HINDUSTAN
INSTITUTE OF TECHNOLOGY & SCIENCE
(DEEMED TO BE UNIVERSITY)

M. Sc. CHEMISTRY

(Duration: 2 Years)

CURRICULUM and SYLLABUS

(Applicable for Students admitted from Academic Year 2024-25)

DEPARTMENT OF CHEMISTRY

SCHOOL OF BASIC AND APPLIED SCIENCES

HINDUSTAN INSTITUTE OF TECHNOLOGY AND SCIENCE

HINDUSTAN INSTITUTE OF TECHNOLOGY AND SCIENCE

Motto:

To Make Every Man *a* Success *and* No Man *a* Failure

Vision:

To be an International Institute of Excellence, providing a conducive environment for education with a strong emphasis on innovation, quality, research and strategic partnership blended with values and commitment to society.

Mission:

- *To create an ecosystem that promotes learning and world class research.*
- *To nurture creativity and innovation.*
- *To instil highest ethical standards and values.*
- *To pursue activities for the development of the Society.*
- *To develop national and international collaborations with institutes and industries of eminence.*
- *To enable graduates to become future leaders and innovators.*

Value Statement:

Integrity, Innovation, Internationalization.

DEPARTMENT OF CHEMISTRY

Vision:

- *The Department of Chemistry strives for the construction of a strong society through Science Education by being adaptive, innovative and constantly meeting the ever-growing demands of the scientific community in inter-disciplinary Chemical Sciences, thus creating prepared minds to face the challenges.*

Mission:

- *To educate the students to gain an understanding of the fundamentals of Chemical sciences through a gradual exposure and equip them with practical skills to face the challenges in Technology Development*

PROGRAMME'S EDUCATIONAL OBJECTIVES (PEO'S):

PEO1. *Excel in his/her professional career and/or pursue higher education including research by applying the knowledge of chemistry.*

PEO2. *Apply chemical principles and theories and acquire skills in synthesis, instrumentation and characterization.*

PEO3. *Work productively as chemistry professional by adopting to environment with lifelong learning and adhering to ethical standards and apply the knowledge acquired for the improvement of the society.*

PROGRAMME'S OUTCOMES (PO'S):

PO1 Scientific Knowledge: *Apply the knowledge of chemical sciences and employ the training in use of scientific data for analysis and interpretation and provide valid conclusion.*

PO2 Problem analysis and Critical Thinking: *Identify, formulate, research literature, and analyze complex scientific problems reaching substantiated conclusions using principles of chemistry.*

PO3 Teamwork: *Function effectively as an individual, independently, as a member or leader in diverse teams, and in multidisciplinary settings of chemical science.*

PO4 Environment and Sustainability: *Understand the impact of the professional scientific solutions in the societal and environmental contexts and provide eco-friendly approaches for sustainable development.*

PO5 The Chemist and the Society: *Apply reasoning within the contextual knowledge to access societal, health, safety and legal issues and the consequent responsibilities relevant to the professional scientific practice in designing innovative chemical routes leading to product development.*

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PROGRAMME'S SPECIFIC OUTCOMES (PSO'S)

PSO1: *Ability to synthesize, separate and characterize compounds using laboratory and instrumentation techniques required for a successful chemist.*

PSO2: *Ability to envisage, understand the current challenges in industrial chemical processes, work as a team and offer suitable solutions.*

PSO3: *A flair for working as a scientist in industry / academy for the development of new methods for environmental pollution control.*

M. Sc – Chemistry

SEMESTER- I								
SL. NO	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**TCH**
1	PC	ACT32001	Chemical and Statistical Thermodynamics	3	0	0	3	3
2	PC	ACT32002	Essentials of Organic Chemistry	3	0	0	3	3
3	PC	ACT32003	Chemical Bonding and Molecular Geometry	3	0	0	3	3
4	PC	ACT32400	Physical Chemistry Practical	0	0	6	3	6
5	DE	ACT325**	Department Elective – 1	2	1	0	3	3
6	DE	ACT325**	Department Elective - 2	2	1	0	3	3
7	AE	GLS42001	Professional Writing Skills	1	0	0	1	1
			Total	**14**	**2**	**6**	**19**	**22**
SEMESTER- II								
SL. NO	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**TCH**
1	PC	ACT32004	Organic Reactions	3	0	0	3	3
2	PC	ACT32005	Inorganic Elements and Solid-State Chemistry	3	0	0	3	3
3	PC	ACT32006	Research Methodology and Software Applications	3	0	0	3	3
4	PC	ACT32401	Inorganic Chemistry Practical	0	0	6	3	6
5	DE	ACT325**	Department Elective – 3	2	1	0	3	3
6	DE	ACT325**	Department Elective - 4	2	1	0	3	3
7	AE	GLS42400	Presentation Skills	0	0	2	1	2
			Total	**13**	**2**	**8**	**19**	**23**

Note: Students will undergo 1 month of Internship during the II semester summer vacation and it will be evaluated in the III semester.

SEMESTER- III								
SL. NO	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**TCH**
1	PC	ACT32007	Quantum Chemistry and Group Theory	3	0	0	3	3
2	PC	ACT32008	Chemical Kinetics and Catalysis	3	0	0	3	3
3	PC	ACT32009	Reagents and Organic Synthesis	3	0	0	3	3
4	PC	ACT32402	Organic Chemistry Practical	0	0	6	3	6
5	DE	ACT325**	Department Elective - 5	2	1	0	3	3
6	DE	ACT325**	Department Elective - 6	2	1	0	3	3
7	SI	ACT32800	Summer Internship	*	*	*	4	*
			Total	**13**	**2**	**6**	**22**	**21**
* Internship to be undergone during summer vacation and assessment in III semester.								

SEMESTER- IV								
SL. NO	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**TCH**
1	RP	ACT32801	Research Project	0	0	40	20	40
			Total	**0**	**0**	**40**	**20**	**40**

Note: Publication acceptance in Peer Reviewed or Indexed Journals / Presenting & Publishing in Conference Proceedings / Patent filing is mandatory.

MOOC/NPTEL is mandatory.

TOTAL CREDITS: (19+19+22+20) = 80

LIST OF DEPARTMENTAL ELECTIVES WITH GROUPING - SEMESTER WISE								
SEM	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**TCH**
Department Elective - 1								
1	DE	ACT32500	Synthetic Methodology in Organic Chemistry	2	1	0	3	3
1	DE	ACT32501	Analytical Chemistry	2	1	0	3	3
Department Elective - 2								
1	DE	ACT32502	Nuclear chemistry and Biomolecules	2	1	0	3	3
1	DE	ACT32503	Process Development of Active Pharmaceutical Ingredients	2	1	0	3	3
Department Elective - 3								
2	DE	ACT32504	Electrochemistry and Electrodics	2	1	0	3	3
2	DE	ACT32505	Heterocyclic Chemistry	2	1	0	3	3
Department Elective - 4								
2	DE	ACT32506	Chemistry of Industrially Important Products	2	1	0	3	3
2	DE	ACT32507	Polymer Chemistry	2	1	0	3	3
Department Elective - 5								
3	DE	ACT32508	Molecular Spectroscopy	2	1	0	3	3
3	DE	ACT32509	Homogeneous & Heterogeneous Catalysis	2	1	0	3	3
Department Elective - 6								
3	DE	ACT32510	Coordination and Organometallic Chemistry	2	1	0	3	3
3	DE	ACT32511	Computational Chemistry	2	1	0	3	3
L – Lecture ; T- Tutorial ; P – Practical ; C – Credit ; TCH – Total Contact Hours								

STRUCTURE OF THE SBAS PG PROGRAMME

S.No	COURSE CATEGORY	CREDIT
1	PROFESSIONAL CORE COURSE -PC	36
2	DEPARTMENTAL ELECTIVE -DE	18
3	SUMMER INTERNSHIP-SI	04
4	RESEARCH PROJECT WORK - RP	20
5	ABILITY ENHANCEMENT COURSES - AE	02
	TOTAL	**80**

