edition , part I, 2001. 9 G.M. Barrow, Physical Chemistry, Tata McGraw Hill Publishing Co. Ltd. New Delhi. 6th Edition, 2025 10 S. Glasstone, Thermodynamics for Chemists, Affiliated East- West Press, New Delhi, 1964. 11 V.R. Gowariker, N.V. Viswanathan, Jayadev Sreedhar, Polymer Science, , New Age International (P) Ltd., Publishers, 2005. **Module 2: Analytical Chemistry** 1 E Prichard, Quality in the analytical chemistry laboratory, John Wiley and sons N.Y 1997 2 W Funk, V Dammann, G. Donnevert, Quality assurance in analytical Chemistry, VCH Weinheim 1995. 3 Douglas A. Skoog, Donald M. West, F. James Holler, and Stanley R. Crouch, Fundamentals of Analytical Chemistry, 7th edition , 1995 4 Gary D. Christian, Purnendu K. Dasgupta, and Kevin A. Schug, Analytical Chemistry, 5th edition, 2013 5 Francis F.Pitard and Maxime A.Pitard, Theory of sampling and sampling practice by CRC Press, 4th Edition, 2025 …………………………………………………………………………………….	
11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Advanced Analytical and Inorganic Chemistry – Paper II

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Advanced Analytical & Inorganic Chemistry I** provides a detailed understanding of classical analytical techniques and fundamental inorganic chemistry concepts essential for quantitative analysis and structural interpretation. The course covers redox, precipitation and complexometric titrations, separation techniques such as solvent extraction and solid phase extraction, and introduces concepts of molecular symmetry, chemical bonding, and solid-state chemistry. Emphasis is placed on theoretical principles, numerical problem-solving, and applications relevant to laboratory analysis, research, and industry.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop understanding of classical quantitative analytical methods including redox, precipitation and complexometric titrations and their applications. **COB2:** Explain principles of solvent extraction and solid phase extraction for separation and determination of metal ions. **COB3:** Develop understanding of selectivity, stability constants and role of indicators in complexometric titration. **COB4:** Explain concepts of molecular symmetry, symmetry elements and point groups relevant to chemical structure.	

	COB5: Develop understanding of bonding in homonuclear and heteronuclear diatomic molecules using theoretical models. **COB6:** Explain structural aspects of solid state chemistry including crystal systems, packing efficiency and density relationships.
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Calculate equivalence points and electrode potentials in redox titrations and select appropriate redox indicators. **CO2:** Apply principles of precipitation titration and complexometric titration using EDTA for quantitative analysis of metal ions. **CO3:** Explain factors affecting solvent extraction and solid phase extraction and compare their analytical applications. **CO4:** Identify symmetry elements, symmetry operations and assign point groups to simple molecules. **CO5:** Explain bonding characteristics of heteronuclear diatomic molecules such as CO, NO and HCl. **CO6:** Solve numerical problems related to crystal structure, packing efficiency and density of unit cells.
9	**Modules**:
	Module 1
	1.1 Classical Methods (8 Hours) 1.1.1 Redox titration (Numerical and word problems expected) 1.1.1.1 Introduction to Redox titration 1.1.1.2 Construction of the titration curves and calculation of Esystem in aqueous medium for one electron system (Fe^{2+} and Ce^{4+}) 1.1.1.3 i) Theory of redox indicators ii) Criteria for selection of an indicator iii) Use of ferroin as redox indicators 1.1.2 Precipitation Titration 1.1.2.1 Introduction to Precipitation titration –Solubility product and common ion effect 1.1.2.2 Methods of Precipitation Titration i) Mohr's Method (direct method) ii) Fajans' Method (adsorption indicator) 1.1.3 Complexometric titration (EDTA with divalent metal ion) 1.1.3.1 Introduction to Complexometric titration 1.1.3.2 i) Absolute and conditional formation constants of metal- EDTA complexes ii) Factors enhancing selectivity of EDTA as a titrant with examples. iii) Methods to increase the selectivity of EDTA as a titrant in complexometric titration

1.1.3.3 Types of EDTA titrations.

i) Direct Titrations

ii) Back Titrations

1.1.3.4 Metallochromic indicators (Metal- Ion indicators): Introduction and requirements

1.2 Methods of Separation (7 Hours)

1.2.1 Solvent extraction:

1.2.1.1 Factors affecting solvent extraction

i) Chelation

ii) Ion pair formation

iii) Solvation

iv) Synergistic extraction

1.2.1.2 Technique of extraction

i) Continuous Extraction- Soxhlet extraction

ii) Counter current extraction - Craigs counter current extraction

1.2.1.3 i) Applications of solvent extraction

ii) Advantages and Limitations of solvent extraction

1.2.2 Solid Phase Extraction (SPE)

1.2.2.1 Principle and Process of Solid Phase Extraction

1.2.2.2 Applications:

i) Determination of copper as the diethyl dithiocarbamate complex.

ii) Determination of Fe(III) with 8-hydroxyquinoline

iii) Determination of nickel by synergistic extraction.

1.2.2.3 Advantages and Limitations of Solid Phase Extraction

1.2.2.4 Comparison of solvent extraction and solid phase extraction

Module 2:

2.1 Molecular symmetry (5 Hours)

2.1.1 Introduction and Importance of Symmetry in Chemistry.

2.1.2 Symmetry elements and Symmetry operations.

2.1.3 Concept of a Point Group with illustrations using the following point groups : (i) $C_{\infty V}$ (ii) $D_{\infty h}$ (iii) C_{2V} (iv) C_{3v} (v)C_{2h} and (vi)D_{3h}

2.2 Chemical Bonding (5 Hours)

2.2.1 Comparison between homonuclear and heteronuclear diatomic molecules.

2.2.2 Heteronuclear diatomic molecules like CO, NO and HCl

2.3 Solid state (5 Hours)

2.3.1 Explanation of terms viz. crystal lattice, lattice point, unit cell and lattice constants.

2.3.2 Closest packing of rigid spheres (hcp, ccp), packing density in simple cubic and bcc lattices.

2.3.3 Relationship between density, radius of unit cell and lattice parameters. (Numerical problems expected)

10 **Reference Books:**

Module 1:Analytical Chemistry

1 Gary D. Christian, Purnendu K. Dasgupta, and Kevin A. Schug, Analytical Chemistry, 5th edition, 2013
2 Skoog, D. A.; Holler, F. J.; Crouch, S. R. Principles of Instrumental Analysis, Cengage Learning: USA, 6th edition 2014
3 Skoog, D. A.; West, D. M.; Holler, F. J.; Crouch, S. R. Fundamentals of Analytical Chemistry,.;Brooks/Cole: USA, 9th edition, 2014.
4 S M Khopkar, Basic Concepts of Analytical Chemistry, New Age International (p) Limited, 2008
5 Sharma, B. K. Instrumental Methods of Chemical Analysis, Goel Publishing House: Meerut, 24th ed. 2012
6 Christian, G. D. Analytical Chemistry, John Wiley & Sons: New York, 6th ed. 2004.
7 Willard, H. H.; Merritt, L. L.; Dean, J. A.; Settle, F. A. Instrumental Methods of Analysis, CBS Publishers: New Delhi, 7th edition, 2004.
8 J Marcus and A. S. Kertes, Solvent extraction and ion exchange, Wiley INC 1969

Module 2: Inorganic Chemistry

Molecular symmetry

1 Gary Wulfsberg, Inorganic chemistry, Viva Books Pvt. Ltd., 2002.
2 J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, Inorganic chemistry-Principles of structure and reactivity, 4th edition, Pearson, 2006.
3 D. F. Shriver and P. W. Atkins, Inorganic chemistry, 3rd edition, Oxford University Press1999.
4 R. L. Carter, Molecular symmetry and group theory, John Wiley & Sons, New York,1998.
5 S. F. A. Kettle, Symmetry and structure-Readable Group Theory for Chemists, 3rd Ed.,John Wiley & Sons, Inc., 2000.
6 K. V. Reddy, Symmetry and Spectroscopy of molecules, New Age International (P) Ltd. 2nd Edition, 2009.
7 A. S. Kunju and G. Krishnan, Group theory and its application in chemistry, PHLLearning Pvt. Ltd., 2012.
8 F. A. Cotton, Chemical applications of group theory, Wiley Eastern Ltd., 1989.
9 Per Jensen and Philip R. Bunker, Fundamentals of Molecular Symmetry, Series in Chemical Physics, CRC Press 2018
10 J. S. Ogden, Introduction to Molecular Symmetry, Oxford University Press
11 Derek W. Smith, Molecular orbital theory in inorganic chemistry Publisher: Cambridge University Press, 2001
12 C. J. Ballhausen, Carl Johan Ballhausen, Harry B. Gray Molecular Orbital Theory: An Introductory Lecture Note and Reprint Volume Frontiers in chemistry PublisherW.A. Benjamin, 1965.
13 J.M. Hollas, Symmetry in Molecules, Chapman and Hall Ltd., 1972.

Chemical Bonding

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 J. Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry–Principles of Structure and Reactivity, 4th Ed., Harper Collins, 1993.
4 G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004
5 C. J. Ballhausen and H. B. Gray, Molecular orbital Theory, McGraw-Hill, New York, 1965.
6 C, M, Day and Joel Selbin, Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 1985.
7 F. A. Cotton and R. A. Walton, Multiple Bonds between Metal Atoms, 2nd edition, Claranden Press, Oxford, 1993.

Solid state

1 U. Muller, Inorganic structural chemistry, 2nd edition, Wiley 2007.
2 A. F. Wells, Structural inorganic chemistry, 5th edition, Clarendon press, Oxford 1984.
3 A. R. West, Solid state chemistry and its chemical applications, 2nd edition, Wiley 2014.
4 L. E. Smart and E. A. Moore, Solid State Chemistry-An introduction, 3rd edition, Taylor and Francis, 2005.
5 H. V. Keer, Principles of Solid State, Wiley Eastern Ltd., 1993.
6 D.K.Chakraborty, Solid State Chemistry, New Age International publishers, 1996
7 C. N. R. Rao and J. Gopalakrishnan, New directions in solid state chemistry, Cambridge University Press, 1997
8 T.R.N Kutty and J.A.K Tareen, Fundamentals of Crystal Chemistry, Universities Press Ltd.(India), 2001
9 V. Raghavan, Materials Science and Engineering, A First Course, Prentice-Hall of India Private Limited, New Delhi, 5th edition 2005
10 Lesley E. Smart, Elaine A. Moore Solid State Chemistry: An Introduction, 2nd Edition CRC Press, 2020
11 L. V. Azaroff, Introduction to Solids, Tata-McGraw Hill Book Co. New Delhi, 1977.
12 N. B. Hanny Solid State Chemistry, Prentice Hall of India Pvt. Ltd. New Delhi, 1976

11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Advanced Inorganic and Organic Chemistry – Paper III

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Advanced Inorganic and Organic Chemistry – Paper III** provides comprehensive knowledge of inner transition elements and advanced organic chemistry concepts relevant to modern chemical research and applications. The course covers the chemistry of lanthanides and actinides, systematic IUPAC nomenclature of complex organic compounds, principles of green chemistry and sustainable synthesis, and fundamental concepts of pericyclic reactions, photochemistry, stereochemistry, and natural products. Emphasis is placed on understanding reaction mechanisms, structural features, stereochemical outcomes, and environmentally responsible chemical processes.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop understanding of electronic configuration, properties and applications of lanthanides and actinides. **COB2:** Explain IUPAC nomenclature rules for bicyclic compounds, biphenyls and cumulenes. **COB3:** Develop understanding of principles of green chemistry including atom economy, E-factor and environmentally benign synthetic methods. **COB4:** Explain fundamental concepts of pericyclic and photochemical reactions including their classification and mechanisms.	

