University of Mumbai

No. AAMS_UGS/ICC/2024-25/141

CIRCULAR:-

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

They are hereby informed that the recommendations made by the **Board of Studies in Chemistry** at its meeting held on 02nd September, 2024 and subsequently passed by the Board of Deans at its meeting held on 3rd September, 2024 **vide** item No. 6.14 (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** is introduced as per appendix (NEP 2020) with effect from the academic year 2024-25.

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

(Dr. Prasad Karande)
REGISTRAR

MUMBAI – 400 032
21st September, 2024

To

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

BOD 6.14(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),

Scanned with OKEN Scanner

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. — 6.14 (N)

UNIVERSITY OF MUMBAI

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

Syllabus for
Semester III & IV

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

(with effect from the Academic year 2024-2025)

UNIVERSITY OF MUMBAI

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: SP-10B	Attached herewith
5	Semesters	Sem. III & IV
6	Program Academic Level	6.5
7	Pattern	Semester
8	Status	New
9	To be implemented from Academic Year	From the Academic Year 2024-25

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

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

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

Preamble

1) Introduction

This program is designed to provide a comprehensive and in-depth understanding of the fascinating world of 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 endeavours. 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 aim and objectives of M.Sc. (Physical Chemistry) course is 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 outcome of M.Sc. (Physical Chemistry) course is 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) (Semesters I, II, III & IV) (Table as per परिशिष्ट-1 with sign of HOD and Dean)

R_____

M.Sc. (Physical Chemistry) Parishishta - 1

Year	Level	Sem	Major				RM	OJT /FP	RP	Cum Cr.	Degree
			Mandatory			Electives					
1	6.0	Sem I	3*4+ 2=14			4	4		-	22	PG Diploma (after 3 Years Degree)
			Physical Chemistry-I (CHEM 501)	TH	4	**Credits 4 (2+2) Course 1:** Organic Chemistry-I + Chemistry Practicals (Organic Chemistry and Analytical Chemistry) (CHEM 50311) **(OR) Credits 4 (2+2) Course 2:** Organic Chemistry II + Chemistry Practicals (Organic Chemistry and Analytical Chemistry) (CHEM 50312)	Research Methodology (CHEM 506)				
			Inorganic Chemistry-I (CHEM 502)	TH	4						
			Analytical Chemistry-I (CHEM 505)	TH	4						
			Chemistry Practical-I (Physical Chemistry and Inorganic Chemistry) (PRCHEMPI 504)	PR	2						
		Sem II	3*4+ 2=14			4	-	4 OJT CHEM 512	-	22	PG Diploma (after 3 year degree)
			Physical Chemistry-II (CHEM 507)	TH	4	**Credits 4 (2+2) Course 1:** Organic Chemistry-III + Chemistry Practicals (Organic Chemistry and Analytical Chemistry) (CHEM 50911)					
			Inorganic Chemistry-II (CHEM 508)	TH	4						
			Analytical Chemistry-II (CHEM 510)	TH	4						

			Chemistry Practical-II (Physical Chemistry and Inorganic Chemistry) (PRCHEMPI 511)	PR	2	**(OR)** **Credits 4 (2+2)** **Course 2:** Organic Chemistry-IV + Chemistry Practicals (Organic Chemistry and Analytical Chemistry) (CHEM 50912)					
Cum. Cr. For PG Diploma			28			8	4	4		44	
Exit Option: PG Diploma (44 credits) after Three Year UG Degree											

Semester - III and IV

R: SP-10B

Years	Level	Sem (2yr)	Major				RM	OJT / FP	RP	Cum. Cr.	Degree
			Mandatory			Electives					
2	6.5	Sem III	3*4+ 2=14			4	-	-	4 Research Project (CHEM 606)	22	P G Degree (after 3 year UG)
			Paper –I Chemistry: Polymer, Surface and Photochemistry (CHEM 601)	TH	4	Advanced Instrumental Techniques-I (CHEM 60511) + Physical Chemistry Practical-II (CHEM 60511) OR Advanced Instrumental Techniques-II (CHEM 60512) + Physical Chemistry Practical-II (CHEM 60512)					
			Paper - II Nano Chemistry, Statistical Mechanics and Nuclear Chemistry (CHEM 602)	TH	4						
			Paper - III Atomic and Molecular - Structure and Spectroscopy (CHEM 603)	TH	4						
			Physical Chemistry **Practical- I** (CHEM 604)	PR	2						
		Sem IV	3*4=12			4	-	-	6 Research Project (CHEM 611)	22	
			Paper - I Polymer, Green, Biophysical and Applied Chemistry (CHEM 607)	TH	4	Intellectual Property and Cheminformatics - I (CHEM 61011) **(OR)** Advanced Techniques in Physical Chemistry-II (CHEM 61012)					
			Paper - II Material science and Non-equilibrium Thermodynamics (CHEM 608)	TH	4						
			Paper - III Symmetry and Spectroscopy (CHEM 609)	TH	4						

Cum. Cr. For 1 Yr PG Degree	28		14	8			10	44	
Cum. Cr. For 2 Yr PG Degree	54		28	16	4	4	10	88	

UNIVERSITY OF MUMBAI

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

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

PROGRAM OUTLINE 2024-2025

Year		Course Code	Course title	Credits	Page No.
M.Sc. Sem-III	Mandatory Course-I	CHEM 601	**Physical Chemistry-I** Polymer, Surface and Photochemistry	04	10
	Mandatory Course-II	CHEM 602	**Physical Chemistry-II** Nano chemistry, Statistical Mechanics and Nuclear chemistry	04	14
	Mandatory Course-III	CHEM 603	**Physical Chemistry-III** Atomic and Molecular structure & spectroscopy	04	17
	Mandatory Course **Practical**	CHEM604	Physical Chemistry Practical -I	02	20
	Elective -I	CHEM 60511	Advanced Instrumental Techniques – I	02	23
	Elective - II	CHEM 60512	Advanced Instrumental Techniques – II	02	25
	Elective Practical	CHEM 60511/CHEM 60512	Physical Chemistry practical –I & II	02	27
	RP	CHEM 606	Research Project	04	30
M.Sc. Sem-IV	Mandatory Course-I	CHEM 607	**Physical Chemistry-I** Polymer, Green, Biophysical and applied Chemistry	04	32

	Mandatory Course-II	CHEM 608	**Physical Chemistry-II** Material science and Non-equilibrium Thermodynamics	04	36
	Mandatory Course-III	CHEM 609	Physical Chemistry-III Symmetry and spectroscopy	04	40
	Elective - I	CHEM 61011	Intellectual property Rights and chemoinformatics	04	44
	Elective - II	CHEM 61012	Advanced techniques in Physical chemistry	04	47
	RP	CHEM 611	Research Project	06	50

PROGRAMME SPECIFIC OUTCOME (PSOs)

1. Gain knowledge of the advanced concepts in the branch of chemistry, scrutinize and accomplish a solution to problems encountered in the field of research and analysis.
2. Apply the basic knowledge of chemistry to perform various tasks assigned to them at the workplace in industry and academia to meet the global standards.
3. Deduce qualitative and quantitative information of chemical compounds using advanced spectroscopic methods which can further be 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.

PROGRAM:- M.Sc.-II		SEMESTER - III			
Mandatory Course : **Paper-I**		**Course Code: (CHEM601)** **Course Title: - Polymer, Surface and Photochemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks 50)	Semester End Examination (Marks- 50)
04	**NA**	**–**	**04**	**50%**	**50%**

Learning Objectives:

1. To enable learners to have comprehensive knowledge and understanding of the concepts in polymer chemistry, surface chemistry and photochemistry.
2. To develop the skill to solve the problems encountered in the field of polymer chemistry to determine the average molecular weight of polymer.
3. To apply the basic knowledge of Polymer chemistry, Surface chemistry and Photochemistry to perform various tasks assigned to them at the workplace in industry and academia to meet the job requirements as per global standards.

Course Outcomes:

After the completion of this course, student will be able to –

1. acquire knowledge about polymers, surface active agents, various sensing techniques, and various novel fluorophores.
2. understand different types of polymers, types of polymerizations , the concept of photochemical principles, photophysical processes, various photochemical reactions, use of various materials for hydrogen storage, radioactive decay engineering and DNA technology.
3. apply various techniques to determine molecular weights of polymers, develop the skill to solve the problems to determine average molecular weights.
4. evaluate the mechanism of fluorescence sensing with respect to photophysical /photochemical processes.

