SCHOOL OF NANOSCIENCE AND NANOTECHNOLOGY

MAHATMA GANDHI UNIVERSITY

CURRICULUM STRUCTURE AND SYLLABI
(BASED ON OUTCOME BASED EDUCATION)

For the Programme,

M. Sc. Chemistry (Nanoscience and Nanotechnology)

(Under the CSS Regulations 2021 of Mahatma Gandhi University

w.e.f. **2022** Admission Onwards)

PREFACE

I am happy to present the revised curricula and syllabi of the following M.Sc. Chemistry (Nanoscience and Nanotechnology) Programme of the School of Nanoscience and Nanotechnology according to the OBE concept (with effect from 2022 admission onwards) for favour of approval by the Faculty and Academic Council of the University.

The Board of Studies has restructured the curriculum as per the Outcome Based Education (OBE) system. OBE is an educational approach that bases each part of the educational system with respect to the goals set for the students. OBE aims to equip the students (learners) with knowledge, competency orientations required for achieving their goals when they depart the institution. Further OBE empowers students to choose what they would like to study and how they would like to study it. The teaching methodologies and the evaluation system are also modified in par with the outcome- based approach. The Programme Specific Outcomes (PSOs) and the Course Outcomes (COs) are presented in the syllabus. The PSOs and the COs are well correlated in the syllabus of each course.

The draft curricula and syllabi for the M.Sc. Chemistry (Nanoscience and Nanotechnology) Programme were discussed in a very effective manner in the Board of Studies of the School of Nanoscience and Nanotechnology. The Board of Studies has also modified the scheme, curricula and syllabi for the M.Sc. Programme in conformity with the Revised CSS Regulations 2020 by the Mahatma Gandhi University to suit the Credit and Semester System. The content of the syllabus has been modified significantly (around 20 % of the total content from the previous syllabus especially by adding new courses such as advanced courses in inorganic, organic and physical chemistry (second and third semesters), Design, synthesis and fabrication of Nanomaterials, Advanced quantum mechanics and Group theory (second semester), Applications of Nanotechnology, Nano biomedicine (third semester). Some advanced and interdisciplinary topics are added as electives also. Another salient feature of the revised curriculum is the inclusion of practical courses named Synthesis of Nanomaterials (second semester) and Characterization of Nanomaterials (third semester).

The BOS feels that appreciable updating could be done in keeping with thecurrent developments and trends in chemistry education.

-sd-

Prof.

(Chairman, Board of Studies of School of Nanoscience and Nanotechnology)

Members of the Expert committee of School of Nanoscience and Nanotechnology (vide UO No: 5435/AD A 7/2022/MGU Dated: 25.05.2022)	
1	**Prof. (Dr.) Sabu Thomas**, Hon. Vice Chancellor & Director of School of Nanoscience and Nanotechnology.
2	**Dr. Sreekala MS**, Joint Director, School of Nanoscience and Nanotechnology.
3	**Dr. Nandakumar Kalarikkal**, School of Pure and Applied Physics.
4	**Dr. Radhakrishnan EK**, School of Biosciences.
5	**Dr. Anitha C Kumar**, School of Chemical Sciences.
6	**Dr. Kuruvilla Joseph**, IIST Thiruvananthapuram.
7	**Dr. Sandhyarani**, NIT Calicut.
8	**Dr. Lissymol Jacob**, SCTIMST, Thiruvananthapuram.
9	**Dr. Anantharaman**, CUSAT.
10	**Dr. Deepthi Menon**, AIMS Kochi.
11	**Dr. Honey John**, CUSAT.

Mahatma Gandhi University

Vision

‘’Mahatma Gandhi University envisions to excel in the field of higher education and caterto the scholastic and developmental needs of the individual, through continuous creation of critical knowledge base for the society’s sustained and inclusive growth.”

Mission

- To conduct and support undergraduate, postgraduate and research-level programmes of quality in different disciplines
- To foster teaching, research and extension activities for the creation of new knowledge for the development of society
- To help in the creation and development of manpower that would provideintellectual leadership to the community
- To provide skilled manpower to the professional, industrial and service sectors inthe country so as to meet global demands.
- To help promote the cultural heritage of the nation and preserve the environmental sustainability and quality of life
- To cater to the holistic development of the region through academic leadership.

Programme Outcomes (PO) of Mahatma Gandhi University

PO 1: Critical Thinking and Analytical Reasoning Capability to analyse, evaluate and interpret evidence, arguments, claims, beliefs on the basis of empirical evidence; reflect relevant implications to the reality; formulate logical arguments; critically evaluate practices, policies and theories to develop knowledge and understanding; able to envisage the reflective thought to the implication on the society.

PO 2: Scientific Reasoning and Problem-Solving Ability to analyse, discuss, interpret and draw conclusions from quantitative/qualitative data and experimental evidences; and critically evaluate ideas, evidence and experiences from an unprejudiced and

reasoned perspective; capacity to extrapolate from what one has learned and apply their competencies to solve problems and contextualise into research and apply one's learning to real life situations.

PO 3: Multidisciplinary/Interdisciplinary/Transdisciplinary Approach Acquire interdisciplinary/multidisciplinary/transdisciplinary knowledge base as a consequence of the learning they engage with their programme of study; develop a collaborative-multidisciplinary/interdisciplinary/transdisciplinary-approach for formulate constructive arguments and rational analysis for achieving common goals and objectives.

PO 4: Communication Skills Ability to reflect and express thoughts and ideas effectively in verbal and nonverbal way; Communicate with others using appropriate channel; confidently share one's views and express herself/himself; demonstrate theability tolistencarefully, read and write analytically, and present complex information in a clear and concise manner and articulate in a specific context of communication.

PO 5: Leadership Skills Ability to work effectively and lead respectfully with diverse teams; setting direction, formulating a goal, building a team who can help achieve the goal, motivating and inspiring team members to engage with that goal, and using management skills to guide people to the right destination, in a smooth and efficient way.

PO 6: Social Consciousness and Responsibility Ability to contemplate of the impact of research findings on conventional practices, and a clear understanding of responsibilitytowards societal needs and reaching the targets for 12 attaining inclusive and sustainable development.

PO 7: Equity, Inclusiveness and Sustainability Appreciate equity, inclusiveness and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity, managing diversity and use of an inclusive approach to the extentpossible.

PO 8: Moral and Ethical Reasoning Ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Capable of demonstrating the ability to identify ethical issues related to one's work and living as a dignified person in the society.

PO 9: Networking and Collaboration Acquire skills to be able to collaborate and network with scholars in an educational institution, professional organizations, research organizations and individuals in India and abroad.

PO 10: Lifelong Learning Ability to acquire knowledge and skills, including "learning how to learn", that are necessary for participating in learning activities throughout life, through self- paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/reskilling.

Scheme and Syllabi

Programme:

M. Sc. Chemistry (Nanoscience and Nanotechnology)

MAHATMA GANDHI UNIVERSITY

SCHOOL OF NANOSCIENCE AND NANOTECHNOLOGY

PROGRAMME	M. Sc. Chemistry (Nanoscience and Nanotechnology)
DURATION	2 years (2022 Admission onwards)
Total credits	80 (for 4 semesters) [Core: 64; Elective: 12; Open: 4]

**The student has to choose two elective courses for semester I, two elective courses for semester II and two elective courses for semester III.

**The student has to choose one open course of 4 credits for semester III from any other School under the Faculty of Science.

*** In the evaluation process internal –Continuous Assessment (CA) - accounts for 40%and the End- Semester Examination will account for the remaining 60%.

Program Specific Outcomes:(PSOs): At the completion of the M.Sc. Chemistry (Nanoscience and Nanotechnology) program, the students from school of Nanoscience and Nanotechnology will be able to:

PSO	Programme Specific Outcome	MGU PO No.
1	Provide a strong foundation in Chemistry that emphasizes scientific reasoning and analytical problem solving.	1,3
2	Provide students with the skills required to succeed in M.Sc., also enrich the students with a basic skill to perform in Chemical industry especially in the field of Nanoscience and Nanotechnology.	1,2,6
3	Promote research interest in students and enable them towards planning and execution of research in frontier areas of chemical sciences.	3,8
4	Expose the students to a level of experimental techniques using modern instrumentation.	1,2
5	Demonstrate teamwork, communication, Time management and leadership skills across multicultural contexts.	4,5,7,9
6	Acquire the ability to synthesize and characterize compounds using sophisticated	1,2

	instrumental techniques and related soft-wares, for the in-depth characterization of nano materials	
7	Develop solid knowledge, understanding and expertise in the domain of Nanoscience and Nanotechnology.	1,2,10
8	Inspire the students to be committed to deliver good to the society by judicious application of scientific skill sets they acquire doing Chemistry at the nanoscale.	3,7,8,9
9	Nurture the quality of rationality and inquisitiveness, so that the students are capable of free and critical thinking to steer clear judgmental and social biases.	2,4,5,9

SEMESTER I (22 credits)						
CourseCode	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						18
NSM22C59	Inorganic Chemistry I - Chemistry of non-transition elements and Coordinationcompounds	2	2	-	3	
NSM22C60	Organic Chemistry I – Structural andMolecular Organic Chemistry	2	2	-	3	
NSM22C61	Physical Chemistry I – Quantum, Statisticaland Chemical dynamics	2	2	-	3	
NSM22C62	Introduction to Nanomaterials	3	2	-	3	
NSM22C63	Practical I - Inorganic Chemistry	-	-	6	3	
NSM22C64	Practical II - Organic Chemistry	-	-	6	3	
***Elective Courses (Choose any two)**						4
NSM22E45	Chemistry of Natural Products	2	-	-	2	
NSM22E46	Green Synthesis	2			2	
NSM22E47	Polymer Chemistry	2	-	-	2	

SEMESTER II (22 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						18
NSM22C65	Advanced Quantum Mechanics and Group Theory	3	2	-	3	
NSM22C66	Organic Chemistry II – Organic Synthesis and Reaction Mechanism	2	2	-	3	
NSM22C67	Inorganic Chemistry II - Organometallics and Bioinorganic chemistry	2	2	-	3	
NSM22C68	Spectroscopic Methods in Chemistry	2	2	-	3	
NSM22C69	Design, Synthesis and Fabrication of Nanomaterials	2	2	-	3	
NSM22C70	Practical III– Synthesis and characterization of Nanomaterials	-	-	6	3	
***Elective Courses (Choose any two)**						4
NSM22E48	Analytical and Nuclear Chemistry	2	-	-	2	
NSM22E49	Surface Chemistry and Catalysis	2	-	-	2	
NSM221E50	Drug design and Medicinal chemistry	2	-	-	2	

SEMESTER III (20 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						12
NSM22C71	Organic Chemistry III – Advanced Organic Chemistry	2	2	-	3	
NSM22C72	Physical Chemistry II – Solid state and Advanced Materials	2	2	-	3	
NSM22C73	Advanced Characterization techniquesfor nanomaterials.	3	2	-	3	
NSM22C74	Practical IV – Physical Chemistry	-	-	6	3	
***Elective Courses (Choose any two)**						4
NSM22E51	Mathematical and Computational Chemistry	2	-	-	2	
NSM22E52	Nanotechnology in Energy	2	-	-	2	
NSM22E53	Advanced Nanobiology	2	-	-	2	
****Open Course**						4
	Open Course	4	-	-	4	

SEMESTER IV (16 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						16
NSM22C75	Dissertation and viva-voce	-	-	-	10	
NSM22C76	Industrial visit/ Review				3	
NSM22C77	Mini Project				3	

****Open Courses offered by School of Nanoscience and Nanotechnology**						4
NSM22O-02	Nanoscience and Nanotechnology: Fundamentals, Essentials and Opportunities	-	-	-	-	
This course can be designed for master's students who belongs to other departments.						

***Addon courses offered by School of Nanoscience and Nanotechnology	
1	Nano catalysis
2	Social, ethical and legal issues of Nanoscience and Nanotechnology
3	Nano sensors
4	Advanced nanobiology
5	Waste management, and Water purification through Nanoscience and Nanotechnology.

	MAHATMA GANDHI UNIVERSITY **Inorganic Chemistry I - Chemistry of non-transition elements and Coordination compounds**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Inorganic Chemistry I - Chemistry of non-transition elements and Coordination compounds**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C59**

Course Summary & Justification	Main group elements, the most abundant elements in the universe were among the first developed in the modern era for diverse inter-disciplinary applications. The study of Main Group Chemistry unravels the basic composition, structures, and properties of elements. Through this learning, it is possible to acquire relevant conceptual and procedural knowledge, to develop understanding and appreciation of developments in various scientific and technological fields. The course also aims to help the students to detail out the bonding, structures and properties of coordination complexes. The description of various bonding theories with emphasizes on the spectral and magnetic properties of coordination complexes helps to predict the characteristic properties of any transition metal complex. Different reactions in transition metal complex with a supportive mechanism will be discussed. The applications of coordination chemistry in various field will also be described at the conclusion part to understand importance of learning this course					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basic knowledge about periodic table and arrangements of elementsunder Groups and Periods. Basic knowledge in Inorganic Chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the classification of elements in the periodic table: general trends and properties of elements and structure of molecules	U	1,3
2	Understand the Chemistry of group III elements and apply Wade's rule and STYX number in rationalizing the structure of main group clusters	U,A	1,2
3	Understand about the diversity of oxides, sulfides,halides and hydrides of group IV, V and VI elements	U,R	2
4	To understand the structure and bonding of coordination complex	U,E	4
5	To predict the shape of coordination complexes usingVBT & CFT	U,S	1, 3
6	To estimate the CFSE of any complex and predicts low spin/high spin nature	U,A	2,3
7	To study spectral and magnetic properties of coordination complexes	U, An,I	1,2
8	Should be able to derive the term symbol for anyelectronic configuration	U, A, An	2
9	Should be able to draw Orgel diagrams and recognise the electronic transition in the spectra of any coordination complexes	U, A	4,5
10	To be able to describe the stability of coordination complexes by the use of formation constants and to calculate thermodynamic parameters from them	U, A	1,2,3, 6
11	To predict the products formed after electron transfer reaction between two coordination complexes	U,Ap	2,7

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Chemistry of Main group Elements** General trends in the properties of the elements, occurrence and extraction; Group I and II elements and their compounds, Chemistry of group III elements: Inorganic chains, rings and cages; Boranes, Boron halides, Diborane, Borazines, Borates, Boron clusters, Higher boranes and borohydrides, Organoboranes: carboranes and metallocarboranes, STYX numbers and WADE's rule,Isolobal concept: molecular geometry and molecular symmetry,Main group clusters: Cyclic and crown ethers, Silicon-oxygen compounds, Silicates, Silicons, Zeolites, Silanes, Silylamines and extended Silicon- Oxygen compounds, Carbides and Silicides. Complexes of Ge, Sn and Pb, Diamond, graphite and other forms of carbon, Hydrides of group V and VI elements, Phosphanes, phosphorous halides and phosphazenes, Oxohalides and Oxoacids of P, S, Se and Te, Oxoacids of halogens, Interhalogen compounds and polihalides,Chemistry of noble gases, Compounds of Xenon (structure and reactivity), Clathrates.	**15 Hrs.**	**1,2,3**
2	**Structural Aspects and Bonding:** Structures and Isomers of Coordination Complexes, Classification of complexes based on coordination numbers and possible geometries, sigma and pi bonding ligands such as CO, NO, CN^-, R3P, and Ar3P, Stability of complexes, thermodynamic aspects of complex formation-Irving William order of stability, chelate effect.Werners cordination theory,Valence Bond theory, Crystal Field Theory,Splitting of d orbitals in octahedral, tetrahedral, square planar, square pyramidal and triagonal bipyramidal fields, LFSE, Dq values, Jahn Teller (JT) effect, theoretical	**15 Hors.**	**1,4**

	failure of crystal field theory, evidence of covalency in the metal-ligand bond, nephelauxetic effect, ligand field theory, molecular orbital theory- M. O energy level diagrams for octahedral and tetrahedral complexes without and with π-bonding, experimental evidences for pi-bonding.		
3	**Spectral and Magnetic Properties of Metal Complexes** **Electronic Spectra of complexes:** Term symbols of dn system, Racah parameters, splitting of terms in weak and strong octahedral and tetrahedral fields, correlation diagrams for d1 and d9 ions in octahedral and tetrahedral fields (qualitative approach), d-d transitions, selection rules for electronic transitions. **Interpretation of electronic spectra of complexes**: Orgel diagrams and demerits, Tanabe Sugano diagrams, calculation of Dq, B and β (Nephelauxetic ratio) values, spectra of complexes with lower symmetries, charge transfer spectra, luminescence spectra. **Magnetic properties of complexes**-paramagnetic and diamagnetic complexes, spin only magnetic moment, Temperature dependence of magnetism- Curie's law, Curie-Weiss law, temperature independent paramagnetism (TIP), spin state cross over, antiferromagnetism-inter and intra molecular interaction, anomalous magnetic moments.	**15 Hrs.**	**1,4,5,6,7,8**
4	**Kinetics and Mechanism of Reactions in Metal Complexes** Thermodynamic and kinetic stability, kinetics and mechanism of nucleophilic substitution reactions in square planar complexes- trans effect-theory and applications. Substitution in tetrahedral and five-coordinate complexes ,Kinetics and mechanism of octahedral substitution- water exchange, dissociative and associative mechanisms, base hydrolysis, racemization reactions, solvolytic reactions (acidic and basic), Replacement reactions involving multidendate ligands- formation of chelates, effect of H+ on the rates of substitution of chelate complexes, metal ion	**15 Hrs,**	**9,10,11**

	assisted and ligand assisted dechelation, Electron transfer reactions: Outer sphere mechanism-Marcus theory, inner sphere mechanism-Taube mechanism, mixed outer and inner sphere reactions, two electron transfer and intramolecular electron transfer.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

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12. D. F. Shriver, P. W. Atkins, Inorganic Chemistry, 5th Edn., Oxford University Press,2010.