	COB5: Develop understanding of stereochemical concepts such as chirality, stereoselectivity and stereospecific reactions. **COB6:** Explain structural features, synthesis and significance of natural products such as terpenoids and alkaloids.
8	**Course Outcomes**: At the end of the course, students will be able to: **CO1:** Describe electronic configuration, oxidation states and important properties of lanthanides and actinides. **CO2:** Assign systematic IUPAC names to bicyclic compounds, biphenyls and cumulenes containing up to two substituents. **CO3:** Calculate atom economy and E-factor and explain advantages of green synthetic approaches such as microwave and ultrasound assisted synthesis. **CO4:** Explain types of pericyclic reactions and photochemical reactions such as electrocyclic reactions, cycloadditions, Norrish reactions and di-π methane rearrangement. **CO5:** Interpret stereochemical outcomes of elimination and addition reactions including enantioselectivity and diastereoselectivity. **CO6:** Explain structural determination and synthesis of natural products such as citral and nicotine and discuss their chemical significance.
9	**Modules**:-
	Module 1:
	1.1 Inner transition elements (8 Hours) 1.1.1 Introduction: Position in periodic table and electronic configuration of lanthanides and actinides. 1.1.2 Chemistry of Lanthanides with reference to (i) lanthanide contraction and its consequences(ii) Oxidation states (iii) Ability to form complexes (iv) Magnetic and spectral properties. 1.1.2 Applications of lanthanides **1.2 IUPAC Nomenclature (4 Hours)** IUPAC Systematic nomenclature of the following classes of compounds (including compounds up to two substituents / functional groups): • Bicyclic compounds – spiro, fused and bridged (up to 11 carbon atoms) – saturated and unsaturated compounds. • Biphenyls • Cummulenes with up to 3 double bonds.

1.3 Green Chemistry & Green Synthesis (3 Hours)

1.3.1 Introduction: Twelve principles of Green Chemistry, concept of Atom Economy and E-factor with their significance (Numerical problems expected)

1.3.2 Green Approach in Chemical Synthesis

i) Reagents: dimethyl carbonate

ii) Starting materials: D-glucose

iii) Solvents: supercritical CO_2

iv) Catalysts: Biocatalysts

1.3.3 Modern Green Techniques in Organic Synthesis:

i) Microwave-assisted Organic Synthesis (Using organic solvents and in solid state)

ii) Ultrasound in Organic Synthesis

Module 2:

2.1 Pericyclic Reactions and Photochemistry (5 Hours)

2.1.1 Definition, general characteristics and classification of pericyclic reactions

2.1.2 Electro cyclic reactions (ring opening and ring closing), cycloaddition reactions, sigma tropic Rearrangement, group transfer reactions, cheletropic reaction (definition and one example of each type)

2.1.3 Definition and general characteristics of photochemical reactions, Difference between thermal and photochemical reactions

2.1.4 Photochemical reactions of olefins - photochemical rearrangement of 1,4- dienes (di- π methane), Photochemistry of carbonyl compounds - Norrish I, Norrish II cleavages.

2.2. Stereochemistry (5 Hours)

2.2.1 Molecular chirality & Chirality of compounds without a stereo genic center: Cummulenes and Biphenyls.

2.2.2 Stereoselectivity and stereospecificity: Idea of enantioselectivity (*ee*) and diastereoselectivity (*de*)

2.2.3 Stereochemistry of –

i) Elimination reactions: E2–Base induced dehydrohalogenation of 1-bromo-1,2-diphenylpropane.

ii) Addition reactions to olefins:

a. Bromination (electrophilic anti addition)

b. Syn hydroxylation with OsO_4 and $KMnO_4$

c. Epoxidation followed by hydrolysis

2.3 Natural Products (5 Hours)

2.3.1 Terpenoids: Introduction, Classification, Isoprene rule, special isoprene rule and the gem-dialkyl rule.

2.3.2 Citral:

i) Structural determination of citral.

ii) Synthesis of citral from methyl heptenone.

2.3.3 Alkaloids: Introduction, Classification and occurrence.

2.3.4 Nicotine:

i) Structural determination of nicotine. (Pinner’s work included).

ii) Synthesis of nicotine from nicotinic acid.

iii) Harmful effects of nicotine.

10 Reference Books:

Module 1 : Inorganic and Organic Chemistry

Inorganic Chemistry

Inner transition elements

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

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

5 H. J. Arniker, Essentials of nuclear chemistry, 4^{th} edition; NAIL publishers 2011.

6 G.Friedlander, J.W.Kennedy, E.S.Macias and J.M.Miller; Nuclear and Radiochemistry, John Wiley and Sons, 1981.

7 Haissinsky, Nuclear Chemistry and its Applications, Addison Wissely, 1962.

8 A.V.R.Reddy, D.D.Sood, Nuclear Chemistry, IANCAS Publishers, 2010

Organic Chemistry

IUPAC Nomenclature

1 Henri A. Favre and Warren H. Powell, Nomenclature of Organic Chemistry: IUPAC recommendations and preferred Names , RSC publication. 2013.

2 S. C. Pal, IUPAC nomenclature Narosa Publishing House pvt. Ltd. Second Edition, 2016

3 Jonathan Clayden, Nick Greeves, and Stuart Warren , Organic Chemistry, Oxford University Press, second edition, 2012.

4 G.J. Leigh, H.A. Favre, W.V. Metanomski, Principles of Chemical Nomenclature A Guide To IUPAC Recommendations, Blackweil Science Ltd, 1998.

Green Chemistry & Green Synthesis

1 Mike Lancaster, Green Chemistry an introductory text RSC Publication.Third Edition, 2016

2 V. K. Ahluwalia, Green Chemistry, Narosa Publishing House Pvt. Ltd. 2012

3 V. K. Ahluwalia, M. Kidwai, New trends in Green Chemistry, Klumer Academic publisher, 2004

4 V. Kumar, An Introduction to Green Chemistry, Vishal Publishing Co.,2013

5 Francis Carey, Organic Chemistry, Tata Mc Graw Hill, 10^{th} Edition, 2017

6 Carey and Sundberg, Advanced Organic Chemistry Springer, 5^{th} Edition,2007

Module 2 : Organic Chemistry

Pericyclic Reactions and Photochemistry

1 Jagdamba Singh and Jaya Singh, Photochemistry and Pericyclic Reactions, New Age International Publishers, 2005

2 Jonathan Clayden, Nick Greeves, and Stuart Warren , Organic Chemistry, Oxford University Press, second edition, 2012.

3 G.R. Chatwal, Organic Photochemistry and Pericyclic Reaction Himalaya Publishing House, 1998

4 R.T. Morrison, R. N. Boyd & S. K. Bhattacharjee, Organic Chemistry, Pearson, 7^{th} Edition,2010

5 John Mc Murry.Organic Chemistry, Cole Cengage Learning, 8^{th} edition, 2012

	Stereochemistry 1 E. L. Eliel, Stereochemistry of Carbon Compounds, Tata McGraw Hill, 1962. 2 P. S. Kalsi, Stereochemistry Conformation and Mechanism New Age International, 11^{th} Edition, 2022 3 D. Nasipuri, Stereochemistry of Organic Compounds: Principles and Applications New Age International, 4^{th} Edition, 2020 **Natural Products** 1 O. P. Agarwal, Organic Chemistry of Natural Products Krishna Prakashan Media, Volume I, 2015 2 O. P. Agarwal, Organic Chemistry of Natural Products Krishna Prakashan Media, Volume II,2023 3 I. L. Finar, Organic Chemistry, Pearson Education / Longman, Volume II, 1964 4 S. V. Bhat, B. A. Nagasampagi and M. Sivakumar, Chemistry of Natural Products, Narosa Publishing House, 2005 ……………………………………………………………………………….	
11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Practicals in Advanced Chemistry - I

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Practicals in Advanced Chemistry – I** provides hands-on training in physical and inorganic chemistry techniques, instrumental methods, and inorganic synthesis. The course develops laboratory skills for determination of molecular weight, reaction kinetics, solubility product, adsorption phenomena, and quantitative estimation using potentiometric, conductometric, pH-metric and colorimetric methods. It also includes synthesis of coordination compounds and volumetric analysis using redox and complexometric titrations. Emphasis is placed on accuracy in experimentation, interpretation of results, scientific reporting, and application of good laboratory practices relevant to academic research and chemical industries.
2	**Vertical :**	Major
3	**Type :**	Practicals
4	**Credit**:	2 credits
5	**Hours Allotted :**	60 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop practical skills in determination of physicochemical parameters such as molecular weight, rate constant and solubility product. **COB2:** Familiarize students with instrumental analytical techniques such as potentiometry, conductometry, pH-metry and colorimetry. **COB3:** Understand principles of adsorption and reaction kinetics through experimental methods and graphical interpretation of data. **COB4:** Develop competence in synthesis and characterization of coordination compounds.	

