University of Mumbai

No. AAMS_UGS/ICC/2024-25/147

CIRCULAR:-

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

They are hereby informed that the recommendations made by the Board of Deans at its meeting held on 3rd September, 2024 **vide** item No. 6.5 (N) have been accepted by the Hon'ble Vice Chancellor as per the power confirmed upon him under section 12(7) of the Maharashtra Public Universities Act, 2016 and that in accordance therewith syllabus for **M.Sc. (Physical Chemistry) (Sem – III & IV) for University Department of Chemistry (Autonomous)** as per appendix (NEP 2020) with effect from the academic year 2024-25.

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

(Dr. Prasad Karande)
REGISTRAR

MUMBAI – 400 032
21st September, 2024

To

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

BOD 6.5(N) 03/09/2024

Copy forwarded with Compliments for information to:-

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

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

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

To,

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

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

BOD – 3/9/2024
12 (7) of M.P.U.A. 2016
Item No. – 6.5 (N)

As Per NEP 2020

University of Mumbai

Title of the P.G. Program
M.Sc. (Physical Chemistry)

Syllabus for

Semester – Sem.- III & IV

Department of Chemistry (Autonomous)

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

(With effect from the academic year 2024-25

University of Mumbai

(As per NEP 2020)

Sr. No.	Heading	Particulars
1	**Title of program** **O:_____**	**M.Sc. (Physical Chemistry)**
2	**Scheme of Examination** **R: _____**	**NEP** **50% Internal** **50% External,** **Semester End Examination** **Individual Passing in Internal and External Examination**
3	**Standards of Passing** **R: _____**	**40%**
4	**Credit Structure** **R:SPA – 20 B**	**Attached herewith**
5	**Semesters**	**Sem. III & IV**
6	**Program Academic Level**	**6.5**
7	**Pattern**	**Semester**
8	**Status**	**New**
9	**To be implemented from Academic Year**	**2024-25**

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

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

Preamble

1) Introduction

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

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

2) Aims and Objectives

The aims and objectives of M.Sc. (Physical Chemistry) course are designed to provide students with a well-rounded and advanced education in the field of Physical Chemistry. These goals focus on equipping students with a deep understanding of chemical principles, fostering research and analytical skills, and preparing them for successful careers in various sectors of the chemical sciences.

The M.Sc. (Physical Chemistry) course aims to produce skilled and knowledgeable professionals who can contribute to scientific research, industrial innovation, and the betterment of society through their expertise in Physical chemistry.

3) Learning Outcomes

The learning outcomes of an M.Sc. (Physical Chemistry) course are designed to equip students with a comprehensive and advanced understanding of the field of chemistry. These learning outcomes reflect the knowledge, skills, and competencies that students are expected to gain upon successful completion of the program.

4) Any other point (if any) : The skills and knowledge acquired during this master's program will make the students well-equipped for diverse roles.

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

R _____

Post Graduate Program: M.Sc. (Physical Chemistry)

परिशिष्ट-1

Year	Level	Sem	Major				RM	OJT/ FP	RP	Cum. Cr.	Degree
			Mandatory			Electives					
1	6.0	Sem I	3*4+ 2=14			4	4		-	22	PG Diploma (after 3 Years Degree)
			Physical Chemistry-I (112016150111)	TH	4	Analytical Chemistry-I (112016150511) **(OR)** Applied Industrial Chemistry-I (112016150512)	Research Methodology (112016150611)				
			Inorganic Chemistry-I (112016150211)	TH	4						
			Organic Chemistry-I (112016150311)	TH	4						
			Chemistry Practical-I (112016150411)	PR	2						
		Sem II	3*4+ 2=14			4	-	4 (112016251211)	-	22	
			Physical Chemistry-II (112016250711)	TH	4	Analytical Chemistry-II (112016251111) **(OR)** Applied Industrial Chemistry-II (112016251112)					
			Inorganic Chemistry-II (112016250811)	TH	4						
			Organic Chemistry-II (112016250911)	TH	4						
			Chemistry Practical-II (CHEM 510)/ 112016251011	PR	2						
Cum. Cr. For PG Diploma			28			8	4	4		44	
Exit Option: PG Diploma (44 credits) after Three Year UG Degree											

R:SPA – 20 B

Year	Level	Sem (2yr)	Major				RM	OJT/FP	RP	Cum. Cr.	Degree
2	6.5	Sem III	3*4+ 2=14			4	-	-	4 (CHEM 606)	22	PG Degree after 3-yr UG or PG Degree after 4-yr UG
			Solid state chemistry & Scientific Computing (CHEM 601)	TH	4	**Elective I:** Interfacial Science (CHEM 60511) OR **Elective II:** Special Topics in Physical Chemistry-I (CHEM 60512)					
			Molecular Spectroscopy (CHEM 602)	TH	4						
			Statistical Thermodynamics and Electrochemistry-I (CHEM 603)	TH	4						
			Physical Chemistry Practical (CHEM 604)	PR	2						
		Sem IV	3*4=12			4	-	--	6 (CHEM 611)	22	
			Atomic Structure, Group Theory, and Chemical Bonding (CHEM 607)	TH	4	**Elective I:** **IPR and Chemoinformatic** **(OR)** **Elective II:** Special Topics in Physical Chemistry-II (CHEM 61012) **Elective 2**					
			Electrochemistry-II (CHEM 608)	TH	4						
			Polymer Science and Photo Chemistry (CHEM 609)	TH	4						
Cum. Cr. For 1 Yr PG Degree			26			8			10	44	
Cum. Cr. For 2 Yr PG Degree			54			16	4	4	10	88	

Sign of HOD

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

Sign of Dean,

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

PROGRAMME SPECIFIC OUTCOME (PSOs)

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

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

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

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

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

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

7. Exhibit professional work ethics and norms of scientific development.

Syllabus for
M.Sc. (Physical Chemistry)
(Sem. III & IV)

Semester – III

SEMESTER: III

PROGRAM(s): M.Sc.-II	SEMESTER: III			
Course: Paper-I	Course Code: CHEM 601 Course Title:- Solid State Chemistry & Scientific Computing			
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50

Learning Objectives:

Solid State Chemistry

- Understand the formation, structure, and types of defects in solid materials.
- Analyze diffusion processes in solids.
- Examine the electrical and magnetic properties of materials.

Scientific computing

- Master the basics of Python installation and setup.
- Develop proficiency in Python for data manipulation and analysis.
- Learn to create and use plots for data visualization.
- Gain skills in writing conditional statements, loops, and user-defined functions.

Course outcomes:-

Solid-State Chemistry:

1. Ability to identify and characterize different types of defects in solids.
2. Capability to model and predict the behavior of materials under different conditions based on their diffusion and electronic properties.
3. Proficiency in understanding the physical principles behind the electrical and magnetic properties of materials

Scientific computing:

1. Proficiency in using Python for scientific computing.
2. Ability to apply programming skills to solve real-world problems in chemistry and materials science.
3. Development of critical thinking and problem-solving skills through programming challenges.

Course Code: CHEM 601

Paper-I

CHEM 601: Solid State Chemistry & Scientific Computing

Unit-I:	**SOLID STATE Chemistry - I**	**[15L]**
	Defects and non-stoichiometry: Types of Defects: Point defects, plane defects, line defects. Thermodynamics of defects, Solid solutions.	
	Diffusion in solids: Mechanisms, Steady state and non-steady state diffusion, factors affecting diffusion, Kirkendall effect.	
Unit-II:	**SOLID STATE Chemistry - II**	**[15L]**
	Electrical Properties: Electrical conductivity of metals, Free electron theory, semiconductors, Intrinsic and extrinsic semiconductivity, Band theory, Superconductivity: Conventional Superconductors, Bardeen-Cooper-Schrieffer (BCS) theory, High temperature Superconductors, Ferromagnetic Superconductors, Uses of High temperature Superconductors.	
	Magnetic Properties: Diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism. Calculation of magnetic moments, influence of temperature on magnetic behaviour, domains and hysteresis, Soft and hard magnetic materials.	
Unit-III:	**SCIENTIFIC COMPUTING - I**	**[15L]**
	Python and Jupyter Notebook: Python, Software, Using Jupyter Notebooks, Markdown, Comments, SciPy Stack	
	Basics of Python: Numbers, Variables, Strings, Boolean Logic, Conditions, List & Tuples, Loops, File Input/ Output (I/O), user defined functions.	
Unit-IV:	**SCIENTIFIC COMPUTING - II**	**[15L]**
	Intermediate Python: Syntactic Sugar, Dictionaries, Set, Python Modules, Zipping and Enumeration, Encoding Numbers, Advance functions, Error Handling.	