	MAHATMA GANDHI UNIVERSITY **Organic Chemistry I - Structural and Molecular Organic Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Organic Chemistry I – Structural and Molecular Organic Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C60**

Course Summary & Justification	The course is designed to address the fundamental concepts and mechanisms of organic and photochemical reactions, basic organic reaction mechanisms, stereochemistry and conformational analysis of organic compounds. Through this learning, the students will be able to describe the chemical and molecular processes that take place in organic chemical reactions, and to differentiate various types of nucleophilic substitution and elimination reactions. They are suggested to understand the basic concepts and various types of aromaticity, and also to have a knowledge of stereochemical aspects of organic reactions. A good understanding of types of isomerism and stereochemical notations are also advisable. This course would help the students to grasp the aforementioned domains with thorough learning and practice.					
Semester	**1**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Prerequisite	Fundamentals of organic chemistry and stereochemical notations					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1.	To revise and understand basic concepts of aromaticityand electron displacement effects	R, U	1,2
2.	To illustrate the reaction mechanism aspects in the contextof addition, elimination and substitution reactions	U, An, E	1,7
3.	To predict the mechanisms of different organic reactions	An, A, S	1,2,3
4.	To have a thorough knowledge of different types ofisomerism	R, U, Ap	2,3,6
5.	To demonstrate chirality in organic molecules using unitssuch as center, axial, planar, and helicity.	U, E,C	4,5
6.	To predict E/Z configuration in organic molecules byapplying concepts of stereochemistry	A, An, S	3,4
7.	To learn basic concepts of organic photochemistry, and to summarize photochemical intermediates involved in organic reactions	U, An, I	2,7
8.	To learn the basic difference between photochemical andthermal reactions	U, E, Ap	3,4
9.	To gain knowledge on the synthetic applications of organic photochemical reactions	U, Ap	1,2
10	To develop skill to propose the possible mechanism of agiven photochemical reaction	A, S	2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C),Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Basic Concepts in Organic Chemistry Review of basic concepts in organic chemistry: Bonding, hybridization, MO picture of butadiene and allyl systems, Electron displacement effects: Inductive effect, electromeric	**15 Hrs.**	**1,2**

	effect, resonance effect, hyperconjugation, steric effect, Bonding weaker than covalent bonds. Concept of aromaticity: Delocalization of electrons - Hückel's rule, criteria for aromaticity, examples of neutral and charged aromatic systems - annulenes, carbon nanotubes and graphene.		
2	**Organic Reaction Mechanisms 1** Mechanism of electrophilic and nucleophilic aromatic substitution reactions with examples, Arenium ion intermediates, S_N1, S_N2, mixed S_N1 and S_N2, S_NAr, $S_{RN}1$, S_Ni, SE1, SE2 and benzyne mechanisms, E_2, E_1 and E_1CB mechanisms. Hoffman and Saytzeff modes of elimination, orientation of the double bond. Mechanistic and stereochemical aspects of addition reactions involving electrophiles, nucleophiles, regio- and chemo selectivity orientation and reactivity. Markovnikov's and anti-Markovnikov's mechanisms. Effect of substrate, reagent, leaving group, solvent and neighbouring group on nucleophilic substitution (S_N2 and S_N1) and elimination (E_1 and E_2) reactions.	**15 Hrs.**	**3**

3	**Stereochemistry of Organic Compounds** Stereochemistry of Organic Compounds: Stereoisomerism: Definition based on symmetry and energy criteria, configuration and conformational stereoisomers, Centre of chirality: Molecules with C, N, S based chiral centres, absolute configuration, enantiomers, racemic modifications, R and S nomenclature using Cahn-Ingold-Prelog rules, molecules with a chiral centre and Cn, molecules with more than one centre of chirality, definition of diastereoisomers, constitutionally symmetrical and unsymmetrical chiral molecules, erythro and threo nomenclature. Axial, planar and helical chirality with examples, stereochemistry and absolute configuration of allenes, biphenyls and binaphthyls, ansa and cyclophanic compounds, spiranes, exo-cyclic alkylidene cycloalkanes, Topicity and prostereo isomerism, topicity of ligands and faces as well as their nomenclature, NMR distinction of enantiotopic/diastereotopic ligands. Geometrical isomerism: nomenclature, E-Z notation, methods of determination of geometrical isomers, interconversion of geometrical isomers.	**15 Hrs.**	**4,5,6**
4	**Photochemistry of Organic compounds** Franck-Condon principle, Jablonski diagram, fluorescence and phosphorescence, Singlet and triplet states, Photosensitization, Quantum efficiency, Photochemistry of carbonyl compounds, Norrish type-I and type-II cleavages, Paterno-Buchi reaction, Photoreduction, Photochemistry of enones and para-benzoquinones, Di π – methane rearrangement, Photodynamic therapy, Photochemical [4+2] cycloaddition using singlet Oxygen; Barton reaction.	**15 Hrs.**	**7,8,9,10**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning,Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** • **Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar • **Semester End examination**

References

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2. Jerry March, Advanced Organic Chemistry: Reactions, Mechanisms, andStructure.
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	MAHATMA GANDHI UNIVERSITY **Physical Chemistry I – Quantum, Statistical and Chemical dynamics**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Physical Chemistry I – Quantum, Statistical and Chemicaldynamics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C61**

Course Summary & Justification	In a broader sense, physical chemistry can be defined as theapplication of physics to chemistry. The physics explains the worldaround us by building various models. The models such as kinetictheory of gases, collision theory of reactions etc. are purely classical-based. In contrast, for subatomic world, one needs to go beyondclassical world and invoke the laws of quantum mechanics todescribe small particles like electron. In classical and quantum worldsalike, the physics needs the support of mathematics to construct itsmodels. Thus, much of physical chemistry is inherently mathematicaland can be conceived faster through exercises and problem solving.Therefore, a recommended approach to succeed in physicalchemistry is to solve as many end-of-chapter problems as possible. This course introduces students to the core area of physicalchemistry, based around the themes of systems, states andprocesses. Topics covered are Quantum mechanics, Classicalthermodynamics, Statistical mechanics and Chemical kinetics.Throughout the course, the relationship between physical phenomena and the molecular structure and reactions underpinning advanced materials will be highlighted. The general goal of learning physical chemistry is to obtain an in-depth understanding of why and how chemical reactions occur, which in turn may enable us toaccurately design reactions leading to novel molecules of the future.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Quantum theory, statistical mechanics, thermodynamics and kinetics (Undergraduate level). Strong mathematical skill in DifferentialEquations and Linear Algebra.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the foundation and postulates of quantum mechanics.	U	2,7
2	Describe the use of simple models for predictive understanding of different molecular systems and phenomena.	U, A	1,2,6,7
3	Illustrate the concept of atomic orbitals by quantum mechanics.	U, R	1,2
4	Understand a comprehensive and rigorous treatment of classical thermodynamics.	U,R	2
5	Understand transformations at the molecular level.	U,S,Ap	1,3,6
6	Evaluate Phase behavior of one and two component systems.	U, A,I	4
7	State and apply basic concepts of thermodynamics into mixtures, Understand thermodynamics of ideal and non-ideal solutions.	U, An	2,4
8	Find the connection between statistics and thermodynamics and differentiate between different ensemble theories used to explain the behaviour of the systems.	U, A, An	1,2,5
9	To understand the properties of macroscopic systems using the knowledge of the properties of individual particles, thermodynamic probability, macroscopic and microscopic states.	U, A	2,3
10	Apply the principles of chemical kinetics in different types of reactions.	U, A,C	1,2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Quantum mechanics - I** Introduction to quantum mechanics, failure of classical mechanics, need of quantum mechanics, black body radiation, photoelectric effect, atomic spectra, wave-particle duality. Postulates of quantum mechanics, quantum	**15 Hrs.**	**1,2,3**

	mechanical operators, Schrödinger equation and nature of its solutions, Born interpretation of the wave function. Model system: particle in 1D box, quantization of energy levels, zero-point energy, probability distribution functions, normalized and orthogonal wave functions. Extension to two and three dimensional box problems, separation of variables and degeneracy of wave function. Qualitative treatment of hydrogen atom and hydrogen-like ions, significance of quantum numbers, radial and angular wave functions for hydrogen atom.		
2	**Thermodynamics I** Mathematical foundations for thermodynamics-variables of thermodynamics, extensive and intensive quantities, equation for total differential, conversion formulas, exact differentials, general formulation, reciprocity characteristics, homogeneous functions, Euler's theorem. Concepts of entropy and free energy: Entropy as measure of randomness and unavailable energy. Entropy changes in reversible and irreversible process and during various processes. Clausius inequality. Variation of entropy with T and P. Helmholtz and Gibbs free energies. Thermodynamic criteria of equilibrium and spontaneity. Variation of free energy with temperature and pressure. Maxwell's relations, Von't Hoff's reaction isotherm and isochore, Gibbs-Helmholtz equation. Determination of free energy changes. Nernst heat theorem and third law of thermodynamics-calculation of absolute entropies and residual entropy. Partial molar Properties: Physical significance, Partial molar volume and partial molar free energy (chemical potential). Determination of partial molar quantities by intercept method and slope methods. Physical significance of chemical potential. Variation of chemical potential with temperature and pressure. Formulation of the Gibbs Duhem equation. Derivation of Duhem-Margules equation.	**15 Hrs.**	**4,5,6,7**

3	**Statistical Mechanics** Brief history about the macroscopic and microscopic approach in science, permutation, probability, Stirling's approximation, macrostate and microstates, equal a priori principle and thermodynamic probability, thermodynamic probability and entropy, phase-space, ensemble, types of ensembles. Boltzmann distribution law, partition function and its physical significance, relation between molecular partition function and molar partition function, distinguishable and indistinguishable particles, partition function and thermodynamic functions, separation of partition function- translational, rotational, vibrational, and electronic partition functions, partition function for hydrogen. Thermal de-Broglie wavelength. Calculation of thermodynamic functions and equilibrium constants, Sackur-Tetrode equation, statistical formulation of third law of thermodynamics, residual entropy, heat capacity of gases - classical and quantum theories. Heat capacity of solids: the vibrational properties of solids, Dulong and Petit's law, Einstein's theory and its limitations, Debye theory and its limitations. Need for quantum statistics, Bosons and Fermions, Bose-Einstein statistics: Bose- Einstein distribution law, Bose-Einstein condensation, first order and higher order phase transitions, liquid helium, Fermi-Dirac statistics: Fermi-Dirac distribution law, application in electron gas, thermionic emission. Comparison of three statistics.	**15 Hrs.**	**8,9**

4	**Chemical Dynamics - I** Reaction rates and order of reactions, determination of order of reactions, complex reactions (free radical chain reactions, branching reactions, hydrogen-oxygen and hydrogen-halogen reactions). Reversible, consecutive and opposing reactions. The Analysis of kinetics results: the method of integration, graphical methods, half life methods, Guggenhiem's method, the differential method. Reactions of variable order, steady state treatment, free radical reactions. Studies of fast reactions by flow method, relaxation method and flash photolysis. Theories of unimolecular reaction and their treatments (Lindemann-Hinshelwood and Rice-Ramsperger-Kassel-Marcus (RRKM) theory. Collision theories of reaction rates, steric factors. Arrhenius equation, activated complex theory, Collision cross section and reaction cross section. Collision theory. Potential energy surfaces and reaction coordinate. Transition state theory. Kinetic theory of gases, transport properties in gases. Kinetics of reactions in solution, diffusion-controlled reactions, effect of solvent on rates of reactions, kinetic salt effect, homogeneous catalysis and heterogeneous catalysis.	**15 Hrs.**	**10**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

REFERENCES

1. D. A. McQuarrie, J. D. Simon, Physical Chemistry – a molecular approach, VivaBooks, 1998.
2. I. N. Levine, Physical Chemistry, 6th Ed., Tata-McGraw-Hill.2009.
3. F. Reif, Fundamentals of Statistical and Thermal Physics, Waveland Press,2009.
4. P. Atkins and J. Paula, Physical Chemistry, 10th Edition, Oxford University Press,Oxford 2014
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6. R. S. Berry, S. A. Rice and J. Ross, Physical Chemistry, 2nd Edition, Oxford University Press, Oxford, 2007
7. D. A. McQuarrie, Statistical Mechanics, University Science Books, California2005
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9. J. Rajaram, J. C. Kuriakose, Kinetics and Mechanisms of Chemical Transformations, Macmillan India, 2000
10. K. J. Laidler, Chemical kinetics, 3rdEdn. , Harper & Row, 1987
11. C. Kalidas, Chemical Kinetic Methods: Principles of Fast Reaction Techniquesand Applications, New Age International, 2005
12. J. W. Moore, R. G. Pearson, Kinetics and Mechanisms, John Wiley & Sons, 1981
13. P. W. Atkins, Physical Chemistry, 9th Edn, Oxford University press, 2010
14. D. A. McQuarrie, J. D. Simon, Physical chemistry: A Molecular Approach,University Sciencem Books, 1997
15. A. W. Adamson, A. P. Gast, Physical Chemistry of Surfaces, 6 th Edn., JohnWiley & sons, 1991.

	MAHATMA GANDHI UNIVERSITY **Introduction to Nanomaterials**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Introduction to Nanomaterials**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C62**

Course Summary & Justification	The emphasis of the course is to understand the chemistry of Nanomaterials in detail and to explore the wide application. Thiscourse provides research-focused teaching and training for post graduates wishing to develop a career in nano and functional materials. Students will gain an in-depth understanding of the principles governing nano and functional materials properties, behaviour and interactions. Also, this course aims to; • Understand and use the properties of Nano-materials in diverse fields. • Gain knowledge about the Nanomaterials, their properties, behaviour, interaction and use of them over many disciplines of science. • The emphasis of the course is to understand the physics of Nanomaterials in detail and to explore the wide application. • Highlights of the course is to provided virtual way of understanding the courses materials. Specially the application-based approach.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Understanding of Solid state (Undergraduate level).					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand and use the properties of Nano-materialsin diverse fields.	U	1,7
2	Gain knowledge about the Nanomaterials, their properties, behaviour, interaction and use of them overmany disciplines of science.	U, A	1,2
3	Understand the physics of Nanomaterials in detail andto explore the wide application.	U, R	1,3
4	Understand the constituents of matter, nanomaterials, properties and usefulness.	U	2,7
5	Able to learn how to understand the basic behaviour of Nanomaterials.	U	1,3
6	Understand size and shape dependent properties of Nanomaterials.	U, A	4,5
7	Gain knowledge about classification of Nanomaterials	U, An	1,3
8	Deep understanding on surface characteristics of Nanomaterials	U, A, An	1,2,3
9	Able to understand different surface energy minimization techniques.	U, A	4,6
10	Able to use the knowledge for higher study andresearch.	U, A	1,2,8
11	Able to explore the possible physics research, their applications in various fields	U	2,8,9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Fundamentals of Nanomaterials** History of Nanotechnology, Feynman's vision on Nano Science & technology, bulk vs nanomaterials. Basic principles of nanomaterial and its relation with properties. Central importance of nanoscale morphology - small things making big differences, nanotechnology as natures	**15 Hrs.**	**1,2,3,4,5**

	technology, clusters and magic numbers, nanoscale architecture. Recent developments, challenges and future prospects of nanomaterials. Examples of nanomaterials in daily life (Health care, energy materials etc.). Foundations of Quantum and Statistical Mechanics for nanomaterials, idea of tunneling, bound state and scattering. Quantum confinement; Properties dependent on density of states.		
2	**Size and shape dependent properties of nanomaterials** Size and shape dependent properties, Melting points and lattice constants, Surface Tension, density of states, Wettability - Specific Surface Area and Pore – Composite Structure - Mechanical properties, Optical properties: Basic principles of nanomaterials- Increase in surface area to volume ratio and quantum confinement effect. Surface plasmon resonance in metal nanoparticles and quantum size effect in in Semiconductors, Electrical conductivity: Surface scattering, change of electronic structure, quantum transport, effect of microstructure.	**15 Hrs**	**4,5,6**

3	**Classification of nanomaterials** Classification based on the dimensionality, Zero-dimensional nanostructures: metal, semiconductor and oxide nanoparticles. One-dimensional nanostructures: nanowires and nanorods, Two-dimensional nanostructures: Thin films, Three-dimensional nanomaterials, Special Nanomaterials: Carbon fullerenes and carbon nanotubes, micro and mesoporous materials, core-shell structures, organic-inorganic hybrids.	**15 Hrs.**	**1,2,4,7**
4	**Surface characteristics of Nanomaterials** Surface science for nanomaterials, surface energy, Surface Energy minimization: Sintering Ostwald ripening and agglomeration, Energy minimization by Isotropic and anisotropic surfaces, Wulff plot, Surface energy, surface curvature and chemical potential, Surface energy stabilization mechanisms, Electrostatic stabilization – Point zero charge (p.z.c), Nernst Equation, Electric double layer. Electric potential at the proximity of a solid surface - Debye-Huckel Screening strength. Interaction between nanoparticles – Van der Waals attraction potential, DLVO Theory, steric stabilization and electro steric stabilization. Nucleation and growth of nuclei, critical radius, homogenous and heterogeneous nucleation.	**15 Hrs.**	**1,2,8,9,10**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **C. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **D. Semester End examination**

REFERENCES

1. A.W. Adamson and A.P.Gast, Physical Chemistry of surfaces, Wiley Interscience,NY 2004.

2. G. Cao and Y. Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial CollegePress, 2004.

3. R. Kelsall, I. Hamley and M. Geoghegan, Nanoscale Science and Technology,Wiley, 2005.

4. K. J. Klabunde, R. M. Richards, Nanoscale Materials in Chemistry, 2nd Ed., Wiley,2009.

5. T. Pradeep, A text book of Nano Science and Technology, Tata McGraw-Hill Education, 2012.

6. G. Schmidt, Nanoparticles: from Theory to applications, Wiley-VCH, 2004

7. Malkiat S. Johal, Lewis E. Johnson, Textbook Series in Physical Sciences, CRCPress, Year: 2018

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9. Micheal F. Ashby, P.J. Ferreria, D.L. Schodek, Nanomaterials, Nanotechnologiesand Design: An introduction for engineers and Architects.2012.

10. Hornyak, G. Louis, Tibbals, H. F., Dutta, Joydeep, Fundamentals of Nanotechnology, CRC Press, 2009.

11. Dieter Vollath, Nanomaterials: An introduction to synthesis, properties andapplication, WILE-VCH, 2008.

12. . C. N. R. Rao, H. C. Mult. Achim Müller, A. K. Cheetham The Chemistry of Nanomaterials: Synthesis, Properties and Applications, 2004.