Semester-III
Paper-I
Course code - CHEM 601

Units	Course Title: Polymer, Surface and Photochemistry	Credits 04/60 L
1	**Polymer Chemistry - I**	**[15]**
1.1.	**Introduction:** Polymer Science, fundamental terms, historical outline, classification based on: the origin (natural, semi-synthetic, synthetic etc.),the structure (linear, branched, network, hyper branched, dendrimer, ladder, cross linked, IPN),the type of atom in formation(condensation, addition), the polymers(random, alternate, block, graft),the main homo chain (homochain, heterochain), the behaviour of polymers on application of heat (thermoplastic and thermosetting),the form and application (plastics, fibre, elastomers and resins).	**5L**
1.2.	**Molar Mass:** Molecular weight averages, fractionation, molecular weight determination by GPC / SEC, end group analysis, viscometry, vapour phase osmometry, gradient elution, and molecular weight distribution curve.	**5L**
1.3	**Types of polymerization:** Condensation, addition (cationic and anionic)and copolymerization(with kinetics),chain transfer reactions.	**5L**
2	**Modern Applications of Surface Chemistry**	**[15L]**
2.1	**Surface active agents and micelles:** Surface active agents and their classification, hydrophile-lipophile balance, **Micellization:** Shape and structure of micelles, hydrophobic interaction, critical Micelles concentration (CMC), factors affecting CMC of surfactants, counter ion binding to micelles, micelle catalysis, and reverse micelles. Emulsions: Solubilisation, micro emulsions, characterization of micro emulsions	9L
2.2	**Hydrogen storage by Adsorption:** Fundamentals physisorption, temperature and pressure influence, chemisorptions, adsorption energy, Electrochemical Adsorption. Practical adsorption: storage of hydrogen with carbon materials, activated carbon, graphite graphene, carbon nanostructures, fullerene. Carbon nanofibers (CNF) and graphite nano fibers electrochemical storage of hydrogen in carbon materials.	6L
3.	**Photochemistry - II**	[15]
3.1	**Photo chemical principles:** Environmental effect on absorption and emission spectra, properties of excited states, excited state acidity constants, dipole moments and redox properties, Importance of photochemistry, origin of life.	4L
3.2	**Photo physical processes in electronically excited molecules:** Types of photo physical pathways, types of radiation less transitions, fluorescence emission, fluorescence and structure. Triplet state and phosphorescence emission, delayed fluorescence–e type and p-type delayed fluorescence.	6L
3.3	**Photochemical reactions:** Ketones, olefins conjugated olefins and aromatic compounds, photosynthesis.	5L

4.	**Applications of Fluorescence Phenomenon**	**[15]**
4.1	Fluorescence sensing: Mechanism of sensing; sensing techniques based on Collisional quenching, energy transfer, electron transfer; examples of pH sensors, glucose sensors and protein sensors.	8L
4.2	Novel fluorophores: Quantum dots, lanthanides and long-lifetime Metal-ligand complexes, Radioactive decay engineering: metal enhanced fluorescence	5L
4.3	DNA technology–sequencing.	2L

Reference books:

Unit-I	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. V. K. Ahluwalia & A. Mishra, Polymer Science, A textbook, Ane-Books Pvt. Ltd,2008. 7. R. Sinha, Outline of Polymer Technology manufacture of Polymers, Prentice hall of India Pvt. Ltd. 2000 8. F. J. Davis, Polymer Chemistry, Oxford University Press, 2000. 9. Walton &P. Lotimer, Polymer, Oxford University Press, 2000. 10. R.Young, Introduction to Polymers, Chapman & Hall, Reprint,1989. 11. V. Jain. Organic Polymer Chemistry, IVY Publishing House, 2003. 12. A. Singh, Polymer Chemistry, Campus Book International, 2003. 13. Harichandra A Parbat, Damodar V Prabhu &Venkat. S Narayan Basic Concepts of Chemical Kinetics, First Edn., Iterative International Publisher, India and USA, 2024.
	Books for further reading:
	1. J. M. G. Cowie, Polymers: Chemistry and Physics of Modern Materials, 2nded. (FirstIndianReprint2004), Replika Press Pvt. Ltd. 2. G. S. Mishra, Introductory Polymer Chemistry, New Age International (P) Limited, Publishers,1993. 3. L. H. Sperling, Introduction to Physical Polymer Science. 2ndEdition, John Wiley and Sons. Inc. 4. Hans-Georg Elias, An Introduction to polymer Science, VCH1997. 5. Charles E. Seymour, Jr., Seymour/Carraher's Polymer Chemistry, 6th ed., Marcel Dekker, Inc.,2003. 6. A. Ravve, Principles of Polymer Science, 2nded, Kluwer Academic/Plenum Publishers, New York,2000. 7. Vidyagauri Lele, Chemical modification of starch by green process, Techno World Press, 2015. 8. Vidyagauri Lele, Graft copolymers of starch-Synthesis & Characterization, Neeraj Publishing House, 2015.

Unit-2	1. M. J. Rosen. Surfactants and Interfacial Phenomena (3rd edn.), John Wiley (2004). 2. Y. Moroi, Micelles: Theoretical and Applied Aspects, (1992) Plenum Press, New York 3. Arun K. Chattopadhyay, Kashmiri Lal Mittal, Surfactants in Solution, Volume 64 of Surfactant Science Series, Volume 64 of Lecture Notes in Pure and Applied Mathematics, illustrated, Marcel Dekker,1996 4. K.L. Mittal, American Chemical Society, micellization, solubilization, and micro emulsions, Volume1 Micellization, Solubilization, and Microemulsions, American Chemical Society, illustrated, Plenum Press,1977 5. Deepak Thassu, Michel Deleers, Yashwant Pathak, Nanoparticle Drug Delivery Systems Volume166 of Drugs and the Pharmaceutical Sciences Series illustrated, CRC Press, 2007
Unit-3	1. C.H.De Puy,O.L.Chapman,Molecular reactions and photochemistry, Prentice hall of India PVT.LTD.1988. 2. K. K. Rohatgi-Mukherjee. Fundamentals of Photochemistry. Reprint 2002. New Age International Publisher, 1978.
Unit-4	1. B. Valeur, Molecular Fluorescence: Principles and Applications, Wiley-VCH (2001). 2. J.R. Lakowicz, Principles of Fluorescence Spectroscopy, Springer (2006).

PROGRAM - M.Sc.-II		SEMESTER - III			
Mandatory Course:- Paper-II		**Course Code: (CHEM 602)** **Course Title: - Nano chemistry, Statistical mechanics & Nuclear chemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks50)	Semester End Examination (Marks- 50)
04	**NA**	**–**	**04**	**50%**	**50%**

Learning Objectives:

1. To study the synthetic methods and applications of nano particles emphasizing their significance in biomedical and chemical contexts.
2. To evaluate the synthesis techniques and biomedical applications of silica nano particles, emphasizing their role in drug delivery and imaging technologies.
3. To apply the principles of thermodynamics to predict energy transformations in chemical systems, demonstrating comprehension and application.
4. To evaluate the principles of statistical mechanics to interpret the behaviour of microscopic particles in macroscopic systems, demonstrating comprehension and analysis.

Course Outcomes:

After the completion of this course, student will be able to -

1. analyze the synthesis methods and applications of gold nano particles, emphasizing their significance in biomedical and chemical contexts, demonstrating comprehension and analysis skills.
2. evaluate the synthesis techniques and biomedical applications of silica nano particles, emphasizing their role in drug delivery and imaging technologies, demonstrating evaluation and synthesis skills.
3. apply the principles of thermodynamics to analyze and predict energy transformations in chemical systems, demonstrating comprehension and application at the level of understanding.
4. apply the principles of statistical mechanics to interpret the behaviour of microscopic particles in macroscopic systems, demonstrating comprehension and analysis skills at an advanced level.

SEMESTER: III
Paper II
Course code- CHEM 602

Units	Course Title -Nano chemistry, Statistical mechanics & Nuclear chemistry	Credits **04**/60 L
1	**Nano chemistry of Gold, Cadmium, Selenide**	**[15L]**
1.1.	Variation of optical and magnetic properties of nanomaterial with size, shape, surface characteristics and impurities	4L
1.2.	Relationship between size and shape of nanomaterial	3L
1.3	Nano architecture: self-assembly and template methods	3L
1.4	Diagnosis and treatment of diseases using nanoparticles	3L
1.5	Safety and ethics of use of nanoparticles	2L
2	**Nano Chemistry of Silica and Poly Dimethyl Siloxane**	**[15L]**
2.1.	Variation of optical and magnetic properties of nano materials with size, shape, surface characteristics and impurities	4L
2.2	Relationship between size and shape of nano materials.	3L
2.3	Nano architecture: self-assembly and template methods.	4L
2.4	Diagnosis and treatment of diseases using nanoparticles.	4L
3	**Statistical Mechanics**	**[15L]**
3.1	**Fundamental Concepts:** Thermodynamic probability, Combinatorial problems, Stirling approximation, Lagrange's method, macro and microstates, ensembles, Boltzmann distribution law.	3L
3.2	Partition functions, ensembles, Boltzmann distribution law including translational, rotational, vibrational, electronic, and nuclear partition functions. Expressions for the thermodynamic functions in terms of partition function -Internal energy, heat capacity, the Helmholtz and Gibbs functions, Enthalpy, entropy and equilibrium constants. Understanding the entropy of an ideal gas from a statistical perspective- The Sackur-Tetrode equation for the entropy of a Monoatomic gas. Molecular partition function.	**7L**
3.3	**Statistical Distributions of Particle systems:** Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics.	3L
3.4	**Specific Applications:** Debye and Einstein theory of specific heats of solids.	2L

4	**Nuclear Chemistry**	(15L)
4.1	Charged particle accelerators: linear accelerator, cyclotron, Betatron, Synchro cyclotron, synchrotron	4L
4.2	Nuclear forces- characteristics and Meson field theory of nuclear forces	2L
4.3	Nuclear Models-Liquid drop model, Fermi Gas Model, Shell Model, Collective Model, Optical Model.	4L
4.4	Applications of Nuclear radiations- geological applications of radioactivity, age of minerals and rocks, age of earth and solar system, medical, industrial and agricultural applications of radiochemistry, positron emission tomography, Radioimmunoassay.	5L

Reference books:

Unit-1 & 2	1. C. N. R. Rao, Achim Müller, Anthony K. Cheetham, Nano materials Chemistry,John Wiley & Sons, 2007 2. Ludovico Cademartiri and Geoffrey A. Ozin, Concepts of Nano chemistry, Wiley– VCH Verlag GmbH&co,2009 3. C. Bréchignac, P.Houdy, Marcel Lahmani, Nano materials and Nano chemistry, Springer,2007 4. Geoffrey A. Ozin, André C. Arsenault, Ludovico Cademartiri, Nano chemistry: A Chemical Approach to Nanomaterials, Royal Society of Chemistry (Great Britain) illustrated, Royal Society of Chemistry,2009.
Unit-3	1. Atkins P.W, Physical Chemistry, Oxford University Press, 6th edition,1998. 2. John M. Seddon & Julian D. Gale, Thermodynamics and statistical mechanics, Tutorial Chemistry Text series,Vol.10, Royal society of Chemistry,2001. 3. Silbey RJ &Alberty R. A, Physical Chemistry,3rd edition, John Wiley and sons, Inc.2002. 4. Laidler K.J. and Meiser J.H., Physical Chemistry, 2nd edition, CBS publishers & distributors,1999. 5. B. K. Agarwal and M.Eisner, Statistical Mechanics,(1988)Wiley Eastern, New Delhi. 6. D. A. McQuarrie, Statistical mechanics, (1976) Harper and Row Publishers, New York.
Unit-4	1. G. Friedlander, J.W. Kennedy .Nuclear and Radio Chemistry. Third. John Wiley and sons, 1981. 2. H. J. Arnikar, Essentials of Nuclear Chemistry second Wiley Eastern Ltd.,1989

PROGRAM - M.Sc.-II		SEMESTER: III		
Mandatory course **Paper -III**		**Course Code: CHEM603** **Course Title: - Atomic and Molecular Structure and Spectroscopy**		
Teaching Scheme			**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Credits	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	NA	04	50%	50%

Learning Objectives:

1. To discuss the variation and perturbation theory and its application to Helium atom.
2. To calculate term symbols for multi electron atoms, exchange of interactions and multiplicity of states.
3. To evaluate hydrogen molecules using the valence bond method.
4. To apply molecular spectroscopy on spherical top, symmetrical top and asymmetrical top molecules.

Course Outcomes:

After the completion of this course, student will be able to–

1. analyze the variation and perturbation theory and apply it to the Helium atom.
2. calculate term symbols for multi-electron atoms, explore exchange interactions, and examine to multiplicity of states.
3. deduce hydrogen molecule using the valence bond method.
4. apply molecular spectroscopy on spherical top, symmetrical top, and asymmetrical top molecules.

SEMESTER: III
Paper - III
Course code: CHEM 603

Units	Course Title: - Atomic and Molecular structure and spectroscopy	Credits 04/ 60 Lectures
1.	**Atomic Structure**	**[15L]**
1.1	Introduction to approximate methods in Quantum Mechanics-	2 L
1.2	Variation Theorem, linear and nonlinear variation functions.	7 L
1.3	Application of variation and perturbation theory to ground state of Helium Atom. Multi–electron atoms: Anti-symmetric and Pauli principle, Slater determinants, Hartree–Fock and configuration interaction wave functions, Slater type orbitals, Gaussian orbitals, orbitals plots, Basis sets. Density functional theory.	6 L
2	**Atomic Spectroscopy**	**(15L)**
2.1	Angular momentum, orbital and spin, total angular momentum, total angular momentum (J) of many electron atoms, Russell Saunders (L-S) coupling and J-J Coupling.	4 L
2.2	Term symbols, term symbols for multi electron atoms like He, Li, Be, B etc.	3 L
2.3	Exchange of interactions and multiplicity of states	3 L
2.4	Anomalous Zeeman Effect and Paschen Back effect.	2 L
2.5	Atomic spectra and selection rules, energy level diagram of atomic sodium.	3L
3.	**Molecular Structure**	**[15 L]**
3.1	The Born–Oppenheimer approximation	2 L
3.2	LCAO method-molecular orbital formation	2 L
3.3	Calculation of energy of hydrogen molecule ion using Valence bond method, Heitler-London treatment, Improvements in Heitler-London treatment.	3 L
3.4	Electronic structure of polyatomic molecules Valence bond method for BeH_2, H_2O, NH_3, BH_3, CH_4.Huckel molecular orbital. Theory for–ethylene, Allyl system, cyclopropenyl system and cyclobutadiene.	8 L
4	**Molecular Spectroscopy**	**[15 L]**
4.1	Rotational spectroscopy: Einstein coefficients, classification of polyatomic Molecules spherical top, symmetric top and asymmetric top molecules, rotational spectra of polyatomic molecules Stark modulated microwave spectrometer	3 L
4.2	Raman Spectroscopy-Classical theory of molecular polarizability, pure rotational, vibrational and vibration-rotation spectra of diatomic and polyatomic molecules polarization and depolarization of Raman lines correlation between IR and Raman spectroscopy instrumentation.	5 L
4.3	Electronic Spectra of molecules: Term symbols for linear molecules, selection rules characteristics of electronic transitions-Franck-Condon principle, types of electronic transitions-d-d, vibrionic, charge transfer, π-π^*, n-π^* transitions, fate of electronically excited states, fluorescence, phosphorescence, dissociation and	7 L

	predissociation.	

Reference books:

Unit – 1, 2 & 3	1. Laidler and Meiser, Physical Chemistry, 2nd edition, CBS publishers, New Delhi. (Chapters 11-14). 2. Silbey and Alberty, Physical Chemistry, 3rd edition, John Wiley and sons, 2000. (Part Two Quantum Chemistry). 3. Atkins P.W, Physical Chemistry, Oxford University Press, 6th edition,1998. 4. William Kemp, Organic spectroscopy, 3rd Edition, ELBS,1996. 5. I.N. Levine, Quantum Chemistry,5th Edition (2000). 6. D.A. McQuarrie and J. D. Simon, Physical Chemistry: A Molecular Approach (1998). 7. J.N. Murrell, S. F. A. Kettle and J. M. Tedder, Valence Theory, 2(1965), John Viley, New York. 8. A. K. Chandra, Introductory Quantum Chemistry,4th edition (1994),Tata McGraw Hill, New Delhi. 9. D.A. McQuarrie, Quantum Chemistry, Viva Books Private Limited, New Delhi, first Indian ed.,2003. 10. R. K. Prasad, Quantum Chemistry,3rd Ed., New Age International Publishers,2006. 11. James E. House, Fundamentals of Quantum Chemistry, Second Ed, Academic Press,2005. 12. T.A. Little field and N. Thorley, Atomic and Nuclear Physics– An Introduction, Van Nostrand,1979.
Unit - 4	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, Macmillan India Ltd.,2003. 4. G. Aruldhas, Molecular Structure and Spectroscopy, Prentice-Hall of India, 2001. 5. J. Michael Hollas, Modern Spectroscopy, 4^{th} Ed., John Wiley and Sons,2004. 6. Harichandra A Parbat, Damodar V Prabhu, Prabodh Chobe, Ajit Datar and Irena Kostova, Concepts of Spectroscopy, First Ed., Gaurang Publishing Globalize Private Ltd, Mumbai, 2024. 7. Harichandra A Parbat, Damodar V Prabhu, Prabodh Chobe and Ajit Datar, Essence of Spectroscopy, First Ed., Iterative International Publisher, India and USA, 2024.

PROGRAM - M.Sc.-II		SEMESTER: III			
Course: Practical		**Course Code: CHEM 604** **Course Title: - Physical Chemistry Practical**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment(CA) (Marks- 25)	Semester End Examination (Marks- 25)
NA	**04**	**NA**	**02**	**50%**	**50%**

Learning Objectives:

1. To collect the knowledge of advanced concepts in pH metry, quantum mechanics, potentiometry and conductometric experiments.
2. To recall advanced concepts of thermodynamics and chemical kinetics in the chemical reactions.
3. To inculcate scientific temper and research-based skills encountered in the field of research.

Course Outcomes:

After the completion of this course, student will be able to –

1. apply fundamental principles and practical knowledge to design experiments, analyze data, and interpret results to draw appropriate conclusions.
2. apply the knowledge handling equipment such as potentiometer, conductivity meter, colorimeter, and spectrophotometer.
3. practice scientific temper and research-based skills in the field of research.

SEMESTER: III
Physical Chemistry Practical

Code: PSCHP3
Credits - 02

A)	**Major experiments (perform <u>any four</u> experiments)**
1.	To determine the formula of the copper (II) ammonia complex by partition method.
2	To determine the transport no. of copper (II) ions by Hittorf's method.
3.	To construct the phase diagram for a two component system forming a simple eutectic.
4.	To construct the phase diagram for a two component system forming a compound.
5.	To determine the mean ionic activity coefficient of Zinc chloride by emf method.
6.	To determine the proton ligand stability constant of an organic acid and metal ligand stability constant of its complex by pH measurement.
B)	**Minor experiments (perform any seven experiments)**
1.	To determine the iso electric point of gelatine by viscosity measurement.
2.	To determine the equilibrium constant for the reaction $CaSO_{4(s)} + 2Ag^{+}_{(aq)} = Ag_2SO_{4(s)} + Ca^{+2}_{(aq)}$
3.	To determine the partial molar volume of ethanol.
4.	To determine the liquid junction potential using with and without transference concentration cell potentiometrically.
5.	To determine the effect of ionic strength of a solution on the reaction between Potassium persulphate and potassium iodide. (3 sets only)
6.	To determine the standard electrode potential (E0) of the quinhydrone electrode.
7.	To determine the formula of the Zinc (II) Ferrocyanide complex by titration of Zn(II) Sulphate with Potassium ferrocyanide.
8.	To determine the molar conductance of a weak electrolyte at infinite dilution hence to determine its dissociation constant.
9.	To determine hydrolysis constant and degree of hydrolysis of ammonium chloride and hence to estimate the dissociation constant of the base.
10.	To determine the ionization constant of bromophenol blue.