	COB5: Provide training in volumetric analysis including redox and complexometric titrations using appropriate indicators. **COB6:** Inculcate good laboratory practices, accuracy in measurement and scientific reporting.
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Determine molecular weight of compounds and calculate reaction rate constants using experimental data and graphical methods. **CO2:** Calculate solubility and solubility product using potentiometric measurements and concentration cell data. **CO3:** Determine velocity constant of hydrolysis reaction using conductometric method and interpret experimental results. **CO4:** Estimate concentration of analytes using pH-metric and colorimetric methods with appropriate calculations. **CO5:** Synthesize coordination compounds and calculate percentage yield from experimental data. **CO6:** Estimate metal ion concentration using redox and complexometric titration methods and report results with appropriate calculations and accuracy.
9	**Modules**:-
	Module 1:
	Non-Instrumental Experiments: 1) To determine the molecular weight of compound by Rast Method. 2) To interpret the order of reaction graphically from the given experimental data and calculate the specific rate constant. **Instrumental Experiments:** 1) To determine the Solubility product and solubility of AgCl potentiometrically using concentration cell 2) To determine the velocity constant of alkaline hydrolysis of ethyl acetate by conductometric method. 3) To find out the strength of sodium carbonate solution by titrating it against HCl pH metrically. 4) To study the adsorption of certain dyes such as methyl violet, picric acid or malachite on charcoal colorimetrically.
	Module 2:

	2.1 Inorganic Preparations and Estimations 1) Preparation of potassium trioxalato chromate (III) complex 2) Preparation of bis acetylacetonato Copper (II) 3) Preparation of Potassium dioxalatocuprate (II), $K_2[Cu(C_2O_4)_2]$ 4) Complexometric titration of Al^{3+} with Xylenol Orange (Back Titration) 5) Estimate the amount of iron present in the given ferric alum solution by using dichromate solution and diphenyl amine indicator 6) Estimation of Nickel using EDTA (Complexometric) using Murexide indicator
10	**Reference Books:** **Module 1: Physical Chemistry** 1 A. M. James and F.E. Prichard, Practical Physical Chemistry Longman publication, 3rd edition,1974 2 R.C. Das and B. Behra, Experiments in Physical Chemistry, Tata Mc Graw Hill, 1983 3 J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2006 4 J. N. Gurtu and R Kapoor, Advanced Experimental Chemistry., S. Chand and Co. Vol I, 1980 5 V.D.Athawale, Experimental Physical Chemistry , New Age International (P) Limited, 2001 6 B. D. Khosla, V. C. Garg and A. Gulati, Senior Practical Physical Chemistry, R Chand and Co.. 2011 **Module 2: Inorganic Chemistry** 1 A. I. Vogel, Quantitative Inorganic Analysis, Longman Scientific and Technical, 5th Edn, 1989. 2 J. D. Woollins, Inorganic Experiments. John Wiley and Sons, 2010 3 W. G. Palmer, Experimental Inorganic Chemistry, Cambridge University Press, 1954 4 G. Raj, Advanced Practical Inorganic Chemistry. Goel Publication, 2010 5 J. E. House, Inorganic chemistry, Academic press, 2nd edition, 2013. 6 G. N. Mukherjee, Advanced Experiments in Inorganic Chemistry., U. N. Dhur & Sons Pvt. Ltd. 2010. 7 W. Conard Fernelius, Inorganic syntheses, Mc-Graw Hill, Vol.II, 1946. 8 G. Pass and H. Sutcliffe, Practical Inorganic Chemistry- Preparation, reactions and instrumental methods, Springer, 2nd edition.1974. 9 G. Marr and B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold Company 1972. 10 G. Christian, Analytical Chemistry, John Wiley, New York 4th edition 1986. ………………………………………………………………………………………

11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

IKS
(2)

Title of Paper: IKS in Chemistry

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**IKS in Chemistry** introduces the scientific contributions of the Indian Knowledge System (IKS) in the development of chemical sciences, medicine, materials and metallurgy. The course explores ancient Indian concepts of matter, historical evolution of chemical knowledge, traditional laboratory apparatus, metallurgical advancements, glass making technology and perfumery practices. It highlights the relevance of classical knowledge to modern chemistry and promotes appreciation of indigenous scientific heritage and sustainable practices.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Introduce the concept of Indian Knowledge System (IKS) and its historical development in chemistry from ancient to medieval periods, including contributions of Indian scholars. **COB2:** Develop understanding of ancient Indian concepts of matter and atomic theory and examine their relevance in comparison with modern chemical concepts. **COB3:** Provide knowledge of traditional chemical practices in Ayurveda, including apparatus, purification of mercury, and properties and uses of important minerals and medicinal substances. **COB4:** Explain the scientific basis of metallurgy in ancient India, including development of copper, iron, wootz steel, and zinc metallurgy. **COB5:** Introduce the principles and techniques involved in ancient Indian glass making technology, supported by archaeological and physico-chemical evidence.	

	COB6: Provide knowledge of ancient Indian perfumery (*Gandhashastra*), classification of aromatic substances, and traditional methods of extraction such as hydrodistillation.
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Explain the concept of Indian Knowledge System and describe the historical development of chemistry and contributions of Indian scholars. **CO2:** Compare ancient Indian ideas of atomic structure and constitution of matter with modern chemical theories. **CO3:** Describe traditional Ayurvedic chemical practices, apparatus, purification processes, and properties of important medicinal minerals. **CO4:** Explain the development and scientific principles of ancient Indian metallurgy, including iron technology, wootz steel, and zinc production. **CO5:** Describe traditional glass making techniques and interpret archaeological evidence of glass technology in ancient India. **CO6:** Explain the chemistry and techniques of traditional perfumery, including classification of aromatic substances and hydrodistillation methods such as the *Deg-Bhapka process.*
9	**Modules**:
	Module 1:
	1.1 Ancient Indian Landscape of Chemistry (5 Hours) 1.1.1 Concept of IKS: Introduction, Definition of IKS, Need to study IKS in current times. 1.1.2 Developmental history in the field of chemistry – five eras of developments (i) The pre-vedic period upto 1500 BCE, including the Harappan period, (ii) The vedic and ayurvedic period upto 700 CE (iii) The transitional period from 700 CE to 1100 CE (iv) The tantric period from 700 CE to 1300 CE and (v) the 'iatro-chemical period' from 1300 CE to 1600 CE. 1.1.3 Ancient atomic theory – constitution and properties of matter; contribution of Maharshi Kapila, Maharshi Kanada - its relevance with modern atomic theory. 1.1.4 Indian Scholars in the field of chemistry: Nagarjuna – Metallurgy, Vagbhata – Rasa Shastra, Sharangdhar – Medicine and Dosage Form, Somdev – Contribution in Chemistry, Acharya P.C. Ray – Contribution in Chemistry, Sir Har Govind Khurana – Contribution in Bio-Chemistry, Shanti Swarup Bhatnagar – Physical Chemistry, C.N.R. Rao – Solid State Chemistry and Nanomaterials **1.2 Indian Knowledge System in Medicine and Ayurveda (10 Hours)**

	1.2.1 Different apparatus used in ancient Indian Chemistry for preparing and purification of medicines - *Dola Yantram, Damaru Yantram, Palika Yantram, Valuka Yantram, Ghat Yantram, Patana Yantram, Khalva Yantram, Udukhala Yantram.* 1.2.2 Purification and importance of mercury as medicine in Ayurveda (eight steps) 1.2.3 Sources, Properties and Uses of *Lavana Shataka*, *Kshara panchak*, *Amlapanchaka*, *Panchaka Vaikranta* (Tourmaline), *Makashika* (Chalcopyrite), *Sasyka* (Blue Vitriol), *Vimala* (Cubic Sulphide of Iron), *Rasaka* (*Jasada* Zinc), *Gandhaka* (Sulphur), *Gairika* (Hematite), *Kasisa* (Green Vitriol), *Kankshi* (Alum).
	Module 2:
	2.1 Materials and Metallurgy in Ancient India (10 Hours) 2.1.1 Introduction to IKS and scientific basis of traditional materials knowledge, Early metallurgy in the Indus Valley Civilization. 2.1.2 Evolution of copper technology (Chalcolithic Period - 3000–1500 BCE with Ahar-Banas Culture, Malwa Culture, Jorwe Culture). Uses of metals in *Rigveda* - Gold (*Hiranya*), Copper/Bronze (*Ayas*) and *Atharvaveda* - Copper/Bronze (*Ayas*), Silver (*Rajata*). 2.1.3 Iron metallurgy: bloomery process, reduction reactions, slag chemistry, Corrosion resistance of the Iron Pillar of Delhi. 2.1.4 Ancient India's advanced metallurgical technologies :- A Tale of Wootz Steel and Zinc production at Zawar Mines. **2.2 Ancient Indian Glass Making Technology (03Hours)** 2.2.1 Literary and archaeological evidence of glass objects: (Archaeological evidence related to *Hastinapur* and *Kaundinyapur*) 2.2.2 Physico-chemical analysis of Indian glass specimens found at *Taxila* and *Rajghat* 2.2.3 Glass furnace (e.g. Glass making kiln at *Nevasa*), glass pots and muffles for making glass objects and glass moulding technique **2.3 Ancient Indian Perfumery (02 Hours)** 2.3.1 Introduction to *Gandhshastra*, Classification of aromatic substances 2.3.2 *Degh-Bhapka* method of hydrodistillation, A case study of Kannauj: The "Perfume Capital of India, The Chemistry of Mitti Attar.
10	**Reference Books** **Indian Knowledge System in Medicine and Ayurveda** 1 Dr Vilas A. Dole, Dr Prakash Paranjpe, A textbook of Rasashastra, Chaukhamba Sanskrit Pratishthan, 2004 2 Ravindra Angadi, Rasa Tarangini of Sri Sadananda Sarma, Chaukhamba Surbharati Prakashan, pg. 548, 2015, 3 Bhudeb Mookerjee, Rasa Jala Nidhi, vol 1: Initiation, Mercury and Laboratory, 1938, https://archive.org/details/in.ernet.dli.2015.382588/mode/2up **Materials and Metallurgy in Ancient India** 1 R. Balasubramaniam, The saga of Indian cannons, Aryan Books International, New Delhi, 2008,

2 P. C. Ray, History of Hindu Chemistry, The Benngal Chemicals and Pharmaceutical works Ltd. 1903, https://archive.org/details/in.ernet.dli.2015.39319/page/n3/mode/2up
3 D. P. Agrawal, Ancient Metal Technology and Archaeology of South Asia, Aryan Books International, 2002.
4 P. T. Craddock, Early Metal Mining and Production, Archetype Pubns, 2010.
5 W. D. Callister, & D. G. Rethwisch, Materials Science and Engineering: An Introduction, Wiley, 10th edition , 2018.
6 R. Balasubramaniam, The Delhi Iron Pillar: New Insights, Aryan Books International.2002
7 R. F. Tylecote, A History of Metallurgy, Maney Publishing.2013
8 B. V. Subbarayappa, Indian Science and Technology in the Eighteenth Century, Munshiram Manoharlal, 1971.
9 D. P. Agrawal, The Archaeology of India, Curzon Press.1982
10 Sharda Srinivasan and S. Ranganathan, India's Legendary Wootz Steel An Advanced Material of the Ancient World, National Institute of Advanced Studies, Bangalore and IISC, Bangalore, 2004
11 Sharda Srinivasan Minerals and Metal Heritage of India, NIAS 2013
12 Sharda Srinivasan, Metallurgy of Zinc, High-tin Bronze and Gold in Indian Antiquity: Methodological Aspects, Indian Journal of History of Science, 51(1), 22-32, 2016.

Ancient Indian Glass Making Industry

1 S. N. Sen, Mamata Chaudhuri, Ancient Glass and India, Published for the National Commission for the Compilation of History of Sciences in India by Indian National Science Academy, Eastend Printers Pg. *49-51, 61-63, 105 - 111, and 143-149,* 1985
2 D. M. Bose, S. N. Sen, B. V. Subbarayappa, A Concise History of Science in India, Indian National Science Academy, New Delhi. University Press, Pg 291-296, 2009
3 Mamata Chaudhuri, The Technique of Glass Making in Ancient India (1400-1800 A.D.), Indian Journal of History of Science, 18(2), 206-219, 1983.

