MODERN EDUCATION SOCIETY'S

Nowrosjee Wadia College, Pune

(An Autonomous College Affiliated to Savitribai Phule Pune University)

Post Graduate Program in Chemistry
(Faculty of Science)

New syllabus (As per National Education Policy -2020) for

M.Sc. Physical Chemistry Part-II

To be implemented with effect from Academic Year 2024-2025

M. Sc. II Physical Chemistry

Program Outcomes:

1. To impart knowledge of chemistry covering all the aspects of physical chemistry.
2. To provide knowledge of quantum chemistry, solid state chemistry, nuclear, polymer chemistry, thermodynamics, ionic equilibria, phase rule, spectroscopy, mass spectrometry, surface chemistry, electrochemistry, material chemistry,catalysis and biophysical chemistry.
3. To expose students to the most recent and upcoming frontier areas of knowledge in physical chemistry such as data analysis, nanotechnology, smart materials, characterization techniques like SEM and TEM.
4. To provide laboratory experience to the students by performing experiments based on instruments such as pH meter, conductometer, colorimeter, and potentiometer.
5. To provide laboratory experience to the students by performing experiments based on advanced techniques using instruments such as flame photometer, photofluorometer, G. M. counter, uv/ visible spectrophotometer, nephelometer, high performance liquid chromatograph, atomic absorption spectrometer, gamma ray spectrometer.
6. To provide laboratory experience to the students by performing experiments based on non instrumental methods such as kinetics, surface chemistry, thermochemistry and viscosity.
7. To give opportunity and experience of presenting seminar on pre-allotted topics related to theory.
8. To make students aware of research methodology and the best research practices.
9. To provide students an opportunity to work on a specific problem, submit a project report and defend the work by presenting a seminar.
10. To impart the habit of self-study, critical thinking and problem-solving.

Course Structure

Sr. No.	Paper No. & Code	Course Name	Major Core/ Major elective	Credits
	Semester III			
1	CHP – 601	Quantum and Solid State Chemistry	Major Core	4T
2	CHP- 602	Nuclear, Radiation and Polymer Chemistry	Major Core	4T
3	CHP- 603	Physicochemical Methods of Analysis	Major Core	2T
4	CHP- 604	Physical Chemistry Practical I	Major Core	2P
5	CHP- 605	Physical Chemistry Practical II	Major Core	2P
6	CHP- 606	A: Special Topics in Physical Chemistry I B: Electrochemistry C: Photochemistry D: Physical Chemistry Practical III	Major Elective **(Any two)**	2T 2P
7	CHP- 607	Research Project	RP	4
		Total credits for semester III		**22**
	Semester IV			
Sr. No.	**Paper No. & Code**	**Course Name**	**Major Core/ Major elective**	**Credits**
8	CHP-651	Molecular Structure and Spectroscopy	Major Core	4T
9	CHP-652	Surface Chemistry and Catalysis	Major Core	4T
10	CHP-653	Physical Chemistry Practical IV	Major Core	2P
11	CHP-654	Physical Chemistry Practical V	Major Core	2P
12	CHP-655	A: Instrumental Methods of Analysis B: Special Topics in Physical Chemistry II C: Techniques in Polymer Chemistry D: Physical Chemistry Practical VI	Major Elective **(Any two)**	2T 2P
13	CHP -656	Research Project	RP	6
		Total credits for semester IV		22
		Total Credits for Second Year		**44**

Detailed Syllabus

SEMESTER III

CHP-601 MJ: Quantum and Solid State Chemistry

Course / paper title	**Quantum and Solid-State Chemistry**
Course code	**CHP-601 MJ**
Semester	**III**
No. of credits	**4 Credits (60 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	Basic postulates of quantum mechanics, eigen functions, eigen values, operators and their types, spin-orbit interaction.
2.	Approximation methods in order to calculate ground state energy of two electron system, Pauli's exclusion principle and Slater determinant.
3.	The virial theorem and its applicability in chemical bonding.
4.	Recapitulation of crystal structure, Bragg equation.
5.	Types of imperfections and related phenomenon.
6.	Various properties of metals, semiconductors and insulators.

Section I: Quantum Chemistry (2Credits, 30L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Quantum Mechanics** Introduction, postulates of quantum mechanics, Schrodinger equation, Born interpretation of the wave function, properties of quantum mechanical operators, eigen functions and eigen values, Hermitian, linear, ladder, and angular momentum operators, numericals. **Ref. 1**, 2, 3	**12**
2.	**Approximation Methods** Introduction, Perturbation theory-non-degenerate perturbation theory, comparison of perturbation and variation method, the variation method-variation theorem and its applications, the first-order energy	**10**

	correction, the first-order wave-function correction, calculation of ground state energy and wave function of Helium atom (two electron system) using variation principle. **Ref.1,** 2, 3	
3.	**Electron Spin and the Pauli's Exclusion Principle:** Introduction, Electron spin, spin and the hydrogen atom, Pauli's exclusion principle, spin - orbit coupling and Slater determinant. **Ref. 2,** 3	**04**
4.	**Virial Theorem:** Introduction, The virial theorem, derivation, the virial theorem and chemical bonding. **Ref. 9**, 10	**04**
Section II: Solid State Chemistry (2 Credits, 30L)		
1.	**Recapitulation of Crystal Structure** Introduction, Space lattice and unit cell, the Bravais lattices, seven crystal systems, Weiss indices and Miller indices, Bragg equation, numericals. **Ref. 9**	**04**
2.	**Imperfections and Related Phenomenon** Introduction, Types of imperfections- point defects, thermodynamics of Schottky and Frenkel defects, lattice defects- line and plane, diffusion in solids- Fick's law of diffusion, types of diffusion, mechanism of diffusion(interstitial, dissociative, vacancy, ring), Kirkendall effect, elastic and plastic deformations, numerical. **Ref. 4,** 5,8	**06**
3.	**Properties of Metals** Introduction, Electrical properties – conductivity in pure metals, conductivity in alloys, Hall effect, magnetic properties– diamagnetism, paramagnetism, ferromagnetism. **Ref. 4,**8	**05**
4.	**Properties of Semiconductors** Introduction, Band theory, intrinsic and extrinsic semiconductors, conductivity -electrons and holes, temperature dependence of conductivity, optical properties- photoconductivity, photovoltaic effect, luminescence, junction properties- metal-metal junctions, metal-semiconductor junctions, p-n junctions, numericals. **Ref. 4**	**08**
5.	**Properties of Insulators** Introduction, Electrical properties- dielectric properties, piezoelectricity, electric breakdown, optical Properties- colourcentres,magnetic properties- exchange interactions, antiferromagnetism, ferrimagnetism. **Ref. 4,** 8	**07**

References:

1. Quantum Chemistry (4th edition), Ira N. Levine, Prentice Hall, of India, Pvt. Ltd, 5th edition, 2006.
2. Quantum Chemistry, A.K. Chandra, 4th edition Tata McGraw-Hill Publishing company Limited , 1994.
3. Quantum Chemistry, D. A. McQuarrie,, Viva Books, New Delhi, 2003.
4. Introduction of Solids, L.V Azaroff , Tata McGraw Hill, Publishing company Ltd, 1981.
5. Principles of the Solid State, H. V. Keer, Wiley Eastern, 1993.
6. Selected Topics in Solid State Physics, Vol. 12, The growth of crystals from Liquids, J. C. Brice, North Holland/American Elsevier, 1973.
7. Defects and Diffusion in Solids. S. Mrowec, Elseivier Publ. 1960.
8. Treatise on Solid State Chemistry, ED-N.B. Hannay, Plenum Press, Vol –2, 1975.
9. Principles of Physical Chemistry. B.R.Puri, L.R.Sharma, M.S.Pathania, Vishal Publishing Co.45thEdn, 2011.
10. Advanced Physical Chemistry, Gurtu-Gurtu, by Pragati Prakashan.

