**UNIVERSITY DEPARTMENTS**

**ANNA UNIVERSITY :: CHENNAI – 600 025**

**Regulations 2013**

**M. Phil. CHEMISTRY**

**SEMESTER I**

| SL. NO. | COURSE CODE | COURSE TITLE | L | T | P | C |
|---|---|---|---|---|---|---|
| **THEORY** | | | | | | |
| 1. | CX8101 | Concepts in chemistry | 4 | 0 | 0 | 4 |
| 2. | CX8102 | Research methodology and analytical techniques | 4 | 0 | 0 | 4 |
| 3. | | Elective I | 4 | 0 | 0 | 4 |
| 4. | | Elective II | 4 | 0 | 0 | 4 |
| | | **TOTAL** | **16** | **0** | **0** | **16** |

**SEMESTER II**

| SL. NO. | COURSE CODE | COURSE TITLE | L | T | P | C |
|---|---|---|---|---|---|---|
| **THEORY** | | | | | | |
| 1. | CX8211 | Research Project | 0 | 0 | 30 | 15 |
| 2. | CX8212 | Seminar | 0 | 0 | 3 | 1 |
| | | **TOTAL** | **0** | **0** | **33** | **16** |

**TOTAL NUMBER OF CREDITS TO BE EARNED FOR THE AWARD OF DEGREE - 32**

**ELECTIVES**

| SL. NO. | COURSE CODE | COURSE TITLE | L | T | P | C |
|---|---|---|---|---|---|---|
| 1. | CX8001 | Advanced Organic Chemistry | 4 | 0 | 0 | 4 |
| 2. | CX8002 | Advanced Physical Chemistry | 4 | 0 | 0 | 4 |
| 3. | CX8003 | Advances in Nanochemistry and Nanotechnology | 4 | 0 | 0 | 4 |
| 4. | CX8004 | Bio-Inorganic Chemistry | 4 | 0 | 0 | 4 |
| 5. | CX8005 | Bio-Separations | 4 | 0 | 0 | 4 |
| 6. | CX8006 | Concepts and Techniques in Catalysis | 4 | 0 | 0 | 4 |
| 7. | CX8007 | Environmental Chemistry | 4 | 0 | 0 | 4 |
| 8. | CX8008 | Enzyme Technology | 4 | 0 | 0 | 4 |
| 9. | CX8009 | Physical Organic Chemistry | 4 | 0 | 0 | 4 |
| 10. | CX8010 | Polymer Chemistry and Technology | 4 | 0 | 0 | 4 |
| 11. | CX8011 | Principles of Biochemistry | 4 | 0 | 0 | 4 |
| 12. | CX8012 | Properties of Polymeric Materials | 4 | 0 | 0 | 4 |
| 13. | CX8013 | Solid State Chemistry | 4 | 0 | 0 | 4 |

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

**CX8101** **CONCEPTS IN CHEMISTRY** **L T P C**
**4 0 0 4**

**OBJECTIVES**

- To train students in kinetics of homogeneous reactions and electro analytical methods and its applications.
- To impart knowledge on organometallic compounds and reactive intermediates.
- To know the students about reagents in organic synthesis.

**OUTCOME:**

- Will have an understanding of the various methods available in all branches of chemistry.
- Will be able to use organometallic compounds appropriately
- Will capable of running an organic synthesis process

**UNIT I KINETICS 12**

Kinetics of homogeneous reactions – Theory of absolute reaction rates, comparison of results with Eyring and Arrhenius equations –Kinetics of Chain reactions, study of fast reactions - study of kinetics by stopped flow technique, flash photolysis, relaxation methods, magnetic resonance technique. Catalysis – homogeneous and heterogeneous- Langmuir –Hindselwood Mechanism, metal ion catalysts and their applications.

**UNIT II ELECTRO ANALYTICAL METHODS 12**

Electroanalytical methods – redox potentials – definition – Potentiometry –applications – ion selective electrodes- Current – voltage relationships – polarography– instrumentation – characteristics of DME – diffusion current – half wave potentials. AC polarography-Amperometric titrations - constant coulometry – constant potential coulometry, cyclic voltammetry – basic principles and applications.

**UNIT III ORGANOMETALLIC COMPOUNDS 12**

Organometallic compounds: Synthesis and applications of organolithium, organoboron, organoaluminium, organoberyllium, organomagnesium organotin and organosilicon compounds.

**UNIT IV REACTIVE INTERMEDIATES 12**

Reactive Intermediates: Generation, structure and reactivity of carbenes, nitrenes and free radicals – addition and rearrangement reactions – substitution reactions by free radicals. Name reactions – Favorskil rearrangement, Stork enamine reaction – Mannich reaction and Baeyer – Villiger oxidation – Chichibabin reaction.

**UNIT V REAGENTS IN ORGANIC SYNTHESIS 12**

Reagents in Organic Synthesis: Uses of NBS, lithium diisopropylamide, aluminium isopropoxide, lithium aluminium hydride, potassium tertiary butoxide and trimethylsilyl iodide. Protecting groups – hydroxyl, amino, carbonyl and carboxylic acid. Synthetic analysis and planning – control of stereochemistry – Retrosynthetic analysis of Longifolene.

**TOTAL: 60 PERIODS**

**TEXT BOOKS**


1. D.F. Shriver and P.W.Atkins – Inorganic Chemistry, 5th Edn. Oxford University Press (2010).
2. Francis A. Carey and Richard J. Sundberg, “Advanced Organic Chemistry”, (Part A and B), 5th Edn., Springer (2007)


**REFERENCES**


1. P. W. Atkins, and J.D. Paula, Physical Chemistry, 8th Edn. Oxford University Press, London (2006).
2. R.K. Mackie and D.M. Smith, Guide book to Organic Synthesis, 2nd edition, ELBS Publications, London (1998).
3. Michael B Smith and Jerry March, “MARCH’s Advanced Organic Chemistry Reactions, mechanisms and structures ”, 6th Edn.,John Wiley & Sons (2007).
4. J.Rajaram and J.C.Kuriacose, “Kinetics and Mechanism of Chemical Transformations”, Macmillan India Ltd. (2000).

| CX8102 | RESEARCH METHODOLOGY AND ANALYTICAL TECHNIQUES | L | T | P | C |
|---|---|---|---|---|---|
| | | 4 | 0 | 0 | 4 |

**OBJECTIVES**

- To make the student conversant with the literature for research and atomic spectroscopy for qualitative and quantitative analysis.
- To enable students know about the molecular spectroscopy for qualitative and quantitative analysis and also advanced spectroscopy.
- To acquire knowledge of thermal and chromatographic techniques.