Ancient Indian Perfumery Industry

1 D. M. Bose, S. N. Sen, B. V. Subbarayappa A Concise History of Science in India, Indian National Science Academy, New Delhi. University Press, Pg. 343 to 34, 2009.
2 Jayant Yashwant Deopujari, Raman Shankar Belge, Gandhashastra (Indian Art and Science of Cosmetology and Perfumery), Independently published 2020.
3 Google Arts & Culture, "Ancient Indian Knowledge of Perfumery". Stories from National Council of Science Museums. https://artsandculture.google.com/story/itr-ancient-indian-knowledge-of-perfumery-national-council-of-science-museums/pgVxuEAUIIOfJw?hl=en
4 Madhu Raj, Technological Interventions in Improving Kannauj Attar (Perfume)., Alternative Futures, 2018.

	5 C. Mcmahon, Indian attars, International Journal of Aromatherapy, 7(4), 10–13, 1996. Online - https://doi.org/10.1016/s0962-4562(96)80023-3. 6 J. N. Kapoor, Attars of India- A Unique Aroma, Jagat Aroma Oils Distillery, Kannauj, India, Perfumer and Flovorist, vol1, 21-24, 1991. 7 Nirmita Mehrota, Genre of Olfactory Aromatic Heritage & Cultural Tourism of Kannauj.Journal of Indian Institute of Architects, 2023 8 Jyoti Marwah, Attars: The Fading Aromatic Culture of India under SAARC, Research Project for Diminishing Cultures of South Asia: Pg. 32 - 35, 2011-2012	
11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Sem. - VI

Vertical – 1

Major

Mandatory

(2+2+2+2+2)

Syllabus
B. Sc. (Chemistry)
(Sem.- VI)

Title of Paper: Advanced Physical Chemistry - Paper IV

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Advanced Physical Chemistry – Paper IV** provides an in-depth understanding of nuclear chemistry, quantum chemistry, electrochemistry and resonance spectroscopy. The course covers fundamental concepts of radioactivity, nuclear reactions, nuclear reactors and applications of radioisotopes as tracers. It introduces the principles of quantum mechanics including wave-particle duality, Schrödinger wave equation, operators and eigen functions, forming the basis for modern chemical theory. The course also discusses electrochemical concepts such as activity coefficients, electrochemical cells, decomposition potential and overvoltage, along with principles of NMR and ESR spectroscopy. Emphasis is placed on theoretical understanding, mathematical treatment and applications relevant to modern chemical research and technology.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop understanding of nuclear chemistry, including radioactive decay processes, nuclear reactions, fission process, nuclear reactors, and applications of radioisotopes as tracers.	

	COB2: Introduce fundamental principles of quantum chemistry, including limitations of classical mechanics, wave-particle duality, uncertainty principle, Schrödinger wave equation, and operator concept. **COB3:** Provide knowledge of electrochemistry, including activity and activity coefficients, ionic strength, Debye-Hückel theory, and classification of electrochemical cells. **COB4:** Explain principles of applied electrochemistry, including decomposition potential, overvoltage, and factors affecting electrode processes. **COB5:** Introduce the fundamental concepts of NMR spectroscopy, including nuclear spin, magnetic moment, relaxation processes, and resonance conditions. **COB6:** Provide knowledge of ESR spectroscopy, including principle, g-value, hyperfine splitting, and interpretation of ESR spectra.
8	**Course Outcomes:** **At the end of the course, students will be able to:** **CO1:** Explain radioactive decay laws, nuclear reactions, working of nuclear reactors, and applications of radioisotopes in chemical studies. **CO2:** Apply fundamental concepts of quantum mechanics including de-Broglie equation, uncertainty principle, Schrödinger equation, and operators**.** **CO3:** Apply concepts of activity and activity coefficients and classify electrochemical cells, including concentration cells and liquid junction potential. **CO4:** Explain decomposition potential, overvoltage, and factors influencing electrode processes in electrochemical systems. **CO5:** Explain principles of NMR spectroscopy and interpret basic spectral features based on nuclear properties. **CO6:** Explain principles of ESR spectroscopy and interpret spectral features such as g-value and hyperfine splitting.
9	**Modules**:
	Module 1:
	1.1. Nuclear Chemistry (10 Hours) 1.1.1. Introduction: Radioactive substance, radioactivity, Types of nuclear radiations Basic terms-radioactive constants (decay constant, half-life and average life) and units of radioactivity. 1.1.2. Detection and Measurement of Radioactivity: Detection and measurement of nuclear radiations using G.M. Counter and Scintillation Counter. 1.1.3. Radioactive Equilibrium: Difference between chemical equilibrium and radioactive equilibrium. 1.1.4. Application of use of radioisotopes as Tracers: Chemical reaction mechanism, age determination- dating by C^{14}.

1.1.5. Nuclear Transmutation: Nuclear transmutation (one example for each projectile), artificial radioactivity, Q- value of nuclear reaction, threshold energy. (Numerical expected)
1.1.6. Fission Process: Fissile and fertile material, chain reaction, factor controlling fission process, multiplication factor and critical size or mass of fissionable material,
1.1.7. Nuclear reactor: Construction and working of Nuclear Power reactor

1.2. Basic of Quantum Chemistry: (5 Hours)
1.2.1. Classical mechanics: Introduction, limitation of classical mechanics, Black body radiation, photoelectric effect, Compton effect.
1.2.2. Quantum mechanics: Introduction, Planck's theory of quantization, wave particle duality, de-Broglie's equation, Heisenberg's uncertainty principle. State function and its significance (Numerical expected)
1.2.3. Progressive and standing waves: Introduction, Schrodinger's time independent wave equation (No derivation expected), Properties of wave function.
1.2.4. Concept of operators: Definition, addition, subtraction and multiplication of operators, commutative and non-commutative operators, linear operator, Hamiltonian operators, Eigen function and Eigen value. (Numerical expected)

Module 2:

2.1. Electrochemistry (7 Hours)
2.1.1. Activity and Activity Coefficient: Lewis concept, ionic strength, Mean ionic activity and mean ionic activity coefficient of an electrolyte, expression for activities of electrolytes. Debye Huckel limiting law (No derivation) (Numerical expected)
2.1.2. Classifications of cells: Chemical cells and Concentration cells., Liquid junction potential, Chemical cells without transference , Electrolyte concentration cells with and without transference. (derivation and Numericals expected)

2.2. Applied Electrochemistry (4 Hours)
2.2.1. Decomposition Potential: Introduction, experimental determination, Factors affecting it.
2.2.2. Over Voltage: Introduction, Experimental determination, Hydrogen over voltage, Tafel's equation for hydrogen overvoltage. (Numerical expected)

2.3. Resonance Spectroscopy: (4 Hours)
2.3.1. NMR -Nuclear Magnetic Resonance Spectroscopy: Principle, Nuclear spin, magnetic moment, nuclear ' g ' factor, energy levels, Larmor precession, Relaxation processes in NMR (spin-spin relaxation and spin- lattice relaxation).
2.3.2. ESR-Electron Spin Resonance Spectroscopy: Principle, Fundamental equation, electron g – factor, hyperfine splitting, ESR spectrum of hydrogen and deuterium.

10 **Reference Books:**

Module 1 and 2: Physical Chemistry

1 Walter D. Loveland, David J. Morrissey, Glenn T. Seaborg , Modern Nuclear Chemistry , Wiley, 2017.
2 H. J. Arnikar, Essentials of Nuclear Chemistry, New Age International (P) Ltd., Publishers, 2011.
3 Ira Levine, Physical Chemistry, Tata McGraw Hill Publishing Co.Ltd. 5th Edition, 2002.

	4 P.W. Atkins, The Elements of Physical Chemistry, Oxford University Press, 2nd Edition, 2003. 5 B.R. Puri, L.R. Sharma, M.S. Pathania, Principles of Physical Chemistry VISHAL PUBLISHING Company, 2008. 6 J.O.M Bockris & A.K.N. Reddy, Maria, Modern Electrochemistry, Gamboa – Aldeco Springer, 2^{nd} Edition, 1^{st} Indian reprint, 2006.	
11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Advanced Inorganic Chemistry – Paper V

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Advanced Inorganic Chemistry – Paper V** provides detailed knowledge of bonding, stability, reactivity and spectroscopic properties of coordination and organometallic compounds. The course introduces Crystal Field Theory and Molecular Orbital Theory for understanding electronic structure, bonding and stability of transition metal complexes. It also covers organometallic compounds, their synthesis and reactions, and the role of transition metals in homogeneous and heterogeneous catalysis. Concepts related to stability constants, ligand substitution mechanisms and factors affecting stability of metal complexes are discussed. The course further explains electronic spectra, term symbols and selection rules for electronic transitions in coordination compounds. Emphasis is placed on theoretical understanding of structure–property relationships and their relevance in catalysis, materials and modern inorganic chemistry.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop understanding of Crystal Field Theory, crystal field splitting in coordination compounds, spectrochemical series, and calculation of crystal field stabilization energy. **COB2:** Introduce Molecular Orbital Theory of coordination compounds, including metal–ligand bonding, ligand group orbitals, and the effect of π-bonding in metal complexes.	

	COB3: Provide knowledge of organometallic compounds of main group metals, including classification, methods of synthesis, and important chemical reactions. **COB4:** Explain the concepts of stability of metal complexes, including thermodynamic and kinetic stability, stability constants, and factors affecting stability. **COB5:** Develop understanding of reactivity of metal complexes, including inert and labile complexes, ligand substitution mechanisms, and types of reactions in coordination compounds. **COB6:** Introduce electronic spectra and catalytic role of transition metals, including electronic transitions, term symbols, and homogeneous catalysis mechanisms such as Wilkinson's catalyst.
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Explain crystal field splitting patterns and calculate crystal field stabilization energy (CFSE) for coordination complexes. **CO2:** Explain bonding in coordination compounds using molecular orbital theory and describe the effect of π-bonding on stability of complexes. **CO3:** Describe classification, synthesis, and reactions of organometallic compounds of main group metals. **CO4:** Explain thermodynamic and kinetic stability of metal complexes and interpret stability constants. **CO5:** Explain mechanisms of ligand substitution reactions and distinguish between inert and labile complexes. **CO6:** Explain electronic transitions in coordination compounds and describe the role of transition metals in catalysis, including Wilkinson's catalyst mechanism.
9	**Modules**:
	Module 1:
	1.1 Crystal Field Theory (6 Hours) 1.1.1 Limitations of Valence Bond Theory. 1.1.2 Fundamentals of Crystal Field Theory 1.1.3 Crystal field Splitting of *d* orbitals in octahedral, square planar and tetrahedral complexes. 1.1.4 Crystal field splitting parameter 10Dq(Δ), factors affecting 10 Dq, spectrochemical series. 1.1.5 Crystal field stabilization energy (CFSE), calculation of CFSE for octahedral complexes with d^0 to d^{10} metal ion configurations.