Learning outcomes:

Sr. No.	After studying this course, students will be able to
1.	Know the different types of quantum mechanical operators and how they operate on functions.
2.	Understand the need of approximation methods in quantum mechanics.
3.	Explain the applications of quantum mechanics in various electron systems of atoms.
4.	Understand several crystal systems and solve numerical based on Weiss, Miller indices and Bragg equation.
5.	Explain various types of imperfections.
6.	Know the properties of metals, semiconductors and insulators.

CHP-602 MJ: Nuclear, Radiation and Polymer Chemistry

Course / paper title	**Nuclear, Radiation and Polymer Chemistry**
Course code	**CHP-602 MJ**
Semester	**III**
No. of Credits	**4 Credits (60 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	The types of nuclear model, calculation of nuclear binding energy, properties of

	isobars, missing elements, magic numbers, filling of nucleon shells.
2.	Bethe's notation, types of nuclear reactions, compound nucleus theory and experimental evidence.
3.	The aspects of nuclear reactor design, types of reactors, types of research reactors.
4.	The theory and type of nuclear detectors.
5.	The process of nuclear fission and fusion, charge distribution, ionic charge of fission fragments, fission cross-section and threshold energy.
6.	The classification of polymers, types of polymer, copolymerization.
7.	Thermodynamics of polymer solutions, the crystalline melting point, glass transition temperature, experimental results with polymer solutions, Flory-Huggins theory, Flory-Krigbaum theory.
8.	The kinetics of polymerization, free–radical chain, cationic and anionic polymerization.
9.	Characterization of polymers and methods for determination of molecular weight of polymers.

Section I: Nuclear and Radiation Chemistry (2 Credits, 30L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Nuclear Structure** Introduction, The liquid drop model, calculation of nuclear binding energies, properties of isobars, missing elements, the nuclear shell model, magic numbers, filling of nucleon shells, the collective and unified models, numericals. **Ref. 1**, 5	**06**
2.	**Nuclear Reactions** Introduction, Bethe's notation, types of nuclear reactions, conservation in nuclear reactions, compound nucleus theory, experimental evidence, specific nuclear reactions, photonuclear and thermonuclear reactions, numericals. **Ref. 1**	**06**
3.	**Nuclear Reactors** Introduction, General aspects of power reactor design, thermal, fast and intermediate reactors, reactor fuel materials, reactor moderators and reflectors, coolants, control materials, shield, regeneration and breeding of fissile matter, types of research reactors, numericals. **Ref. 5,** 1	**07**
4.	**Radiation Detectors** Introduction, Scintillators and their properties, inorganic and organic	**05**

	scintillators, solid state semiconductor detectors - theory, surface barrier, Li drifted and intrinsic detectors. **Ref. 1**, 5	
5.	**Nuclear Fission and Fusion** Introduction, Process of nuclear fission, fission fragments and their mass distribution, charge distribution, ionic charge of fission fragments, fission energy, fission cross-section and threshold energy, nuclear fusion, fusion reactions in sun and star, fusion reactions on earth, numericals. **Ref. 1,** 5	**06**
Section II : Polymer Chemistry (2 Credits, 30 L)		
1.	**Basics Concepts of Polymer** Introduction, Classification of polymers as biological and non biological, types of polymers – linear, branched, network, condensation, addition, homo and heterochain, thermoplastic, thermosetting, copolymerization. **Ref. 8,** 12	**07**
2.	**Thermodynamics of Polymer Solutions** Introduction, Entropy and heat of mixing of polymer solutions, ideal behavior and deviations, experimental results with polymer solutions, Flory-Huggins theory, Flory-Krigbaum theory, the crystalline melting point (T_m), the glass transition temperature (T_g). **Ref. 8**	**09**
3.	**Kinetics of polymerization** Introduction, free–radical chain polymerization, cationic and anionic polymerization. **Ref. 12**	**05**
4.	**Measurements of Molecular Weights** Introduction, Characterization of polymers, molecular weight averages, fractionation and molecular weight distribution, methods for determination of average molecular weight (end group analysis), colligative property measurements, osmometry, diffusion light scattering, viscosity, ultracentrifugation, numericals. **Ref. 8,** 12	**09**

References:

1. Essentials of Nuclear Chemistry, H. J. Arnikar, Wiley Eastern Limited, 4th Edition, 1995
2. Nuclear and Radioactivity, G. Friedlander, J. W. Kennedy and J. M. Miller, John Wiley,1981
3. Introduction to Radiation Chemistry, J. W. T. Spinks and R. J. Woods, John Wiley,1990
4. Introduction to Nuclear Physics and Chemistry, B. G. Harvey, Prentice hall,1963
5. Sourcebook on Atomic Energy-S. Glasstone ,Van Nostrand Company,1967

6. Radiochemistry and Nuclear Methods of Analysis-W .D. Ehman and D. E. Vance, John Wiley,1991
7. Fundamentals of Radiochemistry, D. D. Sood, A. V. R. Reddy, N. Ramamoorthy, Indian Association of Nuclear Chemists and Allied Scientists, 4th Edition, 2010.
8. Textbook of Polymer Science-F.W. Billmeyer Jr., John Wiley & Sons Inc.,1971
9. Principles of Polymer Systems- F. Rodrigues, Tata McGraw Hill Publishing Company, New Delhi
10. Principles of Polymer Chemistry- P. J. Flory, Cornell University Press, Ithaca New York,1953
11. Polymer Chemistry – An Introduction, Seymour- Carraher, Marcel Dekker Inc, New York
12. Polymer Science –Gowarikar, Vishwanathan & Sreedhar, Wiley Eastern Ltd. New York,1988
13. Handbook on Conductiong Polymers – T. A. Skotheim, Ed., Marcel Dekker Inc, New York,1&2,1986

Learning Outcomes:

Sr. No.	After studying this course, students will be able to
1.	Know the types of nuclear model, calculation of nuclear binding energy, properties of isobars, missing elements, magic numbers, filling of nucleon shells.
2	Explain Bethe's notation, types of nuclear reactions, compound nucleus theory and experimental evidence.
3.	Understand the aspects of nuclear reactor design, types of reactors, types of research reactors.
4.	Explain the theory and types of detectors.
5.	Know the process of nuclear fission, charge distribution, ionic charge of fission fragments, fission cross-section and threshold energy, process of nuclear fusion, fusion reactions in Sun and star and on earth.
6.	Explain the classification of polymers, types of polymer, copolymerization.
7.	Understand thermodynamics of polymer solutions, experimental results with polymer solutions, Flory-Huggins theory, Flory-Krigbaum theory.
8.	Understand the kinetics of polymerization, free–radical chain, cationic and anionic polymerization.
9.	Explain characterization of polymer and methods for determination of molecular weight of polymers.

