Department of Nanoscience & Technology

Apri 2018 Examinations

M. Sc – Chemistry – I & II Years

S.No	Course Code	Semester	Theory/Practical	Subject Name	Credit
1.	538201	II	Theory	Inorganic Chemistry-II	5
2.	538202	II	Theory	Organic Chemistry -II	5
3.	538203	II	Theory	Physical Chemistry -II	5
4.	538207	II	Practical	Organic Chemistry **Practical**	5
5.	538503	II	Elective Paper	Non-major **Elective III** (Synthesis and analysis of nanomaterials)	3
6.	551001& 455701	II	Interdepartment Course	**Elective IV –Supportive course** Internet and web design & Economics for Competitive Examination	3
7.	538401	IV	Theory	Application of Nanotechnology	4
8.	538407	IV	Practical	Nanoscience and Technology	3
9.	538504	IV	Elective	**Elective VI :**(Nanocomposites)	4
10.	538999	IV	Project	**Project** - Report & Viva voce	10

Department of Nanoscience & Technology

Apri 2018 Examinations

M. Sc –Nanoscience & Technology – I & II Years

S.No	Course Code	Semester	Theory/Practical	Subject Name	Credit
1.	533201	II	Theory	Synthesis of Nanomaterials	4
2.	533202	II	Theory	Characterization of Nanomaterials	4
3.	533203	II	Theory	Applications of Nanomaterials	4
4.	533207	II	Practical	Nanoscience and Technology Lab – II (Nano-chemistry Experiments)	5
5.	551001 & 455701	II	Interdepartment Course	**Supportive course : Elective :II** Internet and web design & Economics for Competitive Examination	3
6.	533508	IV	Theory	Nanotoxicology	4
7.	533504	IV	Elective	Information Storage Materials and Devices	4
8.	533999	IV	Project	**Project** - Report & Viva voce	10

SEMESTER -II

538201- INORGANIC CHEMISTRY-II

Credit: 4 **Hours: 90**

UNIT-I: ORGANOMETALLIC CHEMISTRY-I (18 hrs)

Review of formalisms such as oxidation state, 18-electron rule, classes of ligands, Valence electron count (16/18 electron rules); Metal carbon bond types- Structure and bonding in mono and polynuclear metal carbonyls; substituted metal carbonyls and related compounds; reactivity of metal carbonyls; vibrational spectra of metal carbonyls; dinitrogen and dioxygen as ligands in organometallic compounds. Wades rule and isolobal relationship. Nitrosyls: terminal bridging and bent

Unit-II: ORGANOMETALLIC CHEMISTRY –II (18 hrs)

Reaction mechanisms of organometallic complexes, ligand substitution, oxidative addition, reductive elimination, migratory insertion and hydride elimination, transmetallation, Reactions of coordinated ligands in organometallics. Fluxional molecules. Catalysis - Hydrogenation, Hydroformylation, hydrosilation, Monsanto process, Wacker process, alkene polymerization-Ziegler-Natta Polymerisation.

Unit-III: ORGANOMETALLIC CHEMISTRY –III (18 hrs)

Synthesis and reactivity of metal alkyls, alkynes and complexes; pi- complexes with olefins, acetylenes. Metal (W, Cr, Rh, Ru, Mo) carbene complexes, Fischer, Schrock and Grubbs type carbene complexes, comparison of their stability and reactivity, simple and cross metathesis reactions, ring opening, ring closing metathesis in organic synthesis, Alkene complexes - synthesis by ligand substitution, reaction with metal salt-structure and bonding with transition metals; cyclopentadienyl complexes- bonding with transition metals- metallocenes- ferrocene; Metal arene complexes- synthesis and reactivity.

UNIT-IV: CAGES AND METAL CLUSTERS (18 hrs)

Inorganic chains - rings - cages and clusters - catenation - heterocatenation - intercalation chemistry - Isopoly, Heteropoly acids and their anions, Silicates, phosphazenes - phosphazene polymers; sulphur nitrogen compounds. sulphur halides, oxo acids of sulpur; Boranes: Structure and bonding in polyhedral boranes and carboranes, styx notation; Wade's rule; electron count in polyhedral boranes; isolobal analogy; borazine: synthesis and structure. Metal clusters - dinuclear clusters - trinuclear clusters - tetranuclear clusters - hexanuclear cluster.

UNIT-V: INORGANIC PHOTOCHEMISTRY (18 hrs)

Photochemistry of Cr(III), Co(III) and Ru(II) - coordination compounds – photoaquation – photoanation – photoisomerisation – photo redox reactions – charge transfer photo chemistry – photosensitisation – solar energy conversiuon – photogalvanic cell – splitting of water to evolve hydrogen and oxygen – photochemistry of Pt(II) and Pt(IV) complexes.

Text Books

1. S.F.A. Kettle, **Co-ordination compounds**, ELBS, 1973.

2. R.Gopalan, **Concise Co-ordination Chemistry**,1E 2nd reprint, VPH (P) Ltd., 2009.
3. A.K.De, **A Text book of Inorganic Chemistry**, 9th Edition, NAIP, 2003.
4. F.A. Cotton, G. Wilkinson, F.A Murillo and M.Bochmann, **Advanced Inorganic Chemistry,** 6th Edition, John Wiley, 2007.
5. K.N. Upathyaya, **A text book of Inorganic Chemistry**, 3rd Edition, Vikas (P) Ltd., 1998.
6. J.E. Huheey, E.A. Keiter, R.L. Keiter and O.K.Methi, **Inorganic Chemistry- Principles of structure and reactivity**, 4th ed. 5th Impression, Pearson-Education, 2009.