1.2 Organometallic Compounds of main group metal (5 Hours)

1.2.1 Introduction to organometallic chemistry: General characteristics of various types of organometallic compounds, viz. ionic, s-bonded and electron deficient compounds.

1.2.2 General synthetic methods of organometallic compounds: (i) Oxidative-addition, (ii)Metal-metal exchange(trans-metallation), (iii) Carbanion-halide exchange,(iv) Metal-hydrogen exchange(metallation) and (v) Methylene-insertion reactions.

1.2.3 Some chemical reactions of organometallic compounds: (i) Reactions with oxygen and halogens, (ii) Alkylation and arylation reactions (iii) Reactions with protic reagents

1.3 Role of transition metal in catalysis (4 Hours)

1.3.1 Comparison between homogeneous and heterogeneous catalysis

1.3.2 Basic steps involved in homogeneous catalysis

1.3.3 Mechanism of Wilkinson's catalyst in hydrogenation of alkenes.

Module 2:

2.1 Molecular orbital Theory (4 Hours)

2.1.1 Limitations of CFT: Evidences for covalence in metal complexes with respect to (i) intensities of d-d transitions (ii) ESR spectrum of $[IrCl_6]^{2-}$ (iii) Nephelauxetic effect.

2.1.2 Identification of the central metal orbitals, their symmetry suitable for formation of σ bonds with ligand orbitals and Construction of ligand group orbitals

2.1.3 Construction of molecular orbitals for ML_6 complex. Examples like $[FeF_6]^{-4}$, $[Fe(CN)_6]^{-4}$, $[CoF_6]^{-3}$ $[Co(NH_3)_6]^{+3}$

2.1.4 Effect of π-bonding on complexes

2.2 Stability of Metal-Complexes (3 Hours)

2.2.1 Thermodynamic and kinetic perspectives of metal complexes with examples.

2.2.2 Stability constants: stepwise and overall stability constants and their interrelationship.

2.2.3 Factors affecting thermodynamic stability.

2.3 Reactivity of metal complexes (4 Hours)

2.3.1 Comparison between Inorganic and organic reactions.

2.3.2 Types of reactions in metal complexes.

2.3.3 Study of Inert and labile complexes with respect to $[Ti(H_2O)_6]^{3+}$ and $[Cr(H_2O)_6]^{3+}$complexes.

2.3.4 Ligand substitution reactions : Associative and Dissociative mechanisms.

2.3.5 Acid hydrolysis, base hydrolysis and anation reactions.

2.4 Electronic spectra (4 Hours)

2.4.1 Origin of electronic spectra, Types of electronic transitions in coordination compounds: intra- ligand, Charge transfer and intra-metal transitions.

2.4.2 Selection rules for electronic transitions.

2.4.3 Electronic configuration and electronic micro states, Terms and Term symbols for transition metal ions, rules for determination of ground state term.

2.4.4 Determination of Terms for p^2 and d^1 electronic configurations.

10	**Reference Books:** **Module 1: Inorganic Chemistry** **Crystal Field Theory** 1 G. A. Lawrance Introduction to Coordination Chemistry John Wiley & Sons.2009 2 R. K. Sharma Text Book of Coordination Chemistry Discovery Publishing House, 2007 3 R. Gopalan and V. Ramalingam, Concise coordination chemistry, Vikas Publishing House Pvt. Ltd. 2007. 4 P. R. Shukla, Advance Coordination Chemistry , Himalaya Publishing House, 2012 5 Glen E. Rodgers, Descriptive Inorganic, Coordination, and Solid-State Chemistry Publisher: Thomson Brooks/Cole, 2011 6 Christoph Sontag, 101 Applications of Crystal Field Theory – properties of transition metal compounds, Createspace Independent Publishing Platform ,2018 7 D. W. Bruce and Dermont O Hare, Inorganic Chemistry, 2nd Ed. John Wiley and Sons, New York, 1966. 8 R. L. Madan and G. D. Tuli, Inorganic Chemistry,5th Ed., S. Chand, 2012. 9 B. W. Pfennig, Principles of Inorganic Chemistry, Wiley, 2015. 10 D. Banerjea, Coordination chemistry, 3rd edition, Asian Books Pvt. Ltd. 2009. 11 R. D. Wijesekera, Coordination Compounds Bonding, Structure and Nomenclature, Narosa Publication House, 2008. **Organometallic Compounds of main group metal** 1 F. A. Cotton, G. Wilkinson, C. Murillo and M. Bochmann, Advanced Inorganic Chemistry, John Wiley, New York, 6th edition, 1999. 2 F.A. Cotton and R.A.Walton, Multiple Bonds between Metal Atoms, Claranden Press, Oxford, 2nd edition, 1993 3 Gary Miessler and Donald Tarr, Inorganic Chemistry, Pearson Education, 3rd Ed. 2004. 4 Shriver and Atkin’s, Inorganic Chemistry, 5th Edition, 2010. 5 B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone Publishers, 2013-2014. 6 Gurudeep Raj, Advanced Inorganic Chemistry, Vol- II, Krishna Prakashan Media Pvt.Ltd, 2014 7 R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, Wiley-Interscience, New York, 2014. 8 Ajay Kumar, Organometallic and Bioinorganic Chemistry AAyush Education, 2014 9 R. C. Mehrotra and A. Singh, Organometallic Chemistry – A Unified Approach, 2nd edition, New Age International Pvt. Ltd., 2000. 10 Gary O. Spessard and Gary L. Miessler, Organometallic Chemistry, Oxford UniversityPress 3rdedn., 2015. 11 Christoph Elschenbroich, Organometallics, Wiley-VCH, 3rd edition, 2005. 12 B. D. Gupta & A. J. Elias Basic Organometallic Chemistry: Concepts, Syntheses and Applications, University press, 2013 13 V. K. Jain, An Introduction to Organometallic Chemistry: Fundamentals and Applications, IIP Iterative International Publishers, 2026.

Role of transition metal in catalysis

1 G. W. Parshall and S. D. Ittel, Homogeneous Catalysis, John Wiley & Sons. Inc. New York, 2nd edition, 1992.
2 F. Basolo and R. G. Pearson, Mechanism of Inorganic Reactions, Wiley, New York, 1967.
3 Jahn Hartwig, Organotransition chemistry-From bonding to catalysis, University science books, California 2010.
4 William L. Jolly, Modern Inorganic Chemistry, McGraw Hill, Inc. 2nd edition 1991

Module 2: Inorganic Chemistry

Molecular orbital Theory

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 C. E. Housecroft and A. G. Sharpe, Inorganic Chemistry, Pearson Education Limited, 2nd Edition 2005.
4 R. L. Dekock and H.B.Gray, Chemical Structure and Bonding, The Benjamin Cummings Publishing Company, 1989.
5 R. Sarkar, General and Inorganic Chemistry, Books & Allied (P) Ltd., 2001.
6 D. Banerjea ,Coordination Chemistry Tata McGraw Hill,1993.
7 C. M. Day and J. Selbin, Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 1985.
8 P. L. Soni, Textbook of Inorganic Chemistry. Sultan Chand & Sons Publisher, 15thEdition .1984.
9 Asim K. Das, Fundamental Concepts of Inorganic Chemistry, Vol. I, II and III, CBS Publication, 2000.

Stability of Metal-Complexes

1 R. Kapoor and R.S. Chopra, Inorganic Chemistry, S. Chand 2019
2 Ajay Kumar, Organometallics and Bioinorganic Chemistry, Aaryush Education, 4th Edn, 2021.
3 M. V.Twigg, Mechanisms of Inorganic and Organometallic Reactions, Springer Nature vol 1., 1985.
4 M. L. Tobe Inorganic Reaction Mechanisms, Thomas Nelson and Sons Ltd. 1972.
5 R..K. Sharma Inorganic Reaction Mechanisms Discovery Publishing House, 2018

Reactivity of metal complex's

1 Gary Wulfsberg, Inorganic Chemistry; Viva Books PA Ltd., New Delhi; 2002
2 R. L. Madan and G. D. Tuli, Inorganic Chemistry,5th Ed., S. Chand, 2012.
3 H. Sosler, Chemistry in Non-aqueous solvents, New York Reinhold Publication, 1965.
4 P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5thEd., Oxford University Press, 2010.

5 B. Douglas, D. McDaniel and J. Alexander, Concepts and Models of Inorganic Chemistry, 3^{rd} Edition., John Wiley & Sons, Inc., 2001.
6 Ajay Kumar, Organometallics and Bioinorganic Chemistry, Aaryush Education, 4^{th} Edn, 2021.
7 M. V.Twigg, Mechanisms of Inorganic and Organometallic Reactions, Springer Nature vol 1., 1985.
8 M. L. Tobe Inorganic Reaction Mechanisms, Thomas Nelson and Sons Ltd. 1972.
9 R..K. Sharma Inorganic Reaction Mechanisms Discovery Publishing House, 2018

Electronic spectra

1 R. Kapoor and R.S. Chopra, Inorganic Chemistry, S. Chand 2019
2 Ajay Kumar, Organometallics and Bioinorganic Chemistry, Aaryush Education, 4^{th} Edn, 2021.
3 M. V.Twigg, Mechanisms of Inorganic and Organometallic Reactions, Springer Nature vol 1., 1985.
4 M. L. Tobe Inorganic Reaction Mechanisms, Thomas Nelson and Sons Ltd. 1972.
5 R..K. Sharma Inorganic Reaction Mechanisms Discovery Publishing House, 2018
6 Gary Wulfsberg, Inorganic Chemistry; Viva Books PA Ltd., New Delhi; 2002
7 R. L. Madan and G. D. Tuli, Inorganic Chemistry,5th Ed., S. Chand, 2012.

Common books for Reference

1 G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004.
2 B. W. Pfennig, Principles of Inorganic Chemistry, Wiley, 2015.
3 J. Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4th Ed., Harper Collins, 1993.

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11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Advanced Organic Chemistry - Paper VI

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Advanced Organic Chemistry – Paper VI** provides comprehensive knowledge of biomolecules, polymers, organic reagents and modern spectroscopic techniques used for structure elucidation of organic compounds. The course covers structure, classification and synthesis of amino acids, polypeptides and proteins, along with important catalysts and reagents used in functional group transformations. It also discusses mechanisms of molecular rearrangements and fundamentals of polymer chemistry including types of polymerization, properties and applications of synthetic and biodegradable polymers. The course further introduces structure and reactions of carbohydrates and principles of UV–Visible, IR and PMR spectroscopy for identification of organic compounds. Emphasis is placed on understanding structure–reactivity relationships and interpretation of spectroscopic data relevant to research, pharmaceutical and polymer industries.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: The course aims to: **COB1:** Develop fundamental understanding of amino acids, polypeptides, and proteins with emphasis on structure, stereochemistry, properties, and biological significance.	