Course Type	
TH	Theory Course
PR	Practical Course
PJ	Project
IN	Internship

PROGRAMME STRUCTURE

PSO1			**PSO2**		**PSO3**	
Ability to synthesize, separate and characterize compounds using laboratory and instrumentation techniques required for a successful chemist.			Ability to envisage, understand the current challenges in industrial chemical processes, work as a team and offer suitable solutions.		A flair for working as a scientist in industry / academy for the development of new methods for environmental pollution control.	
1	2	3	4	5	6	7
Courses - Knowledge based	**Courses related to Analysis**	**Courses on Synthesis**	**Courses - Skill based**	**Courses – Material Science**	**Interdisciplinary domain**	**Problem-Solving**
Coordination and Organometallic Chemistry	Research Methodology and Software Applications	Synthetic Methodology in Organic Synthesis	Organic Chemistry Practical	Chemical Bonding and Molecular Geometry	Chemistry of Industrially Important Products	Chemical and Statistical Thermodynamics
Essentials of Organic Chemistry	Molecular Spectroscopy	Organometallic Chemistry in Organic Synthesis	Inorganic Chemistry Practical	Quantum Chemistry and Group Theory	Computational Chemistry	Process Development of Active Pharmaceutical Ingredients
Organic Reactions	Analytical Chemistry	Reagents and Organic Synthesis	Physical Chemistry Practical	Electrochemistry and Electrodics	Presentation Skills	Homogeneous and Heterogeneous Catalysis
Heterocyclic Chemistry	Polymer Chemistry	Organic Chemistry Practical	Research Project	Inorganic Elements and Solid-State Chemistry	Nuclear chemistry and Biomolecules	Chemical Kinetics and Catalysis

COURSE TITLE	CHEMICAL AND STATISTICAL THERMODYNAMICS			CREDITS	3
COURSE CODE	ACT32001	COURSE CATEGORY	PC	L-T-P-S	3-0-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-3
ASSESSMENT SCHEME					
First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)				ESE
25%	25%				50%
Course Description	**The primary goal of chemical and statistical thermodynamics is the physical explanation of the fundamental principles governing the variety of chemical phenomena taking place in the world around us.**				
Course Objective	1. To give students a conceptual understanding of the main principles of thermodynamics. 2. To provide basic ideas of chemical and statistical thermodynamics and their related aspects. 3. To provide outlines of various laws of equilibrium, non-equilibrium and statistical thermodynamics. 4. To explore the ideas of phase rule in mono and multi-component systems. 5. To make conversant the students about the aspects of non-equilibrium thermodynamics.				
Course Outcome	Upon completion of this course, the students will be able to 1. apply the laws of thermodynamics in heat engine and other devices. 2. apply van't Hoff's isotherm, van't Hoff's isochore and Gibb Helmholtz equation for the determination of spontaneity. 3. calculate change in thermodynamic properties, equilibrium constants, partial molar quantities, chemical potential. Identify factors affecting equilibrium constant. 4. calculate thermodynamic properties of ideal gases, real gases and solids using the principles and techniques of statistical thermodynamics. 5. use the knowledge of non-equilibrium thermo-dynamics, to learn about entropy flow in open systems and microscopic reversibility.				

Prerequisites: An undergraduate thermodynamic course.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	2	1	2	2	1	1	1
CO-2	3	2	1	2	2	1	1	1
CO-3	3	3	1	2	2	1	2	3
CO-4	3	2	1	2	2	1	2	3
CO-5	3	2	1	2	2	1	2	3

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: CHEMICAL THERMODYNAMICS	**(9L)**
Ist Law of thermodynamics - isothermal, adiabatic and isobaric processes - internal energy and enthalpy-bond energies - Hess's law and Kirchoff's law - heat capacities - Joule Thomson effect. IInd law of thermodynamics -entropy, heat engine (Carnot cycle) and its efficiency -entropy and spontaneity of processes–Maxwells Relations- IIIrd law of thermodynamics and entropy at absolute zero.	**CO-1 BTL-2**
MODULE 2: CHEMICAL EQUILIBRIA	**(9L)**
Helmholtz and Gibbs free energies - thermodynamic functions and properties - stand ard free energy of formation as a function of pressure and temperature equilibrium constant - Van't Hoff's isotherm and isochore - Gibbs Helmholtz equation Ellingham diagram. Three component systems – graphical representation. Solid-liquid equilibria- hydrate formation, compound formation.	**CO-2 BTL-2**
MODULE 3: THERMODYNAMICS OF OPEN SYSTEM	**(9L)**
Partial molar properties, chemical potential, partial molar volume, partial molar heat content, variation of chemical potential with temperature and pressure, fugacity, determination of fugacity, variation with temperature and pressure. Thermodynamics of ideal and non-ideal solutions. Concepts of activity and activity coefficients, determination of activity and standard free energy, choice of standard states. - Gibbs Duhem equation - Entropy and free energy of mixing.	**CO-3 BTL-3**

MODULE 4: STATISTICAL THERMODYNAMIC	(9L)
Terminology of statistical thermodynamics - Permutation and combination. Laws of probability. Distribution laws. Gaussian distribution. Distinguishable and indistinguishable particles- Maxwell Boltzmann distribution - thermodynamic properties in terms of partition functions- translational, vibrational and rotational partition function- Heat capacity of solids - Debye and Einstein models. - Fermi Dirac and Bose Einstein statistics – Application of statistical thermodynamics.	**CO-4 BTL-2**
MODULE 5: NON-EQUILIBRIUM THERMODYNAMICS	**(9L)**
Postulates of non-equilibrium thermodynamics, Steady state – conservation of energy and mass-entropy production and entropy flow in open system – Linear laws relative to fluxes and forces – Curie's theorem – microscopic reversibility and Onsager reciprocal relation.	**CO-5 BTL-2**

TEXT BOOKS	
1.	Soni, P.L., Dharmarha, O.P. and Dash, U. N. (2023). *Textbook of Physical Chemistry*, Sultan Chand & Sons.
2.	Sherwood, D., Dalby, P. (2018). *Modern Thermodynamics for Chemists and Biochemists*, Narahari Press.
REFERENCE BOOKS	
1.	Puri, B., Sharma, L., Pathania, M.S. (2016). *Principles of Physical Chemistry*, Vishal Publishing Co, 46th Edition.
2.	Atkins, P. and de Paula, J. (2023). *Elements of Physical Chemistry*, 11th Edition, Oxford University Press.
E BOOKS	
1.	*Introductory Physical Chemistry* by David Ronis - McGill University , 2011
2.	*Physical Chemistry in Brief* by J.P. Novak, S. Labik, I. Malijevska - Institute of Chemical Technology, Prague , 2005
MOOC	
1.	https://www.my-mooc.com/en/mooc/introduction-to-physical-chemistry/

COURSE TITLE	ESSENTIALS OF ORGANIC CHEMISTRY			CREDITS	3
COURSE CODE	ACT32002	COURSE CATEGORY	PC	L-T-P-S	3-0-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4

ASSESSMENT SCHEME

First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)	ESE
25%	25%	50%

Course Description	**This course focuses on the fundamentals of stereochemistry, an analysis on the influence of conformations on reactivity and their application to various organic reactions. This course also describes a detailed account of significant substitution reactions, elimination reactions and rules governing aromaticity.**
Course Objective	1. To impart basic knowledge on stereochemistry of carbon compounds. 2. To make the students understand the influence of molecular conformation on chemical reactivity. 3. To emphasize the mechanistic aspects of various substitution reactions. 4. To illustrate with examples, the elimination reactions and formation of carbon-carbon bond via coupling reactions. 5. To impart knowledge on aromaticity and evolution of reaction mechanisms.
Course Outcome	Upon completion of this course, the students will be able to 1. Analyze molecular symmetry and related stereochemistry. 2. select the suitable conformation for good reactivity. 3. Choose and design a substitution reaction for organic synthesis. 4. Choose a suitable elimination and coupling reaction for organic synthesis. 5. Analyze the reactivity and non-reactivity in aromatic and anti-aromatic compounds.

Prerequisites: Knowledge of Chemistry at undergraduate level.