Instructions:

1. The candidate is expected to submit a journal certified by the Head of the Department/institution at the time of the practical examination.
2. A candidate will not be allowed to appear for the practical examination unless he / she produces a certified journal or a certificate from the Head of the institution/department stating that the journal is lost and the candidate has performed the required number of experiments satisfactorily.
3. The list of the experiments performed by the candidate should be attached with such a certificate.
4. Use of non-programmable calculators is allowed both at the theory and the practical examination.

References books:

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. F. Daniel & Others, Experimental Physical chemistry,1965, Kogakasha Co Ltd., Tokyo.

PROGRAM - M.Sc.-II		SEMESTER: III			
Course - Elective-I		Course Code: CHEM 60511 Course Title: - Advanced Instrumental Techniques - I			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks - 25)	Semester End Examination (Marks - 25)
02	**NA**	**NA**	**02**	**50%**	**50%**

Learning Objectives:

1. Recall the principles of electron spectroscopy techniques such as ESCA (XPS), AUGER, and UPS.
2. To apply the principles of electron spectroscopy to analyze different types of samples.
3. Analyze data obtained from electron spectroscopy experiments to draw meaningful conclusions.
4. Compare and contrast different electron microscopy techniques in terms of their capabilities and limitations.
5. Explain the fundamental principles and applications of thermal methods
6. Demonstrate the knowledge of the instrumentation used in TG, DTA, DSC, Thermometric titrations and EGA.
7. Analyze and interpret thermal analysis data and TA, DTA and DSC curves
8. Evaluate the strengths and limitations of various thermal analysis techniques

Course Outcomes:

Learners will be able to:

1. understand the principles underlying electron spectroscopy techniques including ESCA (XPS), AUGER, and UPS.
2. apply the principles of electron spectroscopy to conduct analysis on various sample types.
3. interpret data gathered from electron spectroscopy experiments to derive significant insights.
4. differentiate electron microscopy techniques by evaluating their respective strengths and limitations.
5. demonstrate understanding of the principles and instrumentation of thermal methods
6. develop skills to accurately analyze thermometric titration curves and interpret thermal analysis data
7. compare different thermal methods

SEMESTER: III
Elective- I
Course Code: (CHEM 60511)

Unit	Course Title -Advanced Instrumental Techniques - I	Credits: 02/30 L
1.	**Electron Spectroscopy and Microscopy**	[15]
1.1	Electron Spectroscopy: Principle, instrumentation and applications of - Electron Spectroscopy for Chemical Analysis (ESCA), AUGER electron spectroscopy, Ultra-Violet Photoelectron Spectroscopy (UPS).	9 L
1.2	Surface electron microscopy: Interaction of sample and electron beam, different types of sources of electron beam, Principle, instrumentation, working and applications of Scanning Probe Microscopy, Atomic Force Microscopy (AFM)	6 L
2	**Thermal Methods**	**[15]**
2.1	**Thermogravimetry (TG):** Principle and Instrumentation, factors affecting thermo gravimetric curves, Interpretation of thermo gravimetric curves. Applications of thermogravimetry.	4L
2.2.	**Differential thermal analysis (DTA):** Principle and instrumentation, Interpretation of DTA curves, applications of DTA. **Differential Scanning Calorimetry (DSC):** Principle, heat flux and power compensated DSC, applications of DSC in determination of heat capacity and glass transition temperature, Interpretation of DSC curves.	5L
2.3	Enthalpimetric methods	2L
2.4	Thermometric titrations: Principle instrumentation and applications	2L
2.5	Evolved Gas Analysis (EGA): Principle and applications.	2L

Reference Books:

Unit -1	1. D. B. Williams and C. B. Carter, Transmission electron microscopy, Springer, 2009 2. W. Zhou, R Apkarian, Z. L. Wang and D. Joy, Scanning microscopy for nano technology Springer, 2007. 3. Skoog D.A.,West DM, Fundamentals of Analytical Chemistry, Thomson Asia Pvt ltd.,8th Ed,(2004) 4. Skoog, Holler, Nieman, Principles of Instrumental Analysis, Thomson Asia Pvt. ltd.,5th Ed(2003) 5. Sharma B. K., Instrumental Methods of Chemical Analysis, Goel Publishing House. 6. Douglas A. Skoog, Holler & Crouch, Instrumental analysis India edition CENGAGE Learning (EighthIndianReprint2011) 7. Robert D. Braun. Introduction to Instrumental Analysis(IndianReprint2006) 8. Pavia, Lapman, Kriz, Introduction to Spectroscopy, Thomson Pub. 9. H. Straw, & K. walker, Spectroscopy Vol. I &II, Science Paper backs. 10. M. Mahindersingh, Analytical chemistry, Instrumental techniques, Dominant Pub. Delhi. 11. F. W.Fiefield, &D. Kealey, Principles and Practice of analytical Chemistry, Blackwell Pub.
Unit -2	1. Thermal Methods, W.W John Wiley, (1986). 2. J.W. Dodd, K. Tonge, Thermal Methods. 3. Analytical Chemistry, open Learning Willard Merrit and Settle, Instrumental Methods of Analysis. 4. G.W. Ewing, Instrumental methods of Chemical analysis, McGraw Hill.

PROGRAM: M.Sc.-II		SEMESTER: III			
Course: Elective-II		Course Code: CHEM 60512 Course Title: - Advanced Instrumental Techniques – II			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks- 25)	Semester End Examination (Marks- 25)
02	NA	NA	02	50%	50%

Learning objectives:

1. To acquire detailed knowledge and understanding needs of hyphenated techniques and electroanalytical methods such as, voltammetric and polarographic techniques.
2. To understand interfacing devices and its applications in hyphenated techniques.
3. Learners should acquire problem solving skills in identification and analysis of samples using hyphenated techniques and determination of elements or compounds using voltammetric and polarographic techniques.
4. To understand types of micro electrodes, and its applications in various types of voltammetric and polarographic techniques.

Course outcomes:

After completion of course learner will be able to:

1. understand the principle involved in various analytical techniques like GC-MS, GC-IR, MS-MS, HPLC-MS, ICP-MS, spectro-electro chemistry and radio-chromatography.
2. apply the various hyphenated Techniques in analyzing samples in industries such as, pharmaceutical, environmental, Bulk chemicals and other chemical industries.
3. determine trace of elemental contaminants or undesired impurities in different types of samples like food stuff, sea water, fuels etc.
4. implement the correct analytical method or technique by knowing the properties of the samples.
5. apply the knowledge learnt in developing new procedures in hyphenated techniques and voltammetric and polarographic techniques for analysis of samples.

SEMESTER: III
Elective- II
Course Code: (CHEM 60512)

Units	**Course Title:- Advanced Instrumental Techniques – II**	Credits: 02 /30L
1.	**Hyphenated Techniques**	**[15 L]**
1.1	Introduction, need for hyphenation, possible hyphenation.	2 L
1.2	Interfacing devices and applications of the following: GC-MS, GC-IR, MS-MS, HPLC-MS, ICP-MS, Spectro-electro chemistry and Radio-chromatography.	13 L
2	**Electro-Analytical Methods.**	**[15L]**
2.1	Overview of electrode process: Electro-capillary curve and electro-capillary maximum potential.	2L
2.2	Micro electrodes: mercury electrodes: Stationary mercury drop electrode (SMDE), Hanging mercury drop electrode (HMDE), Mercury film electrode (MFE), Carbon paste electrode and chemically modified electrodes.	3L
2.3	Introduction to three electrode system: modern polarography and voltammetry necessity and development of new voltammetric techniques and their comparison with classical DC polarography	3L
2.4	Voltammetric methods: Sampled DC polarography, Linear Sweep Voltammetry (LSV), Cyclic Voltammetry (CV), diagnostic criteria of cyclic voltammetry	7L

Reference Books:

Unit- 1	1. R. P. W. Scott, Tandem Techniques, Wiley India Pvt. Ltd. Reprint 2009 2. J. Barker, Analytical chemistry for open learning, Mass spectrometry, Wiley India ED.
Unit -2	1. A.J. Bard and, L.R. Faulkner, Electrochemical Methods,2ndEd,John Wiley and sons, Asia Pvt. Ltd,(2004) 2. J. J. Lingane, Electro-analytical Chemistry, 2ndEd, Inter science Publishers, Inc., New York (1958) 3. A. M. Bond, Modern Polarographic Methods in Analytical Chemistry, Marcel Dekker Publishers, Inc., New York,(1980) 4. A. J. Bard(Ed), Electro-analytical Chemistry, Marcel Dekker Inc., New York (A series of volumes). 5. Donald T. Sawyer, A. Sobkowiak and J. L. Roberts, Jr. Electrochemistry for Chemists, 2nd Ed., John Wiley and Sons, Inc., New York.,(1995). 6. D. A. Skoog, F. J. Holler, J. A. Nieman, Principles of Instrumental analysis, 6th Ed. 7. R. D. Braun introduction to Instrumental Analysis, McGraw hill, 1987. 8. H.A. Willard, L. L. Merritt, J. A. Dean & F. A. Settle, Instrumental methods of analysis, 5th Ed.CBS,1986. 9. M. Noel, K. J. Vasu, Cyclic Voltammetry and Frontiers of electrochemistry, IBH, NewDelhi,1990.