CHP-603 MJ: Physicochemical Methods of Analysis

Course / paper title	**Physicochemical Methods of Analysis**
Course code	**CHP-603**
Semester	**III**
No. of Credits	**2 Credits (30L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	The properties of x-rays, various x-ray methods such as x-ray absorption, x-ray fluorescence, instrumentation and applications.
2.	The principle, theory, instrumentation and applications of electron spectroscopy for chemical analysis.
3.	Various method of thermal analysis such as TGA, DTA, DSC and thermometric titrations.

Physicochemical Methods of Analysis (2credits, 30 L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**X-ray Methods** Introduction, Generation and properties of x-rays, x-ray absorption, concept of absorptive edge, x-ray absorptive apparatus, applications, x-ray fluorescence, fundamental principles, instrumentation, wavelength dispersive and energy dispersive qualitative and quantitative analysis, electron microprobe, numericals. **Ref. 1,** 5	**12**
2.	**Electron Spectroscopy for Chemical Analysis** Introduction, Theory, spectral splitting and chemical shift, ESCA satellite peaks, apparatus used for ESCA, applications, numericals. **Ref. 3**	**09**
3	**Thermal Methods of Analysis** Introduction, TGA, DTA, DSC and thermometric titrations-principle, instrumentation, factors affecting TGA and DTA curve, applications, numericals. **Ref. 2, 3,** 4, 5	**09**

References:

1. Introduction to Instrumental Analysis, R. D. Braun, McGraw Hill (1987).
2. Vogel's Textbook of Quantitative Inorganic Analysis, 4th edition, ELBS and Longman Publication, 1978.
3. Principles of Instrumental Analysis, D. A. Skoog, F. J. Holler, S. R. Crouch, 6th edition, Cengage Learning India Pvt.Ltd., 2015.
4. Instrumental Methods of Analysis, Willard, Merritt, Dean and Settle.
5. Instrumental Methods of Chemical Analysis, Gurdeep R. Chatwal and Sham K. Anand, Himalaya Publishing House, Reprint 2019.

Learning Outcomes:

Sr. No.	After studying this course, students will be able to
1.	Know the properties of x-rays, various x-ray methods such as x-ray absorption, x-ray fluorescence, instrumentation and applications.
2.	Understand the principle, theory, instrumentation and applications of electron spectroscopy for chemical analysis.
3.	Explain various methods of thermal analysis such as TGA, DTA, DSC and thermometric titrations.

CHP- 604 MJP Physical Chemistry Practical I (2 Credits, 30L)

Physical Chemistry Practical I	
Sr. No.	**Title of experiment**
1.	Differential potentiometric titration of halide ion.
2.	Radiolysis of aqueous iodate solution A and determination of its G value.
3.	Determination of relative strength of acetic acid and monochloro acetic acid b y conductometry.
4.	Determination of concentration of sulfuric acid, acetic acid and copper sulfate by conductomeric titration with sodium hydroxide.
5.	Kinetics of the reaction between potassium persulphate and potassium iodide by spctrophotometry.
6.	Determination of molecular weight of a given polymer by turbidimetry.
7.	Analysis of fruit juice for vitamin C / paracetamol by HPLC technique.
8.	Determination of surface tension of liquids by capillary rise method / with stalagmometer.
9.	Determination of the order of reaction for iodination of aniline by molecular iodine.
10.	Determination of the heat of ionization of weak acid.

CHP- 605 MJP Physical Chemistry Practical II (2 Credits, 30L)

Physical Chemistry Practical II	
Sr. No.	**Title of experiment**
1.	Flame photometric determination of Na by calibration curve method.
2.	Flame photometric determination of K by calibration curve method.
3.	Flame photometric determination of Na and K from mixture by calibration curve method.
4.	Determination of the formula of the complex formed between Fe and SSA by Job's method and hence to calculate the stability constant of the complex by spectrophotometry.
5.	Determination of strength of acetic acid in commercial vinegar solution by titrating with standard sodium hydroxide solution using pH meter.
6.	Determination of Cl^- by nephelometric titration or calibration curve method using nephelometer.
7.	Determination of riboflavin, by calibration curve method using photofluororometer.

8.	Determination of riboflavin, by standard addition method using photofluororometer.
9.	Differential potentiometric titration for mixture of two halide ions.
10.	Demonstration practical on AAS: setting of fuel to oxidizer ratio, choice ofconc. of metal ion for AAS (Linearity range) (Use metal ion of which lamp is available with your laboratory).

References:

1. Findlay's Practical Physical Chemistry, ninth edition revised by B. P. Levitt, Longman Group Ltd., 1988.
2. Experimental Physical Chemistry, Farrington Daniels and others, sixth edition McGraw-Hill Book Company Inc., 1956.
3. Experimental Physical Chemistry, V. D. Athavale, Parul Mathur, New Age International Publishers, 2001.
4. Advanced Physical Chemistry Experiments by A. Gurtu, J.N. Gurtu, A Publication of Pragati Prakashan, Meerut, 2000.
5. Practical Chemistry, O. P. Pandey, D. N. Bajpai, S. Giri, S. Chand and Company Ltd., 1972.
6. Experimental Physical Chemistry, R. C. Das and B. Behera, Tata McGraw-Hill publishing Company Ltd., New Delhi, 1983.
7. Experiments in Physical Chemistry, J.M. Wilson and others, Pergamon Press, 2009.
8. Practical Physical Chemistry, A.M. James and P.E. Pritchard, Longman Inc., 1974.

Learning outcomes:

Sr. No.	After studying this course, students will be able to
1.	Prepare solutions of various concentrations (like molar, normal, ppm, percentage etc.) solution.
2.	Use apparatus like stalagmometer, thermostat, and separating funnel which is required for non instrumental experiments.
3.	Perform non-instrumental experiments based on surface tension, thermochemistry, and chemical kinetics.
4.	Calibrate and use instruments like conductometer, potentiometer, colorimeter, pH meter, flame photometer, nephelometer, turbidimeter.
5.	Perform experiments using HPLC, AAS techniques.