	Plotting with Matplotlib: Plotting basic, Plotting types, Overlaying plots, Multifigure plots, 3D plotting, Surface plots.	

*** Numericals/Problems are expected from each Unit-**

Reference books:

1. H. V. Keer, *Principles of the Solid State*, New Age International Publishers,
2. A. R. West, *Solid State Chemistry and its Applications*, John Wiley and Sons (Asia) Pte. Ltd.,
3. L. E. Smart and E. A. Moore, *Solid State Chemistry – An Introduction*, 3rd Ed., Taylor and Francis, 2005.
4. Charles J. Weiss, Scientific Computing for Chemists with Python, licensed under CC BY-NC-SA 4.0.
5. K. A. Tanemura, D. S. Costa and K. M. Merz, Python for Chemists, American Chemical Society.
6. M. Kanagasabapathy, Python for Chemistry, BPB Publications.

PROGRAM(s): M.Sc.-II	SEMESTER: III			
Course: Paper-II	**Course Code:** CHEM 602 **Course Title:-** Molecular Spectroscopy			
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**–**	**04**	**50**	**50**

Learning Objectives:

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

Course outcomes:-

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

Course Code: CHEM 602

Paper-II

CHEM 602: *Molecular Spectroscopy*

Unit-I	**BASIC PRINCIPLES OF SPECTROSCOPY** Absorption and Emission of Radiation, Width and intensity of spectral lines, transition probability and selection rules, Fourier transform spectroscopy, computer averaging of signals (CAT), lasers.	**[15L]**
	Microwave spectroscopy: Rotational spectra of diatomic (non-rigid) molecules, Population of rotational levels and intensity of rotational lines, effect of isotopic substitution, rotational spectra of polyatomic molecules (linear and symmetric top), Stark effect.	
Unit-II	**INFRARED SPECTROSCOPY** Anharmonic oscillator, Rotational-vibrational spectrum, Breakdown of Born-Oppenheimer approximation, combinational differences, vibrations of polyatomic molecules, rotational fine structure of vibrational spectrum of polyatomic molecules.	**[15L]**
	Raman spectroscopy: Classical and quantum theory of Raman scattering, Experimental Methods, Pure rotational, vibrational and rotational-vibrational Raman spectrum of diatomic and polyatomic molecules, polarization and depolarization of Raman lines, correlation of infrared and Raman spectra, normal modes and symmetry, Resonance Raman Scattering, Surface Enhanced Raman Scattering	
Unit-III	**ELECTRONIC SPECTROSCOPY:** Vibrational course structure, Progressions and sequences, The Franck-Condon principle, Deslandres tables, Dissociation energies, Birge-Sponer extrapolation, Rotational fine structure, Fortrat diagram, Predissociation, Electronic spectra of polyatomic molecules.	**[15L]**
	Nuclear magnetic resonance spectroscopy: Chemical shift, spin-spin coupling, Chemical and magnetic equivalence, first and second order spectra, pulsed NMR, relaxation times, multipulse techniques, spin echoes, two- and three- dimensional NMR, NMR of nuclei other than proton, nuclear overhauser effect.	
Unit- IV	**NUCLEAR QUADRUPLE RESONANCE:** Principle, Transitions for axially and non-axially symmetric systems, applications.	**[15L]**
	Electron spin resonance spectroscopy: Basic theory, Instrumental Aspects, The g – factor, hyperfine structure, applications to free radicals, inorganic radicals, transition metal complexes.	

	Mössbauer Spectroscopy: Principles, Recoilless emission and absorption of γ-rays, experimental methods, isomer shift, hyperfine structure (quadrupole interaction), magnetic hyperfine interaction, applications.	

Reference books:

1. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed., Tata-McGraw-Hill, 1994.
2. M. L. Gupta, *Atomic and Molecular Spectroscopy*, New Age International Publishers, 2001.
3. H. S. Randhawa, *Modern Molecular Spectroscopy*, McMillan India Ltd., 2003
4. G. Aruldas, *Molecular Structure and Spectroscopy*, Prentice-Hall of India, 2001.
5. J. Michael Hollas, *Modern Spectroscopy*, 4th Ed., John Wiley and Sons, 2004.

List of Books for further reading:

1. R. Drago, *Physical Methods for Chemists*, Saunders, Philadelphia, 1992.
2. B. P. Straughan and S. Walker (Eds.), Spectroscopy – Vol 1-3, Chapman and Hall, New York, 1976.
3. R. K. Harris, *Nuclear Magnetic Resonance Spectroscopy*, Pitman, London, 1983.
4. Donald L. Pavia, Gary M. Lampman and George S. Kriz, *Introduction to Spectroscopy*, 3rd ed., Thomson, Brooks/Cole, 2001.

PROGRAM(s): M.Sc.-II	SEMESTER: III			
Course: Paper-III	**Course Code:** CHEM 603 **Course Title:- Statistical Thermodynamics and Electrochemistry-I**			
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**–**	**04**	**50**	**50**

Learning Objectives:

1. To gain knowledge of the advanced concepts in molecular dynamics and electrochemistry.
2. Students should be familiar with the principles of statistical mechanics, including probability distributions, ensemble theory, and the connection between microscopic states and macroscopic observables.
3. Students should be familiar with the working principles and wide range of applications of fuel cells and batteries including stationary power generation, transportation (e.g., fuel cell and battery vehicles), portable power, and backup power systems.
4. Students should learn the fundamental principles underlying electroplating, including Faraday's laws, electrodeposition mechanisms, and the factors influencing plating quality.
5. Mastery of the principles of thermodynamics as they apply to biological systems, including concepts such as entropy, enthalpy, Gibbs free energy, and their application to biochemical reactions and equilibrium.

Course outcomes:-

1. Students will learn about various microscopic models used in statistical thermodynamics, such as the classical, quantum, and semiclassical models, and understand their limitations and applications.
2. Students will learn the principles of designing and integrating fuel cell and battery systems into various applications, considering factors such as system efficiency, reliability, durability, and cost.
3. Knowledge of the structure and function of biological membranes, including membrane potential, ion channels, transporters, and the role of membranes in cellular communication and signaling.
4. Students will be familiar with various plating materials (e.g., Gold, silver, nickel, chromium, copper) and the specific processes involved in depositing them onto substrates.

Course Code: CHEM 603

Paper-III

CHEM 603: Statistical Thermodynamics and Electrochemistry-I

Unit-I	**FUNDAMENTALS OF STATISTICAL THERMODYNAMICS**	**[15L]**
	Permutations, probability, microstates and configurations, the most probable distribution, ensembles, distribution laws: Boltzmann distribution, Bose-Einstein statistics, Fermi-Dirac statistics. Partition function, evaluation of translational, rotational, vibrational and electronic partition functions for ideal gases	
Unit- II	**APPLICATIONS OF STATISTICAL THERMODYNAMICS IN CHEMICAL SYSTEMS**	**[15L]**
	Calculation of thermodynamic properties (Energy, Heat capacity, Enthalpy, Entropy, Helmholtz energy, Gibbs energy) in terms of partition functions for mono, di and polyatomic gases, equilibrium constants, residual entropies, heat capacities of ideal gases, heat capacities of solids.	
Unit-III	**THERMODYNAMICS OF BIOLOGICAL SYSTEMS**	**[15L]**
	Thermodynamics of biopolymer solutions, thermodynamics of biochemical reactions involving adenosine triphosphate (ATP), osmotic pressure, membrane equilibrium, muscular contraction and energy generation in mechano-chemical systems.	
	Structures and functions of cell membrane, ion transport through cell membrane and irreversible thermodynamic treatment of membrane transport. Biological Buffers.	
Unit-IV	**ELECTROCHEMISTRY-I**	**[15L]**
	Batteries: Working, principle, cell reactions and cell performances of Lithium Ion Batteries, and their applications.	
	Fuel cells: Classification, H_2–O_2 fuel cell, choice of electrolyte, advantages, disadvantages.	
	Electroplating: Electroplating of metals, throwing power of an electroplating bath, mechanism of electro-deposition, typical electroplating processes and applications of electroplating metal.	
	Super Capacitors: Introduction, classification, and applications	

