

**NORTH MAHARASHTRA UNIVERSITY, JALGAON**  
**SCHOOL OF CHEMICAL SCIENCES**  
**(Academic Flexibility Since-2009)**



**SYLLABUS**

**for**

**MASTER OF SCIENCE in CHEMISTRY**

**With**

**Specialization in**

**PHYSICAL CHEMISTRY**

**M.Sc. II (Semester III and IV)**

**(Choice Based Credit System, 60:40 Pattern)**

**w. e. f. June 2016**

**Syllabus for**  
**M.Sc. Chemistry (with specialization in Physical Chemistry)**  
**[w.e.f. June 2016]**  
**Course Structure for Second Year [Semester III and IV]**

**SEMESTER – III**

<b>SR. NO.</b>	<b>CODE NO.</b>	<b>SUBJECT TITLE</b>	<b>MARKS</b>	<b>CREDITS</b>
1	PH-301	Quantum Chemistry, Symmetry and Group Theory	100	4
2	PH-302	Solid State Chemistry, Radiochemistry and Nanoscience	100	4
3	PH-303	Electrochemistry and Kinetics of Reactions	100	4
4	PH-304	Physical Chemistry of Polymers	100	4
5	PH-004	Physical Chemistry Practical Course	100	3

**SEMESTER – IV**

<b>SR. NO.</b>	<b>CODE NO.</b>	<b>SUBJECT TITLE</b>	<b>MARKS</b>	<b>CREDITS</b>
1	PH-401	Molecular Structure	100	4
2	PH-402	Statistical Thermodynamics, Phase Equilibria and Irreversible Thermodynamics	100	4
3	PH-403	Surface Chemistry and Catalysis	100	4
4	PH-005	Physical Chemistry Practical Course	100	3
5	PH-006	Project and Seminar	100	3

\* The projects will be initiated in the beginning of Semester III and the examination will be conducted at the end of Semester IV.

\* Educational Tour: Organizing Educational Tour aiming at giving practical exposure to second year students is expected (at their own cost).

## **PH-301: Quantum Chemistry, Symmetry and Group Theory**

- Unit I** [12 hrs]  
Wave theory of matter, Failures of classical Mechanics, Black Body Radiation and Quantum theory, Photoelectric Effect, Wave-particle duality of radiation, Hydrogen atom spectra,
- Unit II** [12 hrs]  
Quantum mechanical operators, Eigen values and Eigen functions, angular momentum, Basic Postulates of Quantum Mechanics.
- Unit III** [12 hrs]  
Schrodinger equation, free particles, Particle in a box: infinite potential barriers and finite potential barriers, Spherical coordinates, Degeneracy, Harmonic oscillator, Rigid rotator and the hydrogen atom, Two electron systems, the Helium atom.
- Unit IV** [12 hrs]  
The Variation method and application to Helium atom, Slater determinantal wave function, Application of LCAO-MO theory on the basis of Hückel approximation to conjugated aliphatic molecules and monocyclic conjugated polyenes.
- Unit V** [12 hrs]  
Symmetry elements and Symmetry operations, Point groups, Nomenclature Schenflies and international, Transformation matrices, Multiplication tables, Representation of groups, Orthogonality theorem, Reducible and irreducible Representations, Character tables, Molecular properties and Symmetry types, Orbital symmetries

### **Reference Books:**

1. Quantum Chemistry, R. K. Prasad, Wiley Eastern Ltd, 1992.
2. Introductory to Quantum Chemistry, A. K. Chandra, Tata McGraw Hill, 1979.
3. Quantum Chemistry, I. N. Levine, Allyn and Bacon.
4. Quantum Mechanics in Chemistry – M. Hanna, John Wiley and Sons 1970.
5. Physical Chemistry, P. W. Atkins, ELBS, 3<sup>rd</sup> Edition, 1986.
6. Physical Chemistry, G. M. Barrow, 5<sup>th</sup> Edition, 2007.
7. Basic Physical Chemistry by W. J. Moore, Prentice Hall, 1986.
8. Symmetry in Chemistry, H. H. Jaffe and M. Orchin, Wiley, New York, 1965.
9. Chemical Applications of Group Theory, F. A. Cotton, Wiley, New York, 1971.
10. Group theory and its applications to chemistry by K. V. Ramen, Tata McGraw Hill.