Reference Books

1. Sathyaprakash, J.D.Tuli, S.K. Basu and K.D. Madan, **Advanced Inorganic Chemistry** (Vol I) 1st Edition, S. Chand Publisher, 2006.
2. G. S. Sodhi, **Inorganic Chemistry**, 1st Edition, VB (P) Ltd, 2006. (Paperback – 1 Jan 2011)
3. F.A. Cotton, G. Wilkinson, F.A Murillo and M.Bochmann, **Advanced Inorganic Chemistry**, 6th Edition, John Wiley, 2007.
4. B.N. Figgeis and J. Lewis, **The Magneto Chemistry of Complex Compounds in "Modern coordination Chemistry"** Ed. Lewis and Wilkins, Interscience N.Y.,1967.
5. R. Gopalan and V. Ramalingam; **Concise Co-ordination Chemistry**, 2nd reprint, VPH (P) Ltd., 2006.
6. G. A. Lawrance, **Introduction to Coordination Chemistry**, John Wiley, 2010.
7. David Michael P. Mingos, Peter Day, **Molecular Electronic Structures of Transition Metal Complexes II,** Springer, New York, 2012.
8. Klaus D. Sattler, **Clusters and Fullerenes**, CRC Press, USA, 2010.
9. Peter Atkins**,** Fraser Armstrong**,** Jonathan Rourke**,** Mark Weller and Tina Overton**, Inorganic Chemistry,** Oxford University Press, New York, Fifth edition, 2010.

538202 - ORGANIC CHEMISTRY-II

Credit: 4 **Hours: 90**

Unit I Oxidation and Reduction reaction

Mechanism and application of stereochemical aspect of the following oxidation – reduction reactions: Oxidation reaction involving SeO_2, OsO_4, periodic acid, N-bromosuccinimide, Sharpless asymmetric epoxidation, Hydroboration-oxidation, Baeyer-Villiger oxidation, Woodward-Prevost reactions.

Catalytic hydrogenation- Heterogeneous: Pd/Pt/Rh/Ni, Homogeneous, Wilkinson - Reaction involving lithium aluminium hydride and sodium borohydride – McMurry reaction, Birch reduction – Meerwein Pondorf Verley reduction – Wolff-Kishner reduction - Stereo/enantioselectiviey reductions - Chiral Boranes.

Unit II Reaction mechanisms and molecular rearrangements

Mechanism of Aldol condensation – Perkin reaction – Knoevenagel reaction – Mannich reaction – Cannizaro reaction – Benzoin condensation – Claisen ester condensation – Darzen's reaction – Reformatsky reaction – Wittig reaction – Grignard reactons.

Mechanism of the following rearrangement reactions: Wagner – Meerwein, Pinacol, Beckmann, Hofmann, Curtius, Baeyer – Villeger, Sommelet – Hauser, Favorskii, Benzil –benzilic acid, Claisen, Fries, Dienone – phentol and di-pi methane.

Unit III Aromatic substitution reactions:

Aromatic electrophilic substitution – Mechanism of nitration, halogenation, Friedel-Craft's reaction, sulphonation and Gattermann – Koch Formylation - Reimer-Tiemann reaction - Vilsmeyer- Haack reaction - Kolbe-Schmidt reaction, and Bischer - Napieralski rection
– partial rate factors – ortho/para ratio – Quantitative treatment of reactivity of the electrophile (the selectivity relation).

Aromatic nucleophilic substitution reactions: S_NAr, S_N1 and benzyne mechanisms.
Quantitative treatment of the effect of structure on reactivity – Chichibabin reaction - The Hammett relationship – significance of reaction and substituents constants.

Unit IV Chemistry of Natural products

Steroids: Classification – complete chemistry and stereochemistry of cholesterol, male sex harmones – androsterone and testosterone – female sex harmones – oestrone, equilenin and progesterone.
Vitamins: Structure of A, B12, C, and K.
Nucleic acids:Structures of nucleoside, nucleotide RNA and DNA functions of nucleic acids.

Unit V Conformational analysis

Configuration and Conformation – Conformation of ethane and n – butane – conformational analysis – stereoelectronic and steric factors – conformation of monosubtituted and disubstituted cyclohexanes – correlation of the conformation of acyclic with their physical and chemical properties – Quantitative treatment of Mobile system – Eliel equation– stereo chemistry of ansa compounds.

Text Books

1. E.L.Eliel, S.H.Wilen & L.N.Mander, Stereochemistry of Carbon Compounds, John Wiley & Sons, 2003.
2. I.L.Finar, Organic Chemistry, Vol. II, 5TH edn., ELBS, 1975.
3. Jerry March, Advanced Organic Chemistry, John Wiley & Sons 4^{lh} edn., 2000.
4. E.S. Gould, Mechanism and Structure in Organic Chemistry, Henry Holt& Co., New York, 1959.
5. Gurdeep Chatwal, Organic Chemistry of Natural Products, Volume: I Himalaya Publishing House, Mumbai.

Reference Books

1. D.Nasipuri, Stereochemistry of Organic Compounds – Principles and Applications, 2nd edn., New Age International (P)Ltd., 1994.
2. P.S.Kalsi, Stereochemistry and Mechanism through solved problems, Second Edition, New Age International Publishers, 1994.
3. D.Nasipuri, Stereochemistry of Organic Compounds, 2nd Edition, New Age International Publishers, 1994.

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538203 –PHYSICAL CHEMISTRY-II

Credit: 4 **Hours: 90**

Unit I - QUANTUM CHEMISTRY - II (18hrs)

Application of wave mechanics: rigid rotor, harmonic oscillators, shapes of orbitals, shape quantization. Particle in a box: One and three-dimensional boxes, distortions, John-teller effect, quantum numbers, zero-point energy, orthogonisation and normality, tunneling, perturbation theory.

Unit II - GROUP THEORY- I (18 hrs)

Symmetry elements and symmetry operations, Centre of symmetry, Plane and its types of Symmetry, Proper and Improper axis of Symmetry, Principal axis and subsidiary axes. The concept of groups, Assigning Point groups with illustrative examples, Symmetry operations and order of a group - Group theoretical rules (Group postulates), reducible and irreducible representations, matrix representations of symmetry operations, Construction of Character Tables for C_{2V} and C_{3V} point group molecules, and Great orthogonality theorem and its proof.