	MAHATMA GANDHI UNIVERSITY **Practical I - Inorganic Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Practical I - Inorganic Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C63**

Course Summary & Justification	The laboratory practical course enables the students to understand and apply the lab skills and laboratory safety procedures needed to carry out standard chemistry experimental techniques. This course will facilitate the students to apply the basic concepts of inorganic chemistry to analyze the metal ions in a given sample. Through this course the students will learn to (i) separate and identify cations in a given mixture (ii) estimate the metal ions using colorimetry (iii) perform complexometric titrations of metal ions with double burette method (iv) separate and estimate binary mixture of metal ions using combined volumetric and colorimetric methods and (v) tabulate and analyze the results of all the experiments systematically. This course will improve the analytical skill and critical thinking including observation, hypothesis development, measurement and data collection, experimentation, evaluation of evidence, and employment of mathematical analysis.					
Semester	**I**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total LearningHours
				40	40	80
Pre-requisite	The chemistry laboratory is a place of discovery and learning but at the same time it can be a place of danger if proper common-sense ofprecautions are not taken care. So the students are expected to learn and follow the general safety guidelines to ensure a safe laboratory environment. Also a basic knowledge on inorganic salt analysis, colorimetric estimations and complexometric titrations is preferred.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Perform basic chemical lab procedures by following appropriate lab safety measures & Infer the experimental results with mathematical and analytical reasoning.	U,C,I	3,5, 6,7
2	Separation and identification of the mixture of cations in a given sample	A,E, An, S	5,6,7
3	Estimation of the amount of metal ion present in the whole of the given solution colorimetrically	A, An,S	2,3
4	Preparation and characterization complexes using IR, NMR and electronic spectra	U, An, S,I	1,2,7
5	Develop the skills to carry out basic quantitative and qualitative analytical techniques	S,Ap	3,5,8
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Module No:	Module Content	Hrs	CO. No.
1	**Separation and identification of a mixture of four cations** A mixture of two familiar ions such as Ag+ , Hg^{2+}, Pb^{2+}, Cu^{2+}, Bi^{2+}, Cd^{2+}, As^{3+}, Sn^{2+}, Sb^{3+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+} , Mn^{2+} , $Co^{2+,}$ $Ni^{2+,}$ Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+}, Li^{+} , Na^{+} , K^{+} and $NH4^{+}$ and two less familiar metal ions such as Tl, W, Se, Mo, Ce, Th, Ti, Zr, V, U and Li), Anions which need elimination not to be given, Minimum eight mixtures to be given.	**15 Hrs.**	**1,2,5**
2	**Colorimetric estimation** of Fe, Cu, Ni, Mn, Cr, NH4+, nitrate and phosphate ions.	**10 Hrs.**	**1,3,5**

3	**Preparation and characterization complexes using IR, NMR and electronic spectra,** (a) Tris (thiourea)copper(I) complex (b) Potassium tris (oxalate) aluminate (III), (c) Hexammine cobalt (III) chloride, (d) Tetrammine copper (II) sulphate, (e) Schiff base complexes of various divalent metal ions, (f) Bis(dimethylglyoximato) nickel (II) (g) Prussian blue.	**15 Hrs.**	**4,5**

COURSE CONTENT

TeachingandLearningApproach	**Classroom Procedure (Mode of transaction)** **1.** Direct Instruction: Lecture, Explicit Teaching, E-learning **2.** Interactive Instruction:, Active co-operative learning, Authenticlearning
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** o Two internal tests o Lab skill o Attendance o Viva voce o Lab record **B. Semester End examination**

REFERENCES

1. A.I. Vogel, G. Svehla, Vogel's Qualitative Inorganic Analysis, 7th Edn, Longman,1996.
2. A. I. Vogel, A Text Book of Quantitative Inorganic Analysis, Longman. 1966.
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	MAHATMA GANDHI UNIVERSITY **Practical - Organic Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Practical II - Organic Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C64**

Course Summary & Justification	This course is designed to give the student an awareness about the safety measures to be taken in the lab, familiarizing the different glassware and equipments used, separation of the components present in the given binary mixture organic compounds using appropriate separation methods and analyzing the separated components using standard procedures. Students will learn how to apply common laboratory techniques to determine the structure, reactivity and analysis of organic compounds. Preparation of different organic molecules from simple molecules is also included in the course. They will become familiar with the nomenclature and behavior of organic functional groups through reactions and instrumental analysis. Characterisation of organic compounds by means of spectroscopic methods (IR, NMR and UV-Visible) are also included. Students will also be taught tools such as ChemDraw / Chemsketch which will be very handy in their future studies and career.					
Semester	**1**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
				40	40	80
Prerequisite	Basic knowledge in practical organic chemistry.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1.	To handle organic chemicals, glassware and precautions to be taken for safety in a chemistry lab	R, U, A	1,2,7
2.	To separate the components from a mixture using suitable methods and to analyze the components usingvarious reagents and reactions	U, A, An, S	3,4
3.	To perform experiments individually and to gain knowledge about principles and techniques involved invarious experiments	An, A, S, I	2,3
4.	To evaluate the properties of synthesized compoundsthrough spectroscopic and analytical data	E, An	1,2,5
5.	To analyze the mechanisms of the reactions in the experiment performed	An, U, E, S	2,3,4,6
6.	To characterize organic compounds by means of spectroscopic analysis techniques	R, U, A, An, S, Ap	2,3
7.	To demonstrate organic reaction schemes usingChemDraw / Chemsketch	U, A, C, S, I, Ap	1,2
Remember (R), Understand (U), Apply (A), Analyze (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Organic analysis** o Separation of two-component mixtures o Identification of individual components o Separation, Purification and analysis of the components o Preparation of their derivatives o Determination of physical constants of the components and its derivatives	**15 Hrs.**	**1, 2, 3,4**

2	Isolation of Natural Products and Its Purification o Thin Layer Chromatography o Column Chromatography o Solvent Extraction o Soxhlet Extraction	**15 Hrs.**	**4,5**
3	Characterisation of Compounds o Infra Red Spectroscopy o NMR Spectroscopy o UV-Visible Spectroscopy	**10 Hrs.**	**5,6**
4	o Multi step synthesis and characterizationof organic compounds o Drawing the reaction schemes using ChemDraw / Chemsketch.	**10 Hrs.**	**6,7**

Teachingand Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Library work, Tutorials, Demonstrations,Workshops, Virtual laboratory videos
Assessment Types	**Mode of Assessment** • Lab/Experiment skills • Lab record/Report • Viva-voce • Lab Discipline (participation, punctuality, accuracy)

References

1. A. I. Vogel, Elementary Practical Organic Chemistry, Longman, 1958
2. A. I. Vogel, A Textbook of Practical Organic Chemistry, Longman, 1974
3. R. M. Silverstein, G. C. Bassler, T. C. Merril, Spectrometric Identification of Organic Compounds, John Wiley & Sons, 1981
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	MAHATMA GANDHI UNIVERSITY **Chemistry of Natural Products**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc. Nanoscience and Nanotechnology**
Course Name	**Chemistry of Natural Products**
Type of Course	ELECTIVE
Credit Value	2
Course Code	**NSM22E45**
Course Summary & Justification	Learning this course will provide a strong foundation in natural products such as carbohydrates, proteins and peptides, fattyacids, nucleic acids, terpenes, steroids and alkaloids. Also provide knowledge about biogenesis of terpenoids and alkaloids. Students will be able to study the synthesis of a series of constituents such as camphor, atropine, papaverine, quinine, cyanin, quercetin, β-carotene, testosterone along with biosynthesis of PGE2 and PGF2α, structure of proteins, nucleic acids and methods for primary structure determination of peptides. This course aims to impart basic knowledge on the replication of DNA, flow of genetic information, protein biosynthesis, transcription and translation, genetic code, regulation of gene expression, DNA sequencing, The Human Genome Project, DNA profiling and the Polymerase Chain Reaction (PCR).
Semester	**I**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning	40	40	0	40	120
Pre-requisite	Basic knowledge about natural products and DNA					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	The student should be able to understand the natural products such as carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids.	R, U, E, C	1,2,3, 7
2	Understand the biogenesis of terpenoids and alkaloids	U, A, An, S	1,2,4, 7
3	Gather information about to the synthesis of a series of constituents such as camphor, atropine, papaverine, quinine, cyanin, quercetin, β-carotene, testosterone along with biosynthesis of PGE2 and PGF2α, structure of proteins, nucleic acids and methods for primary structure determination of peptides.	U,R	1,2,4, 6
4	Understand basic knowledge on the replication of DNA,flow of genetic information, protein biosynthesis, transcription and translation, genetic code, regulation of gene expression	U, An, E,S	1,2,3, 7,8
5	Able to understand DNA sequencing, The Human Genome Project, DNA profiling and the PolymeraseChain Reaction (PCR).	U,A, An, Ap	1,2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Natural products, Carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids, Biogenesis of terpenoids and alkaloids.	**15 Hrs.**	**1,2**
2	Syntheis: Synthesis of camphor, atropine, papaverine, quinine, cyanin, quercetin, β-carotene, testosterone, biosynthesis of PGE2 and PGF2α, 5. 3 Structure of proteins, nucleic acids and methods for primary structure determination of peptides (N-terminal - Sanger's method and Edmond's method; C-terminal - Akabora method and carboxy peptidase method).	**15 Hrs.**	**1,3**

3	Replication of DNA**,** flow of genetic information, protein biosynthesis, transcription and translation, genetic code, regulation of gene expression, DNA sequencing, The Human Genome Project, DNA profiling and the Polymerase Chain Reaction (PCR).	**15 Hrs.**	**4, 5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **E. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **F. Semester End examination**

References:

1. L Finar, Organic Chemistry, Volume 2: Stereochemistry and The Chemistry Natural Products, 5/E
2. W. Carruthers, I. Coldham, Modern Methods of Organic Synthesis, Cambridge University Press, 2004
3. A.L. Lehninger, D.L. Nelson, M.M. Cox, Lehninger Principles of Biochemistry, 5th Edn., W.H. Freeman, 2008
4. S.V. Bhat, B.A. Nagasampagi, M. Sivakumar, Chemistry of Natural Products, Narosa, 2005

	MAHATMA GANDHI UNIVERSITY **Green Synthesis**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Green Synthesis**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM22E46**

Course Summary & Justification	Learning this course will provide a thorough knowledge in the use of ultrasound Microwaves, N-alkylation and alkylation of active methylene compounds, Also provides idea about Diels-Alder reaction, deprotection of esters and silyl ethers and oxidation of alcohols and sulfides. Students will be able to understand structure, synthesis and applications of some important ionic liquids in organic synthesis of ionic-liquid. It will help the students to learn about polymer supported reagents in organic synthesis and advantages of polymer supported reagents. Synthesis of oligosaccharides, Dieckmann cyclisation, polymer supported catalytic reactions also discussed in this course. The course will also provide a deep awareness on phase transfer catalysis and reactions and their advantages, crown ethers synthesis and cation deactivation reactions. It will impart a foundational knowledge of the different types of reactions in organic synthesis: Passerini-Ugi, Hantzsch, Biginelli, Doebner-Miller, Ritter, Jacobson, Betti, Robinson-Schopf, Barbier, Baylis-Hillman, Ivanov and Suzuki coupling reaction.

Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning	40	40		40	120
Pre-requisite	Basic knowledge about different organic compounds.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the use of ultrasound and microwaves inorganic synthesis, Diels-Alder reaction, deprotection of esters and silyl ethers, oxidation of alcohols and sulfides	U,A, E	1,2,7
2	The student should be able to understand the structure, synthesis and applications of some important ionic liquids in organic synthesis.	U,R, A	1,2
3	Understand properties of polymer support, advantages of polymer supported reagents, synthesis of polymer boundper acid and its Applications	U,R	1,2,5,6
4	To understand the polymer supported catalytic reactions and application in etherification and acetal formationreactions	U, A,Ap,E,I	2,3,7
5	Gather information about mechanism of phase transfer catalysis, types of phase transfer catalysts and reactions and their advantages.	U,R,A,An	2
6	Able to understand the general synthesis of crown ethersand synthetic applications	U,A,S	2,3,6
7	To study multi-component Reactions such as Passerini-Ugi, Hantzsch, Biginelli, Doebner-Miller	U, A, An	1,2,4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Use of ultrasound and Microwaves in Organic Synthesis** Use of ultrasound: Introduction, instrumentation, the phenomenon of cavitation., Sonochemical-esterification, substitution, addition, alkylation, oxidation, reduction and coupling reactions. Use of Microwaves: Introduction, concept, reaction vessel/medium, specific effects, atom efficiency (% atom utilization), advantages and limitations. N-alkylation and alkylation of active methylene compounds, condensation of active methylene compounds with aldehydes and amines. Diels-Alder reaction. Deprotection of esters and silyl ethers. Oxidation of alcohols and sulfides.	**15 Hrs.**	**1,2**

2	**Ionic-liquids**: Introduction, structure, synthesis and applications of some important ionic liquids in organic synthesis. **Polymer supported reagents in organic synthesis** Introduction- properties of polymer support, advantages of polymer supported reagents and choice of polymers. Applications: Substrate covalently bound to the support: Synthesis of oligosaccharides, Dieckmann cyclisation. Preparation of polymer bound aldehyde and application in aldol reactions. Synthesis of polystyryl boronic acid and use in diol protection reaction. Reagent linked to a polymeric material: Preparation of sulfonamide polymer and application in diazo transfer reaction. Synthesis of polymer bound per acid and its applications.Polymer supported catalytic reactions: Preparation of polymer supported AlCl3 and application in etherification and acetal formation reactions.	**20 Hrs.**	**2,3,4**
3	**Phase transfer catalysis and Crown ethers** Phase transfer catalysis: Introduction, definition, mechanism of phase transfer catalysis. Types of phase transfer catalysts and reactions and their advantages. Preparation of catalysts and their application in substitution, elimination, addition, alkylation, oxidation and reduction reactions. Crown ethers: Introduction, nomenclature, features, nature of donor site. General synthesis of Crown ethers. Synthetic applications: Alkylation, generation of carbenes aromatic substitution and displacement reactions. Generation and application of superoxide anions. Cation deactivation reactions.	**15 Hrs.**	**5,6**

4	**Multi-component Reactions** Studies on the mechanistic aspects and applications of the following reactions in organic synthesis: Passerini-Ugi, Hantzsch, Biginelli, Doebner-Miller, Ritter, Jacobson, Betti, Robinson-Schopf, Barbier, Baylis-Hillman, Ivanov and Suzuki coupling reaction.	**10 hrs.**	**7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

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2. Organic Synthesis-R.E.Ireland (Prentice Hall India), 1969.
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5. Modern Methods of Organic Synthesis-N.Carruthers(Cambridge University), 1996.

MAHATMA GANDHI UNIVERSITY

Polymer Chemistry

School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Polymer Chemistry**
Type of Course	**Elective**
Credit Value	2
Course Code	**NSM22E47**

Course Summary & Justification	Polymer chemistry is a distinctive topic in chemistry having many inter as well as multidisciplinary components. This course is designed as an interdisciplinary course that includes fundamental as well as in-depth knowledge of the polymer science. The syllabus has been designed to cover the fundamental understanding of different fields of polymer chemistry with special emphasis on polymer synthesis and related topics thereby enable the students to work in frontier areas of polymer sciences. This comprises of the history of polymer science and its relevance in the development of human civilization. The syllabus covers the significance polymer molecular weight and its relation with structureand property of various polymers. This course also covers detailed study of the polymerisation reactions and techniques for polymer synthesis. This course further offers an awareness and understanding of the contemporary trends and growth in the field of polymer science. After thecompletion of this course, students will be able to understand the basics associated with polymer materials and the method/mechanism of its synthesis.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Lectures, Group discussions, Seminars, Independant Learning etc..	40	40	0	40	120
Pre-requisite	Understanding of Organic Chemistry (Undergraduate level).					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To Acquire a sound knowledge about the fundamentals and importance of Polymer chemistry.	R, U, An	1,2, 3,7
2	To compare and correlate various polymerization reactions and techniques.	U, A, An	1,2, 3
3	To understand the peculiarities of polymer molecular weight and various determination techniques.	U, A	1,2
3	To Correlate the structure and property relationship in polymeric materials.	An,S	1,4, 5
	To outline the basic concepts of thermal transitions in polymers and the determination methods for it.	U, A, An	1,2, 3
5	To understand and explore properties and advance applications of different polymers in diverse areas.	U, A, An, E,C, I	1,2, 3,6, 7,8, 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Concept of polymer & macromolecules, definition, functionality, classification of polymers. Polymerization reactions: Addition (free radical polymerization reaction, anionic and cationic polymerization, coordination polymerization, Ziegler Natta polymerization) and Condensation polymerization, Co-polymerization. Polymerization techniques: Bulk, solution, suspension, emulsion polymerizations, melt and interfacial polycondensations.	**15 Hrs.**	**1, 2**
2	**Concept of molecular weight of polymers**: number average, weight average, Z average and viscosity average molecular weight, molecular weight distribution and polydispersity index (PDI). Determination of molecular weight of polymers: Light scattering technique, Membrane Osmometry, Gel permeation chromatography (GPC), viscometry, etc.	**15 Hrs.**	**3, 4**

3	Crystalline and amorphous polymers, Factors affecting crystallinity and chain flexibility of polymers. Effect of Crystallinity on the properties of polymers. Thermal transitions in polymers: Glass transition temperature (T_g) and crystalline melting points (T_m), Factors affecting Glass transition temperature, methods to determine T_g and T_m: DSC, TMA, DMA etc.	**15 Hrs.**	**4**
4	Properties and Applications of: Specialty Polymers, Poly electrolytes, ionomers (ion containing polymers), conducting polymers, electroluminescent polymers, fluoropolymers, polymer colloids, thermoplastic elastomers (TPE), polymer blends (heterogeneous plastics), thermally stable polymers, biomedical polymers.	**15 Hrs.**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning,Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

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SEMESTER 2

	MAHATMA GANDHI UNIVERSITY
	Advanced Quantum Mechanics and Group Theory
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Advanced Quantum Mechanics and Group Theory**
Type of Course	**Core**
Credit Value	**4**
Course Code	**NSM22C65**