**OUTCOMES:**

- Will become adept in mining information from literature source available
- Will gain a broad idea about spectroscopy for qualitative and quantitative analysis of material
- Will be conversant with thermal and chromatographic techniques.

**UNIT I LITERATURE FOR RESEARCH 12**

Survey of literature – primary and secondary sources – reviews, treatises, monographs, patents – current literature methods – abstraction of research papers – writing scientific papers – identification and selection of research problems – experimental design – analysis and interpretation of data – writing of thesis.

**UNIT II ATOMIC SPECTROSCOPY FOR QUALITATIVE AND QUANTITATIVE ANALYSIS 12**

Atomic energy levels-flame emission spectrophotometry – Theory, Instrumentation (Source, Types of burners, types of fuels, etc.,), Interferences (Chemical, radiation and excitation interferences), qualitative, quantitative analysis (Standard addition method, internal standard method) and applications. Atomic absorption Spectroscopy - Theory (Different processes in flame), Instrumentation, (Hollow cathode lamp, chopper etc.,), background correction qualitative, quantitative and applications.

**UNIT III MOLECULAR SPECTROSCOPY FOR QUALITATIVE AND QUANTITATIVE ANALYSIS 12**

Molecular energy levels - electronic transitions UV- Vis spectroscopy – Beer Lambert's law (applications and limitations), quantitative analysis of Fe, Ni and nitrite, electronic transitions in organic and inorganic molecules– Woodward Fieser rules for dienes and carbonyl compounds- Spectrophotometric titrations – Multicomponent analysis.

IR Spectroscopy – principles, instrumentation and qualitative analysis by IR, FTIR spectrophotometer

**UNIT IV MAGNETIC RESONANCE SPECTROSCOPY AND MASS SPECTROSCOPY 12**

Magnetic Resonance Spectroscopy – $^{1}$H-NMR – Chemical shift – anisotropic effects – coupling – simplification of complex spectra – principles, instrumentation and applications $^{13}$C-NMR and ESR. Mass spectroscopy – determination of molecular weights – nitrogen rule – metastable peaks – Instrumentation and applications.

**UNIT V THERMAL METHODS AND CHROMATOGRAPHIC TECHNIQUES 12**

Thermal methods – TGA, DTA and DSC techniques – principles, instrumentation and applications -Chromatographic techniques – CC, TLC, GC, PC and HPLC.

**TOTAL : 60 PERIODS**

**TEXT BOOKS**


1. Robert D. Braun, "Introduction to Instrumental analysis", Pharma Book Syndicate, Indian reprint (2006).
2. H.H.Willard, L.L.Merritt Jr., J.A.Dean and F.A.Settle Jr., "Instrumental method of analysis" 7th Edn.,CBS Publishers and Distributors, New Delhi (2004).

**REFERENCES**


1. D.J.Pasto, C.R.Johnson and M.J.Miller, "Experiments and Techniques in Organic Chemistry", Printice Hall, Inc.(1992).
2. Skoog, D.A., Holler, F.J. and Crouch, S.R., "Instrumental analysis, 11 edition Cengage publishers (2012).
3. B. Sivasankar " Instrumental methods of Analysis" Oxford University Press 1st Edition(2012).
4. F.W. Fifield and D.Kealey, "Principles and Practice of Analytical Chemistry, 1st Indian Reprint, Blackwell Pub. (2004).


**CX8001 ADVANCED ORGANIC CHEMISTRY L T P C**
**4 0 0 4**

**UNIT I STEREOCHEMISTRY 13**

Introduction to molecular symmetry and point groups. Topicity and prostereoisomerism, nomenclature of stereotopic ligands and faces, stereoheterotopic ligands – centre of chirality, assignment of absolute stereochemistry, axial chirality, planar chirality and helicity. Conformational analysis – acylic systems, cyclic systems, cyclohexane and decalins. Conformation and reactivity with examples. Stereoselectivity – classification, terminology, principle of stereoselectivity, examples of diastereoselectivity and enantioselectivity including few examples from pericyclic reactions.

**UNIT II REACTIVE INTERMEDIATES 13**

Formation, stability and reactions involving carbonium ions, carbanions, carbenes, nitrenes and radicals – Generation of enolates, enolate selectivities, alkylation of enolates and stereochemistry of enolate alkylation. Mechanism of ester hydrolysis (only $B_{AC}^2$, $A_{AC}^2$ and $A_{AL}^1$). Alkylation of active methylene compounds. Assymmetric alkylation (Evans, Enders and Meyers procedures). Preparation and synthetic utility of enamines - Finkelstein reaction.

**UNIT III OXIDATION AND REDUCTION REACTIONS 12**

Oxidation with Cr and Mn reagents – oxidation with LTA, DDQ and $SeO_2$ – oxidation using DMSO either with DCC or $Ac_2O$ or oxalyl chloride, oxidaion using Dess – Martin reagent – vicinal hydroxylation of olefinic double bonds – Woodward and Prevost procedures – epoxidation using peracids including Sharpless procedure, ozonolysis. Reduction using various reagents – hydrogenation, hydration of carbon – carbon double and triple bonds – asymmetric reduction of carbonyl functions

**UNIT IV ORGANOMETALLIC CHEMISTRY FOR ORGANIC SYNTHESIS 12**

Fundamental concepts in transition metal chemistry for organic synthetic transformations – metal carbenes, synthesis, reactivity, cycloaddition reactions of metal carbenes, synthesis of fused ring systems, Dotz reaction, mechanism of ring formation, application of cobalt carbonyls in organic synthesis, Pauson Khand reacion, Volhardt reaction, Pearson reaction, use of organoiron complexes for stereo specific synthesis of substituted cyclic compounds

**UNIT V APPLICATIONS OF SPECTRAL TECHNIQUES 10**

Principles and applications of UV – Visible, IR, NMR, EPR, XRD and Mass spectrometry in the determination of structure of organic molecules-Optical rotatory dispersion and its applications.