Unit III - GROUP THEORY - II (18 hrs) Direct product representation, Spectroscopy application of group theory to IR spectral activity of vibrational modes of ammonia molecule, selection rules for vibrational IR and RAMAN spectra, Mutual exclusion rule for molecules with center of symmetry, selection rules for rotational spectroscopy. Selection rules for n-π* and π-π* transitions in formaldehyde molecule. SALC procedure, Applications of SALC procedure to ethylene and butadiene molecules.

Unit IV - CHEMICAL KINETICS - II (18 hrs)

Solution and gas phase kinetics: Chain reactions and its rate laws, Hydrogen-bromine reaction, chain-branching explosion reactions, Polymerization kinetics: stepwise and chain polymerizations. Homogeneous catalysis: Features of acid-base catalysis.

Enzymes: Michaelis-Menten mechanism of enzyme catalysis, catalytic efficiency of enzymes, mechanisms of enzyme inhibition.

Fast reaction kinetics: Relaxation methods (T- and P-jump methods), Stopped flow methods, Shockwave technique, Flash photolysis.

Unit V - SURFACE CHEMISTRY AND HETEROGENEOUS CATALYSIS (18 hrs)

Surface and interfaces: Surface tension, solid-liquid interfaces; contact angle and wetting; Solid-gas interface; Physisorption and chemisorptions, Freundlich, Gibbs, Langmuir, and BET adsorption isotherms; Surface area determinations.

Heterogeneous catalysis: Kinetics of surface reactions involving adsorbed species, Langmuir-Hinshelwood mechanism, Langmuir-Rideal mechanism, Rideal-Eley mechanism, Basic aspects of semiconductor catalysis and applications.

Text Books

1. P. W. Atkins, **Physical Chemistry,** ELBS, Oxford University Press, New York, 1998.
2. A. K. Chandra, **Introductory Quantum Chemistry,** 4th ed., Tata McGraw-Hill Education, New Delhi, 16th reprint 2006.
3. Ira N. Levine, **Quantum Chemistry,** Prentice Hall of India; 7th edition, 2013.
4. A. Salahuddin Kunju, G. Krishnan, **Group Theory and its Applications in Chemistry**, PHI Learning private Ltd., New Delhi, 2012.

5. K. V. Raman, **Group Theory and its Applications to Chemistry,** Tata McGraw-Hill Publishing company Ltd., New Delhi, 16th reprint 1997.
6. F. Albert Cotton, **Chemical Applications of Group Theory**, Third Edition John Wiley & Sons, Singapore 2003.
7. K. J. Laidler, **Chemical Kinetics,** 3rd Edition, Pearson Education India, New Delhi, 2nd impression 2008.
8. Gabor A. Somorjai, Yimin Li, **Introduction to Surface Chemistry and Catalysis**, John Wiley & Sons, 2010.

Reference Books

1. Robert J Silbey, Robert A Alberty Moungi G Bawendi, **Physical Chemistry 4th Edition,** N J Hoboken: Wiley 2015.
2. R. K. Prasad, **Quantum Chemistry,** New age International publisher, New Delhi, Revised edition 2014.
3. F. Albert Cotton, **Chemical Applications of Group Theory**, Third Edition John Wiley & Sons, Singapore 2003.
4. K. S. Gupta, **Chemical Kinetics and Reaction Mechanism,** RBSA Publishers, Jaipur, India, Revised edition 2013.
5. Paul L. Houston, **Chemical Kinetics and Reaction Dynamics,** The McGraw-Hill companies, Inc, New York, 2006.
6. J. N. Gurtu & A. Gurthu, **Advanced Physical Chemistry**, Pragathi Prakashan, Meerut , Revised copy 2014.
7. K. S. Birdi, **Handbook of Surface and Colloid Chemistry**, Fourth Edition, CRC Press, 2015.
8. G. W. Castellan, **Physical Chemistry**, Narosa publishing House, New Delhi, Revised edition 2011.

538207 -ORGANIC CHEMISTRY PRACTICAL

Credit: 4 **Hours: 108**

1. Qualitative analysis: Separation and Identification of components in a two component mixture and preparation of their derivatives. Determinations of boiling point/melting point for components and melting point for their derivatives.

2. Double stage Organic preparation

(a) Benzanilide from benzophenone.

(b) Eosin from phthalic anhydride

(c) Methyl orange from Aniline

(d) Benzoic acid from Aniline

3. Quantitative estimations

(a) Aniline

(b) Phenol

(c) Glucose

4. Identification of functional groups of organic compounds prepared and extracted.

(a) UV-VIS spectra of α, β-unsaturated carbonyl systems

(b) FT IR spectra of few organic compounds

Reference Books

1. B.S.Furniss, A.J.Hannaford, P.W.G.Smith and A.R.Tatchell, **Vogel's Practical Organic Chemistry,** 5th edn. ELBS, 1989.
2. Raj K. Bansal, **Laboratory Manual of Organic Chemistry**, III Edn., New Age International (P) Ltd. 1996.
3. A.I.Vogel**, Elementary practical organic chemistry: Quantitative organic analysis Part-III, 2e(pb),** Pearson Education Asia, 2011
4. A.I.Vogel**, Elementary practical organic chemistry: Qualitative organic analysis Part-II, 2e(pb),** Pearson Education Asia, 2011

538503- SYNTHESIS AND ANALYSIS OF NANOMATERIALS

Credit: 4 **Hours: 72**

Unit I: Bulk synthesis

Top down and bottom up approaches–Mechanical alloying and mechanical ball milling Mechano-chemical process, Inert gas condensation technique – Arc plasma and laser ablation.