Course Summary & Justification	This course aims to equip students with advanced knowledge of quantum mechanics necessary to conduct research and understand literature. This course introduces basic concepts of molecular symmetry and group theory in detail. Further it also discuss different aspects of advanced chemical dynamics.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		50	60	0	30	140
Pre-requisite	Quantum theory, statistical mechanics, thermodynamics (Undergraduate level). Strong mathematical skill in Differential Equations and Linear Algebra.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Explain the application of Schrodinger equation to rotational and vibrational model systems	U	1,2, 3,4
2	Explain the approximation methods in quantum mechanics.	U, A	1,2
3	Describe the quantum mechanical explanation oforbitals and chemical bonding.	U, R	2,3
4	Describe advanced symmetry concepts of chemical molecules and its applications .	U, R, I,An	1,3,7
5	To identify the concept of axis , plane, center and the point group.	U	1,2
6	To describe product of symmetry operation and character table of chemical compounds.	U, A	2,3,4
7	Make use character table to predict the spectroscopic properties of the molecule	A, An, S, I	3,4
8	Understand and analyse macroscopic and microscopic kinetcs	U, An	1,2,7,8
9	Evaluate and understand theories of reaction rate-Collision theory and Transition state theory	U, A, E An	1,2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Quantum Mechanics-II Solution of Schrodinger equation to other model systems, vibrational motion of a particle, harmonic oscillator, rotational motion of a particle, rigid rotor, energy levels of harmonic oscillator and rigid rotor, angular momentum. Applications of Tunnelling effect. Schrödinger equation for the hydrogen atom-solutions, s-orbitals, p-orbitals, Beyond hydrogen atom, Schrödinger equation for Helium atom and ions.	**15 Hrs.**	**1,2,3**

2	Approximation methods, Born-Oppenheimer approximation, Variational methods, Self-consistent field method, Hartree-Fock equations, Perturbation theory. Post HF methods, electron correlation methods, configuration interaction methods, Density functional theory methods (DFT). Bonding in polyatomic molecules molecular orbitals, molecular orbital theory for different diatomic molecular systems, Valence bond treatment for chemical bonding in molecules, Hückel molecular orbitals, concept of basis functions, Slater type orbitals (STO) and Gaussian type orbitals (GTO).		
3	**Molecular Symmetry and group Theory** Determination of point groups of molecules and ions (organic / inorganic / complex) belonging to Cn, Cs, Ci, Cnv, Cnh, C∞v, Dnh, D∞h, Dnd, Td and Oh point groups. Crystallographic point groups (no derivation), Hermann Mauguin symbols, Screw axis-pitch and fold of screw axis, glide planes, space groups (elementary idea only).Properties, Abelian groups, cyclic groups, sub groups, similarity transformation, classes - C2v, C3v and C2h, Group multiplication tables (GMTs) - C2v, C3v and C2h, isomorphic groups, Matrix representation of elements like E, Cn, Sn, I, σ-matrix representation of point groups like C2v, C3v, C2h, C4v - trace /character, block factored matrices. Standard reduction formula, statement of great orthogonality theorem (GOT), construction of character tables for C2v, C2h, C3v and C4v.	**15 Hrs.**	**4,5**

4	**Application of Group Theory in Chemical bonding and Spectroscopy** Application in chemical bonding: Projection operator, transformation properties of atomic orbitals, construction of symmetry adapted linear combination of atomic orbitals (SALCs) of C2v, C3v, D3h and C2h molecules. Applications in vibrational spectra: transition moment integral, vanishing of integrals, symmetry aspects of molecular vibrations. Determination of the symmetry of normal modes of C2v,C3v and C2h point groups using Cartesian coordinates and internal coordinates. Complementary character of IR and Raman spectra determination of the number of active IR and Raman lines in Td, Oh and Square planar complexes.	**15 Hrs.**	**6,7**
5	**Chemical Dynamics-II** Macroscopic and microscopic kinetics, Review of theories of reaction rate-Collision theory and Transition state theory, Comparison of collision theory with transition state theory,Arrhenius equation- characteristics, Significance of energy of activation, Temperature coefficient and its evaluation. Thermodynamical formulation of reaction rates (Wyne-jones and Eyring treatment), Reaction between ions in solutions – Influence of ionic strength on reaction rates (primary and secondary salt effects).Kinetics of homogeneous catalysis-kinetics of auto catalytic reactions, kinetics of acid-base catalyzed reactions. Comparison of enzyme catalyzed and chemical catalyzed reactions, Mechanism (Lock and Key theory), Kinetics of enzyme catalyzed reactions – Henri-Michaelis- Menten mechanism, Significance of Michaelis-Menten constant, Lineweaver-Burk plot. Effect of enzyme concentration, pH, Temperature, Activators and Inhibitors on enzyme activity.Theories of uni-molecular reactions: Lindemann theory, and Hinshelwood theory.Surface reactions-Unimolecular and biomolecular surface reactions: mechanism, inhibition and activation energy.	**15 Hrs.**	**8,9**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

REFERENCES

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2. P.W. Atkins, R.S. Friedman, Molecular Quantum Mechanics, 4 th Edn., Oxford University Press, 2005.
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4. R. Anatharaman, Fundamentals of Quantum Chemistry, Macmillan India, 2001.
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	MAHATMA GANDHI UNIVERSITY **Organic Chemistry II – Organic Synthesis and Reaction Mechanism**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Organic Chemistry II – Organic Synthesis and Reaction Mechanism**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C66**

Course Summary & Justification	Starting from the very basic ideas, and moving towards the classification using different approaches, this course deals with advanced organic reaction mechanisms. The course guides through the involvement of reactive intermediates, their structure and reactivity through various organic reactions, as well as the basic concepts in molecular rearrangement reactions. The course is designed to acquaint the students with a detailed knowledge of physical organic chemistry, and ensures the students to understand and acquire knowledge on pericyclic reactions and name reactions, and their further applications in organic synthesis.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Prerequisite	Basics of organic chemistry, stereochemistry, reaction mechanismsand pathways					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1.	To revise and analyse the role of reactive intermediatessuch as carbocations, carbanions and non-classical carbocations in chemical reactions	R, U, An	1,2,7
2.	To assess the reactivity patterns of enolates and their mechanisms	A, An	2,3,5
3.	To synthesize molecules using popularly named reactions	A, C, S	1,2,4
4.	To describe reaction mechanisms in terms of energetics, reaction kinetics, and thermodynamics	An, E	2,3,7
5.	To predict suitable reaction conditions to carry outorganic reactions	E, C, S	1,3,6
6.	To have a thorough knowledge about catalysis by acids, bases and nucleophiles	U, I, S, Ap	1,2,6
7.	To learn basic concepts of pericyclic reactions	U, I, R	1,2,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Organic Reaction Mechanisms 2 Formation, structure and stability of carbanions; Reactions of carbanions: C-X bond (X = C, O, N) formations through the intermediary of carbanions. Chemistry of enolates and enamines. Aldol and Michael reactions, alkylation and acylation of enolates. Nucleophilic additions to carbonyls groups: Name reactions under carbanion chemistry-mechanism of Claisen, Dieckmann, Knoevenagel, Stobbe, Darzen and acyloin condensations, Shapiro reaction and Julia olefination. Favorskii rearrangement. Ylides: Chemistry of phosphorus and sulphur ylides - Wittig and related reactions, Peterson olefination. Formation, structure and stability of carbocations. Classical and non-classical carbocations. C-X bond (X = C, O, N)	**15 Hrs.**	**1, 2**

	formations through the intermediary of carbocations. Molecular rearrangements including Wagner-Meerwein, Pinacol-pinacolone, Semipinacol, Dienone-phenol and Benzilic acid rearrangements, Noyori annulation, Prins reaction. C-C bond formation involving carbocations: Oxymercuration, Halolactonization.		
2	**Named reactions in Organic Chemistry** Reimer-Tiemann, Cannizzaro, Mannich, Demjanov and Mitsunobu reactions, Aldol condensation, Robinson annulation. Addition reactions: Addition of Grignard reagent, Michael addition Reduction reactions: Clemmensen, Wolf-Kishner, MPV Rearrangement reactions: Wolff, Hoffmann, Curtius, Lossen, Schmidt and Beckmann, Fries and Fischer-Hepp.	**15 Hrs.**	**3,4,**
3	**Physical Organic Chemistry** Energy profiles, Kinetic versus thermodynamic control of product formation, Hammond postulate, kinetic isotope effects with examples, Linear free energy relationships-Hammet equation, Taft equation. Catalysis by acids, bases and nucleophiles with examples from acetal, cyanohydrin, Ester formation and hydrolysis reactions of esters - $A_{AC}2$, $A_{AC}1$, $A_{AL}1$, $B_{AC}2$ and $B_{AL}1$ mechanisms, Hard and soft acids, bases - HSAB principle and its applications (organic reactions only)	**15 Hrs.**	**5,6**
4	**Pericyclic reactions** Introduction to pericyclic reaction, Cycloaddition and Diels –Alder reactions, Electrocyclic reactions, Sigmatropic reactions, Chelotropic reactions. Thermal and photochemical pericyclic reactions, Conrotation and disrotation; Electrocyclic closure and opening in 4n and 4n+2 systems. Woodward-Hoffmann selection rules for electrocyclic reactions. Explanation for the mechanism of electrocyclic reactions and examples. Cycloaddition reactions: Suprafacial and antarafacial	**15 Hrs.**	**7**

	interactions. 2π + 2π and 4π + 2π cycloadditions. Diels-Alder reaction, Woodward-Hoffmann selection rules for cycloaddition reactions and examples. Mechanism by orbital symmetry correlation diagrams, Fukui Frontier Molecular Orbital (FMO) theory. Endo-exo selectivity in Diels-Alder reaction and its explanation by FMO theory. Sigmatropic reactions: mechanism of sigmatropic reactions, Cope and Claisen rearrangements.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, Interactive instruction: Active co-operative, Presentation by individual student
Assessment Types	**Mode of Assessment** • **Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar • **Semester End examination**

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1) R. Bruckner, Advanced Organic Chemistry: Reaction Mechanism, AcademicPress, 2002.

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	MAHATMA GANDHI UNIVERSITY **Inorganic Chemistry II - Organometallics and Bioinorganic chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Inorganic Chemistry II - Organometallics and Bioinorganic chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C67**

Course Summary & Justification	This course introduces the basic concepts of organometallic chemistry with emphasis on transition metal complexes. The students will understand the structure and bonding of organometallic complexes bearing various σ-bonded and π-bonded ligands. They will learn about the unique reactions shown by organometallic compounds and its mechanism. This course highlights the application of organometallics in catalysis that is industrially important This course provides the students a detailed knowledge on fundamental aspects of the bioinorganic chemistry. The students will understand the role of metal ions and inorganic complexes in biologicalprocesses. They will learn about metal toxicity as well as the application of inorganic complexes as therapeutics. This course will give a strong foundation to carry out research on metalloenzyme applications, inorganic biomaterials and pharmaceutical development.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	0	40	120
Pre-requisite	Basic knowledge in Inorganic Chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the fundamental concepts of organometallic complexes such as 18 electron rule.	U, R, I	1,3,7
2	Explain and rationalize the structure and bonding of organometallic compounds with σ- and π-bonded ligands	U, R,A	1,3,7
3	Apply spectroscopic techniques to characterize organometallic compounds	U, R, A	1,2,6
4	Identify the fundamental reactions of organometallic compounds and its mechanism.	U, An	1,2,7
5	Describe the application of organometallics in catalysis	U, I	1,7
6	Apply the basic principles in inorganic and general chemistry to bioinorganic chemistry.	U, A, An	1,2,3
7	Understand the importance of metals in biologicalsystems.	U,R, S,E	2,3
8	Remember the structure and functions of metalloproteins and metalloenzymes	U, R	3,4
9	Explain the role of metal ions which are involved in electron transfer reactions in biological systems.	U, E,S	4,6
10	Identify the metal centers involved in oxygen transport in living organisms and comprehend the mechanism of this process.	U, R,A, An	1,7
11	Understand the biological role of Iron, copper, zincand molybdenum	U, R, I	1,2,7

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Reactions of Organometallic Compounds-Synthesis, Structure and Bonding, Haptonomenclature of organometallic compounds, organometallic compounds	**20 Hrs.**	**1,2,3,4**

	with linear pi donor ligands-olefins, acetylenes, dienes and allyl complexes-synthesis, structure and bonding, Synthesis and structure of complexes with cyclic pi donors, metallocenes and cyclic arene complexes, bonding in ferrocene and dibenzene chromium, carbene and carbyne complexes, Metal carbonyls: CO as a π-bonding ligand, synergism, preparation, properties, structure and bonding of simple mono and binuclear metal carbonyls, metal nitrosyls, metal cyanides and dinitrogen complexes, Polynuclear metal carbonyls with and without bridging, Carbonyl clusters-LNCCS and HNCCS, Isoelectronic and isolobal analogy, Wade-Mingos rules, cluster valence electrons, IR spectral studies of bridging and non-bridging CO ligands. Substitution reactions: Nucleophilic ligand substitution, nucleophilic and electrophilic attack on coordinated ligands, Addition and elimination reactions-1,2 additions to double bonds, carbonylation and decarbonylation, Oxidative addition- concerted addition, SN2, radical and ionic mechanisms, Reductive elimination- binuclear reductive elimination and σ-bond metathesis, Oxidative coupling and reductive decoupling, Insertion (migration) and elimination reactions – insertions of CO and alkenes, insertion into M−H versus M−R, α, β, γ and δ eliminations, Redistribution reactions, fluxional isomerism of allyl, cyclopentadienyl and allene systems.		
2	**Catalysis by Organometallic Compounds,** Homogeneous and heterogeneous organometallic catalysis: Tolman catalytic loops, alkene hydrogenation using Wilkinson catalyst, Reactions of carbon monoxide and hydrogen-the water gas shift reaction, the FischerTropsch reaction (synthesis of gasoline), Hydroformylation of olefins using cobalt and rhodium catalysts, Polymerization by organometallic initiators and templates for chain propagation Ziegler Natta catalysts, polymerisation by	**20 Hrs.**	**5, 6**

	metallocene catalysts, arbonylation reactions: Monsanto acetic acid process, olefin hydroformylation- oxo process, carbonylation of alkenes and alkynes in the presence of a nucleophile- the Reppe reaction, Carbonylation of aryl halides in the presence of a nucleophile. photodehydrogenation catalyst ("Platinum Pop"), Oxidation of olefins: Palladium catalyzed oxidation of ethylene-the Wacker process, epoxidation of olefins, hydroxylation by metal-oxo complexes, Asymmetric catalysis- Asymmetric hydrogenation, isomerization and epoxidation, C-H activation and functionalization of alkanes and arenes: Radicaltype oxidation, hydroxylation, dehydrogenation, carbonylation and regioselective borylation of alkanes and cycloalkanes, Radicaltype reactions, electrophilic reactions, carbonylation and borylation of arenes,		

3	**Bioinorganic Compounds,**Essential and trace elements in biological systems, toxic effects of metals (Cd, Hg, Cr,Pband As), structure and functions of biological membranes, mechanism of ion transport across membranes, sodium pump, ionophores, valinomycin, Phosphate esters in biology, Redox metalloenzymes, cytochromes-cytochrome P450, Oxygen carriers and oxygen transport proteins: Structure and functions of haemoglobins and myoglobin, oxygen transport mechanism, cooperativity, Bohreffect, Structure and functions of haemerythrinsandhaemocyanin, Biochemistry of zinc and copper: Structure and functions of carbonic anhydrase, carboxypeptidase A and superoxide dismutase	**10 Hrs.**	**7, 8,9**
4	**Other important metal containing biomolecules:** Vitamin B12 and the vitamin B12 coenzymes, photosynthesis-chlorophyll a, PS I and PS II, Role of calcium in muscle contraction, blood clotting mechanism and biological calcification, Metals in medicine-therapeutic applications of cis-platin, radioisotopes and MRI agents.	**10 Hrs.**	**10, 11**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation byindividual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** o Internal Test – MCQ based and descriptive answer type o Seminar Presentation – the students will be given individual topics for seminar presentation o Assignments o Quizzes **B. Semester End examination**

REFERENCES

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11. J.E. Huheey, R.A. Keiter, R.L. Keiter, Inorganic Chemistry-Principles of Structure and Reactivity, 4th Edn., Prentice Hall, 1997.
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	MAHATMA GANDHI UNIVERSITY
	Spectroscopic Methods in Chemistry
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Spectroscopic Methods in Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C68**