Reference books:

1. D. A. McQuarrie and J. D. Simon, *Molecular Thermodynamics*, Viva Books Private Limited, First Indian Ed., 2004.
2. D. A. McQuarrie and J. D. Simon, *Physical Chemistry, a Molecular Approach*, Viva Books Private Limited, First South Asian Ed., 1998. Chap.
3. E. D. Kaufmann, *Advanced Concepts in Physical Chemistry*, McGraw-Hill, 1966.
4. Robert P. H. Gasser and W. Graham Richards, *An Introduction to Statistical Thermodynamics*, World Scientific Publishing Co. Pte. Ltd., 1995.
5. William Blum and George B. Hogaboom, *Principles of Electroplating and Electroforming*, 3rd ed., McGraw-Hill Book Co., 1949.
6. Frederick A. Lowenheim, *Modern Electroplating*, 3rd ed. John Wiley Sons, Inc., 1974.
7. L. I. Antropov, *Theoretical Electrochemistry*, Mir Publishers, Moscow, 1972.
8. H. H. Uhlig and R. W. Rewic, *Corrosion and Corrosion Control*, John Wiley and Sons, New York, 1985.
9. Mars G. Fortana, *Corrosion Engineering*, 3rd ed., McGraw-Hill Book Co., 1987.
10. Nester Perez, *Electrochemistry and Corrosion Science*, Kluwer Academic Publisher, 2004.
11. R. Narayan and B. Vishwanathan, *Chemical and Electrochemical Energy Systems*, Universities Press (India) Ltd., 1998.
12. C. R. Cantor and P. R. Schimmel, *Biophysical Chemistry*: Part I, II and III, W. H. Freeman and Co., 1980.
13. R. B. Martin, *Introduction to Biophysical Chemistry*, McGraw-Hill New York, 1964.
14. S. Ramakrishnan, *Biophysical Student Mannual*, T. R. Publications (Madras), 1994.
15. J. H. Weil, *General Biochemistry*, New Age International Publishers, New Delhi.

PROGRAM(s): M.Sc.-II	SEMESTER: III			
Course: Paper IV	**Course Code: CHEM 604** **Course Title:-** Physical Chemistry Practical			
Teaching Scheme				**Evaluation Scheme**
Practical (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks 25)**	**Semester End Examination (Marks- 25)**
16	**–**	**02**	**25**	**25**

Learning Objectives:
Physical Chemistry

1.To gain knowledge of the advanced concepts in pH metry, potentiometry and conductometry experiments.

2.To develop scientific temper and research-based skills accomplished to encountered in the field of research.

Course Outcomes:-
Physical Chemistry

1. Learners will acquainted with the Python programming language and apply the same in solving chemical problems.
2. Learners will be able to apply the subject fundamental principles with practical knowledge to design experiments, analyze and interpret data to reach proper conclusions.
3. Learners will train to handle instruments like digital potentiometer, conductivity meter, and spectrophotometer.

Course Code: CHEM 604

Paper-IV

CHEM 604: Physical Chemistry Practical

A) Minor Experiments (Minimum four)

1) Solubility:

Study the variation of solubility of calcium hydroxide in the presence of sodium hydroxide and hence determine the solubility product at room temperature.

2) Viscosity Measurements:

i). To determine limiting viscosity number of polystyrene.

ii). To determine chain linkage in polyvinyl alcohol from viscosity measurements.

iii). To determine relative molecular mass of polystyrene from viscosity measurements.

3) Surface Chemistry:

i). To determine the critical micelle concentration (CMC) of sodium lauryl sulphate/N-cetyl-N,N,N-trimethyl ammonium bromide (CTAB) from measurements of conductivities at different concentrations.

ii). To determine the critical micelle concentration (CMC) of sodium lauryl sulphate/N-cetyl-N,N,N-trimethyl ammonium bromide (CTAB) from measurements of surface tensions at different concentrations.

4) Potentiometry / pH metry:

i). To determine the stability constant of the silver-ammonia complex.

ii). To determine the transport number of silver and nitrate ions in aqueous solution from the cell potential of the concentration cell with liquid junction potential.

iii). To determine the substitution constants in Hammett equation for 3-aminobenzoic acid/4-aminobenzoic acid and 3-nitrobenzoic acid/4-nitrobenzoic acid.

5) Spectrophotometry:

To determine the ionization constant of methyl red/ bromophenol blue.

B) Interpretation of spectra/data- (Minimum four):

i). Interpretation of vibrational-rotational spectra of rigid and non-rigid diatomic molecules

ii). Interpretation of electronic spectra of diatomic molecules.

iii). Interpretation of electronic spectra of simple polyatomic molecules.

iv). Interpretation of ESR spectra.

v). Interpretation of Mössbauer spectra.

vi). Analysis of XRD pattern of cubic system

vii). Interpretation of thermograms.

viii). **Spectral analysis:** Structure elucidation with a given set of spectra, Determination of the degree of un-saturation from molecular formula. Systematic interpretation of set of spectra including some or all of the following: UV-Vis, IR, PMR, CMR, DEPT, Mass. Identification of the compound based on systematic interpretation of spectral data would be preferred.

C) Scientific Computing (Minimum two)

i). Write a Python script that can take in any of the following molecular formulas as a string and print out whether the compound is an acidic, basic, or neutral compound when dissolved in water. The script should not contain pre-sorted lists of compound but rather determine the class of molecule base on the formula.

ii). Write a Python script that takes in the number of electrons and protons and determines if a compound is cationic, anionic, or neutral.

iii). Write a Python script for generating standing wave surface plot for the particle trapped in 2D box.

D) Demonstration of Voltammograms

CV, LSV, DPV, and SWV of the redox system ($K_3[Fe(CN)_6]$/ $K_4[Fe(CN)_6]$)

List of reference Books for Practicals and Spectral Interpretaion:

1. B. Vishwanathan and P. S. Raghavan, Practical Physical Chemistry, Viva Books Private Limited, 2005.
2. A. M. James and F. E. Prichard, *Practical Physical Chemistry*, 3rd ed., Longman, 1974.
3. B. P. Lewitt (ed.), *Findlay's Practical Physical Chemistry*, 9th ed., 1973.
4. C. D. Brennan and C. F. H. Tipper, *A Laboratory Manual of Experiments in Physical Chemistry*, McGraw-Hill, 1967.
5. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed., Tata-McGraw-Hill, 1994.
6. *Introduction to Spectroscopy*, Donald L. Pavia, Gary M. Lampman, George S. Kriz, Thomson Brooks.
7. *Spectrometric Identification of Organic Compounds*, R. Silverstein, G.C Bassler and T.C. Morrill, John Wiley and Sons.
8. *Organic Spectroscopy*, William Kemp, W.H. Freeman & Company.
9. *Organic Spectroscopy-Principles and Applications*-Jagmohan, Narosa Publication.
10. *Organic Spectroscopy*, V.R. Dani, Tata McGraw Hill Publishing Co.
11. *Spectroscopy of Organic Compounds*, P.S. Kalsi, New Age International Ltd.
12. *Organic Structures from Spectra*, 4th ed., L. D. Field, S. Sternhell and J. R. Kalman, Wiley.