## PH-302: Solid State Chemistry, Radiochemistry and Nanoscience

- Unit I** [12 hrs]  
Description of crystal structures, closed packed and hexagonal close packing, Density of closed packed structure, Ionic structures, the radius ratio rule, Lattice energy of ionic crystals, the Born-Haber cycle and thermochemical calculations, Metallic bonding and bond theory, Band structure of metals, insulators and semiconductor, Defect in solids, point and line defect, Solid solutions.
- Unit II** [12 hrs]  
Synthetic Methods: Solid state reaction or shake 'n' bake methods, Nucleation and growth, epitaxy and topotaxi, Examples of solid state reactions: i)  $\text{Li}_4\text{SiO}_4$  and ii)  $\text{Y-Ba}_2\text{Cu}_3\text{O}_7$ , Sol-gel methods for  $\text{MgAl}_2\text{O}_4$  and silica glass, Preparations of YBCO super conductor, Electrochemical and Chemical vapour deposition methods for thin film preparations.
- Unit III** [12 hrs]  
Nuclear stability, Radiation and Nuclear decay, Radiation Detection and Measurement, Nuclear reaction, Production and Separation of isotopes, Nuclear power reactor, Radiolysis of aqueous solutions, Application of radioisotopes, Radiation chemistry Health and Safety aspects
- Unit IV** [12 hrs]  
Introduction to nanoscience and technology, terminology and history, optical and semiconducting properties of nanoparticles, metallic nanoparticles, top-down and top-up fabrication, solution based and vapour phase synthesis, synthesis of frameworks, supports and substrates, physical and chemical vapour deposition, artificially layered materials, quantum wells, self-assembled nanostructures.
- Unit V** [12hrs]  
Principles of SEM, TEM technique, Application of SEM and TEM for characterization of nanoparticles. Carbon nanotubes, mesoporous materials and metal organic frameworks. Applications of  $\text{C}_{60}$ , nano- $\text{TiO}_2$ , Cytochrome.

### Reference Books:

1. Essentials of Nuclear Chemistry, H. J. Arnikar, Wiley Eastern Ltd, 1995.
2. Source-book of Atomic Energy, S. Glasstone, Van Nostrand Company.
3. Introduction to Nuclear Physics and Chemistry, B. G. Harvey, Prentice Hall, 1963.
4. Nuclear and Radiochemistry, G. Friedlander, J. W. Kennedy and J. M. Miller, John Wiley & sons, 1981.
5. Introduction to Radiation Chemistry, J. W. T. Spinks and R. J. Woods, John Wiley, 1990.

6. Introduction of Solid, Leonid V. Azaroff, Tata McGraw Hill, New Delhi, 1977.
7. Solid State chemistry and its Application, A. R. West, Plenum.
8. Basic Solid State Chemistry, A. R. West, John Wiley & sons Ltd., 1999.
9. Solid State Chemistry, D. K. Chakraborty, New Age International.
10. Solid State Chemistry, C. N. R. Rao, Dekker, N. Y.
11. Principles of radiochemistry, D.D. Sood, N. Ramamoorthy and A.V.R. Reddy.
12. Radiation, Detection and Measurement, G.F. Knoll, John Wiley & Sons, New York, 1979.
13. Radiation Chemistry-An Introduction, A.J. Swallow, Longman, 1973.
14. Source book of an Atomic energy, S. Glasstone, Van Nostrand, New York, 1969.

## **PH-303: Electrochemistry and Kinetics of Reactions**

### **Unit I**

**[12 hrs]**

Ion-Solvent and Ion-Ion interactions:

Structure of water, the ion-dipole model, heat of solvation, Born charging process and Bernal-Fowler model for Water & Aqueous solutions.

The failures of Arrhenius theory for strong electrolyte dissociation, The Debye-Hückel theory for activity coefficients in aqueous solutions, Mean ionic activity coefficients and their values based on different standards states, Deviations in Debye-Hückel theory, concept of hydration numbers, Methods to determine hydration number of ions.

### **Unit II**

**[12 hrs]**

Diffusion, Ficks laws, Drift velocity and mobility of ions, the current density, Einstein relation between absolute mobility and the diffusion coefficient, Stokes-Einstein equation, Nernst-Einstein equation and their limitations.

### **Unit III**

**[12 hrs]**

Structure of the electric double layer, Helmholtz, Gouy-Chapman and Stern models, Cathodic and anodic current density, Overpotential, Butler-Volmer equation, Tafel plot.

Fuel cell and its operation, hydrogen / oxygen cell Lead storage battery, Nickel/Cadmium cell.