Course Summary & Justification	Over the last few decades, spectroscopic techniques have grown into a vital instrument for chemical analysis, structure determination, and the study of dynamics in organic, inorganic, material science, and biological systems. Spectroscopic techniques are widely used to correctly investigate the chemical structure of an analyte. In each spectroscopic mathods (eg. UV-Vis, IR, microeave, NMR, Mass, ESR etc.) the electromagnetic radiation is allowed to interact with the molecule. The electric and magnetic property of the radiation is interacted with the atomic, molecular, and structural properties of the substance. Hence, the analyte is identified and characterized for the presence of atoms, bonds, functional groups, basic nucleus, nuclear spin, electron spin, molecular formula, and molecular weight.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basic knowledge about the interaction of electromagnetic radiation with matter involving either absorption, emission, or scattering of radiation.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Elucidate the structure of an unknown organic compoundusing data from various spectroscopic techniques.	U,A	1,2,7
1	Basic principles of spectroscopy, interaction of electromagnetic radiation with matter, atomic and molecular spectroscopy	U	3,4,5
2	Selection rules and allowed transitions, factors effecting the molecular and electronic transitions	U,A	3,4
3	Different laws and principles like Beer-Lamberts Law, Frank-Condon principle, Woodward-Fieser rules, Raman Effect, Mössbuer effect etc	U,R	1,2,7
4	Understand the basics of UV-Visible spectroscopy Learn to derive structural information from the UV-Vis.Spectra of various molecules Understand the applications of this UV technique for various purposes.	U	4,5,6
5	Become aware of starching and banding of various bonds.Understand the role of Vibrational spectroscopy in functional group identification. Interpretation of organic and inorganic compounds using IR spectra.Characterization of various molecules.	U	4,5,6
6	Understand the role of Raman spectroscopic techniques for the characterization of materials Learn the applications of Raman spectroscopy.	U,A	4,5,6
7	Understand the basic principle of NMR spectroscopy,able to interpret the NMR spectrum of organic compounds.	U, An	2,3,4,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Foundations of Spectroscopic Techniques and Electronic Spectroscopy** Electromagnetic radiation, interaction of electromagnetic radiation with matter, intensity of absorption, influencing factors, signal to noise ratio, natural line width, contributing	**15 Hrs.**	**1,2**

	factors, Doppler broadening, lamb dip spectrum. Regions of the electromagnetic radiation, origin of spectrum, Jablonski diagram, intensity of absorption, transition probabilities, Born Oppenheimer approximation. Term symbols of diatomic molecules, selection rules, vibrational coarse structure and rotational fine structure of electronic spectrum, Franck-Condon principle, predissociation, Factors influencing the Electronic Spectroscopy. Application in uv-visible spectroscopy, Woodward-Fieser rules, calculation of heat of dissociation, Birge and Sponer method, Electronic spectra of polyatomic molecules.		
2	**Infrared and Raman Spectroscopy** Morse potential energy diagram, fundamental vibrations, overtones and hot bands, determination of force constants, Factors influencing the vibrational frequency, Vibrations in simple molecules (H_2O, CO_2) and their symmetry notation for molecular vibrations – combined uses of IR and Raman spectroscopy in the structural elucidation of simple molecules. Vibrational spectra of polyatomic molecules, normal modes of vibrations, combination and difference bands, Fermi resonance, FT technique, introduction to FTIR spectroscopy, scattering of light, polarizability and classical theory of Raman spectrum, P, Q, R branches, rotational and vibrational Raman spectrum, complementarities of Raman and IR spectra, mutual exclusion principle, polarized and depolarized Raman lines, resonance Raman scattering and resonance fluorescence. Lasers-Different types of lasers-solid state lasers, continuous wave lasers, Nd:YAG and semiconductor lasers, gas lasers – helium-neon, argon ion and N_2 lasers, frequency doubling, harmonic generation, applications of lasers. Applications of lasers in spectroscopy: two photon and multiphoton absorption, femtosecond spectroscopy.	**15 Hrs.**	**3,4**

3	Microwave, ESR, and Mass Spectroscopy Principal moments of inertia and classification (linear, symmetric tops, spherical tops and asymmetric tops), selection rules, intensity of rotational lines, relative population of energy levels, derivation of Jmax, effect of isotopic substitution, calculation of intermolecular distance, spectrum of non-rigid rotors, Rotational spectra of polyatomic molecules, linear and symmetric top molecules, Stark effect and its application, nuclear spin and electron spin interaction, chemical analysis by microwave spectroscopy. Elementary idea about Mass and ESR spectrometry, interpretation of data and solving problems with spectroscopic techniques.	**15 Hrs.**	**5, 6**
4	**NMR Spectroscopy:** 1H NMR, Spectral parameters – intensity, chemical shift, multiplicity, coupling constant, factors affecting chemical shift, characteristic chemical shifts of common organic compounds and functional groups. Analysis of first order and second - orderspectra – shift reagents - structure determination of organic compounds by 1H NMR spectra. Classification of molecules. (AB, ABX, AMX, ABC, A2B2 etc. types), spin decoupling. Chemical shifts and coupling constants (spin-spin coupling) involving different nuclei (1H, 13C).	**15 Hrs.**	**7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

REFERENCES

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2. Lampman, G. M.; Pavia, D. L.; Kriz, G. S.; Vyvyan, J.R., Spectroscopy, 4 th Ed., Cengage Learning (2010).
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7. Nakamoto, K., Infrared and Raman Spectra of Inorganic and Coordinationcompounds, Wiley-Interscience, New York (2008).
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	MAHATMA GANDHI UNIVERSITY
	Design, Synthesis and fabrication of nanomaterials
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Design, Synthesis and fabrication of nanomaterials**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22E69**

Course Summary & Justification	The course should give a basic introduction to chemical and physical principles in the synthesis of inorganic nanostructured materials. In addition, basic principles of finite size effects as well as fundamental physical and chemical properties of nanomaterials will be covered. The course discusses the kinetics of nucleation and growth of nanoparticles. Mechanism for nucleation and crystal growth along with strategies to control particle size (distribution) also be discussed. The course will also cover different methods for synthesis and characterization of different nanostructures and nanostructured bulk materials. By the end of the course, students will understand the fabrication, characterization, and manipulation of nanomaterials. This course describes the most recent advances in the synthesis, fabrication and characterization of nanomaterials. Topics to be covered: zero-dimensional materials, including nanoparticles, quantum dots and nanocrystals; one-dimensional materials including nanowires and nanotubes; two-dimensional materials including self-assembled monolayers, patterned surfaces and quantum wells etc.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Understanding of Solid state (Undergraduate level), Basics of Introduction to Nanomaterials and general knowledge in chemistry, physics and material science.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	At the end of the course the students should; Describe different mechanisms for nucleation and growth of amorphous and crystalline nanoparticles in relation to the thermodynamic driving force and effective parameters.	U	1,7
2	Quantify nucleation and growth rates for nanoparticles.	U, A	1,2,7
3	Suggest ways of controlling particle size, particle size distribution and morphology based on changes in important system parameters and choice of method.	U, R	1,3,7
4	Understand how surface functionalization can alter end use/applications of nanomaterials	U	1,2,3
5	Understand the fundamentals of characterization techniques most frequently used for studying nanostructures in solution, as well as nanoparticles and catalytic surfaces.	U	3,4,5, 6
6	Describe several synthesis methods for fabrication of inorganic nanoparticles, one-dimensional nanostructures (nanotubes, nanorods, nanowires), thin films, nanoporous materials, and nanostructured bulk materials.	U, A	4,5,6
7	Describe how different lithography methods can be usedfor making nanostructures.	U, An	4,5,6
8	The student should have a theoretical background within synthesis/fabrication of nanomaterials which makes he/she prepared for later literature studies and laboratory work within the field.	U, A, An	4,5,6, 7
9	Perform simple geometric calculations of surface energy, coordination number, and volume fraction related to nanoscale properties and synthesis, and alsosimple chemical calculations related to synthesis	U, A	4,5,6, 7
10	Use the acquired knowledge to evaluate which synthesis methods that can be best suited for fabricating nanostructured materials of various inorganic compounds (metals, semiconductors, oxides, fullerenes) and constructions of these materials.	U, A	3,4,5
11	Consider the basic ethical, health-related and environment-related concerns encountered with respect to nanoparticles and nanomaterials in general, with special emphasis on sustainability.	U	1,2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Fabrication of nanostructures** Bottom-up approaches for nanostructure fabrication: - Self-assembly, Top-down approaches for nanostructure fabrication- Lithography- Photolithography, Phase-shift photolithography Laser lithography. Nanomanipulation and Nanolithography- SPM based lithography (AFM & STM) & nanomanipulation.	**15 Hrs.**	**1,2,3**
2	**Zero-Dimensional Nanostructures: Nanoparticles** Nanoparticles through Homogeneous Nucleation, Synthesis of metallic nanoparticles, Synthesis of semiconductor nanoparticles, Synthesis of oxide nanoparticles, Vapor phase reactions. Heterogeneous Nucleation and Growth- Kinetically Confined Synthesis of Nanoparticles, Synthesis inside micelles or using microemulsions, Aerosol synthesis, Growth termination, Spray pyrolysis, Template-based synthesis, Epitaxial Core-Shell Nanoparticles.	**15 Hrs.**	**4,5,6**

3	**One dimensional and Two-dimensional nanostructures** Nanowires and Nanotubes: Spontaneous growth; Evaporation- condensation - Vapor- liquid - solid (VLS) - surface and bulk diffusion – kinetics – growth of various nanowires –control of size –precursors and catalysts - single- and multiwall CNT - Si nanowires – density and diameter – doping in nanowires. 2-D nanostructures- Thin films, Physical vapour deposition (PVD)- evaporation, MBE, sputtering. Chemical Vapour Deposition (CVD)- kinetics, transport phenomena, CVD methods, Atomic layer Deposition (ALD).	**15 Hrs.**	**7,8**
4	**Synthesis and preparation of Nanomaterials** Synthesis of bulk nanostructured materials - Sol Gel processing- bulk and nano composite materials - Grinding - high energy ball milling – injection moulding - extrusion - melt quenching and annealing. Synthetic Technique (Physical and Chemical): Self-assembly -Self Assembled Monolayers (SAM) - Vapour Liquid Solid (VLS) approach - Chemical Vapour Deposition (CVD) - Langmuir-Blodgett (LB) films - Spin coating - Templated self-assembly Electrochemical approaches: Thin films -Epitaxy - Lithography.	**15 Hrs.**	**9, 10**

5	**Characterization Techniques of Nanomaterials - I** Basic principles and applications of UV-Vis-NIR, FTIR, FT-Raman, Photoluminescence, NMR, ESR and Light Scattering methods. X – ray techniques: X-ray powder diffraction –Quantitative determination of phases; Structure analysis, single crystal diffraction techniques - Determination of accurate lattice parameters - structure analysis-profile analysis - particle size analysis using Scherer formula- Particle Size Analyzer- Ellipsometry-thickness measurements. Electron Spectroscopy: X-Ray Photoelectron Spectroscopy, Auger Electron Spectroscopy, X-Ray Characterization of Nanomaterials – EDAX and WDA analysis – EPMA - Applications to nanomaterials characterization.	**15 Hrs.**	**10, 11**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **C. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **D. Semester End examination**

REFERENCES

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial college Press, (2006).
2. An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, Kazutoshi Fujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005
3. Springer Handbook of Nanotechnology - Bharat Bhushan· Publisher: Springer- Verlag (15 May 2006)
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Horn yak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008).

MAHATMA GANDHI UNIVERSITY

Practical III - Synthesis and characterization of Nanomaterials

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Practical III - Synthesis and characterization of Nanomaterials**
Type of Course	**Practical**
Credit Value	3

Course Code	**NSM22C70**

Course Name	Synthesis and characterization of different Nanomaterials					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		0	0	40	40	80
Pre-requisite	Basic knowledge in practical chemistry (Undergraduate level).					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	To Acquire sound knowledge about the fundamentals and importance of Nanomaterials.	R, U, An	3,4,5
2	To compare and correlate various Nanomaterialssynthesis techniques.	U, A, An	1,3,4,5,6 ,7
3	To learn the handling of different chemicals (for nanomaterial synthesis), glassware, and precautionsto be taken for safety in a chemistry lab	R, U, A	3,4,5
4	To learn the synthesis of different nanomaterials(bio-based nanomaterials, green synthesis of nanomaterials, etc.)	U, A, An, S	4,5
5	To perform experiments individually and to gain knowledge about principles and techniques involvedin various experiments (nanomaterial synthesis)	An, A, S, I	5,6,7
6	To Acquire sound knowledge about the fundamentals and importance of different characterization techniques (chemical, morphological, thermal, electrical etc.) for Nanomaterials.	R, U, An	3,4
7	To compare and correlate various characterization techniques for Nanomaterials.	U, A, An	4,5
8	To learn the handling of different characterization techniques for Nanomaterials and precautions tobe taken for safety.	R, U, A	1,4,5,7

9	To learn the basic/ working principle of different characterization techniques for Nanomaterials.	U, A, An, S	1,4,5,7
10	To perform experiments (characterizations) individually and to gain knowledge about instrument operation and analysing of data.	An, A, S, I, Ap	3,4,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Extraction of Nanocellulose, Extraction of Nanochitin, Synthesis of different sized Ag nanoparticles by aqueous method, Synthesis of different sized Au nanoparticles by aqueous method, Chemical synthesis of CdSe Quantum dots with different sizes.	**20 Hrs.**	**1,3,4,5**
2	Sol-gel synthesis of ZnO nanoparticles, Green synthesis of ZnO nanoparticles, Coprecipitation synthesis of magnetic (iron oxide) nanoparticles, Synthesis of metal oxide nanotubes, Hydro/Solvothermal synthesis of metal oxide nanostructures of different morphology by varying parameters, Synthesis of SnO_2 nanostructures, Hydrothermal synthesis of TiO2 nanoparticles, Synthesis of Graphene and Graphene Oxide. Synthesis of carbon nanotube, Synthesis of nanosilica, Extraction of organic nanosilica.	**20 Hrs.**	**1,2,3,4,5**
3	Studies of (synthesized) different nanomaterials using: Optical microscope, Scanning electron microscope, transmission electron microscope, confocal laser scanning microscopy, and atomic forcemicroscope. Studies of different nanomaterials using X-ray diffraction, UV-visible spectroscopy, FT-IR spectroscopy,Nuclear magnetic resonance spectroscopy, Raman spectroscopy, absorption and emission Spectroscopy.	**20 Hrs.**	**1,2,3**
4	Characterization of different	**20 hrs.**	**4,5**

	nanomaterials using: Thermogravimetric analyser (TGA), differential scanning calorimetry (DSC), and Vibrating sample magnetometer.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Library work, Tutorials, Demonstrations,Workshops, Virtual laboratory videos
Assessment Types	**Mode of Assessment** • Lab/Experiment skills • Lab record/Report • Viva-voce • Lab Discipline (participation, punctuality, accuracy) • **Semester End examination**

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1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006). Publisher: World Scientific Publishing Company; 2 edition (4 January 2011) ISBN-13: 978-9814324557
2. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim(Federal Republic of Germany), 1998. Publisher: Wiley VCH (28 May 1998) ISBN-13: 978-3527294435
3. Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani, Springer-Verlag (2007). (For Unit III-Part I Chapter I)
4. PADINJAKKARA A, Scarinzi G, Santagata G, Malinconico M, Razal JM, Thomas S, Salim NV. Enhancement of Adhesive Strength of Epoxy/Carboxyl-Terminated Poly(butadiene-co-acrylonitrile) Nanocomposites Using Waste Hemp Fiber- Derived Cellulose Nanofibers. ACS Industrial & Engineering Chemistry Research.2020, 59, 23, 10904-10913. https://pubs.acs.org/doi/abs/10.1021/acs.iecr.0c01053
5. Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, ISBN-13: 978-81-203-3608-7.

6. Characterization of Materials Vol 1 &2, by Elton N. Kaufmann, John Wiley and Sons Publication, 2003. New Jersey.

7. Principles of instrumental analysis, Douglas A Skoog, Donald M West, Saunders College, Philadelphia. Publisher: Cengage; 6 edition (1 November 2014) ISBN-13: 978-81-315-25579.

8. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) ISBN-13: 978-0-07- 061788-9

9. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander, Publisher: Wiley-Blackwell; 2nd Revised edition edition (1 January 1974) ISBN-13: 978-0471493693

10. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter, Publisher: Springer; 1st ed. 1996. Corr. 6th printing edition (15 April 2005) ISBN-13: 978-0306453243

11. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton, Publisher: Springer; Softcover reprint of hardcover 1st ed. 2005 edition (12 October 2010) ISBN-13: 978-1441938374

12. Springer handbook of Nanotechnology ed. Bharat Bhushan (Springer), Publisher: Springer-Verlag (15 May 2006) ISBN-13: 978-3540343660

13. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998. Publisher: Wiley VCH (28 May 1998) ISBN-13: 978-3527294435

Supplementary/ Suggested reading

1. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) ISBN-13: 978-0-07- 061788-9

2. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008) ISBN-13: 978-1420047790

MAHATMA GANDHI UNIVERSITY

Analytical and Nuclear Chemistry

SchoolName	**School of Nanoscience and Nanotechnology**					
Programme	**M.Sc.**					
Course Name	**Analytical and Nuclear Chemistry**					
Type of Course	**Elective**					
Course Credit	**2**					
Course Code	**NSM22E48**					
Course Summary &Justification	This course essentially encompasses two components. The first component is the advanced course materials on general analytical chemistry instruments, operation, sampling and their applications. Here the some modern instruments which works under the principle of fluorescence are discussed in order to get an understanding on the present and future applications of these fluorescence microscopes in the field of medicine. In addition a concise discussion on specific sampling methods and titrations in non-aqueous media are also included as an application of analytical chemistry. In the second part nuclear reactions are discussed with an emphasis on nuclear activation techniques, light initiated and heat initiated reactions and their different outcome. Most common and complex nuclear interactions with matter are discussed in order to get an understandingon the synthetic utility of this technique while designing such processes. A special emphasis is given to the importance of nuclear medicine owing to its importance in cancer research, towards the endof the discussion. Therefore the second part basically gives an advanced know how on nuclear chemistry with an added stress on procedure and applications of nuclear radiations in the medical field.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Credit Value & Course Status	2	Elective Course				
Pre-requisite	Basic Inorganic Chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the methods used in sampling for various analytical methods.	U	1,2
2	Learn about the general instrumentation in thermalanalysis, chromatography and microscopy	U	1, 2
3	Identify the utility and specificity of each analytical instrument and will be in a position to generate and explain the output data from the analytical instruments.	An	1, 2, 3,7
4	Critically understand the nuclear reactions, methods of detection and quantification, the scope and limitations of nuclear reactions	U	1, 2, 3
5	Evaluate the utility of fluorescence spectroscopy and nuclear radiation therapy for qualitative and quantitative methods of analysis particularly in medicine.	E	1, 2, 3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C),Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Preparation of sample for analysis, Errors and treatment of data, Solubility and solubility product, Common ion effect, Precipitation phenomena, Homogeneous precipitation, Organic reagents in inorganic analysis. Titrations in non-aqueous media, Potentiometry, Polarography, Amperometry, Bi-amperometry, Spectrophotometry, Flame photometry, Atomic absorption spectroscopy.	**15 Hrs.**	**1,2**
2	Principles of ion-exchange, Solvent extraction, Chromatographic techniques, Thermal method of analysis: Principles and applications of thermogravimetry (TG), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis (DMA). Applications of X-ray diffraction, Small angle X-ray scattering (SAXS), Scanning electron microscopy (SEM),	**15 Hrs.**	**1,3**

	Transmission electron Microscopy (TEM), Scanning probe microscopy (SPM).		
3	Nuclear Chemistry: Nuclear reactions fission and fusion, Spontaneous and induced fission, Q-value, Cross sections, Working of nuclear reactors, Fission energy, Transuranic, Applications of radioactivity, Carbon dating.	**15 Hrs.**	**3,4**
4	Radioactive techniques: Neutron activation analysis, Tracer techniques, GM counter, Interaction of high energy radiation with matter, Radiation chemistry of water, Aqueous solutions and organic compounds.	**15 Hrs.**	**1,4,5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** 1. Direct Instruction: Lecture, Explicit Teaching, E-learning 2. Interactive Instruction:, Active co-operative learning, Seminar/ Presentation by individual student, Assignments, Authentic learning, Quizzes
Assessment Types	**Mode of Assessment** A. Continuous Internal Assessment (CIA) • Internal Test – MCQ based and descriptive answertype • Seminar Presentation – the students will be given individual topics for seminar presentation • Assignments • Quizzes **B. Semester End examination**

References

01. A.I. Vogel, J. Mendhan, Vogel's Texbook of Quantitative Inorganic Analysis, 6thEdn.,

Prentice Hall, 2000.