Elective-I

PROGRAM(s): M.Sc.-II	SEMESTER: III			
Course: Paper-Elective -I	**Course Code: CHEM 60511** **Course Title:- Interfacial Science**			
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**–**	**04**	**50**	**50**

Learning Objectives:

1. Students should learn different types of catalysis, including homogeneous catalysis, heterogeneous catalysis, enzymatic catalysis, and organocatalysis, and their applications in various chemical transformations.
2. Proficiency in various synthesis and characterization techniques specific to nanochemistry, including bottom-up and top-down synthesis methods, spectroscopic techniques (e.g., UV-Vis spectroscopy, X-ray diffraction), electron microscopy (TEM, SEM), and surface analysis techniques (AFM, STM).
3. Students should have comprehensive understanding of surface properties such as topography, roughness, chemical composition, and electronic structure, and their importance in determining material behavior and performance.

Course outcomes:-

1. Students will be able to critically evaluate the advantages and limitations of different catalytic systems and green chemistry approaches, and make informed decisions based on scientific evidence and sustainability considerations.
2. Knowledge of recent advancements, current research trends, and emerging applications in nanochemistry, enabling students to stay updated and contribute to the advancement of the field.
3. Explore the applications of surface characterization techniques in various fields, including materials science, nanotechnology, catalysis, corrosion protection, biotechnology, and semiconductor device fabrication.

Course Code: CHEM 60511

Paper-Elective-1

CHEM 60511: Interfacial Science

Unit-I	**HETEROGENEOUS CATALYSIS**	**[15L]**
	Adsorption on solid surfaces, Chemisorption at metal surfaces and oxides, Kinetics of catalyst reactions, structure, preparation and uses of heterogeneous catalysts, Application of catalysis in energy conversion, petroleum industry and atmospheric pollution control.	
Unit-II	**CATALYSIS AND GREEN CHEMISTRY** Comparison of catalyst types, heterogeneous catalysts, zeolites-composition and structures, synthesis of zeolites, structure determination, uses of zeolites, zeolites as catalyst, zeolites and the bulk chemical industry, catalysts in fine chemicals and pharmaceutical industries, catalytic converters, homogeneous catalysts -transition metal catalysts with phosphine ligands-Wilkinson's Catalyst, greener Lewis acids, asymmetric catalysis, phase transfer catalysis, bio catalysis, photo catalysis.	**[15L]**
Unit-III	**NANOCHEMISTRY** Introduction, Properties of materials & nanomaterials, role of dimensions in nanomaterials, advantages of nanosize over micron size, need of surface/encapsulation of nanomaterials, some important properties of nanomaterials, Techniques for synthesis of nanomaterials- Physical method and chemical method. **Nanocomposites:** Comparison with conventional composites. Manufacture and Characteristics of thermoplastic and thermoset nanocomposites products: Fibre reinforced nanocomposites, copolymer / clay nanocomposites, latex / ZnO nanocomposites, hybrid nanocomposites, PVC / $CaCO_3$ nanocomposites, etc. Effect of modifier concentration on structure, mechanical and viscoelastic properties of nanocomposites, Development and Optimization of Polymer melt process, Nanocomposites preparation by injection moulding	**[15L]**
Unit-IV	**SURFACE CHARACTERIZATION TECHNIQUES** **Principles, instrumentation and applications of:** **Electron spectroscopy:** ESCA, AUGER and UPS. **Electron microscopy:**Scanning electron microscopy, Scanning probe microscopes: The Scanning Tunneling Microscope, Atomic force Microscope.	**[15 L]**

Reference Books:

1. R.P.W.Scott, *Tandem Techniques*, Wiley India Pvt.Ltd. Reprint 2009.
2. J. Barker, *Analytical chemistry for open learning*, *Mass spectrometry*, Wiiley IndiaED.
3. H. J. Arnikar, *Essential of Nuclear Chemistry*, New Age International, 1995.
4. G. C. Bond, *Heterogeneous Catalysis*, 2nd ed., Clarendon Press, Oxford, 1987.
5. Mike Lancaster, Green Chemistry: An Introductory Text, Royal Society of Chemistry, 2002.
6. Paul T. Anastas and John C. Warner, Green Chemistry – Theory and Practice, Oxoford University Press, 1998.
7. Albert S. Matlack, Introduction to Green Chemistry, Marcel Dekker, Inc., 2001.
8. Text/Reference books
9. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
10. Nanomaterials Handbook- Yury Gogotsi
11. Encyclopedia of Nanotechnology- Hari Singh Nalwa
12. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
13. Microwave Properties of Magnetic Films - Carmine Vittoria.
14. Physics of Magnetism - S. Chikazumi and S.H. Charap
15. Physical Theory of Magnetic Domains - C. Kittel
16. Magnetostriction and Magnetomechanical Effects - E.W. Lee
17. Springer Handbook of Nanotechnology - Bharat Bhusan
18. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao
19. Synthesis of Nanostructured Materials –Cao
20. Handbook of Nanoscience, Engineering- Goddard et al
21. Nano Engineering in Science & Technology: An introduction to the world of nano design by Michael Rieth.
22. Introduction to Solid State Chemistry – A. R. West
23. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun
24. Physical Properties of Carbon Nanotubes- R. Saito
25. Carbon Nanotubes (Carbon , Vol 33) - M. Endo, S. Iijima, M.S. Dresselhaus
26. The search for novel, superhard materials- Stan Vepr¡ek (Review Article) JVST A, 1999.

Elective-II

PROGRAM(s): M.Sc.-II	SEMESTER: III			
Course: Paper-Elective -II	Course Code: CHEM 60512 Course Title:- Special Topics in Physical Chemistry-I			
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50

Learning Objectives:

1. Students should be able to understand and analyze the mechanisms of organic reactions, including the movement of electrons, intermediates formed, and overall reaction pathways.
2. Students should Gain insights into optoelectronic devices and photonics, including maser, lasers, and photovoltaic cells, and understand the principles behind their operation and design.
3. To understand the advanced concepts in Polymer chemistry.

Course outcomes:-

1. To develop the skill to solve problems based on Polymer Chemistry.
2. Learners will get knowledge of advanced polymer chemistry.
3. Explore the diverse applications of optical properties in various fields, including materials science, chemistry, biology, medicine, telecommunications, and environmental science.
4. Ability to apply principles of kinetics and thermodynamics to predict and understand the rates and energetics of organic reactions.
5. Insight into the dynamics of organic reactions, including transition state theory, and reaction rates.

Course Code: CHEM 60512

Paper-Elective-2

CHEM 60512: Special Topics in Physical Chemistry-I

Unit-I	**Synthesis and properties of important polymers:** PE, Polystyrene, PVC, Teflon, PVA, Polyacrylic acid, Polyesters, Polyurethanes, Polycarbonates, Polyamides, Polyimides, PF resin, UF, MF, Epoxy resins and Silicones. **Polymers processing :Casting :** Thermoforming, Foaming, Lamination, Reinforcing, processing of fibers, Moulding processes : Compression, Injection, Transfer, Blow, Extrusion, Calendering **Biological polymerizations:** Polysaccharides, Proteins, Nucleic acids, lignin, Melanins.	**[15L]**
Unit-II	**Analysis and testing of polymers:** Chemical analysis of polymers, Spectroscopic methods, X-ray diffraction analysis, Microscopy, Thermal analysis, Physical testing. **Polymers in solid state** - Crystalline state, Crystalline-melting temperature, Crystallization kinetics, Techniques to determine crystallinity, Thermal transition and properties, Mechanical properties **Glass transition temperature:** Glass transition temperature, Factors influencing the glass transition temperature, Glass transition temperature and molecular weight, Glass transition temperature and melting point, Importance of glass transition temperature.	**[15L]**
Unit-III	**Functional Materials**	**[15L]**
	Optical Properties: Electron emission in Metals, Photovoltaic effect, Luminescence, Laser and Maser actions, The Ruby laser, Light emitting diodes, Optical fibers. **Dielectric Properties:** Dielectric constant, Clausius-Mosotti equation, Piezoelectricity, Ferroelectricity, Antiferroelectricity, Ferrielectricity. **Phase transformations in solids:** Buerger's classification, Thermodynamic classification, Kinetics of phase transitions, temperature and pressure induced transformations, Martensitic transformations, Order-disorder transitions.	
Unit-IV	**PHYSICAL ORGANIC CHEMISTRY**	**[15L]**
	Acid-base catalysis-General and specific acid and base catalysed reactions, Acidity functions and acidity strength, Reaction rates and acidity scales, Mechanism of acid-base catalysis.	