PROGRAM - M.Sc.-II		SEMESTER: III			
Course: **Practical - Elective I & II**		Course Code:- CHEMPR60511/CHEMPR60512 Course Title :-Elective Practical			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks- 25)	Semester End Examination (Marks- 25)
NA	**04**	**NA**	**02**	**50%**	**50%**

Learning Objectives:

1. To gain knowledge of the advanced concepts in pH metry, Spectrophotometry, quantum mechanics, potentiometry and conductometry experiments.
2. To recall advanced concepts of thermodynamics and chemical kinetics in the chemical reactions.
3. To foster scientific temper and develop research-based skills encountered in the field of research.

Course Outcomes:

Learners will be able to:

1. apply fundamental principles and practical knowledge to design experiments, analyze data, and interpret results to draw appropriate conclusions.
2. apply the knowledge handling equipment such as potentiometer, conductivity meter, colorimeter, and spectrophotometer.
3. inculcate scientific temper and research-based skills in the field of research.

Semester- III
Elective Practical
Course Code: CHEMPR60511/CHEMPR60512

A)	**Physical Chemistry Practical (any seven)**
	Conductometry
1.	To determine the composition of a mixture of hydrochloric acid, potassium chloride and ammonium chloride by titration with sodium hydroxide and silver nitrate.
2.	To determine ΔG, ΔH and ΔS of dissolution of a sparingly soluble salt.
3.	To titrate Potassium ferrocyanide with Zinc sulphate and hence to determine the formula of the complex.
	Colorimetry / Spectrophotometry
4.	To determine the rate constant and the order of the reaction between Persulphate and Iodide ions.
	pH metry
5.	To determine K_1 and K_2 of a dibasic acid (Malonic acid / Oxalic acid / Succinic acid) by titration with a base.
6.	To determine dissociation constant of p-nitro phenol.
	Non instrumental set
7.	To determine the energy of activation and other thermodynamic parameters of activation for the reaction between persulphate and potassium iodide.
8.	To study the order of the reaction between bromate and bromide.
9.	To determine the molar mass of a non-volatile solute by cryoscopic method.
10.	To determine the Van't Hoff's factor by cryoscopic method.
B)	**Interpretation of spectra/data (any five)**
1.	Interpretation of electronic spectra of simple polyatomic molecules.
2.	Interpretation of electronic spectra of diatomic molecules.
3.	Interpretation of NMR, E.S.R. spectra.
4.	Interpretation of DTA, TG, and DTG curves.
5.	Interpretation of vibrational-rotational spectra of rigid and non-rigid diatomic molecules.
6.	Interpretation of Mossbauer spectra.
7.	Analysis of XRD pattern of cubic system.

Reference books:

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. F. Daniel & Others, Experimental Physical chemistry,1966, Kogakasha Co. Ltd.,Tokyo.

Note:

1. The candidate is expected to submit a journal certified by the Head of the Department / institution at the time of the practical examination.
2. A candidate will not be allowed to appear for the practical examination unless he / she produces a certified journal or a certificate from the Head of the institution / department stating that the journal is lost and the candidate has performed the required number of experiments satisfactorily.
3. The list of the experiments performed by the candidate should be attached with such a certificate.
4. Use of non-programmable calculator is allowed both at the theory and the practical examination.

SEMESTER: III

PROGRAM: M.Sc.-II		Course Title: - **Research Project** Course Code: **(CHEM 606)**			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks-50)	Semester End Examination (Marks-50)
NA	08	--	04	50	50

Learning Objectives:

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

Course Outcomes:

The learner will be able to -

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

Course code: CHEM 606
Course title: Research Project
Guidelines for the conducting the research project.

Each student will perform project separately.

Students should devote enough time to their project work. (08 hours each week).

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

Evaluation of Research Project
Internal Continuous Assessment: 50% (50 Marks)

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

Semester End External Examination: 50% (50 Marks)

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

PROGRAM - M.Sc.-II		SEMESTER: IV			
Course : Paper-I		**Course Code: (CHEM607)** **Course Title: - Polymer, Biophysical, Green and applied chemistry**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment(CA) (Marks 50)	Semester End Examination (Marks- 50)
04	**NA**	**–**	**04**	**50%**	**50%**

Learning Objectives:

1. To enable learners to have comprehensive knowledge and understanding of the concepts in polymer chemistry, bio-physical & green chemistry and photochemistry.
2. To apply the basic knowledge of polymer chemistry, bio-physical & green chemistry and photochemistry to perform various tasks assigned to them at the workplace in industry and academia to meet the job requirements as per global standards.
3. Accomplish a solution to problems encountered in the field of research.

Course Outcomes:

The learners will be able to -

1. remember the principles of green chemistry, study of catalyst in various types of solvents, properties of polymers and various polymer degradation processes.
2. understand various transitions involved in polymers, identification, and characterization of polymers by various advanced techniques, various polymerization techniques and polymer technology, use of biosensors, applications of solar cell and various complex biomolecules.
3. apply photo physical kinetics to biomolecular processes and will study the applications of various commercially important polymers.
4. try to create a solution to difficulty encountered in the field of research.

Semester-IV
Paper-I
Course code- CHEM 607

Units	Course Title - Physical Chemistry-I	Credits 04/60 L
1	**Polymer Chemistry-II**	**[15]**
1.1	Polymers in solid state – Transitions (glass transition and crystalline melting temperature), crystalline behaviour, factors affecting crystallinity, Polymer blends and alloys.	**3L**
1.2	Identification and characterization of polymers: Chemical analysis- End group analysis; Physical analysis by – i) Spectral methods: IR, UV, Raman, NMR, X-ray diffraction analysis ii) Microscopic methods - SEM, TEM and iii) Thermal analysis - TGA, DTA, DSC.	**6L**
1.3	Properties of polymers: Thermal (glass transition temperature and its determination), Mechanical (deformation and fracture) effects in polymers, Viscoelasticity surface (surface tension, hardness, friction, abrasion), Physical (Impact strength, Tensile strength, solubility) of polymers, Weatherability, Rheology and Mechanical models, Mechanical behaviour, Rubber elasticity	**4L**
1.4	Polymer degradation and stabilization: Oxidative, thermal, radiation, Biodegradation	2L
2	**Polymer Chemistry-III**	**[15]**
2.1	Techniques of polymerization: Bulk polymerization, solution polymerization, suspension polymerization, emulsion polymerizations	3L
2.2	Thermodynamics of polymer solutions: Solubility parameter, thermodynamics of mixing, theta temperature	2L
2.3	**Polymer technology:** Polymer auxiliaries, plasticizers, heat Stabilizers, colorants, flame retardants. Fillers, reinforcements. **Elastomers:** Introduction, Processing, Rubber Types, Vulcanization, Properties. Reclaiming. Fibres: Introduction, production, Fibre spinning, Textile fibres, Industrial fibres, recycling. **Film sheets:** Introduction and processing techniques (injection and blow moulding extrusion), Recycling of plastics.	5L
2.4	Properties and applications of some commercially important polymers. Carbon chain polymers- Polyolefin, ABS group, elastomers, vinyl polymers, acrylic polymers, heterochain polymers- polyethers, polycarbonates, polysaccharides, polyamides fluoropolymers, Resins (epoxy, alkyd, phenol-formaldehyde and urea formaldehyde), Silicones, polyphosphazenes, sulphur containing polymers.	5L
3.	**Biophysical Chemistry and Green Chemistry**	**[15]**

3.1	**Biophysical Chemistry**	
3.1.1	**Introduction to Complex Biomolecules:** Proteins, enzymes, DNA, RNA, polysaccharides and lipids, chirality and pH dependence of biomolecules.	2L
3.1.2	**Biosensors:** Enzyme based, Electrochemical, immunosenser, fluorescence, optical, Piezoelectric Biosensors	2L
3.1.3	Electrophoresis (Technique for bio-molecular study: Principle and factors affecting electro-phoretic mobility, zone electrophoresis–Paper electrophoresis, cellulose acetate electrophoresis, Gel electrophoresis. capillary Electrophoresis, Application of electrophoresis.	4L
3.2	**Green Chemistry**	
3.2.1	Recapitulation of principles of green chemistry, Waste minimization techniques.	1L
3.2.2	Catalysis and Green Chemistry: Phase transfer catalysts, biocatalyst, photo catalysis.	2L
3.2.3	Organic solvents, solvent free system, supercritical fluid, ionic liquid, their characteristics, use as catalyst and solvents.	2L
3.2.4	Alternative energy sources for initiation and execution of chemical reaction: Microwave and sonochemistry.	2L
4	**Photochemistry-III: Kinetics and Applications**	**[15]**
4.1	Photo physical kinetics of bimolecular processes, Mechanism of fluorescence, quenching, Collisions in solutions - Kinetics of 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.	10 L
4.2	Solar Cells - Photovoltaic and Photo galvanic cells; photoelectron chemistry; prospects of solar energy conversion and storage, organic solar cells.	5L

Reference books:

Unit-1 & 2	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., NewDelhi,1990. 5. F. W. Billmeyer Jr., Text Book of Polymer Science, 3rd edition, John Wiley and Sons,1984. 6. V. K. Ahluwalia & A. Mishra, Polymer Science, A text book, Ane Books Pvt. Ltd, 2008. 7. R. Sinha, Outline of Polymer Technology manufacture of Polymers, Prentice hall of IndiaPvt.Ltd.2000 8. F. J. Davis, Polymer Chemistry, Oxford university Press, 2000.