CO, PO AND PSO MAPPING								
CO	**PO -1**	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PSO-1**	**PSO-2**	**PSO-3**
CO-1	**3**	**3**	**1**	**1**	**1**	**2**	**1**	**1**
CO-2	**3**	**3**	**1**	**1**	**1**	**2**	**1**	**1**
CO-3	**3**	**2**	**1**	**2**	**2**	**3**	**2**	**1**
CO-4	**3**	**2**	**1**	**2**	**2**	**3**	**2**	**1**
CO-5	**3**	**2**	**1**	**1**	**1**	**3**	**2**	**1**
1: Weakly related, 2: Moderately related and 3: Strongly related								

MODULE 1: MOLECULAR SYMMETRY AND POINT GROUPS	**(9L)**
Topicity and prostereo isomerism- Nomenclature of stereotopic ligands and faces – stereo heterotopic ligands - Centre of chirality molecules with C, N, S and P based chiral centers.- assignment of absolute stereochemistry - CIP rules, axial chirality, planar chirality and helicity. stereochemistry and absolute configuration of allines, diphenyls, binapthyls, spiranes, exocyclic alkylidene cycloalkanes.	**CO-1 BTL-4**
MODULE 2: CONFORMATIONAL ANALYSIS AND STEREOCHEMISTRY	**(9L)**
Acyclic systems, cyclic systems - cyclohexane and decalins - conformation and reactivity with examples from molecular rearrangements - neighboring group participation (Woodward, Prevost method) - elimination reactions- formation and cleavage of epoxides quantitative correlation between conformation and reactivity-Winstein Eliel equation-. Classification, terminology-principle of stereoselectivity examples of diastereoselectivity and enantioselectivity– Circular dichroism - ORD - cotton effect - application of ORD and CD in steroids – examples for the illustration of usefulness of cotton effect. **Suggested Reading**: Fundamental concepts on stereochemistry.	**CO-2 BTL-4**
MODULE 3: SUBSTITUTION REACTIONS	**(9L)**
Nucleophilic substitution: Various types-stability and reactivity of carbocations – nucleophilicity and basicity- steric effects in substitution reaction-classical and nonclassical carbocations- Nucleophilic aromatic substitution- various types. Aromatic electrophilic substitution: Intermediates and orientation - electrophiles - reactivity and selectivity - discussion of electrophilic substitution with reference to Hammett plot- kinetic isotopic effects. Nitration- halogenations- sulfonation- Friedel Crafts reaction, Friedel crafts acylation, - protonation.	**CO-3 BTL-3**
MODULE 4: ELIMINATION AND COUPLING REACTIONS	**(9L)**

Mechanism of different type of elimination reactions (E1, E2 and E1CB). Synthesis of alkenes -Wittig and related reactions - modern methods of synthesis Peterson, McMurry, Shapiro reaction - stereoselective - synthesis from 1,2-diols pyrolytic elimination of sulfoxides and selenoxides- synthesis of alkynes, allenes and cumulenes- Pd catalysed coupling reactions- Heck, Suzuki, Glazer- Eglington coupling	**CO-4** **BTL-2**
MODULE 5: AROMATICITY AND REACTION MECHANISM	**(9L)**
Basic definition of aromaticity - Huckle's rule- NMR as a tool-diamagnetic anisotropy aromatic and anti-aromatic compounds – paratropy – Annulenes - some basic alternate and non-alternate hydrocarbons. Reaction mechanism: - transition state theory- kinetics - qualitative picture - Substituent effects - linear free energy relationships- Hammett equation and related modifications- Basic mechanistic concepts like kinetic vs thermodynamic control- Hammond postulate- Curtin Hammett principle- isotope effects - general and specific acid base catalysis- and nucleophilic catalysis.	**CO-5** **BTL-2**
TEXT BOOKS	
1.	Smith, M.B. (2015). *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, Wiley, 7th Edition.
2.	McMurray, J.E. (2015). *Organic Chemistry*, Cengage Learning, 9th Edition.
REFERENCE BOOKS	
1.	Finar, I.L. (2015). *Organic chemistry*, Pearson Books, 9th Edition.
2.	Graham Solomons, T.W., Fryhle, C.B. (2017). *Solomons's Organic Chemistry*, Global Edition.
E BOOKS	
1.	https://books.google.co.in/books/about/Organic_Reaction_Mechanisms.html?id=KHIvAQAAIAAJ
2.	https://www.chemistry.ucla.edu/organic-chemistry
MOOC	
1.	https://www.mooc-list.com/tags/reaction-mechanisms

COURSE TITLE	CHEMICAL BONDING AND MOLECULAR GEOMETRY			CREDITS	3
COURSE CODE	ACT32003	COURSE CATEGORY	PC	L-T-P-S	3-0-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4

ASSESSMENT SCHEME

First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)	ESE
25%	25%	50%

Course Description	**This course describes the concepts of chemical bonding and molecular geometry and comprises details on atomic structure and molecular forces that are linked with the chemical bonding and molecular geometry.**
Course Objective	1. To make the students understand the structure of atoms and periodic properties of elements. 2. To provide an exposure on the fundamentals of ionic compounds. 3. To provide knowledge on the theoretical basis of crystal structure. 4. To give a strong foundation on the structure of covalent compounds. 5. To demonstrate the acid base concepts.
Course Outcome	Upon completion of this course, the students will be able to 1. use the fundamental knowledge on the structure of atoms in understanding forthcoming topics. 2. predict the nature of forces prevalent in compounds, other than chemical bonding. 3. employ basic knowledge on material structure, in synthesis of novel materials. 4. correlate different properties of chemicals with the covalent bond strength. 5. predict the conditions for possible chemical reactions in aqueous medium.

Prerequisites: Knowledge in fundamentals of chemistry at undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	2	1	1	1	1	1	1

CO-2	**3**	**3**	**1**	**2**	**1**	**1**	**2**	**2**
CO-3	**3**	**2**	**1**	**3**	**2**	**1**	**2**	**2**
CO-4	**2**	**3**	**1**	**1**	**2**	**1**	**2**	**2**
CO-5	**3**	**3**	**1**	**2**	**2**	**1**	**2**	**2**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: ATOMIC STRUCTURE	**(9L)**
The Schrodinger wave equation – quantum numbers- energy level diagram of hydrogen atom and polyelectron atoms - electronic configuration and term symbols - periodic properties of elements – atomic size-ionization energy-electron affinity-electro negativity- covalent and ionic radii-magnetic properties. **Suggested Reading**: Atomic theory – Atomic model- De Brogue's Equation -periodic table.	**CO-1** **BTL-2**
MODULE 2: NON-VALENCE FORCES	**(9L)**
Van deer Waals' forces - hydrogen bond – metallic bond – free electron theory of metals - ionic solids – properties of ionic compounds - lattice energy – Born-Haber cycle - Defects structures- Band theory of solids, p-type & n-type semiconductors-superconductivity Suggested Reading: Crystal lattice - unit cell - lattice point - chemical bonding.	**CO-2** **BTL-2**
MODULE 3: CRYSTAL STRUCTURE OF IONIC SOLIDS	**(9L)**
Radius ratio rules- structures of AX (ZnS, NaCl, CsCl), AX_2 (TiO_2, SiO_2) - layer structure – cadmium iodide - covalent solids – diamond, graphite - Structures of spinels and Perovskite **Suggested Reading**: Coordination number - Structure of metallic crystals.	**CO-3** **BTL-3**
MODULE 4: COVALENT BOND	**(9L)**
Valence bond theory – hybridization – types of hybridization- Molecular Orbital theory-symmetry and overlap – bonding in homonuclear diatomic molecules; O_2, B_2 N_2 and C_2 – bonding in heteronuclear diatomic molecules; CO and HCl - Molecular orbital of triatomic molecules; BeH_2 and NO_2 - VSEPR theory – ammonia, water, PCl_3F_2 (Bent's rule), SF_4, BrF_3, TeF_5 -, ICl_2 -, ICl_4 -, XeF_2, XeF_4, XeF_6, bond angle, ammonia & NF_3 dipole moments, H_2O, OF_2 angle, NH_3, XeO_3 angle, CoF_2. **Suggested Reading:** Concept of resonance - Concept of Promotion of Electrons – Hybridization.	**CO-4** **BTL-4**
MODULE 5: AQUEOUS CHEMISTRY	**(9L)**
Acid base concepts - Bronsted, Lowry, Lux-Flood, Usanovich, Lewis - solvent system and generalized acid base concepts -Measures of acid -base strength -steric effect and solvation	**CO-5** **BTL-4**

effects -Hard and soft acids and bases (HSAB) concept - Non aqueous solvents: classification of solvents – levelling and differentiating solvents ionizing solvents –Liq. NH_3 – Liq. SO_2 - Liq. N_2O_4 - Liq. BrF_3 – acetic acid. **Suggested Reading**: Acidity and Basicity of Molecules.	
TEXT BOOKS	
1.	Keemti, L., Agarwal, S.K. (2017). *Advanced Inorganic Chemistry*, Pragati Prakashan Meerut.
2.	Sharma, K.D. (2015). *A Text book of Complete Inorganic Chemistry Book*, Kalyani Publishers.
REFERENCE BOOKS	
1.	Lee, J. D. (2014). *Concise Inorganic Chemistry*, Wiley, 5th Edition.
2.	Malikm, W.U. (2010). *Selected Topics in Inorganic Chemistry*, S. Chand.
E BOOKS	
1.	http://www.freebookcentre.net/chemistry-books-download/Introduction-to-Inorganic-chemistry.html
2.	http://www.freebookcentre.net/chemistry-books-download/Advanced-Inorganic-Chemistry-by-Robert-L.-Carter.html
MOOC	
1.	https://swayam.gov.in/courses/249-inorganic-chemistry-ii
2.	https://www.mooc-list.com/course/inorganic-chemistry-saylororg