### **Unit IV**

**[12 hrs]**

Collision theory of bimolecular gas phase reactions, Diffusion controlled and activation controlled reactions in solution, Rate constant of diffusion controlled reaction, Activated complex theory of reaction rates, Eyring equation, Activation parameters, Potential energy surfaces of simple reactions, Example of (H + H<sub>2</sub>) reaction.

### **Unit V**

**[12 hrs]**

Acid-base catalysis, Primary salt effect, Rates of electron transfer reactions, Enzymes catalysis, Oscillating chemical reaction.

Kinetics of fast reactions: Study of kinetics by stop-flow technique, relaxation methods such as ultrasonic absorption and NMR relaxation method, flash photolysis.

### **Reference Books:**

1. An Introduction to Electrochemistry, S. Glasstone, Van Nostrand, East-West 1965.
2. Modern Electrochemistry, Vol. I and II, 2<sup>nd</sup> Edition, J. O'M Bockris and A. K. N. Reddy, Plenum, 1977.
3. Electrolytic Solutions, R. A. Robinson and R. H. Stokes, Butterworths, London, 1959.
4. Physical Chemistry, P. W. Atkins, ELBS, 1986.

5. Physical Chemistry, 4<sup>th</sup> Edition, Silbey, Alberty, Bawendi, Wiley, India, 2007.
6. Chemical Kinetics, 2<sup>nd</sup> Edition, K. J. Laidler, TMH.
7. Kinetics and Mechanism, 2<sup>nd</sup> Edition, A. A. Frost and R. G. Pearson.

## PH-304: Physical Chemistry of Polymers

- Unit I** **[12 hrs]**  
Polymers as macromolecules, Nomenclature, Stereochemistry and tacticity, Crystallinity, Glass transition temperature, Nature of bonding, types of intermolecular forces, proteins, DNA, Effects due to shape and size of the molecules on properties like solubility.  
Molecular weight determination: number average, mass average molecular weights, polydispersity, Experimental methods like osmotic pressure, ultracentrifugation, viscosity and light scattering, Polyelectrolytes.
- Unit II** **[12 hrs]**  
Polymer solutions, ideal solutions, Regular solutions, Partial molar functions, Entropy and Heat of mixing of polymer solutions, Vapour pressure and second Virial coefficient, Flory-Krigbaum theory, Flory-Huggins theory, Stability of polymers, chain conformations, disorder in the structure. Thermal effects studied on amorphous and crystalline polymers, DTA and TG studies.
- Unit III** **[12 hrs]**  
Polymerization chemistry and Kinetics: Condensation and radical chain polymerization, Mechanism and Kinetics of stepwise polymerization, control of molecular weight, Mechanism and kinetics of vinyl polymerization, molecular weight and its distribution, Cationic and anionic polymerization; kinetics and example, Importance of Zeigler-Natta catalyst, Mechanism of working and growth steps for polymerization of ethylene.
- Unit IV** **[12 hrs]**  
Rheology and Mechanical properties of Polymers: Viscous flow, Newtonian and Non-Newtonian fluids, Molecular weight and shear dependence, Kinetic theory of rubber elasticity, Stress-Strain behavior of elastomers, Viscoelastic behavior, Stress relaxation and Creep, Models using Maxwell and Voigt element for strain-time relationship, Mechanical properties of crystalline and amorphous polymers.
- Unit V** **[12 hrs]**  
Gel-Formation and Self-assembly: Introduction to Gel, Gel as state of matter, Gel forming substances and role of solvents. Properties of gel (Silica gel/ Agar gel), Characterization of gel by different techniques (DSC), Self-assembly process, Host-guest chemistry, Examples; Crown ethers, Cryptands (Zeolites), Applications of self-assembly (Drug delivery, Catalysis).

### Reference Books:

1. Text Book of Polymer Science, F. W. Billmeyer, John Wiley and Sons, 1984.
2. Principles of Polymer Chemistry, P. J. Flory, Cornell University Press, Ithaka, 1953.



3. Physical Chemistry of Polymers, A. Tager, Mir Publication, Moscow, 1972.
4. Physical Chemistry of Macromolecules, D. D. Deshapande.
5. Physical Chemistry, G. M. Barrow, Tata McGraw Hill, New Delhi, 2007.
6. Polymer Science, V. R. Gowarikar, Vishwanathan Sreedhar, Wiley Eastern Ltd., New York, 1988.
7. Polymer Chemistry An Introduction, 2<sup>nd</sup> Edition, Malcolm P. Stevens, Oxford University Press, 1990.