**TOTAL :60 PERIODS**

**REFERENCES**


1. Jerry March, Advanced Organic Chemistry 5th Edn. Wiley Interscience, New York, (2003).
2. Francis A Carey and Richard J. Sundberg, "Advanced Organic Chemistry- Part A and Part B", 5rd Edn. Plenum Press, New York (2005).
3. E.L. Eliel and S.H.Wilen, Stereochemistry of Organic Compounds, John Wiley and Sons, New York (2005).
4. S.G.Davies, Organotransition Metal Chemistry, Applications to Organic Synthesis, Pergamon Press (1982).

**CX8002 ADVANCED PHYSICAL CHEMISTRY**

| L | T | P | C |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**OBJECTIVES**

- To familiarize the students with the catalysis and photophysics.
- To provide the importance of industrial applications of photochemistry and bio-physical chemistry.
- To provide exposure to the students in understanding macromolecular dynamics.

**OUTCOMES**

- Will be capable of applying catalyst and photochemistry in an industry.
- Will be able to appreciate the significance of photochemistry and bio-physical chemistry in an industry.
- Will get a general idea about macromolecular dynamics.

**UNIT I CATALYSIS 12**

Phase transfer catalysis – concepts – classifications – mechanism – applications (organic and polymer synthesis) - catalysis by ion exchange resins – super acid catalysis –liquid super acids supported on solids - sulphate, metal oxides – applications – microporous and mesoporous catalysis – nanoparticles in catalysis - enzyme like catalysis by synthetic linear polymers.

**UNIT II PHOTOPHYSICS 12**

Interaction of light with molecules, radiative and non-radiative processes-excited states-their properties. Fluorescence, phosphorescence, exciplexes, excimers, delayed fluorescence. Photophysical processes, internal conversion, intersystem crossing, energy transfer, quenching-Stern-Volmer analysis-photosensitization.

**UNIT III INDUSTRIAL APPLICATIONS OF PHOTOCHEMISTRY 12**

Solar energy conversions, semiconductor applications, photovoltaics, photo electrochemistry, photochromism, photopolymerization and photocopying.

**UNIT IV BIO-PHYSICAL CHEMISTRY 12**

Thermodynamics of biochemical reactions-binding of oxygen by hemoglobin. Electrophoresis-types-paper electrophoresis-cellulose acetate electrophoresis-gel electrophoresis-applications-analytical use-uses in molecular biology.

**UNIT V MACROMOLECULAR DYNAMICS 12**

Molar masses – determination – viscometry – osmometry – Donnan membrane equilibrium – ultracentrifugation – light scattering – diffusion – Stokes – Einstein equation – Einstein – Smoluchowski equation – thermodynamics of polymers solution –Flory – Huggin theory.

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. P. W. Atkins, and J.D. Paula, Physical Chemistry, 7th Edn. Oxford University Press, London (2012).
2. B.Viswanathan, S. Sivasankar and A.V. Ramasamy, Catalysis: Priciples and Applications, 1st Edn., Narosa Pub. House, Delhi (2002).


**REFERENCES**


1. P.A. Alberty and R.U. Silbey, Physical Chemistry 1st Edn. John Wiley and Sons Inc. (2000).
2. A.Singh and R. Singh, Biophysical Chemistry,1st edition, Campus Books International, New Delhi (2004).
3. C.M.Starks, Phase transfer catalysis – Principles and Techniques Academic Press, New York (1978).
4. Rohatgi Mukherjee, Fundamentals of Photochemistry, 2nd edition, New Age International (2004).

| CX8003 | ADVANCES IN NANOCHEMISTRY AND NANOTECHNOLOGY | L | T | P | C |
|---|---|---|---|---|---|
| | | 4 | 0 | 0 | 4 |

**OBJECTIVES**

- To introduce the students about nanochemistry and nanomaterials synthesis.
- To teach the importance of characterization of nanomaterials
- To teach the students importance of applications of nanomaterials.

**OUTCOMES**

- Will be aware of the synthesis of nanomaterials.
- Will have clear understanding of nano tube, nano wires and nano composites.
- Will have an idea of the various fields where nanotechnology can be applied.

**UNIT I INTRODUCTION TO NANOCHEMISTRY 12**

Importance of surface – particle shape and surface – surface and volume – atomic structure and particle orientation – energy at nanoscale – the material continuum (zero, one and two dimensional materials) – nanothermodynamics – chemical interactions at the nanoscale – supermolecular chemistry.

**UNIT II NANOMATERIALS SYNTHESIS 12**

Top–down approach (physical vapor deposition, chemical vapor deposition, lithographic method and high energy method) – bottom–up approach (sol–gel, co–precipitation, microemulsions, hydrothermal and solvothermal methods, template synthesis) – growth mechanism (vapor–liquid–solid, solid–liquid–solid).

**UNIT III NANOMATERIALS CHARACTERIZATIONS 12**

Structural characterization (XRD, SAXS, SEM, TEM, SPM) – chemical characterization (optical spectroscopy, electron spectroscopy, ionic spectrometry) – surface characterization (XPS, AES, SIMS).

**UNIT IV ADVANCED NANOMATERIALS AND PROPERTIES 12**

Nanotubes - carbon nanotubes – synthetic methods (CVD and MOCVD) for single walled and multi walled nanotubes; graphene- synthesis, properties and application. Chemical properties- hybridization, solubility, stability and functionalization; physical properties- optical, mechanical, magnetic and electrical properties, quantum size effects, Inorganic nanotubes – synthesis and properties. Nanoporous Materials – Silicon - Zeolites, mesoporous materials – nanosponges and its Applications.

**UNIT V APPLICATIONS OF NANOMATERIALS 12**

Nanocatalysis (transition metal nanoparticles in catalysis, aerogel supported nanoparticle in catalysis, multi metallic nanoparticles in catalysis) – organic/polymeric field–effect–transistors (FET) – polymer based nanocomposites – nano biosensors and energy materials.

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. Gabor L. Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, Introduction to nanosciences, CRC press, Taylor and Francis (2008).
2. GuoZhong Gao, Nanostructures and nanomaterials: synthesis, properties and applications, Imperial college press (2004).