CHP-606 {(A), (B), (C), (D) Major Elective (Any two options is to be selected by candidate)

Elective option A: CHP- 606 (A) Special Topics in Physical Chemistry I (2 credits, 30 L)

Course/paper title	**Special Topics in Physical Chemistry I**
Course code	**CHP- 606 (A) MJ**
Semester	**III**
No. of Credits	**2 Credits (30 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	Mass balance, charge balance, proton condition, concept of ionic equilibria for determining pH and concentration of various species present in solution.
2.	The data analysis with respect to error, accuracy, precision, mean deviation, standard deviation etc., permutations and combinations.
3.	The principle, instrumentation and applications of Nephelometry and Turbidimetry

Special Topics in Physical Chemistry I (2 credits, 30 L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Ionic Equilibria and pH Calculations** Introduction, mass balance, proton condition, charge balance– numericals, approximations on the mass balance and proton condition equations, solution of an equilibrium problem, determination of errors, graphical representation - the logarithmic concentration diagram, numerical on concentration of species in solution. **Ref. 1**	**12**
2.	**Data Analysis** Introduction, errors and its classification, minimization of error, accuracy, precision, significant figure, statistical treatment of data - mean and standard deviation, least square, analysis, correlation and its significance, correlation coefficient, regression analysis, coefficient of determination, permutation and combinations, probability. **Ref.2,**3,4	**10**
3.	**Nephelometry and Turbidimetry** Introduction, turbidimetry and colorimetry, nephelometry and fluorimetry, choice between nephelometry and turbidimetry, theory, comparison of spectrophotometry, nephelometry and turbidimetry, instrumentation, applications of nephelometry and turbidimetry. **Ref. 5,** 6, 7	**08**

References:

1. Ionic Equilibrium: A Mathematical Approach, J. N. Butler, Addison- Wesley Publishing Co. Inc., 1964.
2. Analytical Chemistry by G.D. Christian, 6th edition, Wiley-India.
3. Mathematical Preparation for Physical Chemistry, Farrington Daniels, McGraw -Hill Book Company, Inc., 1956.

4. Principles of Physical Chemistry, B. R. Puri, L. R. Sharma, M. S Pathania, Vishal Publishing Co., 45th Edition, 2011.
5. Instrumental Methods of Chemical Analysis- Gurdeep R. Chatwal and Sham K. Anand, Himalaya Publishing House.
6. Vogel's Textbook of Quantitative Inorganic Analysis, 4th edition, ELBS and Longman Publication, 1978.
7. Principles of Instrumental Analysis, D. A. Skoog, F. J. Holler, S. R. Crouch, 6th edition, Cengage Learning India Pvt.Ltd., 2015.

Learning Outcomes:

Sr. No.	After studying this course, students will be able to
1.	Solve numerical based on mass balance, charge balance, proton condition, determination of pH and concentration of various species present in solution.
2.	Know and calculate error accuracy, precision, mean and standard deviation, permutations and combinations.
3.	Know the principle, instrumentation and applications of nephelometry and turbidimetry.
4.	Apply the theoretical knowledge to perform the experiments based on nephelometry and turbidimetry.

Elective option B: CHP- 606 (B) Electrochemistry (2 credits, 30 L)

Course / paper title	**Electrochemistry**
Course code	**CHP- 411**
Semester	**IV**
No. of Credits	**2 Credits (30 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	The concept of activity and activity coefficient, Debye Huckel theory of activity coefficient, Fick's law of diffusion, Nernst-Einstein equation, relation between absolute and conventional mobilities.
2.	The concept of standard electrode potential, liquid junction potential, zeta potential, electrokinetic phenomena, double layer theories, Butler-Volmer equation, Tafel equation.
3.	Primary cell, secondary cell, fuel cells, lithium ion battery.

Electrochemistry (2 Credits, 30L)		
1.	**Ionics** Introduction, The Debye-Huckel theory of activity coefficients (limiting law), the theoretical mean activity coefficient for the ionic clouds with finite- sized ions (extended law), ion transport in solutions, Fick's first law of steady state diffusion, Einstein relation between diffusion coefficient and absolute mobility, The Nernst-Einstein equation, average drift velocity, absolute mobility, conventional mobility, relation between absolute and conventional mobilities, numericals. **Ref. 1,** 2	**14**
2.	**Electrodics** Introduction, Standard electrode potentials, liquid junction potential, zeta potential, electrokinetic phenomena, electrode-electrolyte interface, the Helmholtz double layer theory, the Gouy-Chapman diffuse charge double layer theory, the stern adsorption double layer theory, Butler- Volmer equation and Tafel equation. **Ref. 1**	**10**
3.	**Applications** Introduction, Fuel cells (hydrogen-oxygen) and batteries- primary cell (Leclanche or dry) and secondary cells (lead storage), fuel cells, lithium ion battery **Ref. 1, 3,** 4, 5	**06**

References:

1. Modern Electrochemistry, John O'M Bockris and Amulya Reddy, Plenum Press, N.Y., 1973.
2. An Introduction to Electrochemistry, Samuel Glasstone, Van Nostrand Reinhold Co.,3rd Edition, 1971.
3. Principles of Physical Chemistry , Samuel H. Maron, Carl F. Prutton, Oxford & IBH Publishing Co. Pvt. Ltd., 4th Edition, 1972.
4. Fuel cells – heir Electrochemistry, John O'M Bockris and S Srinivasan, McGraw Hill,NY (1969).
5. Fuel cell systems, L.I. M Blomen and M. N. Mugerwa, Plenum Press, NY (1993).

Learning Outcomes:

Sr. No.	After studying this course, students will be able to
1.	Understand the concept of activity and activity coefficient, Debye Huckel theory of activity coefficient, junction potential, zeta potential, electrokinetic phenomena, double layer theories, Butler – Volmer equation, Tafel equation.
2.	Explain primary cells, secondary cells, fuel cells, lithium ion battery.

Elective option C: Photochemistry (2credits, 30L)

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	The interaction of light with matter, general features of photochemical and photophysical processes.
2.	Selection rules, lifetimes of excited electronic states of atoms and molecules, types of electronic transitions in organic molecules.
3.	The photophysical kinetics of uni and bimolecular processes.
4.	Photolysis, its types and applications, laser-general principle, and its types of lasers, single photon counting, actinometry, conversion and storage of solar energy.

Photochemistry (2 Credits, 30L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Photochemistry** Introduction, Laws of photochemistry, interaction of light with matter, theory of photoluminescence, general features of photochemical and photophysical processes. **Ref. 1,** 2	**04**
2.	**Mechanism of Absorption and Emission of Radiation** Introduction, Einstein's treatment, selection rules, lifetimes of excited electronic states of atoms and molecules, types of electronic transitions in organic molecules photochemical pathways, Jablonski diagram, fluorescence, phosphorescence **Ref. 1,** 2	**06**
3.	**Photophysical Kinetics** Introduction, Photophysical kinetics of uni and bimolecular processes, delayed fluorescence mechanisms, kinetics of collisional quenching, Stern- Volmer equation, quenching by added substances, charge transfer mechanism, energy transfer mechanism. **Ref. 1,** 2	**08**
4.	**Photolysis** Introduction, Photolysis, Laser-general principles, types of lasers - two, three and four level lasers, solid state Ruby and Nd/YAG laser, self-phase modulation, single photon counting, experimental techniques, flash photolysis - conventional microsecond flash photolysis, nanosecond laser flash photolysis, actinometry. **Ref. 1, 2**	**07**
5.	**Frontiers of Photochemistry** Introduction, Picosecond, femtosecond flash photolysis, applications- solar energy, conversion and storage, photosynthesis. **Ref. 1, 2**	**05**

References:

1. Fundamentals of Photochemistry, K. K. Rohatgi, Mukherjee New Age International,Publishers Revised Edition, Reprint 2003
2. Chemistry and Light, Paul Suppan, The Royal Society of Chemistry, 1994.