Unit II: Chemical approaches

Sol- gel processing- Solvothermal, hydrothermal, co-precipitation, colloidal precipitation, Spray pyrolysis, sonochemical method, Electro spraying and spin coating routes, Self-assembly, self-assembled monolayers, gas phase synthesis. Langmuir-Blodgett (LB) films, micro emulsion polymerization- templated synthesis.

Unit III: Physical approaches

Vapor deposition and different types of epitaxial growth techniques (CVD, MOCVD, MBE, ALD)-pulsed laser deposition, Magnetron sputtering - Etching process: Dry and Wet etching, micro contact printing.

Unit IV: Biological Methods

Use of bacteria, fungi, Actinomycetes for synthesis of nanoparticles - use of viruses for the synthesis of nanostructured materials- use of magnetotactic bacteria for synthesis of magnetic nanoparticles- use of natural plants for synthesis of nanoparticles.

Unit V: Spectroscopic techniques

Principle, theory and instrumentation of UV-Visible spectroscopy-Infra-red spectroscopy- Atomic Spectroscopy-Photoluminescence spectroscopy-Photo Correlation Spectroscopy-Raman Spectroscopy-NMR spectroscopy-Electron Spin Resonance Spectroscopy-Mass Spectroscopy-Fluorescence spectroscopy.

Books for study:

1. Synthesis, Properties, and Applications of Oxide Nanomaterials, edited by José A. Rodriguez, Marcos Fernández-García
2. Nanochemistry: A Chemical Approach to Nanomaterials, By Geoffrey A. Ozin, André C. Arsenault, Ludovico Cademartiri
3. Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers ..., By Daniel L. Schodek, Paulo Ferreira, Michael F. Ashby
4. Nanomaterial Interfaces in Biology: Methods and Protocols, Paolo Bergese, Kimberly Hamad-Schifferli
5. Optical Properties and Spectroscopy of Nanomaterials, Jin Z. Zhang

Books for reference:

1. Nanomaterials: Mechanics and Mechanisms, By K.T. Ramesh
2. Nanoscience and Nanomaterials: Synthesis, Manufacturing and Industry Impacts, By Wei-Hong Zhong
3. Nanoparticles: Synthesis, Stabilization, Passivation, and Functionalization. American Chemical Society. Meeting
4. Handbook of Semiconductor Manufacturing Technology, Second Edition, edited by Yoshio Nishi, Robert Doering
5. Handbook of Immunological Properties of Engineered Nanomaterials, By Marina A. Dobrovolskaia, Scott E. McNeil
6. Biomimetic and Bioinspired Nanomaterials, edited by Challa S. S. R. Kumar
7. Nanoscale Spectroscopy with Applications, edited by Sarhan M. Musa
8. Applied Spectroscopy and the Science of Nanomaterials, edited by Prabhakar Misra
9. Nanomaterials Imaging Techniques, Surface Studies, and Applications ..., edited by Olena Fesenko, Leonid Yatsenko, Mikhaylo Brodin

SEMESTER- IV

538401 – APPLICATION OF NANOTECHNOLOGY

Credit: 4 **Hours: 72**

Unit I: Lithography and sensors

Silicon MEMS fabrication technology, Advanced lithography: Deep UV/E beam/Ion Beam techniques, Dip pen nanolithography-Polymers in Microsystems, Packaging of MEMS devices by anodic/fusion bonding, Pressure sensors and packaging, MEMS performance and evaluation-Surface confined chemical sensors- Nanoparticles sensors- thermal, radiation magnetic, chemical and mechanical nanosensors.

Unit II: Nanomedicine

Principles of nanomedicine – impact of nanotechnology in medicine- nanomedical perspective and the medical applications- nanoparticles delivery for cancer therapy – Bioactive nanomaterials in medicine- Nanodiagnostics - Nanoarrays for diagnostics-nanoparticles for molecular diagnostics-self-assembled protein nanoarrays- protein nanobiochip - Nanobiosensor-CNT biosensor-DNA biosensor.

Unit III: Nanopharmaceutical

Nanoparticles for drug discovery – Nanotechnology for Drug Targeting, Targeted, non-targeted delivery, controlled drug release-protein and peptide based compounds for cancer and diabetes - lipid nanoparticles - vaccination - cell therapy -Gene therapy-nanoparticles drug delivery in cardiology and vascular disease- Nanoparticles and protein interactions-inter relationship between nanotech development and nanopharmaceutical development.

Unit IV: Environmental and Bio-compatibility

Degradation of hazardous organic-pollution abatement- removal of bacteria and microbes-photocatalytic decontamination-heavy metal removal-detection and extraction of pesticides from water-Fuel cell application-thermoelectric and piezoelectric application-chemical and electrochemical sensor using nanomaterials. Antibacterial, antimalarial, antiviral and anticancer activities using nanomaterials.

Unit V: Nanoelectronic

Nanoelectronics-Microelectronics- molecular electronics- photonics–photolithography–carbon nanotubes (CNT) in electronic applications- memories-dye sensitized solar cells-Physical concepts-Quantization of action, charge and flux-electrons in potential well-photons interacting

with electrons in solids-diffusion processes-Effects on structure and Morphology of free or Supported Nanoparticles- Size and confinement Effects.

Books for study:

1. Nanotechnology-Enabled Sensors, By Kourosh Kalantar-zadeh, Benjamin Fry
2. A.R.Jha, MEMS and Nanotechnology based sensors and devices for communication, medical and aerospace applications, CRC press, Taylor & Francis group, 2008.
3. Nanomedicine and Drug Delivery, edited by Mathew Sebastian, Neethu Ninan, A. K. Haghi
4. Nanopharmaceutics: The Potential Application of Nanomaterials, By Xing-Jie Liang
5. Biological and Pharmaceutical Applications of Nanomaterials, edited by Polina Prokopovich
6. K. Goser, *et al*, "Nanoelectronics and Nanosystems", Springer, 2004.