	COB2: Familiarize students with commonly used organic catalysts and reagents and their applications in functional group transformations and selectivity. **COB3:** Provide mechanistic understanding of important molecular rearrangements and their stereochemical aspects. **COB4:** Introduce polymer chemistry including classification, preparation, properties, tacticity, and applications of synthetic and biodegradable polymers. **COB5**: Provide comprehensive knowledge of carbohydrates including classification, interconversion (Fischer and Haworth projections), cyclic structures, and reactions of monosaccharides. **COB6:** Build conceptual clarity in organic spectroscopy (UV–Vis, IR, and PMR) with emphasis on theoretical principles and instrumentation basics. **COB7:** Develop problem-solving skills in interpretation of spectral data for structure elucidation of organic compounds.
8	**Course Outcomes**: At the end of the course, students will be able to: **CO1:** Explain the structure, classification, stereochemistry, properties, and preparation of amino acids, peptides, and proteins. **CO2:** Apply knowledge of catalysts and reagents to predict functional group transformations and synthetic outcomes. **CO3:** Explain mechanisms and stereochemical aspects of molecular rearrangements such as Pinacol–Pinacolone, Benzilic acid, Favorskii, and Curtius rearrangements. **CO4:** Classify polymers and explain their preparation, properties, tacticity, and applications including biodegradable and biomedical polymers. **CO5:** Describe carbohydrates with respect to classification, stereochemistry, cyclic structures, and reactions of D-glucose and D-fructose. **CO6:** Explain principles spectroscopy, interpret characteristic spectral features and elucidate structures using molecular formula, IHD calculation, and combined spectral data (UV–Vis, IR, PMR).
9	**Modules**:-
	Module 1:
	1.1 Amino Acids, Polypeptides and Proteins (4 Hours) 1.1.1 Amino Acids: General Structure, configuration, and classification based on structure and nutrition. Properties: pH dependency of ionic structure, isoelectric point and zwitter ion. Methods of preparations: Strecker synthesis, Gabriel’s phthalimide synthesis.

1.1.2 Polypeptides: Nature of peptide bond. Nomenclature and representation of polypeptides (di-and tri-peptides) with examples, Merrifield solid phase polypeptide synthesis.
1.1.3 Proteins: Introduction, General idea of primary, secondary, tertiary & quaternary structure of proteins, Denaturation of Protein.

1.2 Catalyst and Reagents (4 Hours)
Study of the following catalysts and reagents with respect to functional group transformations and selectivity (no mechanism)
1.2.1 Catalysts:
- i) Raney Nickel
- ii) Pt and PtO_2
- iii) Pd: Rosenmund Reduction and Lindlar's Catalyst

1.2.2 Reagents
- i) $LiAlH_4$ (reduction of carbonyl, carboxylate, nitrile and nitro)
- ii) $NaBH_4$ (reduction of carbonyl)
- iii) SeO_2 (Oxidation of active methyl and methylene groups)
- iv) m-CPBA (epoxidation of alkenes)
- v) NBS (allylic and benzylic bromination)

1.3 Molecular Rearrangements (3 Hours)
Mechanism of the following rearrangements with examples and stereochemistry wherever applicable
- i) Pinacol-pinacolone rearrangement
- ii) Benzilic acid rearrangement
- iii) Favorskii rearrangement.
- iv) Curtius rearrangement

1.4 Polymers (4 Hours)
1.4.1 Introduction to Polymers: Definition of monomer and polymers, Classification of polymers on basis of source and types of polymerization reactions
1.4.2 Preparation, properties, and uses of: Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyvinyl chloride (PVC), and Polytetrafluoroethylene (Teflon), Polycarbonates, Polyurethanes; Polyamides (Nylon)
1.4.3 Tacticity in Polymers: Definition and concept, Types: Isotactic, Syndiotactic, Atactic polymers, and Effect of tacticity on polymer properties
1.4.4 Biodegradable polymers & Biomedical uses of polymers

Module 2:

2.1 Carbohydrates (5 Hours)
2.1.1 Introduction: Classification, Fischer projection (4-6 carbon monosaccharides), D-L notation, reducing and non-reducing sugars.
2.1.2 Ring structures of monosaccharides: Evidences in support of ring structures, Interconversion of open chain into Haworth forms of monosaccharides (Furanose and Pyranose forms of D-Glucose and D-Fructose)
2.1.3 Reactions of D-glucose and D-fructose:
- i) Osazone formation
- ii) Reduction: (i) H_2/Ni (ii) $NaBH_4$
- iii) Oxidation: (i) Bromine water (ii) conc. HNO_3, (iii) HIO_4

	iv) Acetylation* v) Methylation* *with cyclic pyranose forms **2.2. Organic Spectroscopy (10 Hours)** 2.2.1 Introduction: Electromagnetic spectrum, units of wavelength and frequency. 2.2.2 UV-Visible Spectroscopy: Introduction, Electromagnetic radiations, electronic transitions, λmax & εmax, chromophore, auxochrome, bathochromic and hypsochromic shifts 2.2.3 IR Spectroscopy: Introduction, Infrared radiation and types of molecular vibrations, Selection rule, functional group and fingerprint region. Application of IR Spectroscopy 2.2.4 PMR Spectroscopy: Basic theory of PMR, nature of PMR spectrum, chemical shift (δunit),TMS as reference and its advantages, solvents used. Factors affecting chemical shift: (1) inductive effect (2) anisotropic effect (with reference to alkenes, alkynes, aldehyde and benzene ring). Spin-spin coupling and coupling constant, application of deuterium exchange technique. 2.2.5. Problems of structure elucidation of simple organic compounds using individual or combined use of UV-Vis, IR and PMR spectroscopic data. (Molecular Formulae to be provided) (Calculation of Index of hydrogen deficiency should be the first step in solving the problems)
10	**Reference Books:** **Module 1: Organic Chemistry** **Amino Acids, Polypeptides and Proteins** 1 J. M. Berg, J. L. Tymoczko, G. J. Gatto Jr., L. Stryer, W. H. Freeman Biochemistry Eighth Edition, 2015 2 D. L. Nelson and M. M. Cox, Lehninger, W. H. Freeman, Principles of Biochemistry, Seventh Edition, 2017 3 U. Satyanarayana and U. Chakrapani, Biochemistry, CBS, Seventh Edition,2025 4 G. Odian, Principles of polymerisation, John Wiley &Sons., 3 rd edition,2004 5 P. Bahadur, N. V. Sastry, Polymer Chemistry, Narosa Publishing House, 2nd Edition, 2002 6 V. K. Ahluwalia& A. Misra, Polymer Science-A Text Book, Ane Books, India, 1st Edition, 2008 7 Charles E. Carraher Jr., Introduction to Polymer Chemistry, CRC Press, 3rd Edition, 2017 **Module 2: Organic Chemistry** **Catalyst and Reagents / Molecular Rearrangements / Carbohydrates** 1 Jie Jack Li, Name Reactions, Springer, 4th Edition, 2009 2 I. L. Finar, Organic Chemistry, Pearson Education, 6th Edition, 2006 3 Morrison, Boyd and Bhattacharjee, Organic Chemistry Pearson Education, Seventh Edition, 2010. 4 T. W. Graham Solomons, Craig B. Fryhle & Scott A. Snyder, Organic Chemistry Wiley, 12th Edition, 2016 5 B. S. Bahl & Arun Bahl, Advanced Organic Chemistry, S. Chand, Revised Multi-Colour Edition, 2012 6 V.K. Ahluwalia & R.K.Parashar, Organic Reaction Mechanisms, Third Edition 2006

	Organic Spectroscopy 1 Robert M. Silverstein, Francis X. Webster & David J. Kiemle, Spectrometric Identification of Organic Compounds, Wiley, 7th Edition, 2005 2 William Kemp, Organic Spectroscopy, Palgrave Macmillan, 3rd Edition, 1991 3 Donald L. Pavia, Gary M. Lampman, George S. Kriz & James R. Vyvyan Introduction to Spectroscopy, Cengage, 5th Edition, 2015 4 Jag Mohan, Organic Spectroscopy, Narosa Publishing House, 2nd Edition, 2004 …………………………………………………………………………………….	
11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Advanced Analytical Chemistry – Paper VII

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Advanced Analytical Chemistry – Paper VII** provides detailed knowledge of modern analytical techniques used for qualitative and quantitative chemical analysis. The course covers electroanalytical methods such as polarography and amperometric titration, thermal methods including thermogravimetric analysis (TGA), differential thermal analysis (DTA) and thermometric titrations, and optical techniques such as flame emission spectroscopy, fluorescence and phosphorescence spectroscopy. It also introduces advanced chromatographic methods including HPLC, HPTLC and ion exchange chromatography for separation and analysis of chemical and biological samples. Emphasis is placed on understanding principles, instrumentation and applications of modern analytical techniques relevant to pharmaceutical, environmental and industrial analysis.
2	**Vertical :**	Major
3	**Type :**	Theory
4	**Credit**:	2 credits
5	**Hours Allotted :**	30 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop understanding of electro-analytical techniques, including principles, instrumentation, and applications of polarography and amperometric titration. **COB2:** Provide knowledge of thermal analytical techniques such as TGA, DTA, and thermometric titrations, including instrumentation and interpretation of thermal curves. **COB3:** Introduce principles and applications of flame emission spectroscopy, including atomization process, instrumentation, and calibration methods.	

	COB4: Develop understanding of molecular fluorescence and phosphorescence spectroscopy, including Jablonski diagram, factors affecting emission intensity, and instrumentation. **COB5:** Provide knowledge of High Performance Liquid Chromatography (HPLC) and High Performance Thin Layer Chromatography (HPTLC), including principles, instrumentation, and applications. **COB6:** Introduce the principles of ion exchange chromatography, including ion exchange resins, separation mechanisms, and applications in purification and water treatment.
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Explain principles and instrumentation of polarography and amperometric titration, and interpret polarograms and titration curves. **CO2:** Explain working principles of TGA, DTA, and thermometric titration, and interpret thermograms for analytical applications. **CO3:** Explain principle and instrumentation of flame emission spectroscopy and apply calibration methods for quantitative analysis. **CO4:** Explain principles of fluorescence and phosphorescence spectroscopy, interpret Jablonski diagram, and identify factors affecting emission intensity. **CO5:** Explain principles, instrumentation, and applications of HPLC and HPTLC in chemical analysis. **CO6:** Explain separation mechanism and applications of ion exchange chromatography in analytical and purification processes.
9	**Modules**:-
	Module 1:
	1.1 Electro-analytical technique (08 Hours) 1.1.1 Polarography 1.1.1.1 Basic Principle of DC Polarography 1.1.1.2 Polarogram (terms involved): i) residual current ii) diffusion current iii) limiting current iv) half wave potential 1.1.1.3 Role of supporting electrolyte, maxima suppressors and inert gas in Polarographic analysis 1.1.1.4 Dropping Mercury Electrode (DME) : Construction , Working, Advantages and Limitations. 1.1.1.5 Qualitative aspect: Half wave potential , Factors affecting it and its significance

1.1.1.6 Quantitative aspect (Numerical Expected): Ilkovic equation, terms involved, Practical applicability with reference to calibration curve method
1.1.1.7 Applications, Advantages and Limitations of Polarography