Learning outcomes:

Sr. No.	After studying this course, students will be able to
1.	Explain the interaction of light with matter, general features of photochemical and photophysical processes.
2.	Explain types of electronic transitions in organic molecules.
3.	Solve the photophysical kinetics of uni and bimolecular processes and quenching.
4.	Describe photolysis, its types and applications, laser-general principles and its types of lasers, single photon counting and actinometry

CHP- 606 (D) Physical Chemistry Practical III (2 Credits, 30L)

Physical Chemistry Practical III	
Sr. No.	**Title of experiment**
1.	Determination of the equilibrium constant of triiodide ion formation.
2.	Effect of salt on the distribution of acetic acid between water ethyl acetate.
3.	Radiolysis of aqueous iodate solution B and determination of its G value.
4.	To study the characteristics of G.M. counter.
5.	Determination of pKa value of maleic acid or malonic acid by titrating with standard sodium hydroxide solution using pH meter.
6.	Solubility of a sparingly soluble salt by conductometry.
7.	Determination of SO_4^{2-} by nephelometric titration using standard barium nitrate.
8.	Determination of SO_4^{2-} by calibration curve method using nephelometer.
9.	Simultaneous determination of two ions by polarography.
10.	Calibration of gamma ray spectrometer and determination of energy of a given radioisotope.

References:

1. Findlay's Practical Physical Chemistry, ninth edition revised by B. P. Levitt, Longman Group Ltd., 1988.
2. Experimental Physical Chemistry, Farrington Daniels and others, sixth edition McGraw-Hill Book Company Inc., 1956.
3. Experimental Physical Chemistry, V. D.Athavale, Parul Mathur, New Age International Publishers, 2001.
4. Advanced Physical Chemistry Experiments by A. Gurtu, J.N. Gurtu, A Publication of Pragati Prakashan, Meerut, 2000.
5. Practical Chemistry, O. P. Pandey, D. N. Bajpai, S. Giri, S. Chand and Company Ltd., 1972.
6. Experimental Physical Chemistry, R. C. Das and B. Behera, Tata McGraw-Hill publishing

Company Ltd., New Delhi, 1983.
7. Experiments in Physical Chemistry, J.M. Wilson and others, Pergamon Press, 2009.
8. Practical Physical Chemistry, A.M. James and P.E. Pritchard, Longman Inc., 1974.

Learning outcomes:

Sr. No.	After studying this course, students will be able to
1.	Prepare solutions of various concentrations (like molar, normal, ppm, percentage etc.) solution.
2.	Perform non-instrumental experiments based on surface tension, thermo chemistry, and chemical kinetics.
3.	Calibrate and use instruments like conductometer, potentiometer, colorimeter, pH meter, flame photometer, nephelometer, turbidimeter.
4.	Perform experiments using HPLC, AAS techniques.

CHP-607: Research Project 4 credits

Each student will perform project separately. ***Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project (2-3 page) followed by introduction (4 to 7 pages), literature survey (4-7) pages (recently published about 30 papers must be included), experimental techniques, results, discussion, conclusions, Appendix consisting of i) references, 2) standard spectra / data if any and 3) safety precautions.*** If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. ***Systematic record of attendance of project students must be maintained by a mentor.*** Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work and discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.

SEMESTER IV

CHP-651 MJ: Molecular Structure and Spectroscopy

Course/paper title	**Molecular Structure and Spectroscopy**
Course code	**CHP -651**
Semester	**IV**
Number of Credits	**4 Credits (60 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	The principle and technique of NMR with respect to various terms involved in it and their influencing factors, spin-spin coupling, coupling constants, factors affecting,the interpretation of NMR spectra of various compounds, spin-spin relaxation, spin-lattice relaxation, NMR spectra of solids and applications of NMR.
2.	The principle, theory, presentation and applications of ESR.
3.	The principle, theory, presentation and application of the x-ray diffraction technique.
4.	The principle, instrumentations and applications of mass spectrometry technique and interpretation of mass spectra of some compounds.
5.	The differences between electron diffraction and x-ray diffraction techniques, principle, instrumentation, the Weirl equation, applications and limitations.

Section I: Molecular Structure and Spectroscopy I (2 Credits, 30 L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Nuclear Magnetic Resonance Spectroscopy** Introduction, Spin and an applied field-the nature of spinning particles, the interaction between spin and a magnetic field, population of energy levels, Larmor precession, instrumentation of NMR,chemical shift and its measurements, factors influencing the chemical shift, shielding and deshielding of protons, spin-spin coupling, coupling constant and factors affecting coupling constant, interpretation of NMR spectra of ethyl bromide, isopropyl bromide, 1,1 dibromoethane, benzaldehyde, p-nitrotoluene, chemical exchange, spin-spin relaxation and spin-lattice relaxation, nuclear magnetic double resonance, NMR spectra of solids (MAS), nuclear overhauser effect (NOE),Carbon-13 NMR, applications of NMR, numericals. **Ref. 1, 2,** 3, 4, 7	**20**
2.	**Electron Spin Resonance Spectroscopy** Introduction, Principle, theory of ESR, presentation of ESR spectrum, hyperfine splitting with examples, determination of g-	**10**

	value and factors affecting it, line width, zero-field splitting and Kramer's degeneracy, applications of ESR, numericals. **Ref. 1, 2,** 3, 4,7	
Section II: Molecular Structure and Spectroscopy II (2 Credits, 30 L)		
1.	**X-ray Diffraction** Introduction, Principle, interference of wave motions, identification of unit cell from systematic absences in the diffraction pattern, structure factor and its relation to electron density, phase problem in XRD, applications, numericals. **Ref. 2,**6,8	**08**
2.	**Mass Spectrometry** Introduction, instrumentation–inlet systems, ionic sources – electron –bombardment ionization, arc and spark ionization, photoionization, thermal ionization etc., mass analyzers- magnetic analyzers, time-of –flight analyzers etc., resolution, detectors, types of ions produced in a mass spectrometer, a typical examples of interpretation of molecular mass spectra, applications, numericals. **Ref.** 2, **8**	**14**
3.	**Electron Diffraction** Introduction, remarkable differences between electron diffraction and x-ray diffraction technique, principle, experimental arrangement to study electron diffraction of gases , the Wierl equation, applications and limitations. **Ref. 5**	**08**

References:

1. Physical Methods in Inorganic Chemistry, Russell S. Drago, Affiliated East-West Press Pvt.Ltd., New Delhi, 1971.
2. Instrumental Methods of Chemical, G. R. Chatwal, S. K. Anand, Himalaya Publishing House, Reprint 2019.
3. Fundamentals of Molecular Spectroscopy, C.N. Banwell and E.M.McCash, Tata Mc Graw Hill Publishing Co. Ltd., 4th Edition, Reprint 1996.
4. Principles of Physical Chemistry,B. R. Puri, L. R. Sharma, M. S. Pathania, Vishal Publishing Co., 45th Edition, 2011.
5. Molecular structure: A spectroscopic approach. S. N. Singh, R.K, Agarwal and M. Katyal, Discovery Publishing House, New Delhi, 1990.
6. Introduction to Molecular Spectroscopy, G.M. Barrow, Mc Graw Hill Publication Co. Ltd., 1962.
7. Spectroscopy, H. Kaur, Pragati Prakashan, 17th Edition, 2021.
8. Introduction to Instrumental Analysis, R D. Braun, Mc Graw Hill PublicationCo.Ltd., 1987.