## PH-401: Molecular Structure

### Unit I Electric and Magnetic Properties of Molecules: [12 hrs]

Molecular dipole moments, Capacitance and the electric field, Polarization of a dielectric, Polarizability of a dielectric, Orientation polarization, Clausius-Mossotti equation, Refractive index and polarization, Variation of molar polarization with temperature: Debye equation, Bond moments, ionic character, dipole-dipole, dipole-induced-dipole interaction, induced-dipole / induced-dipole dispersion interactions, Lennard-Jones potential and equation, Determination of dipole moment experimental methods.

Magnetic moments, Diamagnetic, Paramagnetic susceptibilities, Molecular interpretations of diamagnetism and paramagnetism, Langevin equation, Van Vleck's formula, Ferro, ferri and Antiferromagnetic behavior, Temperature dependence of susceptibilities, Curie and Neel temperatures, Selected examples of magnetic materials: Metal and alloys, Permanent magnets, Transformer cores, Information storage, Hysteresis, Measurements of magnetic susceptibility by Faraday and Gouy Technique.

### Unit II Spin Resonance Spectroscopy – I, (NMR): [12 hrs]

The nature of spinning particles, Interaction between spin and magnetic field, Resonance condition, The Larmor Precession, Relaxation times, Hydrogen, Deuterium and  $C^{13}$  nuclei, the chemical shift, coupling constant. Analysis of AX,  $A_2$ ,  $A_3$ ,  $A_3X_2$  type NMR spectrums, Exchange phenomenon, NOE (Nuclear Overhauser Effect), Instrumentation and pulsed FT-NMR Spectrometer and the measurements.

### Unit III Spin Resonance Spectroscopy – II, (ESR-Electron Spin Resonance) [12 hrs]

The position of ESR absorption: Field characteristic, Electromagnetic spectrum region, the g factor, Hyperfine structure of ESR absorption (Electron-Nucleus Coupling), Electron-Electron coupling, McConnell relation for mapping the spin density, Instrumental technique and application of ESR in structural elucidation.

### Unit IV Mössbauer Spectroscopy: [12 hrs]

Mössbauer effect and principles of Mössbauer spectroscopy, Experimental arrangements for Mössbauer spectrometers, Chemical shift, Isomer shift and quadrupole splitting, the effect of a magnetic field, the excited and ground state energy levels of  $^{57}\text{Fe}$ , Applications of Mössbauer spectroscopy to understand structures of iron and tin (Sn) compounds.

### Unit V Raman Spectroscopy: [12 hrs]

Scattering, Quantum and Classical theories of the Raman Effect, Raman shifts, Pure Rotational Raman Spectra for linear and symmetric top molecules, Raman active vibrations, Raman and Infrared activities for  $\text{CO}_2$ , Rule of mutual exclusion, Vibrational Raman Spectra, Vibrations of spherical top molecules, Structure determination from Raman and IR spectroscopy, Technique and instrumentation involved in Raman spectroscopy.

### Reference Books:

1. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, McGraw Hill International (UK), 1996.
2. Physical Chemistry, P. W. Atkins, ELBS, Oxford University Press, 1986.
3. Nuclear Magnetic Resonance Spectroscopy, R. K. Harris, Pitman, London, 1983.
4. Spectroscopic Methods in Organic Chemistry, D. H. Williams and I. Fleming, McGraw Hill, New York, 1980.
5. Theory and Applications of Electron Spin Resonance, W. Gordy (ed), Techniques of Chemistry, XV, Wiley-Interscience, New York, 1980.
6. Experimental Aspects of Mössbauer Spectroscopy, R. H. Herber and Y. Hazony, Techniques of Chemistry (A. Weissberger and B. W. Rossiter, eds), Wiley Interscience, New York, 1972.
7. Determination of Dipole Moments, C. P. Smyth, Techniques of Chemistry (A. Weissberger and B. W. Rossiter eds.) IV, Wiley Interscience, New York, 1972.
8. Introduction to Magnetochemistry, Alen Earnshaw, Acad. Press, London, 1968.
9. Magnetic Susceptibility- L. N. Mulay.
10. Molecular Structure and Molecular Spectra by G. Herzberg, Van Nostrand.
11. Molecular Spectroscopy by G. M. Barrow.
12. Molecular Spectroscopy by I. N. Levine, Willey Interscience.