Books for Reference:

1. Biointeractions of Nanomaterials, edited by Vijaykumar B. Sutariya, Yashwant Pathak
2. Environmental Applications of Nanomaterials: Synthesis, Sorbents and Sensors, By Glen E. Fryxell, Guozhong Cao
3. Pharmaceutical Nanotechnology: Fundamentals and Practical Applications, By Costas Demetzos
4. The Handbook of Nanomedicine, By Kewal K. Jain
5. Patenting Nanomedicines: Legal Aspects, Intellectual Property and Grant ..., edited by Eliana B. Souto
6. NanoBioTechnology: BioInspired Devices and Materials of the Future, By Oded Shoseyov, Ilan Levy
7. Handbook of Clinical Nanomedicine: Nanoparticles, Imaging, Therapy, and ..., edited by Raj Bawa, Gerald F. Audette, Israel Rubinstein

538407-NANOSCIENCE AND TECHNOLOGY-PRACTICAL-IV

Credit: 6 **Hours: 108**

1. Synthesis of Iron oxide nanoparticles by Co-precipitation method.
2. Synthesis of ZnO nanoparticles by chemical method.
3. Synthesis of SnO_2 nanoparticles by Chemical sol-gel method.
4. Synthesis of TiO_2 nanoparticles by Chemical sol-gel method.
5. Electrodeposition of nano film of TiO_2
6. Synthesis of Nanocomposite materials by solution method using capping agent
7. Studies on bulk and nanoparticles through UV-Vis spectroscopy.
8. Conductivity studies of polymer-nanocomposite material by four probe method.

Demonstrative Practicals

9. Thin film characterization through AFM.
10. XRD studies for calculating the size of the nanoparticles and nanocomposites by Scherrer's formula and mass approximation method
11. SEM characterization of nanomaterials. for size and surface morphology
12. Raman spectroscopy studies on nanomaterials.

538999-PROJECT WORK & VIVA-VOCE

Credit: 8 **Hours: 270**

ELECTIVE COURSES

538501-INTRODUCTION TO NANOSCIENCE AND TECHNOLOGY

Credit: 4 **Hours: 72**

Unit I: Introduction and History

Background to nanotechnology - scientific revolutions –atomic structure-atomic size – bottom up/top down nanotechnology-chemical reactivity-Incremental nanotechnology-Evolutionary nanotechnology-Radical nanotechnology-Emergence of nanotechnology-Challenging in nanotechnology-Misnomers and misconception of Nanotechnology.

Unit II: Evolution and growth of Nanosystem

Basic problems and limitations - opportunities of nano scale -evolution of band structures and Fermi surface. Nanoparticles through homogeneous and heterogeneous nucleation-Growth controlled by surface and diffusion process- Oswald ripening process - influence of reducing agents-solid state phase segregation- grain growth and sintering precipitation in solid solution-hume rothery rule.

Unit III: Nanomaterials and classifications

Carbon Nanotubes (CNT) - Metals (Au, Ag, Pd, Cu) - Metal oxides (TiO_2, CeO_2, ZnO, MgO) - Semiconductors (Si, Ge, CdS, ZnSe). Classifications of nanomaterials-zero dimensional-one-dimensional-two dimensional-three dimensional nanostructures- Quantum dots-Quantum wire-Quantum well-semiconductors and ceramics.

Unit IV: Special nanomaterials

Carbon fullerenes-fullerene derived crystals- carbon nanotubes. Micro and Mesoporous material-Ordered mesoporous materials-Random mesoporous materials-crystalline microporous materials.Core/Shell structures-Metal oxide structures-Metal polymer structures-Intercalation compounds-nanograined materials.

Unit V: Materials Structure and Properties

Space lattice and unit cells, crystal system, Symmetry operation, Structures of common metallic, Semiconductor ceramic and superconductor materials, Miller Indices, Packing fractions, Formation of dangling bonds-atom like behavior of nanomaterials-physicochemical properties. Optical properties of nanomaterials-semiconductor-metal nanoparticles-Electrical and electronic properties-Thermal properties-Ferro electric properties-mechanical and magnetic properties.

Books for study:

1. Introduction to Nanoscience and Nanotechnology, By Gabor L. Hornyak, H.F. Tibbals, Joydeep Dutta, John J. Moore

2. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, By Guozhong Cao, Ying Wang

3. Organic Nanomaterials: Synthesis, Characterization, and Device Applications, By Tomas Torres, Giovanni Bottari

4. Nanochemistry: A Chemical Approach to Nanomaterials, By Geoffrey A. Ozin, André C. Arsenault, Ludovico Cademartiri

5. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, By Guozhong Cao, Ying Wang

6. Material science and Engineering, by V.Raghawan

Books for reference:

1. Introduction to Nan science, By Gabor L. Hornyak, Joydeep Dutta, H.F. Tibbals, Anil Rao
2. Introduction to Nanoscience and Nanotechnology, By Chris Binns
3. Foundations of Nanotechnology, Volume Two: Nanoelements Formation and ..., By Sabu Thomas, Saeedeh Rafiei, Shima Maghsoodlou, Arezo Afzali
4. Nanocomposite structures and dispersions, By Ignac Capek
5. Morphology Control of Materials and Nanoparticles: Advanced Materials ..., edited by Yoshio Waseda, Atsushi Muramatsu
6. Nanomaterials: Synthesis, Properties and Applications, Second Edition, edited by A.S Edelstein, R.C Cammaratra
7. Nanomaterials: New Research, By B. M. Caruta

Supportive Course

ECONOMICS FOR COMPETITIVE EXAMINATIONS (Non-Major IDC)

Course Code: 455 701 **Credit: 3**

Objectives: To train the students for writing different competitive examinations in the realm of economics.