	9. D. Walton & P. Lotimer, Polymer, Oxford university Press, 2000. 10. R. Young, Introduction to Polymers, Chapman& Hall,reprint, 1989. 11. V. Jain Organic Polymer Chemistry, IVY Publishing House, 2003. 12. A. Singh, Polymer Chemistry, Campus Book International, 2003 13. Harichandra A Parbat, Damodar V Prabhu & Venkat. S Narayan Basic Concepts of Chemical Kinetics, First Ed., Iterative International Publisher, India and USA, 2024.
	Books for further reading: 1. J. M. G. Cowie, Polymers: Chemistry and Physics of Modern Materials, 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. 2ndEdition, 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.
Unit-3	1. U.N Dash, A Text Book of Biophysical Chemistry, MacMillan India Ltd 2. Gurtu and Gurtu, Biophysical Chemistry, Pragati Prakashan. 3. R.P.Budhiraja, Separation chemistry,New Age International (P) Limited, Publisher 4. Avinash Upadhyay, Kakoti Upadhyay, Biophysical Chemistry Principles and Techniques Himalaya. 5. Susan R.Mikkelson,EduardoCorton, Bioanalytical Chemistry, Wiley Interscience. 6. Science, 2nd ed.,Kluwer Academic/Plenum Publishers, New York,2000. 7. Mike Lancaster, Green Chemistry an Introductory Text, Royal Society of Chemistry. 8. V.K. Ahluwalia, M.Kidwai, Kluwer Academic Publisher.
Unit-4	K. K. Rohatgi-Mukherjee. Fundamentals of Photochemistry. Reprint 2002. New Age International Publisher,1978.

PROGRAM - M.Sc.-II		SEMESTER: IV			
Course - Paper-II		Course Code: (CHEM 608) **Course Title: - Material science and Non equilibrium Thermodynamics**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks50)	Semester End Examination (Marks- 50)
04	**NA**	**–**	**04**	**50%**	**50%**

Learning Objectives:

1. To understand solidification: Grasp the basic processes involved in turning liquid materials into solid form.
2. To learn about mechanical behaviour: Understand how materials respond to different forces and stresses applied to them.
3. Explore material properties: Examine the characteristics of materials that affect their behaviour and performance.
4. Understand laser technology: Grasp the basics of how lasers work and their applications in materials science and engineering.

Course Outcomes:

Learners will be able to;

1. understand how liquids turn into solids and why.
2. recognize forces on materials and explain how they affect them.
3. analyze material characteristics and know how they affect material behaviour.
4. explain how lasers work and their uses in making and changing materials.

Semester-IV
Paper II

(Course code- CHEM 608)

Units	Course Title – **Material science and Non-equilibrium Thermodynamics**	Credits 04/60 L
1	**Metals and alloys**	**[15]**
1.1	Solidification of metals and alloys-homogeneous and heterogeneous nucleation Growth of crystals, growth of silicon single crystal.	4L
1.2	Metallic solid solutions-substitutional and interstitial solid solutions.	3L
1.3	Crystalline imperfections-point ,line and boundary defects	4L
1.4	Atomic diffusions in solids-diffusion mechanisms, steady state and non-steady state diffusions,-impurity diffusion into silicon wafers for integrated circuits.	4L
2	**Mechanical properties of Solid materials**	**[15L]**
2.1	Stress and strain in metals- Engineering stress and engineering strain, shear stress and shear strain, the tensile test and engineering stress -strain diagram, modulus of elasticity, yield strength.	5L
2.2	Hardness and hardness testing plastic deformations of metals in single crystals plastic deformation of polycrystalline metals, solid solution strengthening of metals.	5L
2.3	Fracture of metals-ductile and brittle fracture, toughness and impact testing, fatigue of metals, the creep test, creep-rupture test.	5L
3	**Lasers and Superconductors**	**[15L]**
3.1	**Lasers in chemistry** General principles of LASER action - Population Inversion, cavity and mode characteristics, Q-switching, mode-locking. **Practical lasers** - Solid state lasers-Ruby, neodymium, gas lasers - He Ne, Ar, Kr, Carbon dioxide, Chemical and exciplex Lasers, Dye lasers LED and Semiconductor lasers. **Applications of Lasers in chemistry** Spectroscopy at high photon fluxes, collimated beams, Precision, Specified transitions, Isotope separation, Study of fast reactions using pulsed techniques.	10L
3.2	**Super conducting solid materials** Introduction to Superconductivity, Band theory of electrical conductivity, Bardeen – Cooper-Schriffer Theory of superconductivity, the superconducting state, High critical temperature superconductors, magnetic properties of superconductors.	5L

4	**Non-equilibrium thermodynamics**	**[15L]**
4.1	Features of non-equilibrium thermodynamics, second law of thermodynamics, uncompensated heat and its relation to thermodynamics function.	2L
4.2	Entropy production and its rate. Entropy production in heat transfer process and during mixing of gases. Entropy production and efficiency of galvanic cell.	4L
4.3	Onsager theory: Reciprocal relation, principle of microscopic reversibility. Coupled and uncoupled reactions and their condition.	5L
4.4	Transport phenomena across membranes. Electro kinetic effect and thermo mechanical effects.	4L

Reference books:

Unit – 1 & 2	1. William F. Smith, Principles of Material Science and Engineering, 3rd edition, McGraw–HillInc.1996. 2. Keer H.V, Principles of the Solid State, first reprint, Wiley Eastern Limited, 1994. 3. Principles of Material science and engineering, 3rd edition, McGraw Hill Inc.1996.
	List of Books for further reading 1. A. R. West, Solid State Chemistry and its Applications, John Wiley and Sons (Asia) Pvt. .Ltd., 2. L. E. Smart and E.A.Moore, Solid State Chemistry–An Introduction,3rd Ed., Taylor and Francis, 2005. 3. V. Raghavan, Materials Science and Engineering, Fifth Ed. Prentice-Hall of India Pvt. Ltd. New Delhi, 2004. 4. William D.Callister, Jr., Materials Science and Engineering, An Introduction, Fifth Ed., John Wiley and Sons (Asia) Pvt.Ltd.,2001. 5. S. O. Pillai, Solid State Physics, Fifth Ed., New Age International Publishers, 2002. 6. Leonid V. Azaroff, Introduction to Solids, Tata-McGraw-Hill Publishing Co.Ltd., New Delhi, 1977. 7. Sandra E. Dann, Reactions and Characterization of Solids, Royal Society of Chemistry, 2000. 8. C. N. R. Rao and J. Gopalakrishnan, New Directions in Solid State Chemistry, Seconded., Cambridge University Press,1997. 9. N. B. Hannay, Solid State Chemistry, Prentice Hall of India, New Delhi,1976. 10. M. Ali Omer, Elementary Solid State Physics, 5thed. Indian Reprint, Pearson Education, Inc., 1999.

Unit - 3	Atkins P.W, Physical Chemistry, Oxford University Press, 6th edition, 1998.
Unit - 4	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. Ltd.,1995. 5. C. Kalidas and M. V. Sangaranarayanan, Non-Equilibrium Thermodynamics, Principles and Applications, Macmillan India Ltd.,2002.
	List of Books for further reading: 1. M. Dole, An Introduction to Statistical Thermodynamics, Dover, NewYork, 1986. 2. W. Kauzmann, Thermodynamics and Statistics: with applications to gasses, W. A. Benjamin, NewYork,1967. 3. M. C. Gupta, Statistical Thermodynamics, 2nd. Ed., New Age International Publishers, New Delhi,1998. 4. S. Glasstone, Theoretical Chemistry, Affiliated East–West Press Pvt. Ltd., New Delhi, 1973. 5. S. Glasstone, Thermodynamics for Chemists, Affiliated East–West Press Pvt. Ltd., New Delhi,1964. 6. R. Hasse, Thermodynamics of Irreversible Processes, Addison Wesley London,1969. 7. I. Prigogine, Introduction to Thermodynamics of Irreversible Processes, 3rd ed., Interscience ,NewYork, 1967.

PROGRAM- M.Sc.-II		SEMESTER: IV			
Mandatory Course: Paper-III		Course Code: (CHEM 609) Course Title: - **Symmetry and Spectroscopy**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks 50)	Semester End Examination (Marks- 50)
04	**NA**	**–**	**04**	**50%**	**50%**

Learning Objectives:

1. To Gain knowledge of the Fundamental concepts and expertise in the field of NMR spectroscopy, ESR spectroscopy and Mossbauer Spectroscopy.
2. To Gain knowledge of the Fundamental concepts and expertise in the field of ESR Spectroscopy.
3. To Gain knowledge of the Fundamental concepts and expertise in the field of Mossbauer Spectroscopy.
4. To Gain knowledge of the Fundamental concepts and detailed applications of symmetry in inorganic complexes.