## **PH-402: Statistical Thermodynamics, Phase Equilibria and Irreversible Thermodynamics**

- Unit I** [12 hrs]  
Phase Space, Probability, Liouville's theorem, Configuration and weights, the most probable configuration, Ensembles, Boltzmann distribution for energies, Boltzmann, Bose-Einstein and Fermi-Dirac statistics.
- Unit II** [12 hrs]  
Partition function, Rotational, translational, Vibrational and Electronic partition functions for diatomic molecules.
- Unit III** [12 hrs]  
Statistical basis of entropy, Calculations of thermodynamic functions and equilibrium constants using spectral data and partition function, Applications of quantum statistics to derive Planck's law and study of electron gas in metals, Entropies of o- and p- hydrogen, Theories of specific heat for solids.
- Unit IV** [12 hrs]  
Chemical potentials and derivation of phase rule, Pressure-Temperature phase diagram, Interpretation of liquid phase diagrams, Immiscible liquids, Eutectic formation, Solid compound formation, Liquid-vapour, Pressure composition diagram, distillation, One component CO<sub>2</sub>, H<sub>2</sub>O, ice and SiO<sub>2</sub> systems, Lever rule for two component system, The system Fe-C- iron and steel making, Drawing of three components system, Zone refining.
- Unit V** [12 hrs]  
Phenomenological laws, Concept of equilibrium, Free energy and entropy, First and Second principles of thermodynamics, Principle of microscopic reversibility, Onsager reciprocity theory and relations, Entropy production in chemical reaction, fluxes and forces in closed and open system, Prigogine principle of minimum entropy production, Coupling of reactions and cross coefficients, Electrokinetic phenomena and Saxens relations.

### **Reference Books:**

1. Theoretical Chemistry, S. Glasstone, Van Nostrand Co. Inc.
2. Thermodynamics for Chemist, S. Glasstone, Van Nostrand Co. Inc.
3. Elementary Statistical Thermodynamics, L. K. Nash, Addison-Wesley, Reading, 1968.
4. Statistical Thermodynamics, D. A. McQuarrie, Harper & Row, New York, 1976.
5. Statistical Thermodynamics, M. C. Gupta, Wiley Eastern Ltd., 1990.
6. Physical Chemistry, P. W. Atkins, 3<sup>rd</sup> Edition, ELBS, W. H. Freeman and Co., 1986.
7. Basic Solid State Chemistry, A. R. West, John Wiley & sons Ltd., New York,

1999.

8. Irreversible Thermodynamics: Ilya Prigogine.
9. Thermodynamics of Steady State: Denbeigh
10. Advanced Physical Chemistry, J. N. Gurtu, A. Gurtu, A Pragati Edition, Meerat, 2008.

## PH-403: Surface Chemistry and Catalysis

- Unit I** [12 hrs]  
Surface tension, adsorption on solids, electrical phenomena at interfaces including electrokinetic potentials, micelles, Critical Micelle Concentration (CMC), Methods for determination of CMC.
- Unit II** [12 hrs]  
Adsorption at liquid surfaces, Gibb's equation and its verification, Adsorption forces, Thermodynamics of physical adsorption, Heat of adsorption and its determination.
- Unit III** [12 hrs]  
Langmuir adsorption isotherm, Multilayer adsorption, BET and Polanyi models for the adsorption, Harkins and Jura equation and other methods for measurements of surface area of solids, Low energy electron diffraction, Electron emission from surfaces, X-ray photoelectron spectroscopy, Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM).
- Unit IV** [12 hrs]  
Porous solids, Pore size distribution, Adsorption behaviour of porous materials, hysteresis of adsorption, Theory of surface reactions, Molecular sieves, Capillary condensation, micro-pore analysis.
- Unit V** [12 hrs]  
Catalysis:  
Homogeneous catalysis, Autocatalysis and oscillating reaction, Bistability, Kinetics of homogeneous catalysis, Heterogeneous catalysis, Kinetics of heterogeneous catalysis, Development of catalyst, Enzyme catalysis.

### Reference Books:

1. Physical Chemistry, Silbey, Alberty and Bawendi, 4<sup>th</sup> Edition, Wiley-India, 2007.
2. Physical Chemistry of Surfaces, A. W. Adamson, Interscience, New York, 1967.
3. Surfaces Chemistry: Theory and Applications, J. J. Bikerman, Academic Press, New York, 1972.
4. Adsorption, J. Oscik, John Wiley & Sons, New York, 1978.
5. Introduction to collide and surface chemistry by D. J. Shaw.
6. Theory of adsorption and catalysis by Alfred Clark.
7. Physical Chemistry, P. W. Atkins, ELBS, Oxford, 1986.