I. Structure of the Indian Economy: Characteristics of Indian Economy - National Income – Methods of Calculating National Income and its Difficulties – Trends in National Income in India – Sectoral Contribution – Population Growth and Economic Development.

II. Economic Planning: Policy Objectives of Planning –Types of Planning – Planning in India – Review and assessment of New Economic Policy and Liberalization, Privatization and Globalization.

III. Agriculture and Industrial Development: Agricultural Development under Five Year Plans - Structural Change - Impact of New Economic Policy (1991) – Industrial Development under Five Year Plans – New Industrial Policy.

IV. Banking and Fiscal Policy: Indian Banking System – Functions of RBI – Commercial Bank, Development Bank – Co-operative Bank – Stock Exchanges – India's Fiscal Policy – Tax Reform – VAT and GST – Demonetization.

V. Foreign Trade: India and the World Trade - Foreign Trade and Balance of Payments – Exchange Rate Policy – Foreign Capital and Foreign Aid – Meaning of MNC – FEMA - India and WTO.

References:

1. Dutt, G. and A. Mahajan (2016), "*Indian Economy*", S. Chand Publishing, New Delhi.
2. Government of India (various years), "*Economic Survey of India*", Economic Division, Ministry of Finance, Government of India, New Delhi.
3. Government of India (various years), "*Statistical and Abstract*", Ministry of Statistics and Programme Implementation, Government of India, New Delhi.
4. Gupta. K.R and J.R. Gupta (2012), *"Indian Economy",* Atlantic Publishers, New Delhi.
5. Puri. V.K. and S.K. Misra (2017), *"Indian Economy: It's Development Experience"*, Himalaya Publishing House, New Delhi.

www.agricoop.gov.in
www.rbi.org.in
www.finmin.nic.in

Syallbus for M. Sc – Nanoscience & Technology

Semester - II

533201 Synthesis of Nanomaterials

Hours	L	T	P	C
72	4	0	0	4

Unit I. Ultra high Vacuum Techniques:
Ultra high vacuum systems – design – Joule heating – evaporation boats – cold finger – role of inert gases – powder collection – target preparation – prevention of contamination from air – limitations of Joule heating – laser ablation - RF/DC magnetron sputtering – microwave plasma evaporation – control of grain size – scale-up process- Thermal evaporation- transferred arc plasma reactor- Electron beam evaporation.

Unit II. Chemical Methods:
Solvothermal synthesis- Photochemical synthesis-Electrochemical synthesis, Sol-gel technique – control of grain size – co-precipitation hydrolysis – sonochemical method combustion technique – colloidal precipitation – template process – Micellar route-growth of nanorods – solid-state sintering – grain growth.

Unit III. Hydrothermal methods:
Principle, 3D nanostructures – carbon nanotube – Inorganic nanotubes and nanorods – Nanoflowers- nanosprings – Nano-rings – chemical routes for 1D nanotubes and nanorods – Schlenky synthesis of Quantum dots- making bulk nanomaterials.

Unit IV. Mechanical methods:
Grinding – high energy ball milling – types of balls – WC and ZrO_2 – material-ball ratio – medium for grinding – limitations in getting required grain size for low melting point materials – typical systems – severe plastic deformation –melt quenching and annealing

Unit V. Biological Methods:
Biomineralization, biological production of nanoparticles – Phytosynthesis, phycosynthesis, mycosynthesis and Herbal synthesis - bioproduct mediated synthesis of nanoparticles.

Books for Study:

1. ***S. Horikoshi, N. Serpone, Microwaves in Nanoparticle Synthesis: Fundamentals and Application, Wiley-VCH, Germany, 2013.***
2. ***Om V. Singh, Bio-Nanoparticles: Biosynthesis and Sustainable Biotechnological implication, Wiley Blackwell, 2015.***
3. ***A. Sengupta, C.K. Sarkar, Introduction to Nano: Basics to nanoscience and nanotechnology, Springer, London, 2015.***
4. ***S.K. Kulkarni, Nanotechnology: Principles and Practices, Third edition, Springer International Publishing, 2014.***
5. ***V.A. Basiuk, E.V. Basiuk, Green Processes for Nanotechnology: From inorganic to bioinspried nanomaterials, Springer, 2015.***
6. A.C.Venetti, Progress in Materials Science Research, Nova Science Publishers, 2007.

Books for References

1. A.M.Grumezescu, Fabrication and self assembly of nanobiomaterials: Application of Nanobiomaterials, Vol 1, William Andrew, Elseiver, 2015.

2. A.M.Grumezescu, Nanomaterials in Antimicrobial therapy: Application of Nanobiomaterials, Vol. 6, William Andrew, Elseiver, 2016.

533202 Characterization of Nanomaterials

Hours	L	T	P	C
72	4	0	0	4

Unit I: Mechanical Characterization

Micro hardness – nanoindensation – fatigue – failure stress and strain toughness – abrasion and wear resistance – fracture toughness – elasticity of nanomaterials – superplasticity – plastic nature of nanoceramics – nanomembranes – inter connected pores – plastic deformation of nanomaterials.

Unit II: Electrical Characterization

DC electrical conductivity as a function of temperature - Hall effect – types of charge carriers – charge carrier density – impedance spectroscopy – dc electrical resistivity – activation energy – bulk and grain boundary capacitances – relaxation times of dipoles.

Unit III: Spectroscopic Characterization

UV-VIS – calorimetric and spectrophotometric analysis – laws of absorption – instrumentation-chromophores – effect of conjugation on chromophores – qualitative and quantitative analysis -IR – Origin of Infrared transition and experimental techniques–Theory of Infrared Absorption – FT-IR – principle – instrumentation – interpretation of spectra-aliphatic and aromatic hydrocarbons, carboxylic acids – Raman spectroscopy – Stokes and anti – Stokes scattering – surface enhanced raman scattering – PL studies – shape dependent optical properties – optical absorption - optical emission – surface plasma resonance (SPR).