1.1.2 Amperometric Titration
1.1.2.1 Principle
1.1.2.2 Instrumentation (Diagram & Construction), Rotating Platinum Electrode.
1.1.2.3 Titration curves with examples
- i) Titrand is reducible but other species are not
- ii) Titrant is reducible but other species are not
- iii) Both titrand and titrant are reducible but products is not

1.1.2.4 Advantages and Disadvantages

1.2 Thermal methods (07 Hours)
1.2.1 Thermogravimetric Analysis (TGA)
1.2.1.1 Introduction to thermal method and its classification
1.2.1.2 Instrumentation and Working (TGA):Block diagram of thermobalance
1.2.1.3 Factors affecting thermogram and its significance
1.2.1.4 Applications :
1) Identification of primary and secondary standard and
2) Determination of drying and ignition temperature range based on thermogram of
   - i) $CaC_2O_4.H_2O$
   - ii) $CuSO_4.5H_2O$

1.2.2 Differential Thermal Analysis (DTA)
1.2.2.1 Principle, instrumentation ,Block Diagram and types of reference materials
1.2.2.2 Applications: DTA curve with reference to determination of drying and ignition temperature for $CaC_2O_4.H_2O$ (in atm of air)
1.2.2.3 Comparison between TGA and DTA

1.2.3 Thermometric titrations
1.2.3.1 Principle and Instrumentation
1.2.3.2 Thermometric titrations of:
- i) HCl v/s NaOH
- ii) Mixture of Ca(II) and Mg(II) v/s EDTA

Module 2

2.1 Optical methods (8 Hours)
2.1.1 Flame emission spectroscopy (FES)
2.1.1.1 Introduction to FES: Principle, events taking place when sample is aspirated in to the flame
2.1.1.2 Instrumentation: Block Diagram and function of
- i) Nebulizer
- ii) Flame atomizer
- iii) Burner :Types of burner ,advantages and limitations of Total consumption burner and Premix burner
- iv) Wavelength selector and Detector

2.1.1.3 Applications: Qualitative analysis and Quantitative analysis (Calibration Curve method and Standard addition method), Advantages and Limitations

2.1.2 Molecular Fluorescence and Phosphorescence Spectroscopy
2.1.2.1 Introduction:
- i) Principle and Jablonski diagram

	ii) Relationship of Fluorescence intensity with concentration iii) Factors affecting Fluorescence and Phosphorescence 2.1.2.2 Instrumentation, application and comparison of Fluorimetry and Phosphorimetry. **2.2 Chromatography (7 Hours)** 2.2.1 High Performance Liquid Chromatography (HPLC)] 2.2.1.1 Introduction to HPLC: Principle, Isocratic elution and gradient elution 2.2.1.2 Instrumentation: Block Diagram and components, Role of Precoloumn, UV Detector 2.2.1.3 Applications of HPLC 2.2.2 High Performance Thin Layer Chromatography (HPTLC) 2.2.2.1 Introduction to HPTLC: Principle, Stationary phase, Sample application and mobile phase 2.2.2.2 Comparison of TLC and HPTLC 2.2.3 Ion exchange Chromatography 2.2.3.1 Introduction, Principle, Classification of ion exchange chromatography, Ion exchange resin, examples of resins and its ideal properties 2.2.3.2 Factors affecting separation in an Ions i) Selectivity coefficient ii) Ion exchange capacity 2.2.3.3 Applications with reference to i) Protein,peptide and nucleic acid purification ii) Deminarlisation of Water treatment and purification
10	**Reference Books:** **Module 1 and 2 : Analytical Chemistry** 1 Kamala Zutshi, Introduction to Polarography and Allied Techniques, New Age International, 2006. 2 Michael E. Brown, Introduction to Thermal Analysis Techniques and Applications, Springer Nature, 2001 3 P.J Haines, Thermal Methods Of Analysis: Principles Applications and Problems, Springer 1995 4 D.A. Skoog and D. M. West and F. J. Holler Holt., Fundamentals of Analytical Chemistry, Saunders 9th Edition, 2014. 5 S M Khopkar, Basic Concepts of Analytical Chemistry, New academic science ltd. 3rd Edition 2012, 6 Willard, Merritt, Dean, Instrumental methods Of Analysis, CBS Publisher and distribution Pvt Ltd, 7thEdition,1986 7 Skoog, Holler, Nieman, Principles of Instrumental Analysis,Cengage 7th Edition, 2017 8 *Lloyd R. Snyder, Introduction to Modern Liquid Chromatography,* A John Wiley & Sons, Inc., Publication, 3rd Edition, 2010. …………………………………………………………………………………………….
11	**Internal Continuous Assessment: 40%** | **External, Semester End Examination 60% Individual Passing in Internal and External Examination**

12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Practicals in Advanced Chemistry - II

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Practicals in Advanced Chemistry – II** provides practical training in Physical and Inorganic Chemistry through systematic laboratory experiments. The course emphasizes electroanalytical techniques such as potentiometry, conductometry, pH-metry and colorimetry for quantitative determination of ions and evaluation of physicochemical properties. Experiments on phase equilibria, viscosity and reaction kinetics develop understanding of thermodynamic and kinetic principles of physical chemistry. The course also includes preparation of inorganic coordination compounds and estimation of metal ions using complexometric titration methods. Emphasis is placed on experimental accuracy, analytical skills and interpretation of experimental data relevant to physical and inorganic chemical systems.
2	**Vertical :**	Major
3	**Type :**	Practical
4	**Credit**:	2 credits
5	**Hours Allotted :**	60 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop understanding of electroanalytical techniques such as potentiometry, conductometry, pH-metry and colorimetry for quantitative chemical analysis. **COB2:** Explain physicochemical principles underlying phase equilibria, viscosity measurements and reaction kinetics. **COB3:** Apply analytical methods for determination of ions, transport numbers, acid strength and basicity using instrumental techniques.	

	COB4: Develop skills in preparation and characterization of inorganic coordination compounds. **COB5:** Perform quantitative estimation of metal ions using complexometric titration methods and suitable indicators. **COB6:** Interpret experimental data to evaluate thermodynamic, kinetic and analytical parameters with accuracy and precision.
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Determine concentration of halide ions in mixtures using potentiometric titration with silver nitrate. **CO2:** Estimate strength of mixed acids (HNO_3 and H_2SO_4) and basicity of acids using conductometric methods. **CO3:** Determine concentration of Fe^{3+} ions colorimetrically and evaluate transport number of Ag^+ and NO_3^- ions potentiometrically. **CO4:** Study phase diagram of ternary systems and calculate molecular radius using viscosity measurements. **CO5:** Determine energy of activation for second order reactions using experimental kinetic data. **CO6:** Prepare coordination compounds and estimate metal ions such as Mn^{2+} using complexometric titration with appropriate indicators.
9	**Modules**:
	Module 1:
	1.1 Instrumental Experiments: 1) To determine the amount of iodide bromide and chloride in the mixture by potentiometric titration with silver nitrate. 2) To estimate strength of HNO_3 & H_2SO_4 in the mixture of both acids conductometrically. 3) To find out the strength of borax solution by titrating it against HCl pH-metrically. 4) To estimate Fe^{+3} ions by thiocayanate method colorimetrically . 5) To determine the transport number of Ag^+ and NO_3^- ions in $AgNO_3$ potentiometrically. 6) To determine the basicity of an acid such as citric acid conductometrically.
	Module 2:
	2.1 Non- Instrumental Experiments: 1) Phase equilibria::To study phase diagram of three component system water-chloroform/ toluene- acetic acid by weight method. 2) To determine the radius of Glycerol molecule by viscosity measurement. 3) The study of energy of activation of second order reaction i.e. reaction between $K_2S_2O_8$ and KI (Unequal concentrations)

	2.2 Inorganic Chemistry 1) Preparation of Tris(acetylacetonato)iron(III) 2) Preparation of tetraamine copper sulphate $[Cu(NH_3)_4]SO_4.H_2O$ 3) Estimation of Manganese by complexometric titration method using EBT indicator.
10	**Reference Books:** **Module 1 and 2 : Physical Chemistry** 1 A. M. James and F.E. Prichard, Practical Physical Chemistry Longman publication, 3rd edition,1974 2 R.C. Das and B. Behra, Experiments in Physical Chemistry, Tata Mc Graw Hill, 1983 3 J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2006 4 J. N. Gurtu and R Kapoor, Advanced Experimental Chemistry., S.Chand and Co. Vol-I, 1980 5 V. D. Athawale, Experimental Physical Chemistry , New Age International (P) Limited, 2001 6 B. D. Khosla, V. C. Garg and A. Gulati, Senior Practical Physical Chemistry, R Chand and Co.. 2011 **Module 2: Inorganic Chemistry** 1 A. I. Vogel, Quantitative Inorganic Analysis, 5th Edn Longman Scientific and Technical, 1989. 2 J. D. Woolins, Inorganic Experiments. Hohn Wiley and Sons, 2010 3 W. G. Palmer, Experimental Inorganic Chemistry, Cambridge University Press, 1954 4 G. Raj, Advanced Practical Inorganic Chemistry. Goel Publication, 2010 5 J. E. House, Inorganic chemistry, Academic press, 2nd edition, 2013. 6 G. N. Mukherjee, Advanced Experiments in Inorganic Chemistry., U. N. Dhur & Sons Pvt. Ltd. 2010. 7 W. Conard Fernelius, Inorganic syntheses, Mc-Graw Hill, Vol.II, 1946. 8 G. Pass and H. Sutcliffe, Practical Inorganic Chemistry- Preparation, reactions and instrumental methods, Springer, 2nd edition.1974. 9 G. Marr and B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold Company 1972. 10 G. Christian, Analytical Chemistry, John Wiley, New York 4th edition 1986.

11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Practicals in Advanced Chemistry - III

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Practicals in Advanced Chemistry – III** provides advanced laboratory training in analytical chemistry techniques and interpretation of spectroscopic data for structure elucidation of organic compounds. The course develops practical skills in quantitative estimation of analytes such as urea, proteins and casein using titrimetric and colorimetric methods, separation of mixtures using chromatographic techniques, and determination of purity using ion-exchange methods. It also includes application of instrumental techniques such as pH-metry, flame photometry, spectrophotometry and potentiometry for quantitative analysis. Emphasis is placed on interpretation of UV, IR and NMR spectral data for identification of organic compounds and development of analytical competence relevant to research, pharmaceutical and industrial laboratories.
2	**Vertical :**	Major
3	**Type :**	Practical
4	**Credit**:	2 credits
5	**Hours Allotted :**	60 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop practical skills in quantitative estimation of organic and inorganic analytes using titrimetric and colorimetric methods. **COB2:** Provide knowledge of chromatographic and ion-exchange techniques for separation of mixtures and determination of purity. **COB3:** Develop competence in use of instrumental analytical techniques such as pH-metry, flame photometry, spectrophotometry and potentiometry.	