### PH-004: Physical Chemistry Practical Course

1. Determination of solubility of  $PbI_2$  and  $E^0$  of Ag/AgI electrode.
2. Determination of transport number using cells with and without transport.
3. Determination of stoichiometry and stability constant of  $Ag(NH_3)_2$ .
4. Study of triiodide ion formation and its stability.
5. Kinetics and determination of order of reaction between acetone and iodine.
6. Molecular weight determination of polymer by viscosity method.
7. Study of partial molar volumes of solute and solvent for EtOH-H<sub>2</sub>O system at room temperature.
8. Dissociation constant of dibasic acid  $p^H$ -metrically / potentiometrically.
9. Determination of hydrolysis constant for  $CuSO_4$  / Aniline hydrochloride  $p^H$ -metrically / Conductometrically.
10. Study the complex formation between Fe (III) and Salicylic acid using Job/mole ratio method.
11. Analysis of a mixture of Copper (II) and Bismuth (III) by spectrophotometric titration with EDTA.
12. Determination of Critical Micelle Concentration for sodium-dodecyle sulphate in water.
13. Latent heat of fusion by solubility measurements.
14. Solubility diagram for three component system.
15. Analysis of X-ray diffraction data for NaCl and KCl system.
16. Study of characteristic of GM Counter.
17. Determination of molecular weight by freezing point depression method.

### PH-005: Physical Chemistry Practical Course

1. Determination of transport number by moving boundary method.
2. Magnetic susceptibility measurements by Gouy method.
3.  $p^H$ -metric titration of amino- acid and determination of dissociation constants.
4. To study the thermal decomposition of oxalic acid / copper sulphate.
5. Determination of activity coefficient by freezing point depression method.
6. Determination of  $p^K$  of indicators.
7. Study of stability constant of complex between Fe (III) and  $(SCN^-)$  by Frank and Oswald method.
8. Determination of activation thermodynamic parameters for reaction between KI and  $K_2S_2O_4$ .
9. Determination of the dimerization constant of organic acid in benzene.
10. Mean ionic activity coefficients of electrolyte by EMF method.
11. Thermodynamic data of electrochemical cell by EMF measurement.
12. Determination of two ions simultaneously using spectrophotometry / polarography.
13. Estimation of unknown concentration and half-wave characteristics of  $Cd^{+2}$  and  $Zn^{+2}$  ions polarographically.
14. Concentration studies for  $Na^+$  and  $K^+$  ions in water using flame photometry.
15. Determination of riboflavin in medicinal compounds using fluorescence measurements.
16. Study the influence of the ionic strength on the kinetics of reaction.
17. Determination of transition temperature of sodium-sulphate decahydrate by thermometric method.
18. Study of integral heat of solution of a salt using calorimeter.
19. Determination of specific heat of solids.
20. Determination of heat of oxidation using Bomb calorimeter.

#### Reference Books:

1. Practical Physical Chemistry, A. M. James and P. E. Prichards, Longman Group Ltd.
2. Findlay's Practical Chemistry, S. P. Levitt (Editor), Longman Group Ltd.
3. Experimental Physical Chemistry, Das and Behra, Tata McGraw Hill.
4. Advanced Practical Physical Chemistry, J. B. Yadav, Goel Publication, Meerut.
5. Advanced Experiments in Physical Chemistry, J. Rose.
6. Experiments in Physical Chemistry, Schoemaker.
7. Advanced Analytical Chemistry, Meits and Thomos.
8. Experimental Analytical Chemistry, Willard, Merritt and Dean.
9. Vogel's Textbook of Quantitative Chemical Analysis, by J. Mendham, R. Denney, J. Barnes and M. Thomos, ELBS, Pearson, Delhi, 2007.



### **PH-006: Physical Chemistry Project and Seminar**

The student shall undertake project for 100 marks. He can study theoretical, computational, analytical or experimental work with advanced technique or developed technique by himself or herself. One has to select topic of his / her interest having utility / applications in science. He or she at the end will submit report (typed) in two copies to the institute as well as has to make presentation as a seminar. The assessment will be carried out by both internal and external examiner jointly at the end of practical examination of Semester IV.