**REFERENCE BOOKS**


1. Zhen Gao, Li Tan, Fundamentals and application of nanomaterials, Artech house, Bostan (2009).
2. Duncan W. Bruce, Dermof O'Hare, Richard I. Walton, Porous materials, John Wiley and sons, Ltd (2011).
3. Didier Astruc, Nanoparticles and catalysis, Wiley–VCH (2008).
4. P. M. Ajayan, Linda S. Schadler, Paul V. Braun, Nanocomposite science and technology, Wiley–VCH (2003).
5. Thomas Varghese and K.M. Balakrishnan, 'Nanotechnology' , Atlantic publishers, 2012.


Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

**CX8004** **BIO - INORGANIC CHEMISTRY** **L T P C**
**4 0 0 4**

**OBJECTIVES**

- To impart knowledge on metal ions in biological systems and metalloenzymes.
- The students must know about oxygen transport and proteins in electron transport.
- To make the student conversant with the chemotherapy.

**OUTCOMES**

- Will gain in-depth understanding of the role of metal ions in biological systems.
- Understands the function of oxygen transport and proteins in electron transport.
- Will have a wide knowledge about chemotherapy.

**UNIT I METAL IONS IN BIOLOGICAL SYSTEMS** **12**

Survey of metal ions, metal ion transport – passive and active transport –sodium and potassium ion pumps; transport proteins – ionophores; storage proteins – iron, copper and calcium.

**UNIT II METALLOENZYMES** **12**

Structure, active site and general mechanism of catalytic activity – kinetic aspects – ATP hydrolysis, acid catalysis – carboxypeptidases, oxaloacetate decarboxylase.

**UNIT III OXYGEN TRANSPORT** **12**

Hemoglobin, myoglobin, - iron coordination chemistry – Perutz mechanism; hemocyanin, hemeerythrin

**UNIT IV PROTEINS IN ELECTRON TRANSPORT** **12**

Iron–sulphur proteins, cytochromes – cytochrome – P450-Nitrogen fixation – photosynthesis.

**UNIT V CHEMOTHERAPY** **12**

Toxicity and carcinogenicity of metal ions – deficiency, defects and therapy – role of metal ions in diagnosis and treatment – metal complexes and chelating agents in medicine.

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. M. N. Hughes, “Inorganic chemistry of biological processes” 2nd Edn. John Wiley and sons (1985).
2. J.E. Huheey, E.A. Keiter and R.L. Keiter, “Inorganic Chemistry”, 5th Edn. Pearson Education (2005).


**REFERENCES**


1. D. E. Fenton, “Bio-coordination chemistry” Oxford Sci. Pub. (1995).
2. J.J. R. Frausto das Silva and R. J. P. Williams, “The Biological chemistry of the elements – The Inorganic Chemistry of Life”, Oxford Univ. Press (1993).
3. H. Sigel, (Ed) “Metal ions in biological systems” Vol. 1 – 30, Marcel Dekker, (1998).
4. Atkins, Overton, Rourke, Weller and Armstrong “Shriver & Atkins’ Inorganic Chemistry”, 5th Edition, Oxford University Press, 2010

**CX8005** **BIO - SEPARATIONS** **L T P C**
**4 0 0 4**

**OBJECTIVES**

- Students should be conversant with the overview of bio separations and enzyme isolation.
- Students must know about the enzyme purification and also about electro kinetic methods.
- To teach finishing operations.

**OUTCOMES**

- Will be capable of employing bio separations and enzyme isolation practices available.
- Will gain in depth knowledge about enzyme and its action.
- Will be capable of planning final product purification and formulation processes.

**12**

**UNIT I OVERVIEW OF BIO SEPARATIONS**

Bioprocess industries – fermentation broths: release of intracellular products – cell disruption – mechanical and chemical methods; solid – liquid separation – filtration – theory for incompressible and compressible cakes, batch and continuous filtration, centrifugation – Principles, equipment.

**12**

**UNIT II ENZYME ISOLATION**

Isolation of products – membrane process – dialysis, ultra filtration, reverse osmosis and electro dialysis; adsorption – adsorption isotherms, batch and fixed bed adsorption, extraction and aqueous two phase extractions, precipitation – salting out, organic solvent mediated precipitation, selective denaturation and large scale precipitations.

**12**

**UNIT III ENZYME PURIFICATION**

Product purification – Chromatography – principles of chromatographic separation – gel filtration, reversed phase, hydrophobic interaction, ion exchange IMAC and bio affinity chromatographic techniques.

**12**

**UNIT IV ELECTRO KINETIC METHODS**

Electrophoretic separation – gel electrophoresis – analytical and preparative scale, capillary electrophoresis, isoelectronic focusing.

**12**

**UNIT V FINISHING OPERATIONS**

Final product purification and formulation – crystallization; drying and lyophilisation; formulation strategies.

**TOTAL : 60 PERIODS**

**TEXT BOOKS**


1. P A Belter, E.L.Cussler and Wei Shou Hu, “Bioseparations – Downstream Processing for Bio Technology”, Wiley India Pvt. Ltd. (2011).
2. B.Sivasankar, Bioseparations Principles and Techniques, Prentice Hall of India Pvt. Ltd, (2010).


**REFERENCE**


1. E.J.Henley, J.D.Seader, D.Keith Roper, Separation Process Principles, Third Edition, Wiley, (2011).
2. P.Cutler, Protein Purification Protocols, Second Edition, Humana Press Inc, (2004).
3. M.R.Ladisch, Bioseparations Engineering: Principles, Practice and Economics, John Wiley & Sons, (2001).
4. R.K.Scopes,“Protein Purification, Principles and Practice”.Third Editon, Springer Verlag, (1993).

**CX8006 CONCEPTS AND TECHNIQUES IN CATALYSIS**

| L | T | P | C |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**OBJECTIVES**

- To make the students conversant with the fundamentals of catalysis and also catalysts synthesis.
- To make the students knowledgeable in catalysts characterization and catalytic reactors.
- To familiarize the students with the catalytic reactions.

**OUTCOMES**

- Will have in depth knowledge about the catalyst available and their application.
- Will know the characterization techniques.
- Will be able to define conditions of catalytic activity in the industrial environment.