COURSE TITLE	**PHYSICAL CHEMISTRY PRACTICAL**			**CREDITS**	**3**
COURSE CODE	**ACT32400**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**0-0-6-0**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-4**

ASSESSMENT SCHEME

Experimental	Calculation	Result	Viva	Record	ESE
20%	**10%**	**10%**	**5%**	**5%**	**50%**

Course Description	**On successful completion of the course the students should have learnt about the chemical kinetic experiments, the potentiometric and conductometric titrations.**
Course Objective	1. To make the students perform conductometric titration. 2. To make the students perform potentiometric titration 3. To make the students perform pH metric titration. 4. To provide exposure on the determination of critical solution temperature of heterogeneous system. 5. To provide exposure to the spectroscopic estimation of ions.
Course Outcome	Upon completion of this course, the students will be able to 1. determine the strength of the given analyte by principles of electrochemistry. 2. create phase diagram for 2 component systems and ternary system. 3. calculate kinetic parameters of given chemical reactions. 4. apply the concept of chemical equilibria. 5. Operate colorimeter and refractometer and do practical determinations.

Prerequisites: Knowledge of chemistry at an undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**3**	**2**	**1**	**1**	**3**	**1**	**1**
CO-2	**3**	**3**	**2**	**1**	**1**	**3**	**1**	**1**
CO-3	**3**	**3**	**2**	**1**	**1**	**3**	**1**	**1**
CO-4	**3**	**3**	**2**	**1**	**1**	**3**	**1**	**1**
CO-5	**3**	**3**	**2**	**1**	**1**	**3**	**1**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: LAB / MINI PROJECT/FIELD WORK	**(45L)**
1. Conductometric titration – mixture of acids. 2. Potentiometric titration – estimation of ferrous ion.	**CO-1** **BTL-3**
3. Determination of critical solution temperature of heterogeneous (phenol-water) system	**CO-2** **BTL-2**
4. Determination of activity co-efficient of an electrolyte at different concentrations by emf measurements	**CO-1** **BTL-3**
5. Spectrophotometric estimation of iron, Mn in solutions	**CO-5**

	BTL 4
6. Degree of hydrolysis of aniline hydrochloride.	**CO-4** **BTL-4**
7. Basicity of acid. Verification of Ostwald dilution law using weak acid and determination of its dissociation constant.	**CO-1** **BTL-3**
8. Determination of order - acetone-iodine reaction. 9. Determination of rate constant-saponification of ethyl acetate. 10. Study of primary salt effect on the kinetics of ionic reaction	**CO-3** **BTL3**
11. Phase diagram of ternary system (nitrobenzene-acetic acid-water)	**CO-2** **BTL-2**

TEXT BOOKS	
1.	Athawale, V.D., Mathur, P. (2017). *Experimental Physical Chemistry*, New Age International (P) Ltd.
2.	Vishwanathan, B., Raghavan, P.S. (2012). *Practical Physical Chemistry*, Viva Books.
REFERENCE BOOKS	
1.	Shoemaker, D.P., Garland, C.W. (2009). *Experiments in Physical Chemistry*, McGraw Hill, 8th Edition.
2.	Vishwanathan, B., Raghavan, P.S. (2012). *Practical Physical Chemistry*, Viva Books.
E BOOKS	
1.	https://pubs.acs.org/doi/abs/10.1021/ed008p1009.2
MOOC	
1.	https://www.mooc-list.com/tags/chemistry

COURSE	**PROFESSIONAL WRITING SKILLS**			**CREDIT**	**1**
COURSE CODE	**GLS42001**	**COURSE CATEGORY**	**AE**	**L-T–P–S**	**1–0–0–1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL – 4**

ASSESSMENT SCHEME		
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**	**ESE**
25 %	**25%**	**50%**

Course Description	This course is a complete course designed to provide students with the skills necessary to produce clear, effective, and engaging written communication in a professional context. Students will learn to balance professionalism with creativity, ensuring their writing is both functional and captivating. Students will develop their ability to communicate persuasively and effectively in various professional scenarios.
Course Objective	By the end of this course, students will have gained exposure to the various genres of professional and creative writing: 1. Understand and apply the principles of clear and effective business communication. 2. Develop and structure various types of professional documents such as business letters, emails, memos, reports, proposals, promotional videos, presentation, resume, report and executive Summaries 3. Write effectively for digital platforms, including websites, blogs, and social media, with a focus on online etiquette
Course Outcome	Upon successful completion of this course, students will: 1. Demonstrate proficiency in writing clear, concise, and professionally structured business documents. 2. Exhibit the ability to craft persuasive and engaging writings. 3. Apply creative writing techniques to produce compelling marketing content, brand stories, and case studies. 4. Effectively write and manage content for digital platforms, including social media, with an understanding of SEO principles. 5. Utilize storytelling and persuasive writing skills to pitch ideas and engage stakeholders in a professional context.
Prerequisites: Plus Two English-Intermediate Level	

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	-	-	-	1	1	-	1	2
CO-2	-	-	-	1	1	-	1	2
CO-3	-	-	-	1	1	-	1	2
CO-4	-	-	-	1	1	-	1	2
CO-5	-	-	-	1	1	-	1	2

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE1: Introduction to Business & Professional Writing	(3 L)
• Fundamentals of Business Writing: Understanding the importance of clear and effective communication in a professional setting. • Professional Tone and Style: Adapting writing style to suit different audiences and purposes. • Writing Process: Planning, drafting, revising, and proofreading. • Grammar and Punctuation: Key rules and common errors in professional writing.	**CO-1** **BTL-2**
MODULE 2:Advanced Document Design and Structure	**(3 L)**
• Document Design Principles: Layout, readability, and visual aids. • Report Writing: Structuring reports for clarity and impact. • Proposal Writing: Crafting compelling proposals that win approval. • Executive Summaries: Creating concise and informative summaries for business executives. • Preparing minutes of the meeting.	**CO-2** **BTL-2**
MODULE3: Creative Writing for Professional Contexts	**(3 L)**
• Creative Thinking in Business Writing: Incorporating creativity to enhance professional documents. • Storytelling Techniques: Using narrative elements to engage and inform. • Brand Voice Development: Crafting a unique voice for business communications.	**CO-3** **BTL-3**
MODULE 4 :Digital Communication	**(3 L)**
• Digital Writing Skills: Writing for websites, blogs, and online platforms. • Online Etiquette: Best practices for professional communication in digital environments. • Create unique Promotional videos for inspiring customers to give great exposure for a cause, brand, or product	**CO-4** **BTL-3**
MODULE 5: Writing for Social Media	**(3 L)**
• Social Media Content: Crafting posts for various social media channels. • Writing for Marketing and Advertising: Techniques for compelling and persuasive marketing content. • Creating content for flyers and banners	**CO-4** **BTL-4**

TEXT BOOKS	
1.	Kesteven, L., Melrose, A. (2022). Professional Writing: Creative and Critical Approaches. Switzerland: Springer International Publishing.
2.	Acharya, T. (2021). Handbook of Professional, Business & Technical Writing, and Communication and Journalism: A Reference Guide to All Kinds of Writing. (n.p.): Lulu.com.
REFERENCE BOOKS	
1.	Baumgardner, A. (2020). Creative Success Now: How Creatives Can Thrive in the 21st Century. (n.p.): Indie Books International.
2.	Marsen, S. (2019). Professional Writing. United Kingdom: Bloomsbury Publishing.
3.	Alred, G. J., Brusaw, C. T., Oliu, W. E. (2011). The Business Writer's Handbook, Tenth Edition. United States: St. Martin's Press.
E -Book	
1.	MacRae, P. (2019). Business and Professional Writing: A Basic Guide - Second Edition. United Kingdom: Broadview Press.
MOOC Courses	
1	https://www.coursera.org/specializations/creative-writing
2	https://onlinecourses.nptel.ac.in/noc20_hs06/preview

COURSE TITLE	**ORGANIC REACTIONS**			**CREDITS**	**3**
COURSE CODE	**ACT32004**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-4**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**

Course Description	**This course deals with synthetically important reactions involving various types of rearrangement, condensation, addition and photochemistry. This course also describes synthesis and reactions of carbonyl compounds.**
Course Objective	1. To make the students understand, various types of rearrangement reactions. 2. To impart knowledge on the synthesis and reactivity of carbonyl compounds. 3. To illustrate with examples, the significance of condensation reactions. 4. To emphasize the utility of addition reactions. 5. To give an exposure to various photochemical reactions.
Course Outcome	Upon completion of this course, the students will be able to 1. Analyze and interpret the success of pericyclic reactions. 2. Identify and select a suitable carbonyl compound as a reaction substrate. 3. Design the synthesis of an organic molecule involving condensation reaction. 4. suggest a synthetic route for aldehydes, alcohols etc. via addition reactions. 5. Suggest the feasibility of photochemical reaction of organic compounds.