Learning outcomes:

Sr. No.	After studying this course, students will be able to
1.	Explain the principle and technique of NMR with respect to various terms involved in it, applications of NMR.
2.	Describe the principle, theory and applications of ESR.

3.	Explain the principle, theory, and applications of the x-ray diffraction technique.
4.	Understand the principle, instrumentation and applications of mass spectrometry technique and interpret mass spectra of some compounds.
5.	Know the principle and instrumentation of electron diffraction technique, Wierl equation, applications and limitations.

CHP-652: Surface Chemistry and Catalysis

Course / paper title	**Surface Chemistry and Catalysis**
Course code	**CHP- 652**
Semester	**IV**
No. of Credits	**4 Credits (60 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	The concept of adsorption and its types, heat of adsorption and its determination methods.
2.	The critical comparison of various multilayer models, measurement of surface area of solids by different methods.
3.	Theory of adsorption at liquid surfaces, Gibbs equation and its verification, Gibbs monolayer, insoluble films on liquid substrates, wetting, flotation, detergency.
4.	Definition of porous solids, methods to determine pore size, hysteresis of adsorption and its proposed theories and adsorption behavior of porous materials.
5.	General characteristics of catalytic reactions and types of catalysis.
6.	Preparation of catalysts and their characterization using different spectroscopic techniques.
7.	Photocatalysis by metals and semiconductors.
8.	Catalysis in green chemistry and their environmental applications.

Section I: Surface Chemistry (2 Credits, 30 L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Adsorption** Introduction, Adsorption forces, thermodynamics of physical adsorption, heat of adsorption and its determination, measurement of adsorption by different methods, chemisorption and its mechanism, numericals. **Ref. 1,** 2, **3,** 4, 5	**10**
2.	**Multilayer Adsorption** Introduction, Critical comparison of various multilayer models- BET, potential theory (Polanyi model, polarization model) (no derivation),	**08**

	measurement of surface area of solids by different methods-B.E.T. equation, Harkins and Jura equation, point B method,numericals. **Ref. 3,** 4	
3.	**Adsorption at Liquid Surfaces** Introduction, Gibbs equation and its verification, Gibbs monolayer, insoluble films on liquid substrates, wetting, flotation, detergency. **Ref. 1,** 4,5	**08**
4.	**Porous Solids** Introduction, Definition, pore size distribution, methods to determine pore size, hysteresis of adsorption, theories of hysteresis and adsorption behaviors of porous materials. **Ref. 6**	**04**
Section II: Catalysis (2 Credits, 30L)		
1.	**Theories of Catalysis** Introduction, general characteristics of catalytic reactions, Types of catalysis-homogeneous and heterogeneous catalysis, enzyme catalysis, effect of temperature and pH on enzyme catalysis, heterogeneous catalysis- surface reactions, concept of Langmuir-Hinshelwood mechanism and intermediate compound formation theory and adsorption theory, bio catalysis, autocatalysis, negative catalysis, concept of activity, activation of catalysis- calcination and reduction, selectivity, poisoning, promotion and deactivation. **Ref. 3,** 5**,** 6	**10**
2.	**Preparation and Characterization of Catalysts** Introduction, General methods for preparation of catalysts-introduction, precipitation, sol-gel, hydrothermal, impregnation, hydrolysis, vapour deposition methods, catalyst characterization-surface area, pore size distribution, particle size distribution, XPS, AES, UV-Vis, FT-IR. **Ref. 3, 6**	**10**
3.	**Photocatalysis** Introduction, Electronic effect in catalysis by metals, electronic structures and catalysis, catalysis by semiconductors. **Ref. 6**	**06**
4.	**Catalysis in Green Chemistry and Environmental Applications** Introduction, Purification of exhaust gases from different sources-auto-exhaust catalysts (petrol vehicles, diesel vehicles), VOC removal, and ozone decomposition. **Ref. 7, 8**	**04**

References:

1. Physical Chemistry of Surfaces, A.W. Adamson, Interscience publishers Inc., New York, 1967.

2. Surface Chemistry Theory and Applications, J. J. Bikerman, Academics press, New York 1972.
3. Principles of Physical Chemistry,B. R. Puri, L. R. Sharma, M. S. Pathania, Vishal Publishing co., 45th Edition, 2011.
4. Adsorption and Phase rule, Gurudip Raj, Harish Mehra, Goel Publishing house, 1st edition, 1971.
5. Kinetics of Chemical Reactions, S. K. Jain, Delhi S. Nagin & Co.
6. Heterogenous Catalysis, D. K. Chakrabarty, B. Viswanathan, 1st Edition, Published by New Age International Pvt.Ltd.,Publishers.
7. Removal of Volatile Organic Compounds from Polluted Air, Faisal I. Khan, Aloke Kr. Ghoshal, Journal of Loss Prevention in the Process Industries 13, 527-545, 2000.
8. Ozone Decomposition and Stabilisation, Margareta Eriksson, Licentiate Thesis, Department of Chemistry Royal Institute of Technology Stockholm, Sweden, 2005.

Learning Outcomes:

Sr. No.	After studying this course, students will be able to
1.	Know the concept of adsorption and its types, heat of adsorption and its determination.
2.	Understand the critical comparison of various multilayer models, measurement of surface area of solids by different methods.
3.	Understand the theory of adsorption and different phenomena at liquid surfaces.
4.	Explain definition of porous solids, methods to determine pore size, theory of hysteresis of adsorption.
5.	Explain general characteristics of catalytic reactions and types of catalysis.
6.	Explain the preparation of catalysts and their characterization using spectroscopic techniques.
7.	Understand the catalysis in green chemistry and their environmental applications.
8.	Know the concept of photocatalysis.

CHP- 653 MJP Physical Chemistry Practical IV (2 Credits, 30L)

Physical Chemistry Practical IV	
Sr. No.	**Title of experiment**
1.	Selection of amount of sodium thiosulphate for the reaction between KI and $K_2S_2O_8$ for clock reaction method.
2.	Determination of energy of activation for the reaction between KI and $K_2S_2O_8$ by clock reaction method.
3.	Flame photometric determination of Na by standard addition method.
4.	Flame photometric determination of Na and K in given sample by standard addition method.
5.	Determination of quinine sulfate using photoflurometer by working curve method
6.	Determination of quinine sulfate using photoflurometer by standard addition method.