	Potential Energy surfaces, Bell-Evans Polanyi principle, Marcus theory, Curtin-Hammett principle. Kinetic methods: Determination of reaction order and rate constants, Empirical rate equations for parallel reactions, Sequential reactions.	

Text Books:

1. P. Bahadur and N. V. Sastry, Principles of Polymer Science, second edition, Narosa Publishing House, 2005.

2. C. E. Carraher, Jr., Carraher's Polymer Chemistry, 8th edition, CRC Press, New York, 2010.

3. Joel R. Fried, Polymer Science and Technology, Prentice-Hall of India Pvt. Ltd., 2000.

4. V. R. Gowarikar, H. V. Viswanathan and J. Sreedhar, *Polymer Science*. New Age International Pvt. Ltd., New Delhi, 1990.

5. F. W. Billmeyer Jr., *Text Book of Polymer Science*, 3rd edition, John Wiley and Sons, 1984.

6. Mechanism in Organic Chemistry, Peter sykes, 6th edition onwards.

7. Physical Organic Chemistry, Neil Isaacs

8. Modern Physical Organic Chemistry, Eric V. Anslyn and Dennis A. Dougherty

Books for further reading:

1. J. M. G. Cowie, *Polymers: Chemistry and Physics of Modern M*aterials, 2nd ed. (first Indian Reprint 2004), Replika Press Pvt. Ltd.
2. G. S. Misra, *Introductory Polymer Chemistry*, New Age International (P) Limited, Publishers, 1993.
3. L. H. Sperling, *Introduction to Physical Polymer Science*. 2nd Edition, John Wiley and Sons. Inc.
4. Hans- Georg Elias, *An Introduction to polymer Science*, VCH 1997.
5. Charles E. Seymour, Jr., *Seymour/Carraher's Polymer Chemistry*, 6th ed., Marcel Dekker, Inc., 2003.
6. A. Ravve, Principles of Polymer Science, 2nd ed., Kluwer Academic/Plenum Publishers, New York, 2000.

PROGRAM(s): M.Sc.-II	SEMESTER: III			
Course: Research Project	Course Code: CHEM 606 Course Title:- Research Project			
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
	–	04		

Learning Objectives:

1. To understand and discuss the new research topics in the field of chemistry.
2. To understand the importance, relevance, and procedure to gather back ground literature information from various scientific database.
2. To display, organize and represent correlation between different types of data.
3. To summarize and provide a concise summary of research projects carried out.
4. Demonstrate a capacity to communicate research results clearly and comprehensively.

Course outcomes: -

1. Students will define a research question, design objectives and appropriate hypothesis for their project.
2. Students will find and evaluate relevant literature and back ground information related to their project.
3. Students will learn and use the techniques needed to do their experiments.
4. Students will learn and follow appropriate protocols for documenting their research as well to analyse the experimental data.
5. Students will be able to use logic and evidence to draw conclusions and future scope of the research work done.

Course Code: CHEM 606

Paper-Research Project

CHEM 606: Research Project

Guidelines for the conducting the research project.

1. Each student will perform project separately.
2. **Students should devote enough time to their project work (08 hours each week).**
3. Select a topic that is relevant to your interests and social relevance considering the constraints of available resources and time.
4. Consult with faculty members or mentors to select a relevant research topic that has the potential to contribute to the discipline of chemistry.
5. Literature survey for the research project is suggested to be from Journals indexed in globally recognised databases including recently published research papers.
6. Participation in national and international conferences and other project competitions is encouraged.
7. Project report must be written systematically and presented in bound form.
8. Continuous evaluation of the research project will be done by the internal examiner or mentor.
9. Student must do presentation of the research work in external exam.

Evaluation of Research Project Semester - III

Internal Continuous Assessment: 50% (50 Marks)

Sr. No	Criteria for evaluation	Marks
1.	Attendance (DPR to be maintained)	10
2.	Literature Survey	25
3.	Scheme/ Outline of project / Methodology	15
	Total	**50**

Semester End External Examination: 50% (50 Marks)

Sr. No	**Criteria for evaluation**	**Marks**
1.	Presentation	15
2.	Dissertation	20
3.	Viva	15
Total		**50**

Semester – IV

SEMESTER: IV

PROGRAM(s): M.Sc.-II	SEMESTER: IV			
Course: Paper-I	Course Code: CHEM 607 Course Title:- Atomic Structure, Group Theory, and Chemical Bonding			
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50

Learning Objectives:

1. To gain knowledge of the advanced concepts in quantum mechanics, applications of HMO theory, group theory, and molecular dynamics.
2. To understand the advanced concepts in variation methods.

Course outcomes:-

1. To understand the use of Schrodinger wave equation in one and two-electron systems along with applications of HMO theory.

Course Code: CHEM 607

Paper-I

CHEM 607: Atomic Structure, Group Theory, and Chemical Bonding

Unit-I	**APPROXIMATE METHODS**	**[15L]**
	Variation method (linear and non-linear), Non-degenerate first order perturbation theory, Application to helium atom-ground state, Hückel molecular orbital method: conjugated π systems, Dissociation energy and aromaticity, π-electron densities and bond orders, Theory of electrocyclic reactions –Woodward's-Hoffmann rule, Introduction to extended Hückel molecular orbital method	
Unit-II	**MULTI-ELECTRONIC ATOMS & THEORY OF ANGULAR MOMENTUM**	**[15L]**
	Anti-symmetry and Pauli principle, Slater determinants, Slater type orbitals, Basis sets, Russell-Saunders coupling, Term symbols, Hund's rules, Normal and anomalous Zeeman effect, Paschen Back effect	
Unit-III	**GROUP THEORY**	**[15L]**
	Symmetry elements and symmetry operations, Symmetry point groups, Identification of point group of molecules, Representation of groups, Matrix representation of operations, Characters and character tables, Reducible and irreducible representations, Statement of the Great Orthogonality theorem and its consequences, Symmetry adapted linear combination	
Unit-IV	**DIATOMIC & POLYATOMIC MOLEUCLES**	**[15L]**
	Diatomic molecules: Born-Oppenheimer approximation, Valence bond theory of hydrogen molecule, Molecular orbital theory of hydrogen molecule ion, Molecular orbitals of homonuclear and heteronuclear diatomic molecules, Bond order, Term symbols. **Polyatomic molecules:** Hartee-Fock SCF method and configuration interaction, Walsh diagrams.	

Reference books:

1. D. A. McQuarrie and J. D. Simon, *Physical Chemistry - a molecular approach*, Viva Books Private Limited, New Delhi, 1998.
2. D. A. McQuarrie, *Quantum Chemistry*, Viva Books Private Limited, New Delhi, first Indian ed., 2003.

3. R. K. Prasad, *Quantum Chemistry*, 3rd Ed., New Age International Publishers, 2006.
4. Ira N. Levine, *Quantum Chemistry*, 5th Ed., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.
5. James E. House, *Fundamentals of Quantum Chemistry*, Second Ed., Academic Press, 2005.
6. Robert L. Carter, *Molecular Symmetry and Group Theory*, John Wiley and Sons (Asia) Pte. Ltd., 2004.
7. T. A. Littlefield and N. Thorley, *Atomic and Nuclear Physics – An Introduction*, Van Nostrand, 1979.