Unit IV: Magnetic Characterization

Concepts of dia-para-ferro and ferri magnetism – exchange correlation - exchange interaction – Hysteresis loop – coercivity – change of coercivity – grain size – soft magnets – hard magnets – spring exchange magnets – magnetic measurements using VSM – function of temperature - ferromagnetic resonance – magnetic force microscopy – Mossbauer spectroscopy for Fe and Sn containing nanomaterials – NMR – Introduction – Experimental Techniques – Chemical shift, dipolar interaction, spin - spin interaction – Applications – ESR – Principles and Applications of ESR Spectroscopy.

Unit V: Microscopic Characterization

Electron Microscopes – AFM, STM, SEM- and TEM – working principle – instrumentation and applications – microstructures – optical microscope – grain size determination – grain size induced phase transition-surface mapping.

J. Ross Macdonald

Books for study

1.GerdKaupp,Atomic Force Microscopy, Scanning Nearfield Optical Microscopy and nanoscratching, Springer-Verlag, 2006.

2.Rashid, Bashir and Steve Wereley, Biomolecular Sensing, Processing and Analysis, Springer, 2006.

3.Tejal and Desai, Therapeutic Micro /NanoTechnology, Springer, 2006.

William F. Hosford,Physical Metallurgy, CRC Press, 2005.

4.E. Barsoukov and J. Ross Macdonald, Impedance Spectroscopy: Theory, Experiment, and Applications, John Wiley & Sons 2005.
5.Nobertami Kasai, Masao Kakudo, X-ray diffraction,Springer 2005.
6.H,Ishiwara Ferroelectic, random access memories,2004.
7.Micromachines as Tools for Nanotechnology, Springer, 2003.
8.Junji Tominaga, D. P. Tsai,Optical Nanotechnologies, Springer, 2003.
9.Jin Zhong Zhang, Optical properties and spectroscopy of nanomaterials: World scientific, 2009.

Books for references

1. Vitalij K. Pecharsky, Peter Y. Zavalij, Fundamentals of Powder Diffraction and Structural Characterization, Springer.2003.
2. Manfred L, Risting,Kalus, A. Gernot, Particle scattering, X-ray diffraction, and microstructure of solid and liquids, Springer.2002.
3. Parthasarathy, Challenges and opportunities in nanotechnology- Isha books - 2007.
4. K. T. Ramesh, Nanomaterials: Mechanics and Mechanisms, Springer, 2009.
5. R.W. Cahn and P. Haassen, Physical Metallurgy, Ed., 3rd North - Holland, 1983.

533203 Applications of Nanomaterials

Hours	L	T	P	C
72	4	0	0	4

Unit I. Electronic Applications:

Microelectronics – photolithography – Density of microcomponents –molecular electronics – Nanoelectronics – memories – LEDs – Nanotransistors-photonics — carbon nanotubes (CNT) in electronic applications – CNT based MOSFET – MEMS and NEMS – dye sensitized solar cells – CMOS technology-Large Electrochromic Display Devices-low cost Flat-Panel Displays.

Unit II. Magnetic Applications:

Soft magnets for high speed memories – hard magnets – high density memories-High Energy Density Batteries-High-Power Magnets – biological applications – targeted drug delivery – hyperthermia.

Unit III. Applications of Nanoceramics and Nanocomposites:

Near net shaped components – membranes for purification of water – blood and air, catalysis – tooth and bone substitutes – hydroxyappetites – inductive bone – replacements – ceramic valves. Aerospace Components with Enhanced Performance Characteristics.

Unit IV. Environmental applications:

Nanotoxicology – organic dye degradation – textile and leather industries – removal of bacteria and microbes – water resistant composites for walls resistance to fungal attack – sensors for gases – pressure – temperature – DNA etc., - lightening arrestors – varistors. Detoxification of organic /inorganic pollutants.

Unit V. Biological applications:

Dendrimers – Bio-functionalisation of CNT and biological applications – self assembly molecules and their applications – tissue culture – nanopharma. Cancer detection/diagnosis via nanotechnologies and nanosensors/nano biosensor - Biomimetic amplification of nanoparticle homing to tumors-Longer-Lasting Medical Implants.

Books for study:

1. Ram Gupta, and francis ,Nanoparticle Technology for Drug Delivery, 2006.
2. Nicholas. A. Peppas J,Zaoh Hilt,and J.Brock Thomas, Nanotechnology in Therapeuties,current technology and applications , Horizon Scientific press. 2006.
3. Yury Gogotsi, Cabon Nanomaterials, CRC -2006.
4. Chellakumar, Nanomaterials for Cancer Therapy, Wiley –VCH press, 2006.
5. Tejal and Desai, Therapeutic Micro /NanoTechnology, Springer, 2006.
6. Sergey Lyshevski, 2/e, Nano and Microelectromechanical systems: Fundamentals of Nano and Microengineering ,2005.
7. Rashid, Bashir and Steve Wereley, Biomolecular Sensing, Processing and Analysis, Springer, 2006.
8. Victor I. Klimov, etal, Emiconductor and Metal Nanocrystals:synthesis and electronic and optical properties , Marcel,2004.
9. AndrzejWieckowski,*et.al,* Catalysis and Electrocatalysis at Nanoparticle ,2003.

Book references:

1. Challa S.S.Kumar, Nanomaterials: Toxicity, health and environment issues, Wiley- VCH. 2006,
2. Louis Theodore, Robert, G.Kunz- Nanotechnology Environmental Application and Solutions, 2006.
3. Neelina H. Malsch, Biomedical Nanotechnology, 2005.