Prerequisites: Knowledge of Chemistry at undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**2**
CO-2	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-3	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-4	**3**	**2**	**1**	**1**	**2**	**3**	**1**	**1**
CO-5	**3**	**2**	**1**	**1**	**2**	**3**	**1**	**2**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: PERICYCLIC REACTIONS (9L)

Classification - electrocyclic, sigmatropic, cycloaddition, chelotropic and ene reactions, Cope, Diels-Alder, dipolar cycloaddition reaction - Woodward - Hoffmann rules - Frontier orbital and orbital symmetry correlation approaches. Nature of migration - migratory aptitude - nucleophilic, electrophilic and free radical rearrangements - Wagner Meerwein, Dienone –phenol, Stevens, Wittig rearrangements.	**CO-1** **BTL-4**

MODULE 2: CARBONYL COMPOUNDS	(9L)
Modern methods of synthesis from alcohols- Swern and Dess Martin oxidations. Nucleophilic addition to carbonyls organo lithium, organomagnesium, organo zinc, Organocopper reagents Reactions of carbonyl compounds, addition of N, O, and S Nucleophiles-Reduction using hydride reagents –- formation of enols and enamines-kinetic and thermodynamic enolates.	**CO-2** **BTL-2**
MODULE 3: CONDENSATION REACTIONS	**(9L)**
Lithium and boron enolates in aldol and Michael reactions- stereoselective aldol condensations-alkylation and acylation of enolates - Claisen, Dieckman, Knoevenagel, Stobbe and Darzen glycidic ester, acyloin, emphasis on synthetic utility of these reactions -rearrangement reactions. Electron deficient carbon-acylic and wolf rearrangements. Electron deficient nitrogen-lossen Curtius and Schmidt. Electron deficient oxygen-Bayer Villiger oxidation. Base catalyzed rearrangement - Benzylic acid, Favoriski, transannulune, Sommlett Hauser and smiles rearrangement.	**CO-3** **BTL-3**
MODULE 4: ADDITION REACTIONS	**(9L)**
Reactions of alkenes and alkynes. Generation of radical intermediates and its (i) addition to alkenes, alkynes (inter and intra molecules for C=C formation and Baldwin rules. – stereo and enantioselective hydroboration hydrogenation, epoxidation (Sharpless, Jacobson methods) – hydroxylation – oxymercuration- halolactonisation-Preparation and synthetic uses of lithium and copper acetylides.	**CO-4** **BTL-3**
MODULE 5: PHOTOCHEMICAL REACTIONS	**(9L)**
Photofragmentation- photoaddition- Type I and Type II cleavage- photo substitution, Paterno Buchi reaction, isomerization and rearrangement reactions. MC murry coupling, deoxygenation and decarboxylation .photoreduction and photooxidation reactions- singlet oxygen and chemiluminescence – Photoinduced electron transfer reactions – application to solar energy conservation and artificial photosynthetic systems- Photochemical substitution in transition metal complexes- organometallic photo chemistry- substitution of metal carbonyls.	**CO-5** **BTL-2**

TEXT BOOKS	
1.	Norman, R.O.C. (2017). *Principles of Organic Synthesis*, CRC Press, 3rd Edition.
2.	Carey, F., Giuliano, R. (2016). *Organic Chemistry*, McGraw-Hill Education, 10th Edition.
REFERENCE BOOKS	
1.	Taber Douglass, F. (2015). *Organic Synthesis*, Oxford University Press Inc.

2.	Smith, M. (2016). *Organic Synthesis*, Academic Press, 4th Edition.
E BOOKS	
1.	http://www.freebookcentre.net/Chemistry/Organic-Chemistry-Books.html
2.	https://www.infobooks.org/free-organic-chemistry-books-pdf/
MOOC	
1.	https://www.mooc-list.com/tags/organic-chemistry
2.	https://www.cliffsnotes.com/study-guides/chemistry/organic-chemistry-ii

COURSE TITLE	**INORGANIC ELEMENTS AND SOLID-STATE CHEMISTRY**			**CREDITS**	**3**
COURSE CODE	**ACT32005**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**
Course Description	**This course introduces students to the fascinating properties of different kinds of compounds of the main group elements, and boding in inorganic chains, rings and cages. Sound knowledge on the synthesis of the important classes of nonmetal compounds. An introduction to crystallography and crystal diffraction is given. The students will also learn about solid state synthesis and the properties of important solid-state materials such as high temperature superconductors, glasses and refractories.**				
Course Objective	1. To make the student understand the s- block and p- block elements, their physical, chemistry properties. 2. To educate the students about chemistry d- block elements, their physical and chemical properties.				

	3. To educate the students about chemistry d- block elements, their physical and chemical properties. 4. To provide knowledge on the chemistry of non- metals, their synthesis, structure and bonding along with reactions. 5. To make the students learn about the solid- state chemistry, crystals, their defects, superconductivity etc.
Course Outcome	Upon completion of this course, the students will be able to 1. Utilize the knowledge gained on the s-block and p-block elements for research in inorganic materials employed in ceramic industries. 2. prepare various transition metal catalysts, since they have variable oxidation states. 3. Appreciate the significance of compounds formed by f-block elements and their uses in strategic sectors. 4. Acquire knowledge on the preparation methods of industrially important chemicals like boranes, silanes, phosphanes, etc. 5. Utilize the fundamentals on chemistry of crystals for research on crystal growth for various applications.

Prerequisites: Knowledge in periodic properties of elements, bonding and molecular geometry.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	2	1	1	1	2	1	1
CO-2	3	2	1	1	1	2	1	1
CO-3	3	2	1	1	1	2	1	1
CO-4	3	2	1	1	1	3	1	1
CO-5	3	2	1	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: CHEMISTRY OF s-BLOCK & p-BLOCK ELEMENTS (9L)

General characteristics of s-block elements - atomic and physical properties - Alkali metals: physical properties and chemical properties - reactions with oxygen, hydrogen, halogens. Alkaline earth metals: physical and chemical properties - reactions with oxygen, hydrogen and halogens - Anomalous properties of lithium and beryllium. General characteristics of p-block elements: atomic and physical properties - Physical and chemical properties of Boron and its compounds (borax, boric acid). Carbon: Allotropes,	**CO-1** **BTL-2**

properties, oxides of Carbon. Nitrogen: properties and chemical reactivity. Ammonia: Haber process of manufacture, properties and uses. Oxygen: properties and chemical reactivity. **Suggested Reading**: Occurrence and abundance - Periodic properties of s- and p-block elements.	
MODULE 2: CHEMISTRY OF d-BLOCK ELEMENTS	**(9L)**
Electronic configuration and general characteristics -metallic properties, ionization energy, electrode potential, oxidation states, ionic radii, catalytic properties, coloured ions, complex formation, magnetic properties, interstitial compounds and alloys. Preparation and properties of $KMnO_4$, $K_2Cr_2O_7$. Lanthanides – occurrence-isolation-lanthanide contraction, properties-nuclear reactions of uranium, thorium and plutonium-power generation by nuclear reactors- breeder reactor-fusion reaction-radioisotopes and their applications. **Suggested Reading**: Occurrence and abundance - Periodic properties of d-block elements.	**CO-2** **BTL-2**
MODULE 3: CHEMISTRY OF NON-METALS	**(9L)**
B, Si, P & S compounds - E-H, E-X, E-O & E-N bond types in different molecules - chemistry of simple boranes, silanes, phosphanes and sulphanes borazine, boron and silicon nitrides. P-N & S-N rings: Synthesis, structure & bonding reactions of N3P3Cl5 & S4N4 - Halogen and noble gas chemistry: Interhalogen, pseudohalogen ionic oxyhalogen species, xenon-oxides & fluoxides. **Suggested Reading**: Occurrence and structure of the elements – Physical and chemical properties.	**CO-3** **BTL-3**
MODULE 4: SOLID-STATE CHEMISTRY	**(9L)**
Crystallography-laws of crystal structures, crystal systems, X-Ray crystallography -X-Ray, neutron and electron diffraction, types of crystalline solids -Preparative methods: Solid state reaction -precipitative reactions, sol-gel route – Superconductivity and recent high Tc materials -spinels, gamets and perovskites-glasses and refractories. **Suggested Reading**: Metallic bond and metallic structure – theories of bonding in metals.	**CO-4** **BTL-2**
MODULE 5: PROPERTIES AND APPLICATIONS OF SOLIDS	**(9L)**
Magnetic materials - metals and alloys – metal oxides –garnets – ilmenites – magneto plumbites – applications – transformer cores – information storage – memory devices – permanent magnets. Solid state electrolytes – types - examples – applications – electrochemical cells – batteries- sensors and fuel cells. Crystallization – growth of single crystals – Czochralski – Bridgman and Stockbarger – zone melting - melt : flux methods	**CO-5** **BTL-2**