List of Books for further reading:

1. John P. Lowe, *Quantum Chemistry*, 3rd ed., Academic Press, New York, 2006.
2. R. Anantharaman, *Fundamentals of Quantum Chemistry*, McMillan India Limited, 2001.
3. Mahendra R. Awode, *Quantum Chemistry*, S. Chand and Co. Ltd., New Delhi, 2002.
4. David O. Hayward, *Quantum Mechanics for Chemists*, Royal Society for Chemistry, 2002.
5. Jack Simons, *An Introduction to Theoretical Chemistry*, Cambridge University Press, 2003.
6. Victor M. S. Gil, *Orbitals in Chemistry, A Modern Guide to Students*, Cambridge University Press, 2000.
7. A. K. Chandra, *Introduction to Quantum Chemistry*, 4th Ed., Tata-McGraw-Hill, 1994.
8. S. N. Datta, *Lectures on Chemical Bonding and Quantum Chemistry*, Prism Books Pvt. Ltd., 1998.
9. R. McWeeny, *Coulson's Valence*, 3rd. Ed., Oxford University Press, 1979.
10. J. N. Murell, S. F. A. Kettle and J. M. Tedder, *The Chemical Bond*, Wiley, 1985.
11. F. A. Cotton, *Chemical Applications of Group Theory*, 3rd Ed., John Wiley and Sons (Asia) Pte. Ltd., 1999.
12. D. C. Harris and M. D. Bertolucci, *Symmetry and Spectroscopy*, Oxford University.

PROGRAM(s): M.Sc.-II	SEMESTER: IV			
Course: Paper-II	**Course Code:** CHEM 608 **Course Title:-** Electrochemistry-II			
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**–**	**04**	**50**	**50**

Learning Objectives:

1. Familiarity with various electroanalytical techniques including voltammetry, potentiometry, coulometry, amperometry and the instrumentation used in these techniques.
2. Knowledge of different electrode materials and their properties, as well as methods for modifying electrodes to enhance sensitivity, selectivity, and stability in electroanalytical measurements.
3. Understanding the fundamental principles of electrophoresis, including the movement of charged molecules in an electric field, factors influencing mobility, and the role of buffers and pH in separation.
4. Familiarity with different types of electrophoresis techniques such as agarose gel electrophoresis, polyacrylamide gel electrophoresis (PAGE), and capillary electrophoresis (CE),, including their principles, applications, and limitations.

Course outcomes:-

1. Application of electroanalytical techniques to the analysis of various chemical species, including determination of concentrations, detection of trace analytes, and monitoring of reaction kinetics.
2. Understanding of the principles and applications of electrochemical sensors and biosensors for detecting and quantifying analytes in environmental, biological, and industrial samples.
3. Understanding of the applications of electrophoresis in molecular biology and biochemistry, e.g. DNA sequencing,
4. Familiarity with the operation and maintenance of electrophoretic instrumentation, gel tanks, capillary systems, electrodes, and detection systems.
5. Ability to prepare samples for electrophoresis, including denaturation, loading onto gels or

capillaries, and staining procedures.

Course Code: CHEM 608

Paper-II

CHEM 608: Electrochemistry-II

Unit I	**POLAROGRAPHY** Necessity and development of new voltammetric techniques and their comparison with classical DC polarography, Current sampled (TAST) polarography, Pulse (normal, differential and differential double pulse) Polarography,	**[15L]**
Unit II	**VOLTAMMETRY** AC and square wave, linear sweep voltammetry and cyclic voltammetry, criteria of reversibility of electrochemical reactions, Quasi reversible and irreversible processes, stripping voltammetry, adsorptive stripping voltammetry, voltammetry with ultra-micro electrodes, Chemically modified electrodes, Molecularly Imprinted Polymers (MIP), Applications of electrochemical methods in organic synthesis.	
Unit III	**CHRONOTECHNIQUES & SENSORS** Chronopotentiometry, applications of chronopotentiometry, chronoamperometry and chronocoulometry. Electrochemical sensors-potentiometric sensors, amperometric sensors and conductivity measurement; Ion selective field effect transistors - Principle, applications and advantages; Biosensors-Bio catalytic membrane electrodes, enzyme based glucose biosensors; Analysis based on multilayer films-General Principle, film structures; Disposable multilayer pIon systems-General principle, performance and applications; Screen printed electrodes. Quartz Crystal Microbalance: Principles and Applications.	**[15L]**
Unit IV	**ELECTROPHORESIS** Zone electrophoresis, factors affecting migration rates, supporting media (gel, paper, cellulose acetate, starch, polyacrylamide, agarose, sephedax, and thin layers). Techniques of electrophoresis: low and high voltage, SDS-PAGE, isoelectric focusing; continuous and discontinuous electrophoresis, Capillary electrophoresis, electro osmotic flow; Techniques of capillary electrophoresis: zone, gel, isoelectric focusing, isotechophoresis and micellar electrokinetic capillary chromatography, detection and applications.	**[15L]**

Reference books:

1. D. A. Skoog, F. J. Holler, and T. A. Nieman, *Principles of Instrumental Analysis*, 5th ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8th ed., Philadelphia: Saunders College Publishing, 2004.
3. A. J. Bard and L. R. Faulkner, *Electrochemical Methods*, Wiley, New York, 1980.

4. A. M. Bond, *Modern Polarographic Methods in Analytical Chemistry*, Marcel Dekker, New York, 1980.
5. J. J. Lingane, Electroanalytical Chemistry, 2nd ed.
6. A. Braithwaite and F. J. Smith, *Chromatographic Methods*, 5th ed., Kluwer Academic Publisher, 1999.
7. F. W. Fifield and D. Kealey, *5th ed*., Blackwell science Ltd. 2000.
8. Andrew G. Ewing, Ross A. Wallingford, and Teresa M. Olefirowicz, *Analytical Chemistry*, Vol. 61 No. 4.

PROGRAM(s): M.Sc.-II	**SEMESTER: IV**			
Course: Paper-III	**Course Code:** CHEM 609 **Course Title:-** Polymer Science and Photo Chemistry			
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**–**	**04**	**50**	**50**

Learning Objectives:

1. To gain knowledge of the advanced concepts in polymer chemistry and photochemistry.
2. To develop the skills to solve the problems encountered in the field of polymer chemistry and photochemistry.

Course outcomes:-

1. Students will learn the mechanism of absorption of light, different types of photophysical processes, and kinetics of photophysical processes.
2. Students will gain knowledge of the molecular weights of polymers, the kinetics of polymers, and different aspects of the polymers.

Course Code: CHEM 609

Paper-III

CHEM 609: Polymer Science and Photo Chemistry

Unit I	**POLYMER SCIENCE-I**	**[15l]**
	Introduction: Polymer science, Classification of Polymers, Nomenclature of polymers, Isomerism in Polymer chains, History of Polymers, Intermolecular forces in Polymers, Conformations in polymer chains. **Molecular weight of polymers:** Solubility, Average molecular weight values, Fractionation of polydisperse systems, Light scattering, GPC, Collegative molecular weights : Osmometry, End group analysis, Other techniques : Ultracentrifugation, Mass spectrometry, Viscometry.	
	The Synthesis of Polymers: **Chain growth (Addition) polymerization:** Mechanism, and kinetics of free radical, cationic and anionic polymerization, Chain transfer reactions, Mayo equation, Thermodynamic aspects of polymerization	
	Copolymerization: Kinetics of copolymerization, monomer reactivity ratios, determination of monomer reactivity ratios, The *Q-e* scheme, block copolymers, graft copolymers, dendtires	
Unit II	**POLYMER SCIENCE-II**	**[15L]**
	Techniques of polymerization (Phase systems in polymerisation): Bulk polymerization, Solution polymerization, Precipitation polymerization, Suspension polymerization, Emulsion polymerization	
	Step-growth polymerization (Polycondensation): Molecular weight in a step-growth polymerization, Mechanism of polycondensation, Kinetics of polycondensation.	
	Polymer reactions, degradation and additives: Polymer analog reactions and Cross-linking reactions.	
	Polymer degradation and stability: Thermal degradation, Oxidative and UV stability, Chemical and hydrolytic stability, Radiation effect	
	Polymer additives: Plasticizers, Stabilizers (Heat & UV), Flame retardants, Colorants, Curing agents and other polymer additives	
	Polymer solutions: Solubility parameter, Solubility of crystalline and amorphous polymers, Thermodynamics of polymer solutions, Flory-Huggins theory of polymer solutions.	