Course Outcomes:

Learners will be able to:

1. apply these mathematical notations into objects and molecules.
2. analyze infrared, Raman, and electronic spectra of simple molecules.
3. apply the principles of NMR, ^{13}C-NMR, EPR/ESR, Mossbauer spectroscopy.
4. differentiate various resonance techniques used in the analysis of molecules

Semester-IV
Paper - III
Course code: CHEM 609

Units	Course title:- **Symmetry and Spectroscopy**	Credits 04 /60L
1	**Symmetry in Chemistry**	**[15 L]**
1.1	Recapitulation: Point groups, character tables	02 L
1.2	Reduction formula, application of reduction formula to vibrational modes of water molecule.	02 L
1.3	Application in vibrational spectroscopy, selection rules for IR spectroscopy for molecules such as H_2O, CO_2, HF, H_2	03 L
1.4	Application to Raman spectra, selection rules, comparison of IR and Raman selection rules, general approach to vibrational spectroscopy.	02 L
1.5	Symmetry in chemical bonding: symmetry adapted linear combination of molecular orbitals, H_2^+,H_2, LiH, BeH_2, BH_3, CH_4, molecular orbital energy, and bond order.	06 L
2	**N. M. R. Spectroscopy-I**	**[15L]**
2.1	A review of one dimensional NMR spectroscopy.	01 L
2.2	Spin-relaxation. Nuclear Overhauser Effect (NOE). Polarization transfer.	03 L
2.3	Two-dimensional NMR. Correlated spectroscopy (COSY)	03 L
2.4	Nuclear Overhauser effect Spectroscopy (NOESY)	02 L
2.5	Hetero nuclear correlation Spectroscopy (HETCOR)	02 L
2.6	Solid-state NMR	02 L
2.7	Magnetic Resonance Imaging(MRI)	02 L
3	**ESR and Mossbauer Spectroscopy**	**[15 L]**
3.1	**Electron spin Resonance Spectroscopy- (ESR)**	
3.2	Basic principle, hyperfine splitting (isotropic systems)	02 L
3.3	G-value and the factors affecting thereof; interactions affecting electron energies in paramagnetic complexes (Zero-field splitting and Kramers degeneracy);	03 L
3.4	An isotropic effect (the g-value and the hyperfine couplings), the EPR of triplet states; Structural applications to transition metal complexes.	02 L
3.5	Fundamentals and hyperfine splitting, application to study of free radicals spin densities McConnell relationship Zero field splitting	03 L
3.6	Mossbauer Spectroscopy: Principles, Recoilless emission and absorption of γ-rays, experimental methods, isomer shift, hyperfine structure. (Quadrupole interaction), magnetic hyperfine interaction, applications.	05L

4	^{13}C-N.M.R. Spectroscopy	[15 L]
4.1	Elementary ideas, instrumental difficulties, FT technique advantages and disadvantages, proton noise decoupling technique advantages and disadvantages, off-resonance technique.	05 L
4.2	Chemical shifts of solvents, factors affecting chemical shifts, analogy with ^{1}H NMR.	03 L
4.3	Calculations of chemical shift of hydrocarbons, effect of substituents on chemical shifts, different types of carbons (alkene, alkyne and allene).	03 L
4.4	Chemical shift of aromatic carbons and effect of substituent.	02 L
4.5	Chemical shifts of carbonyl, nitrile, and oxime carbons.	02 L

Reference books:

Unit - 1	1. K. Veera Reddy, Symmetry and Spectroscopy of molecules,2nded, new age International publishers. 2. U.C. Agarwala, H / L / Nigam, S. Agarwal, S. S. Kalra, Molecular symmetry in Chemistry via group theory, 2013, Ane Books Pvt. ltd. 3. H. N. Dass, symmetry and group theory for chemists,2004 Asian Books Pvt. Ltd. K.V. Raman, group theory and its applications to Chemistry,1980,Tata McGraw hill Pub. Co. Pvt.Ltd. 4. P. K. Bhattacharya, Group theory and its chemical applications,1999, Himalaya, Pub. House. 5. F. A. Cotton, Chemical applications of Group Theory, Wiley Student Ed., 2006, John Wiley and Sons,(Asia) Pvt. Ltd. 6. R. L. Carter, Molecular symmetry and Group theory, Wiley Student Ed.,1996,John Wiley and Sons, (Asia) Pvt. Ltd. 7. S. Swarnalakshmi, T. Saroja, R. M. Ezhilarisi, A simple approach to Group theory in chemistry, 2008, Universities Press (India) Pvt. Ltd.
Unit – 2 & 3	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: 6. R. Drago, Physical Methods for Chemists, Saunders, Philadelphia, 1992. 7. B. P. Straughan and S. Walker (Eds.), Spectroscopy – Vol 1-3, Chapman and Hall, New York,1976. 8. R. K. Harris, Nuclear Magnetic Resonance Spectroscopy, Pitman, London,1983. 9. Donald L. Pavia, Gary M. Lampman and George S. Kriz, Introduction to Spectroscopy,3rd ed.,Thomson,Brooks/Cole,2001. 10. Harichandra A Parbat, Damodar V Prabhu, Prabodh Chobe, Ajit Datar and Irena Kostova, Concepts of Spectroscopy, First Ed., Gaurang Publishing Globalize Private Ltd, Mumbai, 2024. 11. Harichandra A Parbat, Damodar V Prabhu, Prabodh Chobe and Ajit Datar, Essence of Spectroscopy, First Ed., Iterative International Publisher, India and USA, 2024.

Unit - 4	1. A. E. Derome, Modern NMR Techniques for Chemistry Research, Pergamon, Oxford (1987) 2. J.K.M. Sanders and B.K. Hunter, Modern NMR Spectroscopy, 2nd edition (1993), Oxford University Press, Oxford. 3. R. K. Harris, Nuclear Magnetic Resonance Spectroscopy,(1986) Addison-Wesley, Longman Ltd.,London 4. Organic spectroscopy by William Kemp,3rd Edition, ELBS, 1996.

PROGRAM: M.Sc.-II	SEMESTER: IV
Course: **Elective-I**	Course Code: CHEM 61011 Course Title: - **Intellectual property Rights and Chemoinformatics**

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

Learning Objectives:

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

Course Outcomes:

After completion of course learners will be able to;

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

Elective- I
Course Code: CHEM 61011

Units	**Course title:-Intellectual Property Rights** & **Cheminformatics**	Credits 02/30 L
1.	**Intellectual Property Rights**	**[15]**
1.1	**Introduction to Intellectual Property:** Historical Perspective, Different types of IP, Importance of protecting IP.	2L
1.2	**Patents:** Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Health care-balancing promoting innovation with public health, Software patents and their importance for India.	5L
1.3	**Industrial Designs:** Definition, How to obtain, features, International design registration.	2L
1.4	**Copyrights:** Introduction, How to obtain, Differences from Patents.	2L
1.5	**Trade Marks:** Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, trade names etc.	2L
1.6	**Geographical Indications**: Definition, rules for registration, prevention of illegal exploitation, importance to India.	2L
2	**Intellectual property organisation and enforcement methods**	[15]
2.1	Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.	2L
2.2	**IP Infringement issue and enforcement:** Role of Judiciary, Role of law enforcement agencies – Police, Customs etc.	2L
2.3	**Economic Value of Intellectual Property:** Intangible assets and their valuation, Intellectual Property in the Indian context – Various Laws in India Licensing and Technology transfer.	2L
2.4	Different International agreements: **a) World Trade Organization (WTO):** • General Agreement on Tariffs and Trade (GATT), • Trade Related Intellectual Property Rights (TRIPS) agreement • General Agreement on Trade Related Services (GATS) Madrid Protocol. • Berne Convention	5L

	• Budapest Treaty	
2.5	b) **Paris Convention** WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity.	4L
3.	**Chemoinformatics:**	**[15]**
3.1	**Introduction to Chemoinformatics:** History and evolution of cheminformatics, use of cheminformatics, prospects of chemoinformatics, molecular modeling and structure elucidation.	5L
3.2	**Representation of molecules and chemical reactions:** Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and SD files, Libraries and toolkits, Different electronic effects, Reaction classification.	5L
3.3	**Searching Chemical Structures:** Full structure search, substructure search, basic ideas, similarity search, three dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.	5L
4.	**Applications of Chemoinformatics**	[15]
	Prediction of Properties of Compound, Linear Free Energy Relations, Quantitative Structure – Property Relations, Descriptor Analysis, Model Building, Modeling Toxicity, Structure – Spectra correlations, Prediction NMR, IR and Mass spectra, Computer Assisted Structure elucidations, Computer assisted Synthesis Design, Introduction to drug design, Target Identification and Validation, Lead Finding and Optimization, analysis of HTS data, Virtual Screening, Design of Combinatorial Libraries, Ligand-based and Structure based Drug design, Application of Chemoinformatics in Drug Design.	

Reference Books:

Unit -1	1. Rupinder Tewari and Mamta Bhardwaj, Intellectual Property – A Ptemer for Academia, Publication Bureau, Punjab University, (2021). 2. Aoron Schwabach, Intellectual Property – A Reference Handbook, ABC CLIO, Inc, (2007). 3. David Bainbridge, Intellectual Property, 8thed, Pearson Education Limited (2010). 4. Ramesh Shahabadkar and Sai Satyanarayana Reddy, Intellectual Property Rights, Notion Press, Chennai (2019). 5. Stephan Elias and Richard Stim, Patent, Copyright & Trademark, 7th edn, Delta Printing Solutions, Inc, (2004)
Unit - 2	1. Andrew R. Leach and Valerie J. Gillet, An Introduction to Chemoinformatics, Springer, (2007). 2. S. P. Gupta, QSAR and Molecular Modeling, Anamaya Publishers, (2011). 3. J. Gasteiger and T. Engel, Chemoinformatics A Textbook, Wiley VCH (2003)

PROGRAM - M.Sc.-II	SEMESTER: IV
Course: Elective-II	Course Code: CHEM 61012 Course Title: - Advanced Techniques in Physical chemistry

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

Learning objectives:

1. To understand various advanced spectral methods and principle involved in such methods Such as, Reflectance, Photo-acoustic, Polarimetry, Chemiluminescence, Nuclear quadrupole resonance spectroscopy.
2. To prepare learners equipped with the comprehensive knowledge of modern electroanalytical techniques like, ion selective electrode, bio catalytic electrode, chrono electroanalytical methods and fused electrolysis.
3. To study applications of spectral method, electroanalytical methods in the field of material and catalytic chemistry.
4. To understand the principles of radio analytical methods and radiometric titrations
5. Explore the role of radioanalytical techniques in various scientific and industrial applications
6. To Gain knowledge of different Pulse polarographic techniques
7. To Understand the principles of electrochemical methods used in organic synthesis

Course Outcomes:

After completion of course learner will be able to:

1. explain principles involved in modern spectral methods and advance electroanalytical methods used in material science.
2. offer solutions to problems associated with metallurgical processes, catalytic material, solid and liquid phase electrolytic processes etc.
3. use techniques in electroanalytical, radioanalytical and spectral methods effectively and correctly in analysis of rare samples.
4. describe the basic concepts and principles of activation analysis, isotopic dilution method , radiometric titrations, Auto, X-ray and Gamma radiography
5. explain the applications of radioanalytical methods and electrochemical methods
6. demonstrate understanding of the principles of normal pulse, differential pulse, Sinusoidal AC and square wave polarography
7. apply electrochemical methods in organic synthesis

Semester-IV
Elective - II
Course Code: CHEM 61012

Units	Course Title:- Advanced Techniques in Physical Chemistry	Credits: 04/60L
1	**Spectral Methods** Principle, instrumentation and applications of the following,	[15]
1.1	Reflectance spectroscopy	3L
1.2	Photo-acoustic spectroscopy	3L
1.3	Polarimetry : Optical Rotatory Dispersion (ORD), Circular Dichroism (CD)	4L
1.4	Chemiluminescence method	2L
1.5	Nuclear quadrupole resonance spectroscopy, Electron-nuclear double resonance spectroscopy **(**ENDOR), ELectron-electron DOuble Resonance **(**ELDOR)	3L
2	**Electro-analytical Methods – I** **Principles, instrumentation and applications**	**[15]**
2.1	Ion selective field effect transistors, bio catalytic membrane electrodes, disposable multilayer ion systems, screen–printed electrodes.	8L
2.2	Chronopotentiometry and chronoamperometry	5L
2.3	Fused salt electrolysis	2L
3	**Radio-analytical Methods**	**[15]**
3.1	Activation analysis-basic principles, fast neutron activation analysis, radio chemical method inactivation analysis	4L
3.2	Isotopic dilution method-principle and applications.	2L
3.3	Auto, x-ray and gamma radiography	4L
3.4	Radiometric Titrations	3L
3.5	Applications of radio-analytical techniques.	2L
4	**Pulse polarography:**	[15]
4.1	Normal pulse polarography (NPP), Differential pulse polarography (DPP), Double differential pulse polarography (DDPP)	8L
4.2	Sinusoidal AC polarography, Square wave polarography	5L
4.3	Applications of electrochemical methods in Organic synthesis.	2L

Reference Books:

Unit - 1 & 2	1. A. J. Bard and L. R. Faulkner, Electrochemical Methods, 2nd Ed, John Wiley and sons, Asia Pvt. Ltd, (2004). 2. J. J. Lingane, Electro-analytical Chemistry, 2nd Ed, Inter science Publishers, Inc., New York (1958) 3. A. M. Bond, Modern Polarographic Methods in Analytical Chemistry, Marcel Dekker Publishers, Inc. ,New York,(1980) 4. A.J. Bard (Ed), Electro-analytical Chemistry, Marcel Dekker Inc., New York (A series of volumes). 5. Donald T. Sawyer, A. Sobkowiak and J. L. Roberts, Jr. ,Electrochemistry for Chemists, 2nd Ed. ,John Wiley and Sons, Inc., NewYork.,(1995). 6. D. A. Skoog, F. J. Holler, J. A. Nieman, Principles of Instrumental Analysis, 6th Ed. 7. R. D. Braun introduction to Instrumental Analysis, McGraw hill,1987. 8. H.A. Willard, L. L. Merritt, J. A.Dean & F.A.Settle, Instrumental methods of analysis, 5th Ed.CBS,1986. 9. K. J. Vasu, Cyclic Voltammetry and Frontiers of electrochemistry, IBH, NewDelhi,1990. 10. P. T. Kissinger, W. R. Heinman, Laboratory Techniques in electro analytical Chemistry, Dekkar, NY.1984.
Unit -3	1. J. Rutickaand J.Stary, Sub stoichiometry in Radiochemical Analysis, Pergamon Press,(1968) 2. R.A. Faires and G. G. J. Boswell, Radioisotope Laboratory Technique,4th Edn, Rutterworths; London, (1981) 3. D. Brune, B. Forkman, B. Person, Nuclear Analytical Chemistry, Chartwell- Bratt Ltd.,(1984) 4. Maheshwar Sharon and Madhuri Sharon, Nuclear Chemistry, Ane Books Pvt. Ltd.(2009) 5. Nuclear Chemistry by Arnikar.
Unit - 4	1. M. Noel and K. I.Vasu, Cyclic voltammetry and the frontiers of Electrochemistry, IBH, New Delhi,(1990 2. A.M.Bond, Modern Polarographic Methods in Analytical Chemistry, Marcel Dekker Publishers, Inc., New York,1980. 3. A. J. Bard and Faulkner, Electrochemical Methods, 2ndEd, John Wiley and Sons (Asia) Pvt. Ltd., 2004.

PROGRAM: M.Sc-II		**SEMESTER: IV**			
Course code: CHEM 611		**Course Title:- Research Project**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks- 75)	Semester End Examination (Marks- 75)
NA	12	–	06	50%	50%

Learning Objectives:

1. To understand and discuss the new research topics in the field of chemistry.
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.
5. Ability to demonstrate oral/poster presentation.

Course Outcomes:

At the end of the course student will be able to –

1. understand key concepts and principles relevant to the research topic.
2. apply diverse research methodologies proficiently
3. effectively communicate research findings through clear and persuasive written and oral presentations using various mediums and formats, including project reports.
4. critically evaluate research findings and methodologies.
5. design and execute original research projects independently.

SEMESTER IV

Course: Research Project

Course Code: RPCHEM

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.

A) CONTINUOUS ASSESSMENT - 50%

Sr. No.	Evaluation Type	Marks
1	Experimental work	**30**
2	Characterization & Interpretation	**25**
3	Conclusion	**20**
	Total	**75**

B) SEMESTER END EXAMINATION - 50%

Sr.No	Evaluation Type	Marks
1	Report	**25**
2	Presentation	**50**
	Total	**75**

Semester – III
Modality of Assessment - Mandatory course
Theory Examination Pattern

A	Continuous Assessment (50%)	50 Marks per paper
B	Semester end examination (50%)	50 Marks per paper

A) Continuous Assessment: 50 Marks

1	Written objective / short answer examination	25 marks
2	Industrial visit report / Assignment / Presentation	25 marks

B) Semester End Theory Examination: 50 marks

a) Duration - These examinations shall be of **two hours** duration.

b) **Theory question paper pattern**

- There shall be 05 questions each of 10 marks on each unit and one mix question for 10 marks.
- All questions shall be compulsory with internal choice within the questions.

Question Paper Pattern for 50 marks

Question no.	Options	Marks
Q.1	2 out of 4	10
Q.2	2 out of 4	10
Q.3	2 out of 4	10
Q.4	2 out of 4	10
Q.5	5 out of 8	10
	Total	**50**

Modality of Assessment - Elective Papers
Theory Examination Pattern

A	Continuous Assessment - (50%)	25 Marks per paper
B	Semester end examination - (50%)	25 Marks per paper

A) Continuous Assessment: 25 Marks

1	Written objective / short answer examination	15 marks
2	Industrial visit report / Assignment / Presentation	10 marks

B) Semester End Theory Examination: 25 marks

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

b) Theory question paper pattern:

- There shall be **02 questions each of 08 marks on each unit** and **one mix question for 09 marks.**
- All questions shall be compulsory with internal choice within the questions.

Question no.	Options	Marks
Q.1	2 out of 4	08
Q.2	2 out of 4	08
Q.3	3 out of 6	09
	Total	25

Practical Examination pattern: 50 marks

(For mandatory and elective)

A) Continuous Assessment (CA): 25 marks

Sr. No.	Evaluation Type	Marks
1	**Assessment during practical** (interaction / performance) Skill, accuracy, precision of measurements, record of observations, calculations, graph, result and conclusion. Timely submission of journal	**20**
2	**Overall performance** (Attendance, punctuality, interaction during practical session throughout the semester)	**05**
	Total marks	**25**

B) Semester end practical examination: 25 marks

Sr. no.	Particulars	Marks
1	Laboratory work	15
2	Viva-voce	05
3	Journal	05
	Total marks	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/ Programme CGPA Semester/ Programme	% of Marks	Alpha-Sign/ Letter Grade Result	Grading Point
9.00 - 10.00	90.0 - 100	O (Outstanding)	10
8.00 - < 9.00	80.0 - < 90.0	A+ (Excellent)	9
7.00 - < 8.00	70.0 - < 80.0	A (Very Good)	8
6.00 - < 7.00	60.0 - < 70.0	B+ (Good)	7
5.50 - < 6.00	55.0 - < 60.0	B (Above Average)	6
5.00 - < 5.50	50.0 - < 55.0	C (Average)	5
4.00 - < 5.00	40.0 - < 50.0	P (Pass)	4
Below 4.00	Below 40.0	F (Fail)	0
Ab (Absent)	-	Ab (Absent)	0

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

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

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