7.	Determination of dissociation constant of an acid-base indicator by spectrophotometry.
8.	Radiation dose measurement by Fricke dosimeter or ceric sulphate dosimeter using spectrophotometer.
9.	Determination of second order velocity constant of ethyl acetate by conductometry.
10.	Determination of half -life of two isotopes in a mixture.

CHP- 654 MJP Physical Chemistry Practical V (2 Credits, 30L)

Physical Chemistry Practical V	
Sr. No.	**Title of experiment**
1.	Determination of absorption coefficient and half thickness of lead for gamma radiation by G.M. counter.
2.	Kinetics of iodination of aniline: pH effect
3.	Kinetics of iodination of aniline: base catalysis.
4.	Effect of KCl salt on kinetics of the reaction between KI and $K_2S_2O_8$.
5.	Determination of amount of boric acid by conductometric titration with standard NaOH solution.
6.	Flame photometric determination of Na or K in given sample by internal standard method (Li as internal standard).
7.	Determination of formula of the complex formed between Fe and SSA by slope ratio method using spectrophotometer.
8.	A photometric titration of a mixture of (Cu + Fe) or (Cu + Bi) with EDTA.
9.	Amperometric titration with rotating platinum electrode.
10.	Determination of Fe / Cu/ Zn / Mn / by AAS from soil / water sample.

References:

1. Findlay's Practical Physical Chemistry, ninth edition revised by B. P. Levitt, Longman Group Ltd., 1988.
2. Experimental Physical Chemistry, Farrington Daniels and others, sixth edition McGraw-Hill Book Company Inc., 1956.
3. Experimental Physical Chemistry, V. D.Athavale, Parul Mathur, New Age International Publishers, 2001.
4. Advanced Physical Chemistry Experiments by A. Gurtu, J.N. Gurtu, A Publication of Pragati Prakashan, Meerut, 2000.
5. Practical Chemistry, O. P. Pandey, D. N. Bajpai, S. Giri, S. Chand and Company Ltd., 1972.
6. Experimental Physical Chemistry, R. C. Das and B. Behera, Tata McGraw-Hill publishing Company Ltd., New Delhi, 1983.
7. Experiments in Physical Chemistry, J.M. Wilson and others, Pergamon Press, 2009.
8. Practical Physical Chemistry, A.M. James and P.E. Pritchard, Longman Inc., 1974.

Learning outcomes:

Sr. No.	**After studying this course, students will be able to**
1.	Prepare solutions of various concentrations (like molar, normal, ppm, percentage etc.) solution.

2.	Perform non-instrumental exp eriments based on chemical kinetics and viscosity measurements.
3.	Perform experiments using conductometer, colorimeter, flame photometer and uv-visible spectrophotometer.

CHP-655 Major Elective {A, B C or D} (Any two options is to be selected by candidate)

CHP-655 (A) Instrumental method of Analysis (2 credits, 30L)

Course / paper title	**Instrumental method of Analysis**
Course code	**CHP-655 (A)**
Semester	**IV**
No. of Credits	**2 Credits (30 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	Principle, components, instrumentation, working and applications of SEM and TEM.
2.	The technique of coulometry and its methods.
3.	The concept of luminescence and its types with instrumentation and their applications.
4.	The principle, instrumentation and applications of electroanalytical technique such as voltammetry, polarography and amperometry.

Instrumental Methods of Analysis (2 Credits, 30)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Scanning Electron Microscopy(SEM)** Introduction, Principle, components of SEM, instrumentation and working, interaction of electron beam with specimen, sample preparation for SEM, applications, advantages and disadvantages. **Ref. 6,7**	**05**
2.	**Transmission Electron Microscopy(TEM)** Introduction, Principle, components of TEM, instrumentation and working,electron interaction with matter, TEM sample preparation, applications. **Ref. 6,7**	**05**
3.	**Coulometry** Introduction, Current-voltage relationship, controlled potential	**06**

	coulometry, controlled current coulometry, primary and secondary coulometric titrations, errors in titration, applications, numericals. **Ref. 1**,5	
4.	**Luminescence** Introduction, Luminescence-fluorescence, phosphorescence (principle, apparatus), factors affecting photoluminescence, qualitative andquantitative analysis, applications. **Ref. 1**, 3, **5**	**06**
5.	**Voltammetry** Introduction, types of voltammetry- hydrodynamic voltammetry, cyclic voltammetry, polarography, amperometry and amperometric titrations (principle, instrumentation and applications), numericals. **Ref. 1, 2, 3,** 4	**08**

References:

1. Introduction to Instrumental Analysis, R. D. Braun, McGraw Hill (1987).
2. Vogel's Textbook of Quantitative Inorganic Analysis, 4th edition, ELBS and Longman Publication, 1978.
3. Principles of Instrumental Analysis, D. A. Skoog, F. J. Holler, S. R. Crouch, 6th edition, Cengage Learning India Pvt.Ltd., 2015.
4. Instrumental Methods of Analysis, Willard, Merritt, Dean and Settle.
5. Instrumental Methods of Chemical Analysis, Gurdeep R. Chatwal and Sham K. Anand, Himalaya Publishing House, Reprint 2019.
6. A Text on Fundamentals and Applications of Nanotechnology, K.S.Subramanian
7. Nanotechnology Principle and Practices. S. K. Kulkarni, 2007.

Learning outcomes:

Sr. No.	After studying this course, students will be able to
1.	Know the principle, instrumentation and applications of electroanalytical techniques such as voltammetry, polarography,amperometry.
2.	Understand the concept of luminescence and its types with instrumentation and applications.
3.	Explain the technique of coulometry and its methods.
4.	Compare the principle, working and applications of SEM and TEM in characterization of different compounds.

CHP-655 (B) Special Topics in Physical Chemistry II (2 credits, 30L)

Course / paper title	**Special Topics in Physical Chemistry II**
Course code	**CHP-655 (B)**
Semester	**IV**
No. of Credits	**2 Credits (30 L)**

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	Materials of solid devices and their properties.
2.	Preparation techniques of thin film and their properties along with applications.
3.	Smart materials and their study with different aspects in chemistry.
4.	The synthesis of nanomaterials by various methods, analysis techniques, propertiesand its applications.