02. D.A. Skoog, D.M. West, F.J. Holler, Fundamentals of Analytical Chemistry, 7thEdn., Sauders College, 1996.

03. W.W. Wendlandt, Thermal Analysis, 3rdEdn., Wiley, 1986.

04. G. Cao, Y.Wang, Nanostructures and Nanomaterials: Synthesis, Propertiesand Applications, World Scientific, 2010.

05. H.R. Arnikor, Essentials of Nuclear Chemistry, Wiley- Eastern, 1983.

	MAHATMA GANDHI UNIVERSITY
	Surface Chemistry and Catalysis
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Surface Chemistry and Catalysis**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM22E49**

Course Summary & Justification	Introduce the main techniques of surface science and to understand how these techniques can be used to investigate the structure, composition and reactivity of surfaces with a particular focus on systems of relevance to heterogeneous catalysis. To introduce the important general concepts of the chemistry of heterogeneous catalysis and to describe and illustrate the main types.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Bachelors degree in chemistry, with physics and mathematics as subsidiaries.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To introduce the concepts of adsorption and desorption	U	1,2,7
2	To explain many of the proposed hypotheses of surfaces in terms of fundamental concepts.	A	1,7
3	Be able to apply the knowledge in order to predict and rationalize the properties of catalysts.	Ap	3,5,6
4	To understand the role of a catalyst in relation to thermodynamics and to appreciate the relevance of catalyst activity, selectivity, deactivation and regeneration.	A	3,5,7
5	Recognize assumptions and limitations in the scientific models and their possible impact on the results by training on case studies, lectures, assignments, quizzes	U	1,7
6	Having a clear understanding of the subject related concepts and of contemporary issues.	U	1,2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Adsorption at Liquid Surfaces** Adsorption at liquid surfaces - Gibb's equation and its verification, adsorption forces, Thermodynamics of physical adsorption, Heat of adsorption and its determination.	**10 Hrs.**	**1,2**
2	**Adsorption on Solids** Adsorption on solids, Langmuir adsorption isotherm, Multilayer adsorption, BET and Polanyi models for the adsorption. Electrical phenomena at interfaces including electrokinetic potentials, Micelles, Critical Micelle Concentration (CMC). Relevance of surfaces and interfaces: colloids, nanomaterials & biology	**15 Hrs.**	**2**

3	**Characterization of Solid Surfaces** Harkins and Jura equation and other methods for measurements of surface area of solids, Diffraction and thermal methods - Powder X-Ray diffraction- peak broadening and particle size analysis, N_2 adsorption -surface area, pore size analysis, thermal analysis using TGA and DTA, Morphology and particle size analysis - SEM, AFM and HR-TEM.	**15 Hrs.**	**2,3**
4	**Adsorption Behaviour of Porous Materials** Porous solids, Pore size distribution, Adsorption behaviour of porous materials, hysteresis of adsorption, Theory of surface reactions, Molecular sieves, Capillary condensation, micro-pore analysis.	**10 Hrs.**	**4,5**
5	**Catalysis** Homogeneous catalysis, Autocatalysis and oscillating reaction, Kinetics of homogeneous catalysis, Heterogeneous catalysis, Kinetics of heterogeneous catalysis, Development of catalysts, Enzyme catalysis.	**10 Hrs.**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **E. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **F. Semester End examination**

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	MAHATMA GANDHI UNIVERSITY **Drug design and Medicinal Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Drug design and Medicinal Chemistry**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM22E50**

Course Summary & Justification	This course aims to impart basic knowledge on the important terminology in medicinal chemistry, drug, pharmacy, pharmaceutics, toxicology, pharmacodynamics agents, pharmacophore, pharmacodynamics, metabolites and anti-metabolites, and chemotherapy. Through this learning, it is possible to acquire types of drugs on the basis of therapeutic action nomenclature of drugs anddifference between drugs and medicines. It will help the students to know the mechanism of chemotherapeutic actions, biological defences, chemical defenses. Learning this course will provide a strong foundation in drug design and development, concept of prodrugs and soft drugs. This course also provides a detailed studyon drug absorption, enzymes as drug targets. Introduction to molecular modeling, molecular mechanics, concepts of virtual screening and topological drug classification.
Semester	II

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning	40	40		40	120
Pre-requisite	Basic knowledge about drugs, drug design and computer aided drug design					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understand the important terminology in medicinal chemistry, drug, Pharmacy, and pharmaceutics, mechanism of chemotherapeutic actions and classification of drugs	U	1,7
2	Learn the procedure followed in drug design, drug discovery without lead and development of drug	U,A	1,2,3,7
3	Gather information about prodrugs and soft drugs in detail	U,R	2,3,7
4	To understand the drug absorption, drug removal from kidneys and liver	U	1,2,7
5	Gather information about enzymes and receptors as drug targets	U	1,2,7
6	To estimate the CFSE of any complex and predicts low spin/high spin nature	U,A	3,7
7	Able to study molecular modelling, ligand preparation, and molecular mechanics and concepts of virtual screening	U, An	6,7
8	Should be able to understand computational Protein- Ligand docking Techniques with the help of dockingservers, Types- Rigid Docking, Flexible or induced fit Docking.	U, A, An	5,6,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Concepts of Medicinal Chemistry**: Important terminology in medicinal Chemistry, Drug, Pharmacy, Pharmaceutics, Toxicology, Pharmacodynamics agents, Pharmacophore, pharmacodynamics, metabolites and anti-metabolites, chemotherapy. Mechanism of chemotherapeutic actions: 1) Biological defenses. 2) Chemical defenses. a) Surface active agents; b) Metabolic antagonism. Assay of Drugs: Chemical Assay,Biological Assay, Immunological Assay, LD50, ED50, IC50 and ID50.	15	1,2
	Classification and nomenclature of Drugs Classification of drugs on the basis of therapeutic action. Nomenclature of Drugs. Difference between drugs and medicines		
2	**Drug Discovery** Introduction. Procedure followed in Drug Design. a) Drug Discovery without a lead b) Lead Discovery. Lead Modification: Drug Design and Development Identification of active part: The pharmacophore b) Functional group modification, c) Structure-activity relationship d) Structure modification to increase potency and the therapeutic index: 1. Homologation; 2. Chain branching; 3. Ring-chain transformation; 4. Bio-isosterism Structural Modification to increase oral Bioactivity.1) Electronic Effect; 2) The Hammet equation; 3) Lipophilicity effect. **Concept of Prodrugs and soft drugs** a) Prodrugs: i) Prodrugs designing, types of prodrugs; ii) Prodrug formation of compounds containing various chemical groups, Prodrugs and Drug delivery system b) Soft drugs: i) soft drug cocept; ii) Properties of soft drugs.	15	3,4

3	**Drug Absorption:** Drug Entry into the Bloodstream, Oral, Injection, Transdermal, Other Routes, Topical, Distribution: Drug Transport, Blood, Crossing Membranes, Blood–Brain Barrier, Pharmacodynamics: At the Drug Target, Metabolism and Elimination: Drug Removal, Kidneys and Liver. **Enzymes as Drug Targets** Introduction, Definition, Structure, Case Study Use of a-Helices to Cross Cell Membranes, Types, Mode of Action, Kinetics, Single Substrate, Multiple Substrates, Inhibitors, Reversible and Irreversible, Pharmaceutical Concerns, Mutational Resistance to Inhibitors, Concentration Effects, Metabolism of Drugs. **Receptors as Drug Targets** Receptors, Similarities and Differences from Enzymes, Classification, Ligand-Gated Ion Channels, G-Protein–Coupled Receptors, Tyrosine Kinase–Linked Receptors, Nuclear Receptors, Types of Ligands, Agonists, Antagonists, Inverse Agonists, Receptor Theories, Occupancy Theory, Allosteric Theory, Rate Theory, Drug-Target Residence Time.	**15**	**5,6**

4	***In-silico* and Computer Aided Drug design** Introduction to Molecular Modeling, Lipinski's rule of five, Protein preparation, Ligand preparation, Molecular Mechanics, force fields (Potential energy function), Energy Minimization Methods, Conformational Analysis. Concepts of Virtual Screening, Drug likeliness, Screening-Counting Schemes, Functional Group Filters, Topological Drug Classification-Pharmacophore Point Filter-Focused Screening Libraries for Lead Identification, Pharmacophore Screening, Structure-Based Virtual Screening, Protein Structures, Computational Protein-Ligand Docking Techniques with the help of docking servers, Types-Rigid Docking, Flexible or induced fit Docking, i*n silico* De Novo design.	**15**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **C. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **D. Semester End examination**

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2. Medicinal Chemistry an Introduction-Gareth Thomas 2nd Ed. Wiley
3. An introduction to Medicinal Chemistry-Graham L. Patrick 5th Ed. Oxford
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5. Medicinal Chemistry-Ashutosh Karr
6. Medicinal Chemistry the Modern Drug Discovery Process- Erland Stevens, 2014by Pearson Education.

7. Quintessence of Medical pharmacology-Sujit K. Choudhary, New Central bookagency
8. Principles of Medicinal chemistry Vol I & II- S.S Kadam, K.R. Mahadik, K.G. Bothara, Nirali Prakshan.
9. Drug design volumes by Ariens
10. Principles of Drug design by Smith
11. Strategy of Drug design by Brucell
12. The Organic Chemistry of the Drug design and Drug action by Richard B.Silverman

SEMESTER 3

	MAHATMA GANDHI UNIVERSITY **Organic Chemistry III – Advanced Organic Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Organic Chemistry III – Advanced Organic Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C71**

Course Summary & Justification	The course describes different types of advanced organic reactions andreagents as tools for the synthesis of organic compounds. Principles ofprotecting group chemistry and retrosynthetic approach towards organic synthesis are also dealt with. Analysis and interpretation of molecular recognition and supramolecular chemistry are also aimed at, along with the understanding of basic principles of green chemistry. The course also aims at acquainting students with the role of reagents andcatalysts in organic synthesis.					
Semester	**3**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Prerequisite	Knowledge in oxidation and reduction reactions in organic chemistry. Fundamental understanding of green chemistry.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1.	To apply the basic oxidation and reduction reactions on organic molecules	U, A	1,7
2.	To describe protective groups in organic synthesis	U, I	1,2,7
3.	To equip the students to synthesize complex natural and unnatural compounds of importance by practicingretrosynthetic analysis	A, C, S	1,6,7
4.	To analyse the difference in the basic types of synthetic approaches	An, E	6,7
5.	To understand the fundamentals of supramolecular chemistry	U, I	1,2,7
6.	To distinguish and synthesize cation, anion and neutral molecule binding host molecules	U, A, C	6,7
7.	To demonstrate the applications of supramolecular chemistry	U, Ap	1,7
8.	To understand green chemistry and sustainability developments that affect society, environment and economic development	I, Ap	1,2,7
9.	To analyse and compare chemical/industrial processes basedon their relative "greenness"	An, E, S	1,2,7
10.	To understand the role of reagents and catalysts in organicsynthesis	U, I	2,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill(S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Organic Synthesis 1** Metal based and non-metal-based oxidationsof a) Alcohols to carbonyls I. Chromium based reagents (John's oxidation, Collin's oxidation, Sarrett oxidation) II. Manganese, aluminium and DMSO based reagents (Swern oxidation, Moffatt–Pfitzner	**15**	**1,2,3**

	oxidation, Kornblum oxidation, Corey-Kim oxidation) b) Alkenes to epoxides (peroxides/peracids based) - Sharpless asymmetric epoxidation, Jacobsen epoxidation, Shi epoxidation c) Alkenes to diols (manganese and osmium based) - Prevost reaction and Woodward modification d) Alkenes to carbonyls with bond cleavage (manganese based,ozonolysis) e) Alkenes to alcohols/carbonyls without bond cleavage – hydroboration - oxidation, Wacker oxidation, selenium based allylic oxidation f) Ketones to ester/lactones – Baeyer - Villiger oxidation g) Catalytic hydrogenation I. Heterogeneous: Palladium/Platinum/Rhodium and Nickel II. Homogeneous: Wilkinson h) Metal based reductions: Birch reduction, pinacol formation, acyloin formation i) Enzymatic reduction using Baker'syeast		
2	**Organic Synthesis 2** Reagents in organic synthesis: Metal hydride reductions using $NaBH_4$, $LiAlH_4$, DIBAL, K-selectride, Sodium	**15 Hrs.**	**3,4**

	cyanoborohydride, Lithium diisopropylamide (LDA), Dicyclohexyl Carbodiimide (DCC), Gilman's reagent, DDQ Protecting group chemistry: Protection, activation and deprotection process in organic synthesis, protection and deprotection of hydroxyl, carboxyl, carbonyl and amino groups. Retrosynthetic analysis: Basic principles and terminology, Synthesis of aromatic compounds, One group and two group C- X disconnections, One group C-C and twogroup C-C disconnections. Retrosynthesis of D-luciferin, Functional equivalents and reactivity – Umpolung / polarity inversion reaction (Ireland-Claisen rearrangement).		

3	**Advances in Organic Chemistry** Supramolecular Chemistry: Introduction to supramolecular chemistry: Host, Guest,Host-Guest complex, Lock and key principle, Preorganisation, Complementarity. Cation binding hosts (Crown ethers, Podands, Calixarenes), Anion binding hosts (Cyclophanes), Naturally occurring cyclic host (Cyclodextrin), Molecular clefts and tweezers, Macrocyclic polyamines (Nitrogen based cyclic hosts), Naturally occurring Siderophores, Rhodopsin – A Supramolecular photonic device. Introduction to Green Chemistry: Twelve principles of Green Chemistry. Green Solvents: Ionic liquids, supercritical CO_2, fluorous solvents, PEG. Green Alternatives to Organic Synthesis (Microwave assisted and Sonochemical synthesis) with examples (Synthesis of adipic acid from cyclohexene, synthesis of Ibuprofen).	**15 Hrs.**	**5,6,7**

4	**Catalysis in Organic Chemistry** Baylis-Hillman reaction, Henry reaction, Nef reaction, Kulinkovich reaction, Ritter reaction, Sakurai reaction, Tishchenko reaction. Brook rearrangement. Tebbe olefination. Metal mediated C-C and C-X coupling reactions: Heck, Stille, Suzuki- Miyaura, Negishi, Sonogashira, Nozaki- Hiyama-Kishi, Buchwald-Hartwig, Ullmann and Glaser coupling reactions. Click reactions (Huisgen 1,3-dipolar addition). Ugireaction, Passerini reaction and Biginelli reaction.	**15 Hrs.**	**8,9,10**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning,Active co-operative learning, Library work, E-learning Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** • **Continuous Internal Assessment (CIA)** ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar • **Semester End examination**

References

1) M.B. Smith, Organic Synthesis, 3rdEdn., Wavefunction Inc., 2010.
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	MAHATMA GANDHI UNIVERSITY **Physical Chemistry II - Solid state and AdvancedMaterials**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Physical Chemistry II - Solid state and AdvancedMaterials**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C72**

Course Summary & Justification	The course describes advanced chemical thermodynamics, application of phase rule to three component systems and principles and classification preparation of solids. It also describes the importance and properties of defects in solid, band theories of solids, and optical , magnetic and electrical properties of solids. The last modules gives an insights to analysis of advanced electrochemistry also introduced machine learning approaches in nanoscience.					
Semester	**3**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		60	40	0	40	140

Prerequisite	Knowledge in solid state chemistry, thermodynamics andelectrochemistry (Graduate level).

COURSE OUTCOME

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understanding of advanced concepts of thermodynamics	U, A	1,2,7
2	Illustrates application of phase rule to three component systems.	U,A	1,2,7
3	Describes general principles and classification preparation of solids	U	1,7
4	Describe the importance and properties of defects in solid	U,A	1,7
5	Describe the free election , band theories of solids	U,R	1,7
6	Illustrate the optical , magnetic and electrical properties of solids	U	2,3,7
7	Design and development of solid materials with pre-required properties based on the structure of solids.	U	2,3,7
8	Analyze the physical-chemical ,unique optical, electrical, magnetic, thermal, and mechanical properties of solids.	U,A	3,5
9	Understanding and analysis of advanced electrochemistry	U, R	1,2,7
10	Introduced machine learning approaches in nanoscience	U, I, A	1,7

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Thermodynamics II** Fugacity: Relation between fugacity and pressure, determination of fugacity of gases. Variation of fugacity with temperature and pressure. Activity and activity coefficients. Variation of activity with temperature and pressure. Determination of activity coefficients by electrical methods. Thermodynamics of dilute solutions: Raoult's law, Henry's law. Ideal and non-ideal solutions. Discussion and thermodynamic derivation of the laws of osmotic pressure, cryoscopy and ebullioscopy. Determination of molecular weights. Thermodynamic treatment using the concept of chemical potentials. Phase Rule Studies: Thermodynamic derivation of phase rule; application of phase rule to the two component systems: simple eutectic type, compound formation with congruent melting point and incongruent melting points, systems involving the formation of a continuous series of solid solutions. Application of phase rule to three component systems: Systems of three liquids and systems of two salts and a liquid.	15	1,2,3

2	**Solids State and AdvancedMaterials** Structure – Types and classification of solids, distinction between crystalline and amorphous solids. Unit cell, Bravais lattice, symmetry elements, Miller indices, Bragg's law. Classification of crystals based on bondtype and packing in crystals. Imperfections in crystals – Types of defects, stoichiometric defects – Schotky and Frenkel. Non-stoichiometric defects – Metal excess and metal deficient, consequences of metal deficiency defects. Inorganic crystals – Coordination number, radius ratio rule and shapes of ionic crystals.Structure of Pervoskite, spinels and inverse spinels, structures of ionic crystals – AX type: CsCl, ZnS (Zinc blende, Wurtzite), AX2 type: CaF2, TiO2 , Cd2. Experimental methods of crystal structure determination: X - ray diffraction, electron diffraction and neutron diffraction. Comparative study of the three diffraction methods.Electrical, Magnetic and Optical Properties: Band theory of solids, significance of band gap, conductors, semi- conductors and insulators. Electrical & optical properties: Electrical conduction in metals. Super conductivity, origin of superconductivity, type I and type IIsuperconductors, meisner effect, Bardeen, Cooper and Schriefer (BCS) theory, Cooper pairs. High	**15 Hrs.**	**4,5**

	temperature superconductors, super conducting cuprates - YBaCu oxide system. Josephson's Junction, conventional superconductors, organic superconductors. Electrical properties: thermoelectric effects, Thomson effects, Peltier effect, seebeck effect, thermocouples, Hall Effect. Magnetic properties: Origin of magnetic dipoles in solids, ferrimagnetic materials, spontaneous magnetization. Dielectric materials, ferro, pyro, piezo electricity and their relations, applications.		