**UNIT I FUNDAMENTALS OF CATALYSIS 12**

Acid-base catalysis – catalysis by transition metal ions and their complexes – supported transition metal complexes as catalysts – catalysis by enzymes – phase transfer catalysis - photocatalysis – adsorption – chemisorption on metals, metal oxides and semiconductors. Catalyst deactivation and regeneration.

**UNIT II SYNTHETIC METHODS 12**

Impregnation, Adsorption and ion-exchange- Co-precipitation- sol-gel process - hydrothermal synthesis – skeletal metal and supported metals - metal oxides - Superacids - hydrotalcites - zeolites - zeotypes - mesoporous aluminosilicates, aluminophosphates and carbon based catalysts. Unit operations in catalyst manufacture- drying and calcination.

**UNIT III CATALYSTS CHARACTERIZATION 12**

BET – surface area and pore size distribution - XRD, XPS, Auger electron spectroscopy, X-ray absorption spectroscopy EXAFS, X-ray fluorescence, Electron probe micro analysis - Electron microscopy, Mossbauer spectroscopy, Temperature programmed techniques – TPD, TPR, TPS, TPO - MAS NMR - $^{29}$Si, $^{31}$P, $^{27}$Al-, LEED, EELS Scanning Probe microscopy, STM, AFM, SEM, TEM, DRS UV-Vis and DRIFT spectroscopy.

**UNIT IV CATALYTIC REACTORS 12**

Integral and fixed bed reactors – Two-Phase Reactors, Three-Phase Reactors, Suspension Reactors – Reactors for Homogeneously Catalyzed Reactions. Stirred flow reactors – micro catalytic reactors of pulse type - static reactors - Reaction monitoring by GC.

**UNIT V CATALYTIC REACTIONS 12**

Production of Inorganic and Organic Chemicals, Refinery Process, Catalysts in Environmental Protection, Industrial processes-Bulk Chemicals, Ammonia Synthesis, Hydrogenation, Methanol Synthesis, Selective Oxidation of propane, Olefin Polymerization, Catalytic asymmetric synthesis – C-C, C-H bond formation, oxidation – acid catalysed isomerisation - Heterogeneous hydrogenation, dehydrogenation, Alkylation, Ethylene Epoxidation, oxidation - Metathesis of olefins - Synthetic fuels. Hydrotreating Reactions (HDS).

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. B.Viswanathan, Catalysis selected application, Narosa, 2009.
2. Concepts of Modern Catalysis and Kinetics, I.Chorkendorff and J.W.Niemantsverdriet WILEY-VCH Verlag GmbH& Co. Weinheim, Germany (2003).


**REFERENCES**


1. J.M.Thomas and W.J.Thomas, Principles and Practice of Heterogeneous Catalysis, VCH Publishers Inc., New York, USA., 2008.
2. Industrial Catalysis Jens Hagen,WILEY-VCH Verlag GmbH& Co. Weinheim, Germany (2006).
3. D.K. Chakrabarty and B. Viswanathan, Heterogeneous Catalysis, New Age, 2008.
4. The Chemistry of catalytic conversions, Herman Pine, Academic Press, New Delhi (1981).

**CX8007 ENVIRONMENTAL CHEMISTRY**

| L | T | P | C |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**OBJECTIVES**

- The students should be conversant with the Chemistry of environmental toxicology
- To impart knowledge on water pollution and wastewater treatment.
- To know the students about Sludge handling and disposal.

**OUTCOMES**

- Will have a clear understanding of environmental pollution.
- Will be able to discuss pollution abatement methods.
- Will be capable of developing skills and technology towards green chemistry.

**UNIT I ENVIRONMENTAL SEGMENTS** **12**

Ecosystem and natural cycles of the environment – chemical and photochemical reactions in the atmosphere – ozone chemistry – oxides of sulphur and nitrogen – organic compounds – greenhouse effect and global warming – acid rain – environmental fate of pollutants – biological activity – biodegradation of carbohydrates, fats and oil, proteins, detergents, pesticides.

**UNIT II CHEMICAL TOXICOLOGY** **12**

Toxic chemicals in the environment – toxic effects – biochemical effects of arsenic, cadmium, lead, mercury, copper, chromium – biochemical effects of some gaseous pollutants, cyanide, pesticides, asbestos – air pollutants – air quality standards – sampling and analysis – air pollution control – noise pollution – injurious effects of noise.

**UNIT III WATER POLLUTION** **12**

Water quality parameters and standards – turbidity, color, pH, acidity, solids, hardness, chlorides, residual chlorine, sulphates, fluorides, phosphates, iron and manganese, nitrogen, DO, BOD, COD, grease, volatile acids – analytical techniques in water analysis – soil pollution.

**UNIT IV WASTEWATER TREATMENT** **12**

Primary treatment - equalization, neutralization, proportioning, sedimentation, oil separation, floatation, coagulation- aeration – air stripping of volatile organics; biological treatment process – lagoons, activated sludge process, trickling filtration, anaerobic decomposition – adsorption – theory of adsorption - properties of activated carbon – ion-exchange, chemical oxidation - ozone, hydrogen peroxide, chlorine – wet oxidation; photochemical oxidation.

**UNIT V SLUDGE HANDLING AND DISPOSAL** **12**

Characteristics of sludge – disposal methods – aerobic digestion, gravity thickening, floatation, thickening, centrifugation, specific resistance, vacuum filtration, pressure filtration, sand bed drying, land disposal, incineration – energy and environment – non-renewable and renewable energy – energy sources and resources – energy conservation – nuclear energy and the environment – disposal of nuclear waste; wastewater reclamation and reuse – effluent disposal.

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. A.K De, “Environmental Chemistry”, 5th Edn., New Age International Pub., New Delhi (2004).
2. C N.Sawyer, “Chemistry for Environmental Engineering”, 4th Ed., McGraw – Hill Inc.(1994).


**REFERENCES**


1. M.S.Sethi,“Environmental Chemistry”, Shri Sai Printographers, New Delhi (1994).
2. V. K. Ahluwalia., M. Kidwai, New Trends in Green Chemistry, Anamaya Publishers, 2nd Ed. (2007).
3. Metcalf & Eddy, “Wastewater Engineering”, 3rd ed., McGraw Hill, Inc. (1991).
4. W.Wesley, Eckenfelder, Jr., “Industrial Water Pollution Control”, McGraw – Hill Book Company, 1989.


Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

**CX8008** **ENZYME TECHNOLOGY** **L T P C**
**4 0 0 4**

**OBJECTIVES**

- To impart knowledge on enzyme isolation and enzyme immobilization.
- To make the student conversant with enzyme catalysis and industrial enzymes.
- To acquaint the student with enzyme reactors.

**OUTCOMES**

- Will gain in depth knowledge about enzyme and its action.
- Will gain the knowledge of enzymes, their kinetics and action in general.
- Will be in a position to use enzymes in the industry.

**UNIT I ENZYME ISOLATION** **12**

Sources of enzymes; enzyme extraction; principles of enzyme assays and kinetics studies; effects of enzyme concentration; expression of enzyme activity; effect of substrate concentration.

**12**

**UNIT II ENZYME IMMOBILIZATION**

Immobilization techniques; Adsorption; entrapment; covalent cross – linking with bi or multifunctional reagents; covalent coupling to polymeric supports.

**12**

**UNIT III ENZYME CATALYSIS**

Immobilized enzyme catalytic reactor design, enzyme catalysis in aqueous and non-aqueous solvents, polymerization esterification, ester hydrolysis; peptide synthesis.

**12**

**UNIT IV INDUSTRIAL ENZYMES**

Production, applications in various industries, food processing; bakery products, dairy products, brewing: leather industry detergents, enzyme in medicine diagonostics, enzyme sensors, Biosensors; Use of enzymes in analysis – types of sensing – gadgetry and method, Use of unnatural substrates – artificial enzymes – enzyme mimicking.

**12**

**UNIT V ENZYME REACTORS**

Design and operation of ideal reactors – CSTR and PER; design and packed bed and fluidized – bed immobilized enzyme reactors: membrane reactors for immobilized enzyme systems.

**TOTAL: 60 PERIODS**

**TEXT BOOKS**


1. N.Krishna Prasad, Enzyme Technology: Pacemaker of Biotechnology, PHI Learning Private Ltd,(2011).
2. A.S.Mathuriya, Industrial Biotechnology, Ane Books Pvt. Ltd, (2009)


**REFERENCES**


1. M.R.Ladisch, Bioseparations Engineering: Principles, Practice and Economics, John Wiley & Sons, (2001).
2. A.Pandey,C.Webb,C.R.Soccol, C.Larroche, Enzyme Technology, Springer, (2006)
3. C.Ratledge, B.Kristiansen, “Basic Biotechnology”, 3rd Edition, Cambridge University Press, (2006)
4. Jean-Louis Reymond, Enzyme Assays, Wiley-VCH, (2006)


**CX8009** **PHYSICAL ORGANIC CHEMISTRY** **L T P C**
**4 0 0 4**

**OBJECTIVES**

- To impart knowledge on chemical kinetics and isotopic effects on kinetics.
- The students must know about structure and reactivity relationship.
- To make the student conversant with organic reaction mechanisms and photochemical reactions

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

**OUTCOMES**

- Will be able to apply kinetics to study organic reaction mechanisms.
- Will be capable of correlating structure and reactivity of a compound.
- Will get a general idea about photochemical processes.

**UNIT I CHEMICAL KINETICS 12**

Kinetics of homogeneous reactions in solution – Transition state model – activation parameters – rate determining step – Isokinetic relationship – location of transition state – Hammond Postulate – reactivity and selectivity – Kinetic and thermodynamic control of products – Principles of least motion and microscopic reversibility – Effect of substituents, solvent and ionic strength – Study of fast reactions – Techniques and methods – Flow technique, Relaxation methods and Flash photolysis.

**UNIT II KINETIC ISOTOPE EFFECTS 12**

Primary and secondary salt effects – acid base catalysis – acidity functions – resonance and steric effects on acidity and basicity – Bronsted catalysis – solvent isotope effect – deduction of reaction mechanisms – Kinetic and non-kinetic methods – mechanistic interpretation of rate law – Effects of temperature on reaction rates – reaction series – enthalpy and entropy relationship – Exner plot – Isokinetic temperature.

**UNIT III STRUCTURE AND REACTIVITY RELATIONSHIP 12**

LFER – Hammett equation – substituent and reaction constants – theories of substituent effects – Deviations from the Hammett equation – Dual parameter correlation –Taft Model.

**UNIT IV ORGANIC REACTION MECHANISMS 12**

Substitution reactions – mechanisms of $S_N1$, $S_N2$ and $S_Ni$ reactions – effects of solvent, substrate, nucleophile and leaving group – stereochemistry of substitution reactions – Elimination reactions – mechanism of E1, E2 and E1CB mechanisms – effects of substrate, base, leaving group and medium – Pyrolytic elimination – Mechanism of oxidation and reduction of organic substrate – catalytic hydrogenation – Retrosynthetic analysis of simple organic compounds – mono and bi-functional open chain and bicyclic target molecules.

**UNIT V PHOTOCHEMICAL REACTIONS 12**

Excitations – spin multiplicity sensitization and quenching – techniques of photochemistry – Photochemistry of C=C – Di-methane rearrangement – Photoaddition to alkenes – Photoreaction of carbonyl compounds – photosubstitution at aromatic ring – Photo Fries rearrangement – Photocyclic additions and photooxidation – Pericyclic reactions – Suprafacial and antrafacial geometrics – Diels Alder reactions – Stereo and regio specificity – Retro Diels Alder reactions – (2 + 2) Cyclo additions– Electrocyclic, Chelotropic and Sigmotropic reactions.

**TOTAL: 60PERIODS**

**TEXT BOOKS**


1. Peter Atkins' and Julio De Paula, "Physical Chemistry", 9th Ed., Oxford University Press, (2010).
2. J.March, "Advances in Organic Chemistry", 5th Ed., John Wiley & Sons, New York (2003)


**REFERENCES**


1. E.V.Anslyn and D.A.Dougherty, "Modern Physical Chemistry", University Science Books, Sausalito, USA (2006).
2. Photochemistry of Organic Compounds: From Concepts to Practice, PetrKlán, JakobWirz, John Wiley & Sons, Ltd, West Sussex, United Kingdom,2009.
3. E.L. Eliel, S.H. Wilen and L.N. Mander, Stereochemistry of Carbon Compounds, John Wiley and Sons, New York (2005).
4. F.A.Carey and R.J.Sundberg, "Advanced Organic Chemistry", (Part A and B) 5th edition, Plenum Press, New York (2005).


Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

**CX8010 POLYMER CHEMISTRY AND TECHNOLOGY L T P C**
**4 0 0 4**

**OBJECTIVES**

- To make the students conversant with the basic concepts of polymer science and copolymerization.
- To familiarize the students with the crystalline and amorphous polymers and also processing of polymers.
- To acquaint the students with the specialty polymers.

**OUTCOMES**

- Will be aware of preparation and properties of polymers at length.
- Will be able to methodically discuss moulding techniques.
- Will develop capacity to characterize polymers and draw a parallel to their properties

**UNIT I BASIC CONCEPTS OF POLYMER SCIENCE 12**

Classification of polymers – chain polymerization – mechanism of free radical, cationic, anionic and co-ordination polymerization – Living polymers- atom transfer radical polymerization (ATRP)– chain transfer reaction and constant – Alfin catalysts – Iniferter – Step-growth polymerization-kinetics of esterification in presence and absence of external catalyst.

**UNIT II COPOLYMERIZATION 12**

Copolymer equation – determination of reactivity ratios & its significance– sequence length – copolymer composition by 1H-NMR. Preparation of block and graft copolymers. Thermal, group transfer, metathetical, electrochemical and ring opening polymerization. Techniques of polymerization – bulk, solution, emulsion, suspension, interfacial, solid state and melt polycondensation.

**UNIT III CRYSTALLINE AND AMORPHOUS POLYMERS 12**

Crystalline and amorphous polymers-factors affecting crystallinity and crystallizability -effect on polymer properties. Glass transition temperature- thermal transitions-Determination of Tg and Tm – factors affecting Tg Polymer characterization by IR, NMR, TGA, DTA and DSC – Molecular weight of polymers and its distribution – molecular weight determination by GPC and Viscosity measurement- Mark – Houwink equation.

**UNIT IV PROCESSING OF POLYMERS 12**

Compounding of polymers, moulding techniques – compression, injection, extrusion, blow moulding, rotational moulding, thermoforming, vacuum forming, calendaring, casting, reaction injection moulding, injection blow moulding and lamination.

**UNIT V SPECIALTY POLYMERS 12**

Interpenetrating polymer net works (IPN) - Heat resistant polymers – Ladder polymers-conducting polymers – photocrosslinking polymers - liquid crystalline polymers - Bio-compatible polymers – polymer composites- polymers for optical storage devices.

**TOTAL : 60 PERIODS**

**TEXT BOOKS**


1. V.R.Gowariker, N.V.Viswanathan and Jayadev Sreedhar, “Polymer Science” New Age International (p) Ltd., New Delhi (2006).
2. F.W.Bill Mayor, “Text Book of polymer science” 3rd Edition – John Wiley & sons, Inc., New York (2002).


**REFERENCES**


1. George Odian “Principles of polymerization”, 3rd Edition – John Wiley & sons, Inc., New York (2003).
2. J.A.Brydson, “Plastic materials”, Newnes – Butterworths, London (2002).
3. Krzysztof Matyjaszenski, “Hand Book of Radical Polymerisation”,-Wiley, John & Sons. (2003).
4. M.S.Bhatnagar, “ A Text Book of Polymer chemistry and technology, Vol I, II & III, 1st Edn., S.Chand and Company, New Delhi, (2007).
5. R.J.Crawford, “Plastics Engineering” Third Edition, Butterworth-Heinmann Publication, (1998).
6. Joel.R.Fried, “Polymer science and technology”, Prentice Hall PTR, 1995

**CX8011 PRINCIPLES OF BIOCHEMISTRY L T P C**

**4 0 0 4**

**OBJECTIVES**

- To provide exposure to the students to understand concepts of carbohydrates and lipids and also proteins..
- To make the students conversant with enzymes and also nucleic acids.
- To impart knowledge on metabolism and energetics

**OUTCOMES**

- Will be familiar with concepts of carbohydrates and lipids and also proteins.
- Will gain the knowledge of enzymes, their kinetics and action in general.
- Will understand the metabolism and energetics in animal tissues.

**UNIT I CARBOHYDRATES AND LIPIDS 12**

Basic concepts of biochemistry – Biomolecules and their interactions with water and other biological substances, carbohydrates – Mono, di,oligo and polysaccharides, complex carbohydrates, Lipids – properties and structure of glycerolipids, phospholipids, sphingolipids, glycolipiods, steroids and prostaglandin.

**UNIT II PROTEINS 12**

Properties and structure of amino acid, peptides, proteins and conjugated proteins. Protein conformation: Native conformation of protein molecules, the secondary structure of fibrous protein, the alpha helix, beta pleated sheet, collagen helix, tertiary structure of globular proteins, quaternary structure of oligomeric proteins.

**UNIT III ENZYMES 12**

Enzyme synthesis, isolation and purification, effect of charge and hydrophobicity, activity and turnover number. Enzyme kinetics: Michaelis–Menton equation, $K_m$, enzyme denaturation, enzyme regulation and activities; occurrence, structure, properties and functions of coenzymes and cofactors.

**UNIT IV NUCLEIC ACIDS 12**

Properties and structure of purines, pyrimidines, nucleosides, nucleotides, poly nucleotides; ribo nucleic acids, and deoxyribo nucleic acids and nucleo protein complexes and structure of chromosomes. Replication, transcription and translation of genetic information. Ribosome and protein synthesis, genetic code and regulation of protein synthesis.

**UNIT V METABOLISM AND ENERGETICS 12**

Carbohydrate, lipid, protein and nucleic acid metabolism inter-conversion of biological substance, glycolysis, TCA cycle, oxidation of fatty acids in animal tissues, urea cycle, respiratory chain, ATP cycle and other energy rich compounds.

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. D.L.Nelson, M.M.Cox. " Lehninger Principles of Biochemistry:" Sixth Edition, MacMillan International Edition, (2012).
2. J.Berg, J.L. Tymoczko, L.Stryer, "Biochemistry", Seventh Edition, W.H. Freeman and Company (2010).