Special Topics in Physical Chemistry II (2 Credits, 30L)		
Unit Number	**Title with Contents**	**Number of Lectures**
1.	**Materials of Solid Devices** Introduction, Rectifiers, transistors, capacitors, IV-V compounds low dimensionalquantum structures, optical properties. **Ref. 1**	**06**
2.	**Thin Films Langmuir – Blodgett Films** Introduction, Preparation techniques, sputtering, chemical process, MOCVED, Langmuir – Blodgett films, photolithography, applications of LB films. **Ref. 2**	**05**
3.	**Smart Materials** Introduction, design of intelligent, piezolecteric, elecrtostrictive, magnetostrictive, electrorheological, and magnetorheological materials, thermoresponsive, pH sensitive, light sensitive materials, smart polymers, shape memory alloys. **Ref. 3**	**07**
4.	**Nanoscience and Nanotechnology** Introduction to nanoworld, synthesis of nanomaterials – physical, chemical and biological methods, analysis techniques of nanomaterials, properties of nanomaterials. **Ref.** 4-8	**06**
5.	**Nanomaterials and their Applications** Introduction, Fullerene, carbon nanotubes, aerosols, zeolites, quantum dots, applications in electronics, environment andenergy, space anddefence, medicine and health, textile and cosmetics. **Ref.** 4-8	**06**

References:

1. Material Science & Engineering: An Introduction, W.D. Callister, Wiley, 2018.

2. Materials Science for Engineering, J.C. Anderson, K.D.Leaver, Rees Rawlings, Taylor and Francis, 2003.
3. Handbook of Materials Selection, James A. Harvey,John Wiley and Sons, Inc, New York,2002.
4. A Text on Fundamentals and Applications of Nanotechnology, K. S. Subramanian.
5. Nanotechnology Principle and Practices. S. K. Kulkarni, 2007.
6. A Handbook on Nanotechnology, A. G. Brecket,Dominant Publishers and Distributors,New Delhi, 2008
7. Nanotechnology: Principles and Practices, Sulabha Kulkarni, Capital Publishing Company, 2007.
8. Introduction to Nanoscale Science and Technology, Massimiliano Di Ventra, Stephane Evoye and James Heflin, Springer Publication.

Learning outcomes:

Sr. No.	After studying this course, students will be able to
1.	Know the applications of various electronic devices and their physical significance.
2.	Explain the preparation, properties and applications of thin film.
3.	Explain smart materials and their applications in various fields.
4.	Describe the synthesis of nanomaterials by various methods, analysis techniques, properties and its applications.

CHP-655 (C) Techniques in Polymer Chemistry(2 credits, 30L)

Aims and Objectives of the Course

Sr. No.	Students should understand and learn
1.	Configuration of polymer chains, crystal structure of polymer, mechanical properties of crystalline polymers.
2.	The glass transition, properties involving large and small deformation, polymer utilization.
3.	Polymer processing such as plastic technology, fibre technology and elastomer technology.
4.	The kinetics and mechanism of polymerization in the liquid and solid phases.

Techniques in Polymer Chemistry (2 Credits, 30 L)		
1.	**Morphology and Rheology of Polymers** Introduction, Configuration of polymer chains crystal structure, crystallization processes, viscous flow, rubber elasticity, viscoelasticity, the glassy state and glass transition and mechanical properties of crystalline polymers. **Ref. 1,**	**09**

2.	**Polymer Structure and Physical Properties** Introduction, The crystalline melting point Tm - the glass transition temperature (Tg) - properties involving small and large deformations- polymer requirements and polymer utilization. **Ref. 1,** 2	**06**
3.	**Polymer Processing** Introduction, Plastic technology - moulding, other processing techniques fibre technology - textile and fabric properties, spinning fibre after treatments, elastomer technology - natural rubber, vulcanization, reinforcement, and carbon blocks. **Ref. 1**	**08**
4.	**Radiation-Induced Polymerization** Introduction, Kinetics and mechanism of polymerization in the liquid and solid phases, effect of irradiation on polymers - degradation and cross- linking, block copolymerization. **Ref. 3**	**07**

References:

1. Textbook of Polymer Science-F.W. Billmeyer Jr., John Wiley & Sons Inc.,1971
2. Polymer Science –Gowarikar, Vishwanathan & Sreedhar, Wiley Eastern Ltd. New York,1988
3. Contemporary Polymer Chemistry, H. R. Allcock, F. W. Lampe, J. E. Mark, third edition, Pearson Education.
4. Principles of Polymer Systems- F. Rodrigues, Tata McGraw Hill Publishing Company, New Delhi
5. Principles of Polymer Chemistry- P. J. Flory, Cornell University Press, Ithaca New York,1953
6. Polymer Chemistry – An Introduction, Seymour- Carraher, Marcel Dekker Inc, New Yor

Learning outcomes:

Sr. No.	**After studying this course, students will be able to**
1.	Explain configuration of polymer chains crystal structure of polymers, mechanical properties of crystalline polymers.
2.	Explain glass transition, properties involving large and small deformation.
3.	Describe polymer processing - plastic technology, fibre technology, elastomer technology.
4.	Understand the kinetics and mechanism of polymerization in the liquid and solid phases.

CHP- 655 D Physical Chemistry Practical VI (2 Credits, 30L)

Physical Chemistry Practical VI	
Sr. No.	**Title with Contents**
1.	Determination of the molecular weight of poly (vinyl alcohol)viscosity measurements
2.	Effect of addition of a salt on the solubility of an acid in water.

3.	Determination of formula of complex formed between Fe and SSA by mole ratio method using colorimeter.
4.	Determination of relative strength of acetic acid and trichloroacetic acid by conductometry.
5.	Determination of transport number of silver and nitrate ions by potentiometry.
6.	Determination of molecular weight of a polymer by end group estimation method.
7.	Flame photometric determination of Na and K in given mixture by internal standard method (Li as internal standard).
8.	Determination of first order velocity constant of decomposition of H_2O_2 by volume determination of O_2.
9.	Determination of energy of activation of decomposition of diacetone alcohol using dilatometer.
10.	To study the effect of the extended conjugation on the λ_{max} of p-nitrophenol by recording spectrum in acidic and alkaline medium.

References:

1. Findlay's Practical Physical Chemistry, ninth edition revised by B. P. Levitt, Longman Group Ltd., 1988.
2. Experimental Physical Chemistry, Farrington Daniels and others, sixth edition McGraw-Hill Book Company Inc., 1956.
3. Experimental Physical Chemistry, V. D.Athavale, Parul Mathur, New Age International Publishers, 2001.
4. Advanced Physical Chemistry Experiments by A. Gurtu, J.N. Gurtu, A Publication of Pragati Prakashan, Meerut, 2000.
5. Practical Chemistry, O. P. Pandey, D. N. Bajpai, S. Giri, S. Chand and Company Ltd., 1972.
6. Experimental Physical Chemistry, R. C.Das and B. Behera, Tata McGraw-Hill publishing Company Ltd., New Delhi, 1983.
7. Experiments in Physical Chemistry, J.M. Wilson and others, Pergamon Press, 2009.
8. Practical Physical Chemistry, A.M. James and P.E. Pritchard, Longman Inc., 1974.

Learning outcomes:

Sr.No.	After studying this course, students will be able to
1.	Prepare solutions of various concentrations (like molar, normal, ppm, percentage etc.) solution.
2.	Perform experiments using colorimeter, uv-visible spectrophotometer, flame photometer, potentiometer and conductometer.
3.	Perform non instrumental experiments based on chemical kinetics and viscosity.

CHP-656: Research Project 6 credits

Each student will perform project separately. ***Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project (2-3 page) followed by introduction (4 to 7 pages), literature survey (4-7) pages (recently published about 30 papers must be included), experimental techniques, results, discussion, conclusions, Appendix consisting of i) references, 2) standard spectra / data if any and 3) safety precautions.*** If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. ***Systematic record of attendance of project students must be maintained by a mentor.*** Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work and discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.