Suggested Reading: Properties and growth of crystals.	
TEXT BOOKS	
1.	Keemti, L., Agarwal, S.K. (2017). *Advanced Inorganic Chemistry*, Pragati Prakashan Meerut.
2.	Sharma, K.D. (2015). *A Text book of Complete Inorganic Chemistry Book*, Kalyani Publishers.
REFERENCE BOOKS	
1.	Lee, J.D. (2014). *Concise Inorganic Chemistry*, Wiley, 5th Edition.
2.	Malik, W.U. (2010). *Selected Topics in Inorganic Chemistry*. S. Chand.
E BOOKS	
1.	http://www.freebookcentre.net/chemistry-books-download/Advanced-Inorganic-Chemistry-I.html
2.	http://www.freebookcentre.net/chemistry-books-download/Principles-of-Inorganic-Chemistry-III.html
MOOC	
1.	https://swayam.gov.in/courses/249-inorganic-chemistry-ii
2.	https://www.mooc-list.com/course/inorganic-chemistry-saylororg

COURSE TITLE	**RESEARCH METHODOLOGY AND SOFTWARE APPLICATIONS**			**CREDITS**	**3**
COURSE CODE	**ACT32006**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**

Course Description	**The course provides a brief introduction to research and practical skills in analysis.**
Course Objective	1. To learn different methods of research and types of analysis. 2. To learn the different methods of conducting literature review on the specified topic. 3. To. learn the analysis of data obtained through experiments. 4. To learn the basic software used in analyzing the data. 5. To learn the method of presenting the research findings and document the same.
Course Outcome	Upon completion of this course, the students will be able to 1. Identify different types of research and apply for the given field of research. 2. Choose a suitable method of collecting required literature on the given field of research. 3. Analyze the data obtained from the experiments and arrive at conclusions. 4. Use software for drawing and scientific research. 5. Prepare documents for reporting/dissertation and articles for publishing in journals.

Prerequisites: Knowledge in fundamentals of chemistry at a higher secondary level.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**1**	**2**	**-**	**3**	**1**	**1**	**3**
CO-2	**3**	**1**	**2**	**-**	**3**	**2**	**2**	**3**
CO-3	**3**	**1**	**2**	**-**	**3**	**3**	**3**	**3**
CO-4	**3**	**1**	**2**	**-**	**3**	**2**	**2**	**3**
CO-5	**3**	**1**	**2**	**-**	**3**	**3**	**3**	**3**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: – METHODS AND TYPES OF RESEARCH	**(9L)**
Research methods vs Methodology. Types of research, Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical.	**CO-1 BTL-3**
MODULE 2: LITERATURE REVIEW	**(9L)**
Importance of literature review in defining a problem, Primary and secondary sources, reviews, treatise, monographs-patents, Defining and formulating the research problem, Selecting the Problems.	**CO-2 BTL-3**

MODULE 3: ERROR ANALYSIS	(9L)
Limiting errors – types of errors – Gross, systematic and Random – central value – statistical treatment of data – rejection of data. of combination of components – uncertainty analysis and treatment of single sample data.	**CO-3** **BTL-3**
MODULE 4: SCIENTIFIC SOFTWARES IN RESEARCH DESIGN	**(9L)**
Data Analysis using Tools like MS Excel, ChemDraw and MATLAB, google scholar, chemspider, scifinder, scopus, research gate; web resources, e-journals, e-books, journal access, subscribing TOC alerts, hot articles, citation index, h-index and i-index, Impact factor.	**CO-4** **BTL-3**
MODULE 5: REPORTING, DOCUMENTATION AND PRESENTATION	**(9L)**
Scientific Document; Organization and writing of research papers, short communications, review articles, monographs, peer reviewing, ethics in publishing, predatory journals and publishers, technical and survey reports, authored book and edited books and dissertation.	**CO-5** **BTL-3**

TEXT BOOKS	
1.	Singh, Y.K. (2021). *Fundamentals of Research Methodology & Statistics*, New Age International.
2.	George Thomas, C. (2021). *Research Methodology and Scientific Writing*, Springer.
REFERENCE BOOKS	
1.	Leedy. P.D. and Ormrod, J. E. (2004). *Practical Research: Planning and Design*, Prentice Hall.
2.	Garg, B. L. Karadia, R. Agarwal, F. and Agarwal, U. K. (2022). *An introduction to Research Methodology*, RBSA.
E BOOKS	
1.	https://www.sultanchandandsons.com/book/617/research-methodology-and-applications-of-spss-in-social-science-research
2.	https://sde.uoc.ac.in/sites/default/files/sde_videos/IV%20Sem%20-research%20methodology%20slm%20FINAL.pdf
MOOC	
1.	https://onlinecourses.nptel.ac.in/noc23_ge36/preview
2.	https://onlinecourses.swayam2.ac.in/nou21_cm03/preview

COURSE TITLE	INORGANIC CHEMISTRY PRACTICAL			CREDITS	3
COURSE CODE	ACT32401	COURSE CATEGORY	PC	L-T-P-S	0-0-6-0
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4

ASSESSMENT SCHEME

Experimental	Calculation	Result	Viva	Record	ESE
20%	10%	10%	5%	5%	50%

Course Description	**Students will gain an understanding of the basic knowledge of qualitative analysis of mixture of salts, colorimetric analysis and water quality parameters analysis.**
Course Objective	1. To learn the qualitative analysis of mixture of salts. 2. To learn colorimetric analysis. 3. To learn various water quality parameters.
Course Outcome	Upon completion of this course, the students will be able to 1. Relate the chemical reactions and the corresponding anions and cations in the given salt. 2. Estimate the quantity of metal in a mixture by gravimetric analysis. 3. Formulate method for the determination of metals, ferrous and non-ferrous alloys. 4. Prepare the inorganic complexes with suitable parameters. 5. Do research on fine-tuning the quantitative analysis of CaO in lime and chlorine content.

Prerequisites: Knowledge of chemistry at an undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	3	1	2
CO-2	3	3	1	1	1	3	1	2
CO-3	3	3	1	1	1	3	1	2
CO-4	3	3	1	1	1	3	1	2
CO-5	3	3	1	1	1	3	1	2

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: LAB / MINI PROJECT/FIELD WORK		(45L)
1.	Separation and Analysis of an "Inorganic mixture containing two common and two less common metal ions" including the following: Common Ions: Pb, Cu , Bi, Cd, Al, Ni, Co, Mn, Zn, Ba, Ca, Sr and Mg; Less common Ions: W, Se, Te, Mo, Ce, Th, Zr, Ti, V, U, and Li.	**CO-1** **BTL-4**
2.	Estimation of metals in a mixture (Volumetry and Gravimetry) a. Copper (V) - Nickel (G) b. Copper (G) – Zinc (V) c. Iron (V) – Nickel (G) Iron (V) – Magnesium (G)	**CO-2** **BTL-4**
3.	Colorimetric Estimation of Cu,Cr,Fe,Ni and Mn.	**CO-3** **BTL-4**
4.	Preparation of any five of the following complexes: i. Tetraamminecopper(II) sulphate, ii. Potassium trioxalatochromate(III), iii. Hexaureachromium(III) chloride, iv. Sodium trioxalatoferrate(III), v. Tris(acetylacetanato)copper (II), vi. Tris(ethylenediamine)nickel (II) chloride	**CO-4** **BTL-4**
5.	Analysis of cement -silica, mixed oxide – Fe_2O_3, Al_2O_3 & CaO/MgO. $BaSO_4$ in lithophone.	**CO-5** **BTL-4**

TEXT BOOKS	
1.	Svehla, G., Sivashankar, B. (2012). *Vogel's Qualitative Inorganic Analysis*. Pearson Education India.
2.	Mendham, J. (2009). *Vogel's Quantitative Chemical Analysis*, Pearson Education.