Unit III	**PHOTOCHEMISTRY-I**	**[15L]**
	Mechanism of Absorption and Emission processes: Electric dipole transition, Einstein's treatment of absorption and emission phenomena, Time-dependent Schrodinger equation, Time-dependent perturbation theory, correlation with experimental quantities, Intensity of electronic transitions, rules governing transition between two energy states	
	Physical Properties of Electronically excited molecules: Nature of changes on electronic excitation, Electronic, vibrational and rotational energies, potential energy diagram, Frank-Condon principle, Emission spectra, Environmental effect on absorption and emission spectra, properties of excited states, excited state acidity constants, dipole moments and redox properties. Types of transitions, fluorescence emission, e-type and p-type delayed fluorescence, phosphorescence emission.	
Unit IV	**PHOTOCHEMISTRY-II**	**[15L]**
	Photo-physical Kinetics: Photokinetic scheme for determination of quantum yields, Kinetics of self and collisional quenching and Stern- Volmer equation and deviations from Stern Volmer equation, Concentration dependence of quenching and excimer formation, Quenching by added substances: charge transfer mechanism and energy transfer mechanism.	
	Photo-chemical reactions: Types of photo-chemical reactions, Selection rules, Kinetics of Photo-chemical reactions. Photochemical reactions of ketones, olefins conjugated olefins and aromatic compounds. Woodward-Hoffman rule of electro-cyclic reactions.	
	Applications of Photochemistry: Importance of photochemistry, mutagenic effect of radiation, photosynthesis, mechanism of vision, photo electrochemistry, prospects of solar energy conversion and storage, organic solar cells.	

Reference books:

1. P. Bahadur and N. V. Sastry, *Principles of Polymer Science*, second edition, Narosa Publishing House, 2005.
2. C. E. Carraher, Jr., Carraher's Polymer Chemistry, 8th edition, CRC Press, New York, 2010.
3. Joel R. Fried, *Polymer Science and Technology*, Prentice-Hall of India Pvt. Ltd., 2000.
4. V. R. Gowarikar, H. V. Viswanathan and J. Sreedhar, *Polymer Science*. New Age International Pvt. Ltd., New Delhi, 1990.
5. F. W. Billmeyer Jr., *Text Book of Polymer Science*, 3rd edition, John Wiley and Sons, 1984.
6. K.K. Rohatgi-Mukherjee, *Fundamentals of Photochemistry*, New Age International Publishers, Revised Edition (2003).

7. C.H.DePuy and O.L.Chapman, *Molecular reactions and photochemistry*, Prentice hall of India PVT.LTD. 1988.

Books for further reading:

7. J. M. G. Cowie, *Polymers: Chemistry and Physics of Modern M*aterials, 2nd ed. (first Indian Reprint 2004), Replika Press Pvt. Ltd.
8. G. S. Misra, *Introductory Polymer Chemistry*, New Age International (P) Limited, Publishers, 1993.
9. L. H. Sperling, *Introduction to Physical Polymer Science*. 2nd Edition, John Wiley and Sons. Inc.
10. Hans- Georg Elias, *An Introduction to polymer Science*, VCH 1997.
11. Charles E. Seymour, Jr., *Seymour/Carraher'sPolymer Chemistry*, 6th ed., Marcel Dekker, Inc., 2003.
12. A. Ravve, Principles of Polymer Science, 2nd ed., Kluwer Academic/Plenum Publishers, New York, 2000.

PROGRAM(s): M.Sc.-II	SEMESTER: IV			
Course: Paper-Elective -I	Course Code: CHEM 61011 Course Title:- IPR and Chemoinformatic			
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50

Learning Objectives:

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

Course outcomes:-

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

Course Code: CHEM 61011

Paper-Elective-I

CHEM 61011: INTELLECTUAL PROPERTY RIGHTS & CHEMOINFORMATICS

Unit-1		15 L
	Introduction to Intellectual Property Histroical Perspective, Different types of IP, Importance of protecting IP. **Patents:** Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Health care-balancing promoting innovation with public health, Software patents and their importance for India. **Industrial Designs:** Definition, How to obtain, features, International design registration. **Layout design of integrated circuits:** Circuit boards, Integrated Chips Importance for electronic industry. **Copyrights:** Introduction, How to obtain, Differences from Patents. **Trade Marks:** Introduction, How to obtain, Different types of marks-Collective marks, certification marks, service marks, Trade names, etc.	
Unit-II		**15 L**
	Geographical Indications: Definition, rules for registration, prevention of illegeal exploitation, importance to India. **Trade Secrets:** Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection. **IP Infringement issue and enforcement:** Role of Judiciary, Role of law enforcement agencies-Police, Customs, etc. **Economic Value of Intellectual Property:** Intangible assests and their valuation, Intellectual Property in the Indian Context- Various Laws in India Licensing an technology transfer. **Different International agreements:** **(a) World Trade Organization (WTO):** (i) General Agreement on Tariffs & Trade (GATT) , Trade Related Intellectual Property Rights (TRIPS) agreement (ii) General Agreement on Trade related Services (GATS)	

	Madrid Protocol (iii) Berne Convention (iv) Budapest Treaty **(b) Paris Convention** **WIPO** and **TRIPS, IPR** and Plant Breders Rights, IPR and Biodiversity	
Unit-III		**15L**
	Introduction to Cheminformatics: History and evolution of cheminformatics, Use of cheminformatics, Prospects of cheminformatics, Molecular Modeling and Structure elucidation. **Representation of molecules and chemical reactions:** Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification. **Searching chemical structures:** Full structure search, sub-structure search, basic ideas, similarity search, three dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.	
Unit-IV		**15L**
	Applications: Prediction of Properties of Compound, Linear Free Energy Relations, Quantitative Structure-Property Relations, Descriptor Analysis, Model Building, Modeling Toxicity, Structure-Spectra correlations, Prediction of NMR, IR and Mass spectra, Computer Assisted Structure elucidations, Computer assisted Synthesis Design, Introduction to drug design, Target Identification and Validation, Lead Finding and Optimization, Analysis of HTS data, Virtual Screening, Design of Combinatorial Libraries, Ligand-Based and Structure Based Drug Design, Application of Cheminformatics in Drug Design.	

Reference books:

1. Andrew R. Leach & Valerie, J. Gillet (2007) *An introduction to Cheminformatcs*. Springer: The Netherlands.
2. Gasteiger, J. & Engel, T. (2003) Cheminformatics: a text-book. Wiley-VCH.
3. Gupta, S.P. *QSAR and Molecular Modeling,* Springer-Anamaya Pub.: New Delhi.

PROGRAM(s): M.Sc.-II	SEMESTER: IV			
Course: Paper-Elective -II	**Course Code: CHEM 61012** **Course Title:- Special Topics in Physical Chemistry-II**			
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**–**	**04**	**50**	**50**

Learning Objectives:

1. To gain knowledge of the advanced instrumental techniques for chemical analysis.
2. Students should learn the environmental impact of chemical processes, products and waste .
3. To understand the advanced concepts in colloidal chemistry.

Course outcomes:-

1. Students will learn the basic principles and instrumentation of different analytical instruments that are used in chemical analysis.
2. Students will be familiar with sustainable synthetic methods to reduce waste generation and improve process efficiency.
3. Students will understand the phenomenon of surface and colloidal chemistry

Course Code: CHEM 61012

Paper-Elective-II

CHEM 61012: Special Topics in Physical Chemistry-II

Unit-I	**COLLOIDAL SCIENCE**	**[15L]**
	Applied colloids-Surface chemistry and nanocatalysts: Introduction to the nature of colloidal solution, Surface Tension, Wetting, Solubilisation, Dispersion, Detergency, contact angle measurement, lotus effect, Surfactants and Self-assembly, Emulsions and Micro emulsion, Role of surfactants in synthesis of nanoparticles **Nanocatalysts:** Role of transition metals & metal oxides in homogeneous and heterogeneous catalysis and their mechanism of catalysis, manufacture of these catalysts in nano-form and their characterization.	
Unit-II	**GREEN CHEMISTRY**	**[15L]**
	Principles and Concepts of Green Chemistry: Sustainable development and green chemistry, Atom economy, examples of atom economic and atom un-economic reactions, reducing toxicity.	
	Waste: Production, Problems and Prevention: Sources of waste from chemical industry, waste minimization techniques, on-site waste treatment (Physical treatment, Chemical treatment and bio-treatment plants), and design for degradation: Degradation and surfactants, DDT, Polymers, rules for degradation. **Organic solvents:** Environmentally benign solutions: solvent free systems, supercritical fluids-Supercritical carbon dioxide, decaffeination process, $ScCO_2$ as reaction solvent, Supercritical water, ionic liquids as catalysts and solvents.	
Unit-III	**INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS**	**[15L]**
	Hyphenated Techniques: Introduction, need for hyphenation, possible hyphenation, interfacing devices and applications of the following: GC-MS, GC-IR, MS-MS, LC-MS, ICP-MS and Spectro-electrochemistry.	