**REFERENCES**


1. D.Voet, J.G.Voet, " Biochemistry" Fourth Edition, John Wiley & Sons (2011).
2. R.J. Simond, Chemistry of Biomolecules, Royal Society of Chemistry, U.K. London (1992).
3. M.K.Campbell, S.O.Farrel, "Biochemistry", Sixth Edition, Thomson Brooks/Cole, (2009).
4. P.Cutler, Protein Purification Protocols, Second Edition, Humana Press Inc, (2004).

**CX8012 PROPERTIES OF POLYMERIC MATERIALS**

| L | T | P | C |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**OBJECTIVES**

- To provide exposure to the students to understand the mechanical properties and also thermal and electrical properties.
- To make the students conversant with optical properties and polymeric materials characterizations.
- The students should be conversant with quality control and testing organizations.

**OUTCOMES**

- Will be aware of preparation and properties of polymers at length.
- Will be able to methodically discuss moulding techniques.
- Will develop capacity to characterize polymers and draw a parallel to their properties

**UNIT I MECHANICAL PROPERTIES 12**

Introduction- Tensile strength and modulus- Tensile Test- Flexural Properties-Compressive Properties-Creep Properties- Damping- Stress Relaxations- Stress cracking – Impact Properties- Shear Strength – Abrasion- Hardness Tests-Specific gravity- Nondestructive testing.

**UNIT II THERMAL AND ELECTRICAL PROPERTIES 12**

Introduction- Test for elevated temperature Performance – Thermal Conductivity- Thermal Expansion- TGA,DTA,DSC and TMA - Brittleness Temperature - Specification of thermal evaluation and classification of electrical insulation – Determination of resistivity – Relative resistance of solid insulating materials – Relative resistance of insulating materials to breakdown by surface discharges – Artificial pollution tests of H.V. insulator – AC, DC.

**UNIT III OPTICAL PROPERTIES 12**

Introduction- Refractive Index- Luminous Transmittance and Haze- Haze meter- Photo elastic Properties- Light transmissions and Colour- Visual color evaluation- Specular Gloss - Birefringence – Stress Optical sensitivity examination.

**UNIT IV POLYMERIC MATERIALS CHARACTERIZATIONS 12**

Introduction – Melt index Test- Capillary Rheometer Test- Density by Density gradient test- Water absorption-Moisture analysis- Sieve analysis. Test – Cup viscosity test- Burst Strength Test – Crush Test- End product testing- Oxygen Index Test – Smoke Generation Test- UL 94 Flammability Testing- Flammability test- Incandescence Resistance Test.

**UNIT V QUALITY CONTROL AND TESTING ORGANIZATIONS 12**

Introductions- Statistical quality control – Quality control system – Professional and testing organizations-ANSI- ASTM – NBS – NEMA – NFA – NSF- PTEC –SPE- SPI and UL.

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. V. R. Gowariker, N. V. Viswanathan, Jayadev Sreedhar, New Age International (P) Ltd, 2005.
2. F. W. Billmeyer, Textbook of Polymer Science, 4th Edition, John Wiley, 2004


**REFERENCES**


1. R. J. Young and P. A. Lovell, Introduction to Polymers, 2nd Edition, Chapman and Hall, 2002.
2. Vishu Shah, Handbook of Plastics Testing Technology, John Wiley & Sons, 1998
3. G. Odian, Principles of Polymerization, Fourth edition, Wiley-Interscience, 2004.
4. L. H. Sperling, Introduction to Physical Polymer Science, Wiley- Interscience, 1986
5. M. Rubinstein and R. A. Colby, Polymer Physics, Oxford University Press, 2003.
6. M. H. Ferry & A.V. Becker, Hand Book of Polymer Science and Technology-Volume 2,CBS Publishers, New Delhi,2004.

**CX8013** **SOLID STATE CHEMISTRY** **L T P C**
**4 0 0 4**

**OBJECTIVES**

- The students should be conversant with the crystal chemistry and preparative methods.
- To impart knowledge on characterization of solids and electrical properties.
- To teach the students about magnetic, optical and thermal properties.

**OUTCOMES**

- Gets a general understanding of the essentials of crystal chemistry and their applications
- Understands the structure of solids and methods to characterize them.
- Is conversant with basics of magnetic, optical and thermal properties.

**UNIT I CRYSTAL CHEMISTRY 12**

Structures of complex oxides and related compounds – defects in solids – origin and types of defects, non-stoichiometry – defects and physical properties – ionic conductivity and optical properties.

**UNIT II PREPARATIVE METHODS 12**

Polycrystalline materials by solid state, precipitation, precursor, ion exchange, sol-gel, intercalation methods – high pressure synthesis, preparation of single crystals – different methods – preparation of thin films, amorphous and nano crystalline materials.

**UNIT III CHARACTERIZATION OF SOLIDS 12**

X-ray diffraction, electron and neutron diffraction – thermal methods – TGA, DTA, DSC and TMA – electron microprobe, EDAX – SEM, TEM spectroscopic methods – XPS, Auger, ISS, SIMS – principles and techniques.

**UNIT IV ELECTRICAL PROPERTIES 12**

Band theory of solids – metals, non-metals, semiconductors – thermo power – Hall effect – insulators – measurement by 2 probe and 4 probe methods – dielectric, ferroelectric, pyroelectric and piezoelectric materials – superconductivity – theory – high TC materials.

**UNIT V MAGNETIC, OPTICAL AND THERMAL PROPERTIES 12**

Dia, para, ferro and antiferromagnetic properties – measurement of magnetic susceptibilities – Guoy and Faraday methods – magnetic ordered solids – soft and hard materials. Optical and thermal properties of solids.

**TOTAL :60 PERIODS**

**TEXT BOOKS**


1. A.R.West – “Solid State Chemistry and its applications” John Wiley (2003).
2. C.N.R.Rao and J.Gopalakrishnan – “New Directions in Solid State Chemistry” Cambridge U. Press (1997).


**REFERENCES**


1. H.K.Moudgil – “Textbook of Physical Chemistry” PHI Learning Pvt. Ltd. (2010).
2. Lesley Smart and Elaine Moore – “Solid State Chemistry – an introduction” Chapman and Hall (1992).
3. D.K.Chakrabarty – “Solid State Chemistry” New Age Pub. (1996).
4. L.V.Azaroff – “Introduction to Solids” Tata McGraw Hill (1990).