4	**Machine learning in Nanoscience** Introduction – workflow, Data preprocessing and feature engineering. Basic ML Algorithms – Regression analysis, Naïve Bayes classifiers, Support vector machine (SVM), Decision tree and random forest, Artificial neural network (ANN), Deep learning. Cross-validation. The theoretical basis of assisting DFT with ML. Machine Learning to Analyze Large Data Sets- Analysis of Spectra, Images, and Biological Outcomes, Deconvoluting Components in Mixed Signals, Machine Learning for Metrology of Nanoelectronics. Machine Learning for Design and Discovery- Inverse Design and Adversarial Networks in Nanophotonics, Active	**15 Hrs.**	**6,7**
	Learning, Automated Experimentation, Prediction of new 2D Materials and Heterostructures, Nanoscience to Advance Hardware for Machine Learning, Challenges and Opportunities for Machine Learning and Nanoscience.		

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1. F. Reif, Fundamentals of Statistical and Thermal Physics, Waveland Press, 2009.

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	MAHATMA GANDHI UNIVERSITY
	Advanced Characterization techniques for Nanomaterials
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Advanced Characterization techniques for Nanomaterials**
Type of Course	**Core**
Credit Value	**3**
Course Code	NSM22C73

Course Summary & Justification	This course aims to provide a comprehensive overview of characterization of nanoparticles, nanocomposites and hierarchical materials with nanoscale features. Course modules will cover the fundamental scientific principles controlling assembly of nanostructured materials; characterization, measurement and computational tools; new properties at the nanoscale, and existing and emerging applications of nanomaterials. It will introduce advanced nanomaterials characterization techniques, including neutron and X- ray scattering and diffraction, crystal structure analysis, electron microscopy, and nuclear magnetic resonance (NMR).					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Introduction to Materials Science (Undergraduate level)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understanding of mechanical, magnetic and electrical properties measurements.	U	1,2,3,7
2	Provides an insights to characterization, measurement and computational tools.	U,A	4,5,6
3	Understand and analyse new properties at thenanoscale.	U,R	1,2,7
4	Overview of Instrumentation and Sample preparation	U	4,5,6
5	Understanding of principles of advanced characterization techniques.	U,A	4,5,6
6	Understanding of Optical, confocal and Fluorescence microscopes.	U,A,An	4,5,6
7	To learn and analyse Nanostructured materials and applications**.**	U, An	1,2,7
8	Understanding of nano polymers and nanoceramics.	U, A, An	1,2,3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Mechanical, Magnetic and electrical properties measurement** Nanoindentation principles- elastic and plastic deformation -mechanical properties of materials in small dimensions- models for interpretation of Nanoindentation load displacement curves- Nanoindentation data analysis methods-Hardness testing of thin films and coatings- MD simulation of nanoindentation. Vibration Sample Magnetometer,	**15**	**1,2**

	Impedance Spectroscopy- PPMS, - Measurement of Magnetic and electrical properties of nanomaterials.		
2	**Advanced Characterization Techniques for Nanomaterials** Principles, Overview of Instrumentation and Sample preparation, Experimental techniques adopted in: Scanning Electron Microscopy: SEM and FESEM - Transmission Electron Microscopy (TEM) – HRTEM- application for analysis of Nanomaterials. Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy AFM)-Non-contact contact- Tapping- conducting mode- .Near Field Scanning Optical Microscopy; Scanning capacitance Microscopy- Scanning Microwave Microscope- Magnetic Force Microscopes MFM)- Chemical Force Microscope (CFM)- Applications for analysis of nanomaterials .	**15**	**3,4**

3	**Optical and Confocal microscopes** Use of polarized light microscopy – Phase contrast microscopy – Interference Microscopy – hot stage microscopy - surface morphology – Etch pit density and hardness measurements. -Confocal Microscopes - Confocal Raman – Application in Nanobiotechnology. Fluorescence Microscope: Principle and Instrumentation of Thermogravimetry; Differential Thermal Analysis and Differential scanning calorimetry-Importance of thermal analysis for nanostructures. New Advances and challenges in biological and biomedical materials characterizations- Dynamic light scattering spectroscopy.	**10**	**5,6**

4	**Nanostructured materials and applications** Nano Composites and their Applications, Metal-Metal nanocomposites for nuclear energy applications, Magnetic nanocomposites for Spintronics application, Ceramic nanocomposites for high temperature applications. Nano ceramics: Dielectrics, ferroelectrics and magneto ceramics, Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Applications of Nanopolymers in Catalysis. Classification of conducting polymers: Intrinsic and extrinsic conducting polymers - Chemical and electrochemical methods of the synthesis of conducting polymers – Applications of conducting polymers in corrosion protection, sensors, electronic and electrochemical energy devices. Miscellaneous applications of nanotechnology: dental implants, consumer products, biomimetic nanomaterials for tissue engineering, biopolymer tagging, semiconductor quantum dots.	**10**	**7,8**

5	**Societal Implications of Nanoscience and Nanotechnology** Introduction, First industrial revolutionto Nano revolution, Milestones of the trajectory of Nanotech. Implications on society, Issues. Green Nanotechnology. Nano Economy, Nano policies and Institutions, Nano Rules and Regulations, Nano ethics. Nanotech and war – Nano Arms race.Public perception and Public involvement in the Nano discourse, Harnessing Nanotechnology for Economic and Social development.	**10 Hrs.**	**6,7,8**

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10. Advanced Magnetic Structures, David Sellmyer and Ralph Skomski, Springer 2009

11. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor

12. Nanoscale materials -Liz Marzan and Kamat.

13. Physical properties of Carbon Nanotube-R Satio.

14. Polymer nanocomposites: Edited by Yiu-Wing Mai and Zhong-Zhen Yu, First published2006, Woodhead Publishing Limited and CRC Press LLC, USA.

15. Physics of Magnetism - S. Chikazumi and S.H. Charap.

16. Magnetostriction and Magnetomechanical Effects - E.W. Lee.

17. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.

18. Nano the Essentials, Understanding Nanoscience and Nanotechnology,T. Pradeep,Tanta Mc Graw- Hill Publishing.

	MAHATMA GANDHI UNIVERSITY
	Practical IV - Physical Chemistry
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Practical IV - Physical Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM22C74**

Course Summary & Justification	To have hand-on experiences of techniques for verifying physicaland chemical properties					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		0	0	40	40	80
Pre-requisite	Bachelors degree in chemistry, with physics and mathematics as subsidiaries.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To conduct the experiment on various instrumentaltechniques.	A	3,4,6
2	To measure various physical and chemical properties.	A	3,4
3	To describe the principles behind the experiment performed in the laboratory.	Ap	3,4
4	To interpret the experimental results obtained by various techniques.	An	4,5,6
5	To understand the principles behind the experiment performed in the laboratory.	U	5,6,7
6	The students will acquire knowledge of experimental techniques for controlling the chemical reactions.	C	1,2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Module 1** **Surface Chemistry** Study the adsorption of acetic acid by activated charcoal andverify the Langmuir and Freundlich adsorptionisotherms. **Chemical Kinetics** Study the kinetics of the acid- catalysed hydrolysis of methyl acetate and evaluate the valueof the rate constant. Evaluate the activation energy for the acid catalysed hydrolysis of methyl acetate. **Phase Equilibria** Determine the transition temperature of the given salt hydrate.	**15**	**1,2**
2	**Thermodynamic Properties of Solution** Determine the partition coefficient for the distribution of succinic acid between water and 1-butanol. Determination of partitioncoefficient of benzoic acid between toluene and water. **Conductometry** Determination of cell constant Verification of Onsager equation and determine the equivalent conductance at infinite dilution of strong electrolyte	**15 Hrs.**	**2,3**

	Determine the concentration of the given strong acid by conductometric titration with a strong base		
3	Determine the refractive index of the given liquid by Abbe refractometer, and hence the specific and molar refraction Determine the molar refractivity of water, methanol, acetic acid, ethyl acetate, 1,4-carbon tetrachloride and calculate the refraction equivalents of C, H, Oand Cl. Determine the specific, molecular and intrinsic rotations of the given optically active substance. Determine the concentration of the unknown solution of the optically active compound by polarimetric measurements. To study kinetics of inversion of cane sugar by optical rotation measurement.	**15 Hrs.**	**4,5**
4	**Absorption Spectroscopy** Verify the Beer-Lambert's law and determine the unknown concentration of a given solution. Simultaneous estimation of manganese and chromium in a solution of dichromate and permanganate mixtures. Study the effect of extended conjugation on the wave length of maximum absorption of organic compounds. Characterize the given organiccompounds by IR, and UV-vis.spectroscopic techniques.	**15 Hrs.**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Interactive Instruction: Active co-operative learning, Seminar, Group Assignments Authentic learning, Library work and Group discussionon the theoretical back ground of the experiments to be carried out. Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) • Experiments done in the laboratory and recording the results • Seminar Presentation – theory of each experiment tobe discussed and present in the seminar • Attendance and punctuality • Viva-voce examination

REFERENCES

1. Experiments in Physical Chemistry, Third Editon, Shoemaker, Garland andSteinfeld, McGraw-Hill,1967.
2. Practical Physical Chemistry, B. Viswanathan and P. S. Raghavan, Viva Books Pvt.Ltd., N. Delhi, 2005
3. Advanced Practical Physical Chemistry, J. B. Yadav, 29th edn., 2010, Krishna Prakashan Media Pvt. Ltd., Meerut

	MAHATMA GANDHI UNIVERSITY **Mathematical and Computational Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Mathematical and Computational Chemistry**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM22E51**

Course Summary & Justification	Provide an overview and basic understanding of mathematical, theoretical, and computational chemistry problems and provide practical/programming skills to perform scientific computations to solve chemical problems.

Semester	3		**Credit**		2	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basics of Energy production, conversion and storage systems. (Graduate Level)					
Others- Library, seminar and assignment preparations, test, journal,discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understanding of the basic principles of computational chemistry.	U	1,2,7
2	Performance of simple computational experiments in energy evaluation, potential energy surface modeling, conformational analysis.	U,A	1,2,3,7
3	Skill development to design, perform and analyze chemistry problems using computational tools	U,R	2,3
4	Understanding of the molecular orbitals and basis sets and its classification	U	1,7
5	Describe the electronic properties of molecules by Semi-empirical, ab initio methods, Hartree Fock, post HartreeFock, and density functional methods and its limitations and application	U,A	1,3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Introduction to Computational Quantum Chemistry** Introduction and basic concepts of computational quantum chemistry, potential energy surfaces,conformational search, global minimum, local minima, saddle points. Introduction to LINUX operating system, basic commands in LINUX operating system. Molecular geometry input: Cartesian coordinates and internal coordinates, Z-matrix of polyatomic molecules. General input file format of Psi4/GAMESS/Firefly/Gaussian software, single point energy calculation, geometry optimization, frequency calculation. Molecular dynamics (MD) methods; features of molecular mechanics force field-bond stretching, angle bending, torsional terms, non-bonded interactions and electrostatic interactions. Commonly used force fields- AMBER and CHARMM.	**15**	**1,2**
2	**Semiempirical and Ab-Initio Quantum Chemical Methods** Semi-empirical quantum chemistry methods, ab initio quantum chemistry methods:Pauli principle, antisymmetric wave functions and Slater determinants.self-consistent field (SCF) procedure, independent electron approximations, Hartree-Fock approximation, Basic concepts for Hartree-Fock (HF) method, Restricted Open-Shell Hartree-Fock (ROHF) and Unrestricted Hartree-Fock (UHF) methods. Basis sets and its classification,Slater and Gaussian functions, Pople	**15 Hrs**	**2,3**

	style basis sets, polarization and diffuse functions,		
3	**Post-Hartee Fock methods and Density Functional Theory** Introduction to post-Hartree-Fock methods: Møller-Plesset perturbation theory, Configuration Interaction (CI), Coupled Cluster (CC). Density Functional Theory: foundations, example of functional. The Hohenberg-Kohn theorems, The Kohn-Sham ansatz. The local spin density approximation (LSDA), Generalized-gradient approximation(GGAs) , Local Density Approximation, hybrid functionals.	**15 Hrs.**	**3,4**
4	**Numerical methods in Chemistry** Solutions of equations using numerical methods- Newton Raphson's method, Linear algebra, Matrix manipulations including Gauss Jordan and Gauss sidel methods, Numerical solution ofdifferential equation. Precision and Accuracy, Determinate and indeterminate errors, computational error struncation and rounding off errors, algorithm errors-absolute andrelative errors-Error propagation. Measures of Dispersion range,arithmetic mean, mean deviation variance and standard deviation –movements – skewness and kurtosis. Interpolation: interpolation for linear fit, linear interpolation in non-linear fit, polynomial interpolation – Lagrange interpolation formula – Application to complex equilibria. Numerical techniques of solving ordinary firstorder differential equations:- Euler'smethod, Predictor-corrector method, Rungae Kutta method-application to chemical kinetics.	**15 Hrs.**	**4,5**

REFERENCES

1. J. H. Jensen, E. G. Lewars, Computational Chemistry: Introduction to the Theoryand Applications of Molecular and Quantum Mechanics, 2nd Edn., Springer, 2011

2. F. Jensen, Introduction to Computational Chemistry, 2nd Edn., John Wiley &Sons, 2007

3. A. R. Leach, Molecular Modelling: Principles and Applications, 2nd Edn., Pearson Education Ltd., 200

4 . K. I. Ramachandran, G. Deepa, K. Namboori, Computational Chemistry andMolecular Modeling: Principles and Applications, Springer, 2008

5. A. Hinchliffe, Molecular Modelling for Beginners, 2nd Edn., John Wiley & Sons,2008

6. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2ndEdn., John & Sons, 2004

7. D. C. Young, Computational Chemistry: A Practical Guide for Applying Techniques Real-World Problems, John Wiley & Sons, 2001.

8. E.Kreyszig, Advanced Engineering Mathematics, 10 th Edn., John Wiley andsons, 2011

	MAHATMA GANDHI UNIVERSITY
	Nanotechnology in Energy
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Nanotechnology in Energy**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM22E52**

School Name	**School of Nanoscience and Nanotechnology**
Programme	
Course Name	**Nanotechnology in Energy**
Type of Course	Elective
Course Code	**NSM22E52**
Course Summary & Justification	This main objective of this course is to give a theoretical and practical overview of nanotechnology with applications in energy production, conversion and storage. The specific objectives of this course are to familiarize with nanomaterials, manufacturing processes, characterization and also reliability characteristics. Upon completion of the course on Nanotechnology in Energy, students will understand the fundamental laws governing energy conversion and storage efficiency, the importance of favourable nanomaterials in the energy conversion, and storage application and reliability of materials. This paper encompasses a detailed exposure to the alternative energy technologies with a special focus on solar-photovoltaic, batteries and hydrogen-fuel cell technologies. The proposed course will be one of the elective courses to introduce students to applications of nanotechnology through five different modules. The modules are selected in order to have hierarchy in student learning in three different areas (renewable energy technologies, batteries, fuel cells, hydrogen storage and solar photovoltaics) of alternative

	energy technologies.					
Semester	3		**Credit**		2	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basics of Energy production, conversion and storage systems.(Graduate Level)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	The module encompasses a detailed exposure to energy challenges, development and implementation of renewable energy technologies. Nanotechnology enabled renewable energy technologies are also be discussed (Module 1)	U, A	1,2,7
2	This module discusses Nanomaterials for Energy Storage Systems. The student will able to understand principles and material design of different nanostructured carbon-based materials. Current status and future trends on energy storage systems are also discussed. (Module 2)	U, A	1,2,3,7
3	This module is to designed to help the students to provide adequate knowledge regarding nanomaterials in fuel cells, hydrogen Storage, thermoelectric materials (in nano scale), supercapacitors (Module 3).	An, E	2,3,7
4	Understanding of application of nanomaterials for hydrogen storage and photocatalysis.	E	2,3
5	This module gives an insights of role of various nanomaterials for Photovoltaic Solar Energy Conversion Systems.	An, E	2,3,7

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Renewable Energy Technology Energy challenges, development and implementation of renewable energy technologies, nanotechnology enabled renewable energy technologies, Energy transport, conversion and storage- Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si- composite structure, various techniques of Si deposition	**15**	**1,2**
2	Nanomaterials for Energy Storage Systems Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium ion Batteries), Cathode and anode materials, Capacitor Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon- based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.	**15**	**2,3**