	Radio-chemical methods: Auto, X-ray and gamma radiography.	
Unit-IV	**ADVANCED INSTRUMENTAL TECHNIQUES**	**[15L]**
	Electron microprobe method, Reflectance spectroscopy, Chemiluminescence method, Photoacoustic spectroscopy, Polarimetry: ORD, CD.	

Reference books:

1. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
2. Nanomaterials Handbook- Yury Gogotsi
3. Encyclopedia of Nanotechnology- Hari Singh Nalwa
4. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
5. Microwave Properties of Magnetic Films - Carmine Vittoria.
6. Physics of Magnetism - S. Chikazumi and S.H. Charap
7. Physical Theory of Magnetic Domains - C. Kittel
8. Magnetostriction and Magnetomechanical Effects - E.W. Lee
9. Springer Handbook of Nanotechnology - Bharat Bhusan
10. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao
11. Synthesis of Nanostructured Materials –Cao
12. Handbook of Nanoscience, Engineering- Goddard et al
13. Nano Engineering in Science & Technology: An introduction to the world of nano design by Michael Rieth.
14. Introduction to Solid State Chemistry – A. R. West
15. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun
16. Physical Properties of Carbon Nanotubes- R. Saito
17. Carbon Nanotubes (Carbon , Vol 33) - M. Endo, S. Iijima, M.S. Dresselhaus
18. The search for novel, superhard materials- Stan Vepr¡ek (Review Article) JVST A, 1999.
19. Mike Lancaster, *Green Chemistry: An Introductory Text*, Royal Society of Chemistry, 2002.
20. Paul T. Anastas and John C. Warner, *Green Chemistry – Theory and Practice*, Oxoford University Press, 1998.
21. Albert S. Matlack, *Introduction to Green Chemistry*, Marcel Dekker, Inc., 2001.
22. R.P.W.Scott, *Tandem Techniques*, Wiley India Pvt.Ltd. Reprint 2009.
23. J. Barker, *Analytical chemistry for open learning, Mass spectrometry*, Wiiley IndiaED.
24. H. J. Arnikar, *Essential of Nuclear Chemistry*, New Age International, 1995.
25. G. C. Bond, *Heterogeneous Catalysis*, 2nd ed., Clarendon Press, Oxford, 1987.

PROGRAM(s): M.Sc.-II	SEMESTER: IV			
Course: Research Project	**Course Code: CHEM 611** **Course Title:- Research Project**			
Teaching Scheme				**Evaluation Scheme**
Lectures (Hours per week)	**Tutorial (Hours per week)**	**Credit**	**Continuous Assessment (CA) (Marks- 75)**	**Semester End Examination (Marks- 75)**
	–	**06**		

Learning Objectives:

1. To understand and discuss the new research topics in the field of chemistry.
2. To understand the importance, relevance, and procedure to gather back ground literature information from various scientific database.
2. To display, organize and represent correlation between different types of data.
3. To summarize and provide a concise summary of research projects carried out.
4. Demonstrate a capacity to communicate research results clearly and comprehensively.

Course outcomes: -

1. Students will define a research question, design objectives and appropriate hypothesis for their project.
2. Students will find and evaluate relevant literature and back ground information related to their project.
3. Students will learn and use the techniques needed to do their experiments.
4. Students will learn and follow appropriate protocols for documenting their research as well to analyse the experimental data.
5. Students will be able to use logic and evidence to draw conclusions and future scope of the research work done.

Course Code: CHEM 611

Paper-Research Project

CHEM 611: Research Project

SEMESTER IV

Course: Research Project

Guidelines:

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

Evaluation of Research Project Semester - IV

A) CONTINUOUS ASSESSMENT - 50%

Sr. No.	Evaluation Type	Marks
1	Attendance (DPR* to be maintained)	**20**
2	Experimental/ Interpretation	**35**
3	Conclusion/ output	**20**
	Total	**75**

DPR: Daily Progress Report

B) SEMESTER ENDEXAMINATION - 50%

Sr.No	Evaluation Type	Marks
1	Presentation	**20**
2	Dissertation	**30**
3	Viva	**25**
	Total	**75**

Theory Examination Pattern:

Internal Assessment- 50%- 50 Marks per paper

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

External Examination- 50%-

Paper Pattern:

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

Semester End Practical Examination:

Particulars	Continuous assessment (CA)	Semester end external examination
Laboratory work	15	15
Viva	05	05
Journal	**05**	**05**
Total	**25**	**25**

PRACTICAL BOOK/JOURNAL

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

Letter Grades and Grade Points

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

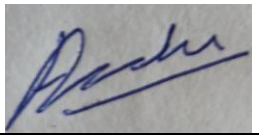
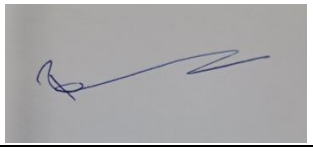
Sign of HOD

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

Sign of Dean,

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

Team for Creation of Syllabus

Name	Department/College Name	Sign
Dr. Navinchandra G. Shimpi	Department of Chemistry, University of Mumbai	
Dr. Vishwanath R. Patil	Department of Chemistry, University of Mumbai	
Dr. Purav M. Badani	Department of Chemistry, University of Mumbai	
Dr. Arun K. Kadu	Department of Chemistry, University of Mumbai	
Dr. Ravindra Kawde	Department of Chemistry, Kirti College, Mumbai	
Dr. Youraj Malghe	Department of Chemistry, Institute of Science, Mumbai	

Sign of HOD

Sign of Dean,

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

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

Appendix B

Justification for M.Sc. (Physical Chemistry)

1.	The necessity for starting the course:	M.Sc. (Physical Chemistry) course is necessary for those who seek to deepen their knowledge, specialize in a particular area, and pursue advanced careers in research, industry, academia, or other chemistry-related fields. It offers numerous opportunities for personal and professional growth, enabling you to make a positive impact on the world through scientific exploration and discovery.
2.	Whether the UGC has recommended the course:	Yes
3.	Whether all the courses have commenced from the academic year 2023-24	The course has already commenced from the academic year from 1967 and in the academic year 2022-23 it is restructured under NEP 2020
4.	The courses started by the University are self-financed, whether adequate number of eligible permanent faculties are available?:	This course is not self-financed. Currently, twelve permanent faculty members are working in the department out of 26 sanctioned faculty positions.
5.	To give details regarding the duration of the Course and is it possible to compress the course?:	The duration of the program is two years (4 semesters). It is not possible to compress the course. Under NEP 2020 students have option of exit at the end of first year with PG Diploma in Physical Chemistry.
6.	The intake capacity of each course and no. of admissions given in the current academic year:	The intake capacity of the program is 20. Number of admissions for the academic year 2022-23 is 20.
7.	Opportunities of Employability / Employment available after undertaking these courses:	M.Sc. (Physical Chemistry) students have a wide range of employment opportunities across various sectors. The skills and knowledge acquired during their master's program make them well-equipped for diverse roles. Some of the common areas where M.Sc. (Physical Chemistry) students can find employment include; Research and Development (R&D), Pharmaceutical Industry, Chemical Manufacturing, Environmental and Analytical Chemistry, Quality Assurance and Control, Materials Science and Nanotechnology, Teaching and Academia, Healthcare and Clinical Research

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

Sign of HOD

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