REFERENCE BOOKS	
1.	Gulati, S. (2017). *Practical Inorganic Chemistry*, CBS Publication.
2.	Mumtazuddin, S., Sinha, S.K. (2017). *Inorganic Lab Manual*, Atlantic Publishers and Distributors Pvt Ltd, 1st Edition.

E BOOKS	
1.	https://pubs.acs.org/doi/abs/10.1021/ed011p62.2
2.	Inorganic Chemistry Practical by Dr Deepak Pant - read free book online - download eBook (bookrix.com)
MOOC	
1.	https://www.mooc-list.com/tags/inorganic-chemistry
2.	Chemistry Laboratory Techniques | Chemistry | MIT OpenCourseWare

COURSE TITLE	**PRESENTATION SKILLS**			**CREDITS**	**1**
COURSE CODE	**GLS42400**	**COURSE CATEGORY**	**AE**	**L-T-P-S**	**0-0-2-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
CIA					**ESE**
50%					**50%**
Course Description	**This practical course is designed to provide students with hands-on experience in conducting research, writing research papers, and delivering presentations tailored to real world contexts. Through a combination of theoretical instruction, practical exercises and experiential learning opportunities, students will develop the essential skills and competencies needed to excel in academic and professional settings.**				
Course Objectives	1. Toeffectivelyconductresearch,criticallyevaluatesources,andsynthesize information to produce well-structured and persuasive written documents. 2. To develop the skills necessary to deliver engaging and professional presentations, including effective public speaking techniques, slide design principles, and audience engagement strategies. 3. To provide hands-on exercises, collaborative projects, and constructive feedback, cultivate the ability to communicate complex ideas clearly and confidently in both written and oral formats, preparing them for success in academic, professional, and Personal contexts.				

	4. To develop technical documents and presentations through the creation, editing, and application of visual aids. 5. To organize a diverse portfolio of technical writing and presentations.
Course Outcomes	Upon completion of this course, the students will be able to 1. Discuss research ideas and findings in clear and well-structured written research documents that communicate effectively. 2. Develop project proposal structures by analyzing successful examples and engaging in peer reviews. 3. Apply techniques for structuring technical presentations, integrating visuals, demonstrating delivery skills, and evaluating peers' work. 4. Develop technical documents and presentations through the creation, editing, and application of visual aids. 5. Organize a diverse portfolio of technical writing and presentations.

Prerequisites: NIL

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	-	-	-	**1**	**1**	**1**	**1**	**2**
CO-2	-	-	-	**1**	**1**	**1**	**1**	**2**
CO-3	-	-	-	**1**	**1**	**1**	**1**	**2**
CO-4	-	-	-	**1**	**1**	**1**	**1**	**2**
CO-5	-	-	-	**1**	**1**	**1**	**1**	**2**

1: Weakly related, 2: Moderately related and 3: Strongly related

Module 1: Writing for Presentation	**(6 L)**
Introduction to Ms power point-Structuring technical presentations: introduction, main content, conclusion-Crafting clear and engaging presentation content-Types of presentation: informative, persuasive and demonstrative- Using images, animations and videos to enhance the quality of presentation- Customizing the presentation according to audience. **Lab Exercises:** • Making PowerPoint presentation. • Adding animations and videos.	**CO-1** **BTL-2**

Module 2: Effective Offline presentation	**(6 L)**
Searching and organising the content- Checking for feasibility of presentation aids- preparatory checks before presentation: voice, mike, system, lights, speaker, etc- handling fear and nervousness during the presentation. –importance of non-verbal communication: body language, gesture and eye contact. handling mishap- stage management and bonding with the audience during presentation. **Lab Exercises:** • Micro presentation practice. • Practice for Handling mishap.	**CO-2** **BTL-2**
Module 3: Effective Online Presentation	**(6 L)**
Customizing the presentation for online- introduction to online presentation tools: Zoom, Ms-Teams, Google meet, etc- handling camera, lights, mike and audience during online presentation. Using visuals and multimedia effectively in presentations- handling mishap in online presentation- Time management during presentation. **Lab Exercises:** • Practice for micro-online presentation • Handling mishap during online presentations.	**CO-3** **BTL-3**
Module 4: Concluding the Presentation	**(6 L)**
Summarising the presentation- handling the question-and-answer section- inspiring the audience for action- closing anecdote or quote. Paying complements and gratitude- exercises and feed backs- Presenting vote of thanks. **Lab Exercises:** • Practice for handling question and answer section. • Practice for presenting vote of thanks.	**CO-4** **BTL-3**
Module 5: Dressing attributes for presentation	**(6 L)**
Importance of dressing for men and women- Use of proper dress code to meet the occasion- Importance of tie knots, shoes, belt, makeup, hairstyle, etc- Dressing for online presentation-Do and Don’t in dressing- self assessment and reflection. **Lab Exercises:** • Practice for dressing for the different occasions. • Practice for tying the knot.	**CO-5** **BTL-3**

TEXT BOOKS	
1	Technical Writing, Presentation Skills, and Online Communication: Professional Tools and Insights by Raymond Greenlaw
REFERENCES	
1	The Elements of Style by William Strunk Jr. and E.B. White Slideology: The Art and Science of Creating Great Presentations by Nancy Duarte
E-BOOKS	
1	https://www.site.uottawa.ca/~rhabash/ELG2911TechnicalWritingandPresentation.pdf

COURSE TITLE	**QUANTUM CHEMISTRY AND GROUP THEORY**			**CREDITS**	**3**
COURSE CODE	**ACT32007**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**
Course Description	**The overall objective is to acquaint students with the fundamentals of symmetry and group theoretical methods and how to apply them to vibrational and electronic spectroscopy and to the study of molecular structure, bonding, and chemical reactivity.**				
Course Objective	1. To expose the students to old postulates in quantum mechanics. 2. To make the students understand the principles of quantum mechanics related to chemistry. 3. To educate the students on the concept of linear combination of atomic orbitals to hybridization. 4. To make the students aware of symmetry and group theory. 5. To make them understand applications of group theory.				

Course Outcome	Upon completion of this course, the students will be able to 1. Relate concepts in modern atomic physics to molecular systems and solve the model problems in quantum mechanics. 2. Recognize the most significant and elementary solutions of Schrodinger equation through a study of time independent perturbation theory and apply quantum mechanical principles to solve simple systems. 3. Apply the concept of linear combination of atomic orbitals to hybridization and direct bonding in polyatomic molecules 4. Assess and perform the symmetrical operations on various molecules 5. Appreciate symmetry element and related spectroscopic behavior.

Prerequisites: Knowledge of Chemistry at undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-2	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-3	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-4	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-5	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: REVIEW OF OLD QUANTUM THEORY	**(9L)**
Concept of the Quantum Theory: Planck's Quantum Hypothesis, Photoelectric Effect, De Broglie Waves Observed, Two-Slit Experiments, Heisenberg Uncertainty Principle; Postulates of quantum mechanics - State Functions, Operators and Classical Variables, Observable Quantities and Eigenvalues, Commutators and the Uncertainty Principle, Hermitian Operators, Hermitian Operators and Orthogonality, Commuting Operators and Mutual Eigenfunctions, Probability of a Measurement and Fourier Coefficients.	**CO-1** **BTL-2**
MODULE 2: SOLUTIONS OF SCHRONDINGER EQUATIONS	**(9L)**
Time-dependent and time independent Schrodinger Equation. Particle-in-a-box - particle-in-a-ring - harmonic oscillator and rigid rotor - Solution of the Schroedinger equation for the hydrogen atom. Angular Momentum and Measurements, Determination of the Eigenvalues.	**CO-2** **BTL-2**

One-Dimensiona Classical Wave Equation, Separation of Variables, Oscillatory Solutions to Differential Equations, Superposition of Normal Modes, Vibrating Membrane, Interference of Waves.	
MODULE 3: CHEMICAL BONDING	**(9L)**
Degenerate states - Variational method - Helimann - Feynman theorem. Born Oppenheimer approximation- Hydrogen molecule ion- Hydrogen molecule: Valence bond and molecular orbital methods- Polyatomic molecules and hybridization- Molecular Term Symbols and Symmetry Properties.	**CO-3** **BTL-3**
MODULE 4: GROUP THEORY	**(9L)**
The concept of groups- symmetry equations and symmetry elements in molecules-Matrix representations of symmetry operations- Point groups- irreducible representations.	**CO-4** **BTL-2**
MODULE 5: APPLICATIONS OF GROUP THEORY	**(9L)**
Great Orthogonality Theorem, Character Table & their uses, Direct Products and Reduction Formula, Application of group theory to atomic orbital in ligand fields- molecular orbitals- hybridization - classification of normal vibrational modes- selection rules in vibrational and electronic spectroscopy.	**CO-5** **BTL-2**