3	Nanomaterials in Fuel Cell and Storage Technology Micro-fuel cell technologies, integration and performance for micro-fuel cell systems, thin film and microfabrication methods, design methodologies, micro-fuel cell power sources, Supercapacitors, Specific energy, charging/discharging, EIS analysis.		
4	Nanomaterials for Hydrogen Storageand Photocatalysis Hydrogen storage methods, metal hydrides, size effects, hydrogen storage capacity, hydrogen reaction kinetics, carbon-free cycle, gravimetric and volumetric storage capacities, hydriding/dehydriding kinetics, multiple catalytic effects, degradation of the dye, nanomaterials based photocatalyst design, kinetics of degradation.	**15**	**3,4**
5	Nanomaterials for Photovoltaic Solar Energy Conversion Systems Principles of photovoltaic energy conversion (PV), Types of photovoltaics Cells, Physics of Photovoltaic cells, Organic photovoltaic cell cells, thin film Dye Sensitized Solar Cells, Quantum dot (QD) Sensitized Solar Cells (QD- SSC), Organic- Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Current status and future trends.	**15**	**4,5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning,seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. Twidell. J. and Weir. T "Renewable Energy Resources", E & F N Spon Ltd, 1986.
2. Martin A Green, "Solar cells: Operating principles, technology and system applications", Prentice Hall Inc, Englewood Cliffs, 1981.
3. Moller. H J "Semiconductor for solar cells", Artech House Inc, 1993. 4. Ben G Streetman, "Solid state electronic device", Prentice Hall of India Pvt Ltd.,1995
4. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw- Hill, New York (1995).
5. Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley,CRC Press
6. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, KulwerAcdemic Publishers, Dordrecht, Netherlands (2004).
7. J. Larmine and A, Dicks, Fuel Cell System Explained, John Wiley, New York (2000).
8. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).
9. Hydrogen from Renewable Energy Sources by D. Infield 2004

	MAHATMA GANDHI UNIVERSITY **Advanced Nanobiology**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Advanced Nanobiology**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM22E53**

Course Summary & Justification	This course comprises the implications and applications of nanostructured materials in medical and health care area. There are four modules for this course and each module covers a detailed explanation from introduction of nanomedicine to advanced applications in different biomedical areas. This course aims to make the learner to understand the nanobio interphase as well as the implications and applications of nanotechnology in health and medicine. The objective of the course content is to create a sound awareness about the recent developments in biomedical sector in the areas of therapeutic and diagnostic strategies through the intervention of Nanotechnology.					
Semester	**3**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basic knowledge about periodic table and arrangements of elements under Groups and Periods. Basic knowledge in InorganicChemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the characteristic properties of bio-derrived nanostructured materials	U, An	1,2,7
2	Understand the biocompatibility issues and pharmacokinetic properties of nanomaterials	U, E	2,7
3	Learn different types of nanomaterials useful for biomedical applications	U,E	3,7
4	Understand the nano-bio interphase and their applications in disease diagnosis and therapy.	U, A	3,7
5	Understand nanopharmaceuticals and different therapeutic approaches by using nanostructured materials	U, A	1,3,7
6	Understand the basics of tissue engineering and regenerative medicine	U,A	1,2,7
7	Different methods for nanoengineered scaffolds andimplants for tissue engineering applications	U, A	1,2,3, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create(C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Introduction to Nanomedicine and Biological Nanostructures:** Introduction of biomolecules (enzymes, proteins, liposomes, antibodies, aptamer), Biologically relevant molecular nanostructures, Protein, Lipids and DNA based nanostructures, DNA–Nanoparticle Conjugates. Interactions of biomolecules and cell with nanomaterials: biocompatibility, surface functionalization of nanomaterials to enhance biocompatibility, nanomaterials biodistribution drug release kinetics and transport mechanism, in biological system, toxicity evaluation andregulatory issues.	**15**	**1,2,3**

2	**Different types of Nanomaterials and their biomedical applications:** Biomedical application of nanotechnology, Nano- pharmaceutical materials, Metalnanoparticles, Semiconductor materials, polymeric nanomaterials, Fullerenes, Dendrimers, Cubosomes, Ferritin nanoparticles. Therapeutic potential of nanomaterials, Drug delivery and Controlled release, Nanomicrobicidals, Nanobiosensors; cantilevers as biosensors for molecular diagnosis, carbon nanotubes, FRET based DNA nanosensors, viral nanosensors, Fluorescent Nanoparticles.	**15 Hrs.**	**3,4**
3	**Nanostructured materials for therapeutic applications:** Nanopharmaceuticals; therapeutic applications of metal nanoparticles, dendrimers, fullerenes, liposomes, nanoshells, Site directed drug delivery and targeted destruction of cancer cells. Photothermal therapy (PTT), Photodynamic Therapy (PDT), Magnetic hyperthermia for the destruction of malignant cells. stem cell therapy, gene therapy, nanomachines for gene delivery, antisense therapy, nanodevices for medicine and surgery.	**15 Hrs.**	**5,6**
4	**Nanostructures for Tissue Engineering/Regenerative Medicine;** Basics of regenerative engineering, Factors affecting regeneration, Scaffolds for tissue regeneration, Materials for scaffold fabrication, scaffolds, fabrication techniques: particulate leaching, phase separation, three-dimensional pore formation, nanofibers, nanocomposite scaffolds, micro and nanopatterned scaffolds, Engineering of biomaterial to control cell function, Engineering of nanomaterialsas implant material,	**15 Hrs.**	**6,7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **G. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answertype ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **H. Semester End examination**

REFERENCES:

1. Nanobiotechnology: Bioinspired Devices and Materials of the Future: Odedseyov and Ilan Levy.
2. Nanomaterials and Nanosystems for Biomedical Applications: M. Reza Mozafari
3. The Handbook of Nanomedicine , Kewal K. Jain
4. BioNanotechnology, Elisabeth S. Papazoglou, Aravind Parthasarathy
5. Biomedical Nanostructures, Kenneth E. Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair
6. Nanomedicine; Vijay K. Varadan, Linfing Chen, Jining Xie.

OPEN COURSE CREDIT 4

SEMESTER 4

	MAHATMA GANDHI UNIVERSITY
	Dissertation

School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M.Sc.**					
Course Name	**Dissertation and Viva-Voce**					
Course Credit	**10**					
Type of Course	**CORE**					
Course Code	**NSM22C75**					
Course Summary &Justification	The candidate shall do a research project in any of the research institute. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.					
Semester	**IV**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Library work, lab work, Team work, independent learning	-	-	-	-	-
Pre-requisite						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the course the students are expected to		
	To clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively.	A	2, 3, 4, 5
2	Acquire a comprehensive knowledge of the area subject of study	Ap	1, 7
3	Gain deeper knowledge of methods in the topic of study.	A	6
4	Able to contribute to research and development work.	U	3

5	Undertake independent, original and critical research on a relevant topic.	U	5
6	Able to plan and use adequate methods to conduct specific tasks in given frameworks and to evaluate this work.	U	6
7	Create, analyse and critically evaluate different problemsand their solutions.	C	7
8	Gain a consciousness of the ethical aspects of research.	E	6

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work, laboratory work, Team work, independent learning and Group discussion, Presentation of research work.
Assessment Types	**Mode of Assessment** Evaluation of the presentation by both internal and externalexaminers.

	MAHATMA GANDHI UNIVERSITY
	Industrial visit / Review

School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Industrial Visit / Review**
Course Credit	**3**
Type of Course	**CORE**
Course Code	**NSM22C76**
Course Summary& Justification	The Industrial visit/ Review shall be conducted by the School of Nanoscience and Nanotechnology. The students have to visit an industry in the presence of a faculty member of the School during the programme and submit a report on the same at the end of the fourth semester.
Semester	**IV**

Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total LearningHours
	Visiting the industry and interacting with the personnel	-	-	-	-	-
Pre-requisite	Basic knowledge in chemistry practicals and industrial chemistry					

1	Demonstrate the applications of chemical concepts and principles learned in classroom.	A	1, 2, 3
2	Illustrate processes and products manufactured in the chemical industries.	A	2, 4
3	Develop awareness of the principles and technological aspects in the chemical industries.	C	2
4	Improve interpersonal skill by communicating directly with industrial personnel.	S	5
5	Aware of the impacts of industrial processes on health, safety, environment and society.	E	6, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Main aim of industrial visit is to provide an exposure to studentsabout practical working environment. They also provide students a good opportunity to gain full awareness about industrial practices. Through industrial visit students get awareness about new technologies.
Assessment Types	**Mode of Assessment** The report shall be evaluated by the Examination Boardconsisting of the Chairman, the Internal Examiner.

	MAHATMA GANDHI UNIVERSITY
	Mini project

School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M.Sc.**					
Course Name	**Mini project**					
Course Credit	**3**					
Type of Course	**CORE**					
Course Code	**NSM22C77**					
Course Summary & Justification	The candidate shall do a mini project under the guidance of school faculty in relevant area.					
Semester	**IV**					
Total Student Learni ngTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Library work, lab work, Team work, independent learning	-	-	-	-	-
Pre-requisite						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the mini project the students are expected to		
1	To clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively.	A	2, 3, 4, 5
2	Acquire a comprehensive knowledge of the area subject of study	Ap	1, 7
3	Gain basic knowledge of methods in the area	A	6
4	Able to contribute to research and development work.	U	3

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work, laboratory work, Team work, independent learning and Group discussion, Presentation of research work.
Assessme nt Types	**Mode of Assessment** Evaluation of the presentation by both internal and external examiners.

****Open Courses offered by School of Nanoscience and Nanotechnology**

	MAHATMA GANDHI UNIVERSITY
	Open Course - Nanoscience and Nanotechnology: Fundamentals, Essentials and Opportunities

School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Nanoscience and Nanotechnology: Fundamentals, Essentialsand Opportunities**
Type of Course	**Open course**
Credit Value	**4**
Course Code	**NSM22O-02**
Course Summary & Justification	The open course in Nanoscience and Nanotechnology is offered at School of Nanoscience and Nanotechnology in collaboration with IIUCNN, Mahatma Gandhi University, and provides an overview of nanomaterials, their synthesis, properties, and specific applications of nanotechnology in material science, biomedical fields, electronic devices, modelling and simulation, environmental solutions, and in energy production.

	The open course program is designed to produce students that can apply fundamental knowledge of physics, chemistry, biology, material science, and computational science, to get fundamental knowledge in how to model and solve problems related to design, synthesis, characterization, fabrication, and optimization of functional nano materials. Recognizing the multidisciplinary nature of the field, the teaching and project guidance will be accordingly delivered by qualified faculty from the School of Nanoscience and Nanotechnology and IIUCNN, including, nano engineering, chemical engineering, chemistry, physics, biology, and materials science divisions.					
Semester	**IIII**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Literature survey, independent learning					
Pre-requisite	-					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To introduce the students to the world of nanoscience andprovide knowledge of various synthesized/developed and natural nanomaterials and their possibilities.	U	1,2,7
2	To create understanding of the fundamentals of nanoscience and the properties of nanomaterialswhich are different from their bulk counterparts.	U,A	1,2,3,7
3	To create understanding of Size and shape dependence of properties at nanoscale.	U,R	2,3,7
4	Explain the properties of carbon nanomaterials.	U	2,3,7
5	Outline the structure, properties and applications of nanomaterials	U	3,7
6	Understand the various approaches for nanomaterialssynthesis	U,A	5,6,7
7	To understand the applications of nanomaterials in the fields of material science, biomedical fields, electronic devices, modeling and simulation, environmental solutions, and in energy production	U,A	4,5,6
8	Understand the toxicity and environmental Risks ofNanomaterials	U,A	1,2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Fundamentals of Nanoscience andNanotechnology** General introduction and history of nanomaterials, Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic	**10**	**1,2**

	nanomaterials. Classification of nanostructures, Zero dimensional, one dimensional two dimensional nanostructures. Size and shape dependant properties and their uniqueness, energy at nanoscale – surface characteristics of nanomaterials, quantum confinement effect. Carbon based nanomaterials; properties and applications of fullerene, carbon nanotube, graphene, carbon onion, nanodiamond. Core-shells, quantum dots, nanoclusters, core-shells, organic, inorganic, hybrid nanomaterials, biomimetic nanomaterials.		
2	**Properties of Nanomaterials** General Introduction to electronic, optical, magnetic, catalytic, mechanical, and thermal properties of nanomaterials. Fundamental types of electronic nanomaterials. Microelectronics, Band structure-conductor and semiconductor. Electrical conductivity in nanomaterials. Optical and photonic properties: Interaction of light with matter, the surface plasmon – SPR and scattering color generation from nanoparticles and nanostructures. Quantum dots – Optical properties related to quantum confinement. Magnetic Properties: Introduction – magnetic phenomena and their classical interpretation- the nanoperspective. Introduction to nanomagnetism-characteristics of nanomagnetic materials- Magnetization and nanostructures. Mechanical & Thermal properties: Nanomechanics- Introduction-lattice mechanics- linear elasticity relations	**10 Hrs.**	**3,4**
3	**Synthesis and Preparation ofNanomaterials** Understand the principles behind synthesis of nanomaterials such as top down, bottom up	**10 Hrs.**	**4,5**

	approaches, and solid-state synthesis methods. Fabrication of nanomaterials by physical methods: ball milling, physical vapor deposition, sputtering, laser ablation, ion sputtering, laser pyrolysis, molecular beam epitaxy, Langmuir-Blodgett growth, electrospinning. By chemical routes: chemical precipitation and coprecipitation, sol-gel methods, chemical vapour deposition (CVD). General methods for preparation, properties, and characterization of nanoparticle/polymeric blends and its applications. General methods for the preparation of bionanoparticle/polymeric blends and its applications. Surface modification of polymeric nanomaterials.		

4	**Characterization Methods and Analytical tools for Nanoparticles** General introduction to spectroscopic techniques, Optical Microscopy, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunnelling Microscopy, Optical Absorption and Emission Spectroscopy, Thermo Gravimetric Analysis, DifferentialScanning Calorimetry, Thermomechanical Analysis, X-Ray Diffraction, UV-Visible spectroscopy, Raman Spectroscopy, Dynamic Light Scattering (DLS), Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Contact Angle Analysis, Scanning Probe Microscopy (SPM), X-ray Photoelectron Spectroscopy (XPS), electrochemical characterization measurements, Introduction to LASER spectroscopy and its applications.	**10 Hrs.**	**5,6**

5	**Applications of Nanoscience andNanotechnology** Applications of nanostructured materials for clean energy-related applications. Nanomaterials for photovoltaic solar energy conversion systems. Functional nanostructured materials for electrochemical energy storage systems, fuel cells, nanocatalyts, nanomagnetic materials and devices, nano sensors. Applications of nanobiotechnology in tissue engineering, biopolymers for tissue engineering, nanomedicines, wound healing, drug delivery, diagnostic and therapeutic applications of nanoformulations. Applications of nanotechnology in medicine and dentistry. Nanostructured materials for EMI shielding applications. Graphene Functionalization for Applications. Applications of conducting polymer nanocomposites, modeling of advanced nano energy materials, electronic structure of nanoparticles, Modeling, design and simulations of nanostructured materials. Photonic and opto-electronic properties and applications of nanoparticles. Environmental application of nanomaterials, water purification system.	**10 Hrs.**	**6,7**

6	**Health, Environmental risk, Toxicology and Safe Handling ofNanomaterials** General introduction to Environmental risk, Toxicology of nanomaterials. Developing Environmental Regulations Pertinent to Nanotechnology, Analyses of Nanoparticles in the Environment, Ecological hazards of nanomaterials. Assessing nanotechnology health risk, treatment of nanoparticles in waste water, nanoparticles in pollution control, Development of sustainable nanotechnology. Toxicology and risk assessment, determination of potential toxicity, nanoparticles in work place, biodistribution and interaction of nanoparticles, nanoparticle dose in humans- issues and challenges.	**10 Hrs.**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work , laboratory work, Team work, independent learning and Group discussion, Presentation of research work
Assessment Types	**Mode of Assessment** Evaluation of the presentation by internal examiner.

REFERENCES

1. H. S. Nalwa (Ed.), "Encyclopedia of Nanoscience & Nanotechnology", American Scientific Publishers, California, 2004

2. M. D. Ventra, S. Evoy and J. R. Heflin, “Introduction to Nanoscale Science and Technology”, Kluwer Academic Publishers, 2004.

3. Anke Krueger, Carbon Materials and Nanotechnology, Wiley-VCH Verlag GmbH &Co. KgaA, 2010.

4. B.P.S. Chauhan (Ed), Hybrid Nanomaterials: Synthesis, Characterization, and Applications,Wiley-VCH Verlag GmbH, 2011.

5. Cao, G., Nanostructures and Nanomaterials Synthesis, Properties, and Applications, Imperial College Press, 2004

6. M. A. Ratner and D. Ratner, “Nanotechnology: A Gentle Introduction to the Next BigIdea”, Prentice Hall, 2002.

7. M. D. Ventra, S. Evoy and J. R. Heflin, “Introduction to Nanoscale Science and Technology”, Kluwer Academic Publishers, 2004.

ADD-ON COURSES

In addition to Core, elective and practical courses, School of Nanoscience and Nanotechnology,Mahatma Gandhi University will offer add-on courses such as;

- Nano catalysis
- Social, ethical and legal issues of Nanoscience and Nanotechnology
- Nano sensors
- Advanced nanobiology
- Waste management, and Water purification through Nanoscience and Nanotechnology.

The course structure and syllabus will be announced before commencement of each semesters. The lectures will be delivered by reputed Professors/ Scientists from other Universities/ Institutions in India or Abroad.

MODEL QUESTION PAPER

SCHOOL OF NANOSCIENCE & NANOTECHNOLOGY

MAHATMA GANDHI UNIVERSITY

SEMESTER

PROGRAMME

EXTERNAL EXAMINATION (YEAR/ MONTH)

COURSE CODE: COURSE NAME

Time: 3 Hours **Max. Marks: 60**

Part A. Answer any 10 Questions (Each question carries 2 marks)

1. ……
2. ……
3. ……
4. ……
5. ……
6. ……
7. ……
8. ……
9. ……
10. ……
11. ……
12. ……
13. ……
14. ……

Part B. Answer any 4 Questions (Each question carries 5 marks)

1. ……
2. ……
3. ……
4. ……
5. ……
6. ……
7. ……

Part C. Answer any 2 Question (Each question carries 10 marks)

1. ……
2. ……
3. ……
4. ……