	COB4: Provide understanding of estimation of biomolecules such as proteins and casein using standard analytical procedures. **COB5:** Develop ability to interpret spectroscopic data (UV, IR and NMR) for structural elucidation of organic compounds. **COB6:** Enhance analytical reasoning for selection of appropriate analytical techniques based on chemical nature of analytes.
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Estimate urea, casein and protein content using titrimetric and colorimetric methods and calculate quantitative results. **CO2:** Determine percentage purity of common salt using cation exchange method and perform chromatographic separation of indicators by calculating Rf values. **CO3:** Determine concentration of maleic acid using pH-metric titration and calculate result. **CO4:** Determine potassium content using flame photometry and chromium content using spectrophotometric method with calibration data. **CO5:** Perform potentiometric titration of KCl using $AgNO_3$ and calculate concentration of analyte. **CO6:** Interpret UV, IR and NMR spectral data to identify structure of at least three monofunctional organic compounds.
9	**Modules**:
	Module 1:
	1.1 Analytical Chemistry (Non -Instrumental) 1) Estimation of Urea content in commercial urea sample by back titration method 2) Estimation of Casein from Milk Powder 3) Estimation of protein by Lowry method 4) Determination of percentage purity of common salt using a cation exchanger. (Amberlite IRC-50) (Standardization is expected). 5) To separate the mixture of Indicator by Paper Chromatography (any two) and find the Rf value i. Methyl Red + Methylene Blue ii. Methyl Red + Bromocresol Green iii. Bromothymol Blue + Methyl Red
	Module 2:
	2.1 Analytical Chemistry (Instrumental) 1) Determination of Maleic acid pH-metrically. 2) Determination of potassium content in a commercial salt sample by flame photometry.

	3) Estimation of Chromium in water sample spectrophotometrically using diphenylcarbazide 4) Potentiometric titration of a standard solution of KCl against $AgNO_3$ **2.2 Analysis of Spectral Data (UV, IR and NMR) (Minimum 3 compounds)** Interpretation and analysis of UV, IR and NMR spectra for structural elucidation of aliphatic and aromatic monofunctional organic compounds. Students shall study and interpret spectral data corresponding to the following suggestive compounds: *(The list is indicative only; equivalent suitable compounds may be included for spectral analysis)* i) 2-Butanone ii) Propionic acid iii) Ethyl acetate iv) Pinacol v) Iodoethane vi) 2-propanol vii) 1-Nitropropane viii) Anisole ix) Benzyl amine x) Benzyl alcohol
10	**Reference Books:** **Module 1 and 2: Analytical Chemistry** 1 Vogel, A. I. Vogel's Textbook of Quantitative Chemical Analysis, 6th ed.; Pearson Education: London, 2000. 2 Harris, D. C. Quantitative Chemical Analysis, 9th ed.; W. H. Freeman and Company: New York, 2016. 3 Mendham, J.; Denney, R. C.; Barnes, J. D.; Thomas, M. J. K. Vogel's Quantitative Chemical Analysis, 6th ed.; Pearson Education: New Delhi, 2000. 4 Fifield, F. W.; Kealey, D. Principles and Practice of Analytical Chemistry, 5th ed.; Blackwell Science: Oxford, 2000. 5 Day, R. A.; Underwood, A. L. Quantitative Analysis, 6th ed.; Prentice Hall: New Delhi, 1991. 6 Jeffery, G. H.; Bassett, J.; Mendham, J.; Denney, R. C. Vogel's Textbook of Quantitative Chemical Analysis, 5th ed.; Longman Scientific: London, 1989. 7 Khosla, B. D.; Garg, V. C.; Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi, 2010. 8 Dash, U. N.; Dharmarha, O. P.; Soni, P. L. Advanced Practical Chemistry, S. Chand & Company: New Delhi, 2009. **Module 2: Organic Chemistry** 1 Robert M. Silverstein, Francis X. Webster & David J. Kiemle, Spectrometric Identification of Organic Compounds, Wiley, 7th Edition, 2005 2 Donald L. Pavia, Gary M. Lampman, George S. Kriz & James R. Vyvyan, Introduction to Spectroscopy, Cengage, 5th Edition, 2015 3 William Kemp, Organic Spectroscopy, Palgrave Macmillan, 3rd Edition, 1991 4 Jag Mohan, Organic Spectroscopy, Narosa Publishing House, 2nd Edition, 2004 5 L. D. Field, S. Sternhell & J. R. Kalman, Organic Structures from Spectra, Wiley, 5th Edition, 2013

11	**Internal Continuous Assessment: 40%**	**External, Semester End Examination 60% Individual Passing in Internal and External Examination**
12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

Title of Paper: Practicals in Advanced Chemistry - IV

Sr. No.	Heading	Particulars
1	**Description of the course :** **Including but Not limited to :**	**Practicals in Advanced Chemistry – IV** provides laboratory training in Inorganic and Organic Chemistry through systematic experimental work. The course develops practical skills in preparation of coordination compounds and quantitative estimation of metal ions using complexometric titration techniques. Qualitative and quantitative analysis of inorganic salts helps in understanding analytical methods and identification of impurities. The organic component of the course focuses on separation of binary liquid–liquid and liquid–solid mixtures using microscale distillation techniques, enabling students to identify components based on their physical and chemical properties. Emphasis is placed on accuracy, systematic experimental approach, purification techniques and interpretation of analytical data relevant to inorganic and organic chemistry.
2	**Vertical:**	Major
3	**Type:**	Practical
4	**Credit**:	2 credits
5	**Hours Allotted:**	60 Hours
6	**Marks Allotted**:	50 Marks
7	**Course Objectives**: **The course aims to:** **COB1:** Develop skills in synthesis of inorganic coordination compounds using appropriate laboratory techniques. **COB2:** Explain principles of complexometric titration for quantitative estimation of metal ions. **COB3:** Apply qualitative and quantitative analytical methods for identification of cations and anions in inorganic salts. **COB4:** Develop understanding of principles involved in separation of binary liquid–liquid and liquid–solid mixtures. **COB5:** Apply microscale distillation techniques for purification and identification of organic compounds.	

	COB6: Interpret experimental observations for accurate analysis and characterization of inorganic and organic substances..
8	**Course Outcomes**: **At the end of the course, students will be able to:** **CO1:** Prepare coordination compounds such as ferrous ethylenediammonium sulphate and copper chloride dimethyl sulfoxide using standard laboratory procedures. **CO2:** Determine calcium and copper content using EDTA complexometric titration with suitable indicators. **CO3:** Analyze water soluble salts for percentage purity and detect impurity ions using wet chemical methods. **CO4:** Identify type of binary mixture and select appropriate method for separation of liquid–liquid and liquid–solid systems. **CO5:** Separate components of binary mixtures using microscale distillation technique. **CO6:** Identify purified organic components based on physical properties and systematic experimental observations.
9	**Modules**:
	Module 1
	1.1 Inorganic Chemistry 1) Preparation of Ferrous ethylene diammonium sulphate 2) Preparation of copper chloride Dimethyl Sulfoxide 3) Determination of Calcium in presence of Magnesium by EDTA titration using Patton Reader indicator 4) Complexometric titration of copper with EDTA using Fast sulphon Black F indicator 5) Determination of percentage purity of the given water soluble salt and qualitative detection w.r.t added impurity cation and/or anion (any Two) Salts of selected Main group metal ions viz. Mg, Ba, Sr/Ca, . Quantitative analysis by titration method. (complexometric titration of all ions using Eriochrome Black T indicator). Qualitative analysis by wet test method. Impurity : NH_4^+,K^+, Cl^-, NO_3^-, I^-, (Note: Standardization of EDTA is not expected)
	Module 2
	2.1 Separation of Binary liquid-liquid and liquid- solid mixture. (Minimum 6 mixtures) 1) Minimum six mixtures to be completed by the students. 2) Components of the liquid-liquid mixture should include volatile liquids like acetone, methyl acetate, ethyl acetate, isopropyl alcohol, ethyl alcohol, EMK and non-volatile liquids like chlorobenzene, bromobenzene, aniline, N, N- dimethylaniline, acetophenone, nitrobenzene, ethyl benzoate.

	3) Components of the liquid - solid mixture should include volatile liquids like acetone, methyl acetate, ethyl acetate, ethyl alcohol, IPA, EMK and solids such as water insoluble acids, phenols, bases, neutral. 4) A sample of the mixture one ml to be given to the student for detection of the physical type of the mixture. 5) After correct determination of physical type, separation of the binary mixture to be carried out by distillation method using microscale technique. 6) After separation into component A and component B, either Volatile Liquid or Solid to be given for identification.
10	**Reference Books:** **Module 1: Inorganic Chemistry** 1 A. I. Vogel, Quantitative Inorganic Analysis, 5th Edn Longman Scientific and Technical, 1989. 2 J. D. Woolins, Inorganic Experiments. Hohn Wiley and Sons, 2010 3 W. G. Palmer, Experimental Inorganic Chemistry, Cambridge University Press, 1954 4 G. Raj, Advanced Practical Inorganic Chemistry. Goel Publication, 2010 5 J. E. House, Inorganic chemistry, Academic press, 2nd edition, 2013. 6 G. N. Mukherjee, Advanced Experiments in Inorganic Chemistry., U. N. Dhur & Sons Pvt. Ltd. 2010. 7 W. Conard Fernelius, Inorganic syntheses, Mc-Graw Hill, Vol.II, 1946. 8 G. Pass and H. Sutcliffe, Practical Inorganic Chemistry- Preparation, reactions and instrumental methods, Springer, 2nd edition.1974. 9 G. Marr and B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold Company 1972. 10 G. Christian, Analytical Chemistry, John Wiley, New York 4th edition 1986. **Module 2: Organic Chemistry** 1 Furniss, Hannaford, Smith & Tatchell, Vogel's Textbook of Practical Organic Chemistry, Pearson Education, 5th Edition, 1989 2 F. G. Mann & B. C. Saunders, Practical Organic Chemistry, Pearson Education, 4th Edition, 2009 3 John C. Gilbert & Stephen F. Martin, Experimental Organic Chemistry —Cengage Learning, 5th Edition, 2011 ……………………………………………………………………………………………….

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12	**Continuous Evaluation through:** Quizzes, Class Tests, presentation, project, creative writing, assignment (any 2)	

QUESTION PAPER PATTERN
(External)

Time: 1 Hour Marks: 30

N.B.:

1. All Questions are Compulsory.

2. Draw neat and labelled diagrams wherever necessary.

Q. No	Type	Marks	Module
Q.1	Multiple Choice Question / Fill in the Blanks (Any 5 out of 10) (5 from each Module)	5	1 & 2
Q.2	Answer in 1–2 Sentences: (Any 5 out of 10) (5 from each Module)	5	1 & 2
Q.3	Answer any 2 of the following. (Any 2 out of 4)	10	1
Q.4	Answer any 2 of the following. (Any 2 out of 4)	10	2

Letter Grades and Grade Points:

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