4. Ralph S, Nanoscale Technology in Biological systems, 2004.

533207 Nanoscience and Technology Lab – II

(Nano-chemistry Experiments)

Hours	L	T	P	C
108	0	0	6	6

1. Synthesis of Iron oxide nanoparticles by Co-precipitation method.
2. Synthesis of ZnO nanoparticles by chemical method.
3. Synthesis of SnO_2 nanoparticles by Chemical sol-gel method.
4. Synthesis of TiO_2 nanoparticles by Chemical sol-gel method.
5. Synthesis of colloidal nanocmaterials of Au and Ag nanoparticles
6. Preparation of polymer nanocomposites.
7. Studies on bulk and nanoparticles through UV-Vis spectroscopy.
8. Raman spectroscopy studies on nanomaterials.
9. Demo Thin film characterization through AFM.
10. Conductivity studies of polymer-nanocomposite material by Four probe method.
11. XRD demo studies for calculating the size of the nanoparticles and nanocomposites by Scherrer's formula and mass approximation method
12. SEM demo characterization of nanomaterials. for size and surface morphology

IV Semester - 533508 NANO TOXICOLOGY

Hours	L	T	P	C
54	3	0	0	3

Unit I: Introduction

Concept of Nanotoxicology - Laboratory rodent studies - Ecotoxicologic studies - Methodology for Nanotoxicology - in vitro and in vivo toxicity testing

UNIT II:Mechanism

Mechanism of nanosize particle toxicity - Reactive oxygen species meditated NSP toxicity - Interactions between Nanoparticles and Living Organisms: Mechanisms and Health Effects - Interactions of Nanoparticles with Cells and their Cellular Nanotoxicology - Cytotoxicity of Ultrafine Particles - Cytotoxicity and Potential Mechanism of Nanomaterials- Immunotoxicity.

UNIT III: Pollution

Nanopollution – Nanomaterials in Environment - Toxicology of Airborne - Manufactured nanomaterials in the environment- Physicochemical characteristics of nanomaterials.

UNIT IV:Human exposure to Nanosized Materials

Biological Activities of Nanomaterials and Nanoparticles - nanoparticles interaction with biological membrane-Entry routes into the human body- Disposition of NSPs in the respiratory - Disposition of NSPs in the respiratory -Epithelial translocation - Translocation to the circulatory system - Neuronal uptake and translocation -Translocation of NSPs in the blood circulation to bone marrow in mice - Studies of neuronal translocation of UFPs from respiratory tract -Exposure via GI Tract and Skin- toxicity of nanoparticles in the eye.

Unit V:Risk Assessment and Execution

Portals of entry and target tissue – Risk assessment – Ethical – Legal and Social Implications - Nanoparticle Toxicology and Ecotoxicology, The Role of Oxidative Stress – Development of Test Protocols for Nanomaterials – Regulation of Engineered Nanomaterials in Europe and USA

Books for Study

1. N. Duran, S.S. Guterres, O.L. Alves, Nanotoxicology: Materials, Methodologies, and Assessments, Springer, Newyork, 2014.
2. T. Otsuki, Y. Yoshioka, A. Holian, Biological Effects of Fibrous and Particulate Substances,Springer, Japan, 2016.
3. A.M. Gatti, S. Montanari, Case Studies in Nanotoxicology and Particle Toxicology, Academic Press, UK, 2015.
4. Nancy A. Monteiro-Riviere, C. Lang Tran, Nanotoxicology: Progress towards Nanomedicine, Second edition, CRC Press, Taylor and Franscis, Boca Raton, 2014.
5. G. Ramachandran, Assessing Nanoparticle Risks to Human Health, William Andrew, Elsevier, USA, 2011.
6. J. Njuguna, K. Pielichowski, H. Zhu, Health and Environmental Safety of Nanomaterials:

Polymer Nancomposites and other material containing nanoparticles, Woodhead Publishing, Elsevier, UK, 2014.
7. Harry Salem, Sidney A. Katz, Inhalation Toxicology, Third Edition, CRC Press, London, 2015.

533504 INFORMATION STORAGE MATERIALS AND DEVICES

Hours	L	T	P	C
54	3	0	0	4

Unit I: Overview of Information Storage and Nanotechnology
Different types of information storage materials, solid state memory, optical memory, magnetic recording, emerging technologies, role of nanotechnology in data storage.

Unit II: Optical Data Storage
Write and read techniques (signal modulation, disk format, data reproduction), read and write principles (read-only, write-once, phase-change, magnetooptic disks), optical pickup heads (key components, diffraction-limited laser spot, focusing and tracking error signals, servo-loop design, actuator), optical media, near field optical recording, holographic data storage.

Unit III: Basics of Magnetism for Magnetic Data Storage
Magnetic field, magnetic moment, spin, exchange coupling, ferromagnetic and anti-ferromagnetic materials, magnetic anisotropy, demagnetisation field, magnetic domain, magnetic hysteresis, super paramagnetism.

Unit IV: Magnetic Media
Inductive read and write head, AMR head, GMR effect, spin-valve sensor, magnetic tunnelling junction, GMR head, ultra-small head design. Longitudinal recording media, media design, thin film technology, media noise, superparamagnetic limit.

Unit V: Solid state Memory
Charge, spin and phase change based memories (DRAM, SRAM, Flash, FeRAM, MRAM, CRAM, RRAM, NVFDRAM). Probe storage, molecular memory, atomic memory and quantum information storage.

References:

1. Erwin R. Meinders , Matthias Wuttig, Liesbeth Van Pieterson, Andrei V.Mijiritskii, Optical Data Storage, Springer, 2006.
2. Seth Lloyd and Y. Jack Ng., Black Hole Computers, Scientific American Magazine November 2004.
3. Jacob D.Bekenstein, Information in the Holographic Universe, Scientific American Magazine, August, 2003.
4. Wu YH, "Nano Spintronics for Data Storage", Encyclopedia for Nanoscience and Nanotechnology, vol.7, American Scientific Publishers, 2003.
5. Mechanics and Reliability of Flexible Magnetic Media, Bharat Bhushan, 2000, ***Springer.***