TEXT BOOKS	
1.	Alan, V. (2016). *Molecular Symmetry and Group Theory - A Programmed Introduction to Chemical Applications*, John and Willy & Sons Ltd.
2.	Prasad, R.K. (2020). *Quantum Chemistry*, New Age.
REFERENCE BOOKS	
1.	Mcquarrie, D.A. (2016). *Quantum Chemistry*, Viva Books.
2.	Singh, M.K. and & Singh, S.N. (2022). *Group Theory I*, S Chand.
3.	Cotton, F.A. (2016). *Chemical Applications of Group Theory*, Wiley NY.
E BOOKS	
1.	http://store.doverpublications.com/0486432475.html
2.	https://www.ebookselibrary.com/book-detail/higher-education/mathematics/GROUP-THEORY-594
MOOC	
1.	https://onlinecourses.nptel.ac.in/noc16_cy07/preview
2.	https://www.open.edu/openlearn/science-maths-technology/introduction-group-theory/content-section-0

COURSE TITLE	CHEMICAL KINETICS AND CATALYSIS			CREDITS	3
COURSE CODE	ACT32008	COURSE CATEGORY	PC	L-T-P-S	3-0-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4
ASSESSMENT SCHEME					
First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)				ESE
25%	25%				50%
Course Description	The course imparts an extensive knowledge and understanding about the various chemical and photochemical reactions based on kinetics, theories of reaction rate, heterogeneous and homogeneous catalysis-mechanism and applications.				
Course Objective	1. To understand the basic principles of various types of chemical reaction based on kinetics. 2. To make the students learn about the theories of reaction rates. 3. To educate the students about the kinetics of various photochemical reactions and their mechanism. 4. To provide knowledge on the homogeneous catalysis including enzyme catalysis and effect of different conditions like temperature, pH etc. 5. To make the students learn about the surface reactions and heterogeneous catalysis, adsorption, catalytic promotion and poisoning.				
Course Outcome	Upon completion of this course, the students will be able to 1. apply the knowledge gained for the study of kinetics in complex reactions. 2. apply elementary laws of chemical kinetics, analyze reaction mechanisms, changes in transport properties of chemical reactions and collision processes. 3. study in depth the kinetics of photochemical reactions. 4. propose suitable rate equation for acid-base catalyzed reactions and enzyme catalyzed reactions.				

	5. suggest and design new catalysts for industrially important reactions, and for green chemical processes.

Prerequisites: Basic knowledge in Kinetics at undergraduate level

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	2	1	1	1	1	2	1
CO-2	3	2	1	1	1	1	2	1
CO-3	3	2	1	1	1	1	2	1
CO-4	3	2	1	2	2	1	3	2
CO-5	3	2	1	2	2	1	3	2

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: KINETICS OF COMPLEX REACTIONS	**(9L)**
Complex reactions: kinetics of opposing reactions, parallel reactions and consecutive reactions – Kinetics of chain reactions - H_2 & Br_2, H_2 & O_2, decomposition of CH_3CHO & N_2O_5 - Study of fast reactions, flow technique, stopped flow technique, temperature and pressure jump methods, shock tubes. Radiation Chemistry: Source - interaction of high energy radiation with matter - primary and secondary processes- G-value- Radiolysis of water and aqueous solutions-Dosimetry .	**CO-1** **BTL-3**
MODULE 2: THEORY OF REACTION RATES	**(9L)**
Effect of temperature on reaction rates, Arrhenius equation for simple reactions, Energy of activation. Potential energy surfaces, an introduction, kinetic theory of collisions - collision cross section, comparison with Arrhenius equation, Conventional transition state theory, thermodynamic treatment, Eyring equation - Elementary gas phase reactions: Lindemann - Hinsheldwood mechanism and Rice Ramsperger Kassel (RRK) theory. **Suggested Reading**: Rate equation , rate law	**CO-2** **BTL-2**
MODULE 3: KINETICS OF PHOTOCHEMICAL REACTIONS	**(9L)**
Kinetics in the excited electronic states-Jablonskii diagram-kinetics of unimolecular photophysical and photochemical processes- photoisomerisation-bimolecular photophysical and photochemical processes-excimers, exciplexes and sensitization-Mechanism of fluorescence quenching SternVolmer equation. Charge transfer mechanisms, energy transfer mechanism, donor acceptor interaction in energy transfer.	**CO-3** **BTL-3**

MODULE 4: HOMOGENEOUS CATALYSIS	(9L)
Acid - Base Catalysis: Specific and general catalysis- Skrabal diagram – prototropic and protolytic mechanisms - secondary salt effect- examples - Bronsted Catalysis Law, acidity function: Ho H- scales –Overlap, Zucker-Hammett and Bunnet hypothesis. Enzyme catalysis- Michaelis Menten method - equation - Lineweaver -Burk and Eadie plots- Effect of temperature and pH on enzyme catalyzed reactions.	**CO-4 BTL-4**
MODULE 5: SURFACE CHEMISTRY & HETEROGENEOUS CATALYSIS	**(9L)**
Adsorption – gas on solid – types of adsorptions – Freundlich, Langmuir, B.E.T adsorption isotherms, determination of surface area, Harkins and Jura method, importance of surface area, heat of adsorption, applications: adsorption chromatography, purification of water by zeolites, etc. Surface Reactions: thermodynamics of surface *reactions*, Langmuir Hinshelwood and Eley Rideal mechanisms. General aspects, co adsorption, poisoning and promotion effects, model reactions. Industrially important surface catalyzed reactions - examples CO oxidation and methanation, ammonia synthesis, epoxidation reactions.	**CO-5 BTL-4**

TEXT BOOKS	
1.	Atkins, P., de Paula, J., Keeler, J. (2023). *Atkins' Physical Chemistry*, Oxford, 11th Edition.
2.	Barrow, G.M. (2016). *Physical Chemistry*, Tata McGraw Hill Education, 6th Edition.
REFERENCE BOOKS	
1.	Selvaraj, V.K. (2013). *Advanced Chemical Kinetics*, Campus Books International.
2.	Rajaram, J., Kuriacose, J. C. (2011). *Kinetics and Mechanisms of Chemical Transformations*, Macmillan India.
E BOOKS	
1.	https://www.kotapointedu.in/2020/06/physical-chemistry-by-narendra-awasti.html
2.	https://www.pdfnotes.co/rc-mukherjee-physical-chemistry-pdf/
MOOC	
1.	https://www.my-mooc.com/en/mooc/introduction-to-physical-chemistry/

COURSE TITLE	REAGENTS AND ORGANIC SYNTHESIS			CREDITS	3
COURSE CODE	ACT32009	COURSE CATEGORY	PC	L-T-P-S	3-0-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4

ASSESSMENT SCHEME		
First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)	ESE
25%	25%	50%

Course Description	**This course emphasizes the various aspects of retro-synthetic analysis, role of protecting groups in organic synthesis, various oxidizing and reducing agents well-illustrated with examples. In addition, this course also describes the structural elucidations of terpenoids and steroids and current synthetic methods.**
Course Objective	1. To expose the students in the area of retro-synthesis and protecting groups 2. To train the students in selecting suitable oxidizing agents. 3. To impart a sound knowledge on the various reducing agents in organic synthesis. 4. To expose the students to the current synthetic methods employed for organic synthesis. 5. To make the students understand the structural elucidation of terpenoids and steroids.
Course Outcome	Upon completion of this course, the students will be able to 1. Justify the suitability of a design for the synthesis of organic molecules such as pharmaceutical drugs. 2. Suggest and select a suitable oxidizing agent for the given reaction. 3. Suggest and select a suitable reducing agent for the given reaction. 4. Analyze the development and merits in the current organic synthesis. 5. understand the role terpenoids and steroids, that are very essential in synthesizing important drugs.

Prerequisites: Knowledge of Chemistry at undergraduate level.

CO, PO AND PSO MAPPING								
CO	**PO-1**	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PSO-1**	**PSO-2**	**PSO-3**
CO-1	**3**	**3**	**1**	**2**	**2**	**3**	**2**	**1**
CO-2	**3**	**3**	**1**	**2**	**2**	**3**	**2**	**1**
CO-3	**3**	**3**	**1**	**2**	**2**	**3**	**2**	**1**
CO-4	**3**	**3**	**1**	**2**	**2**	**3**	**2**	**2**
CO-5	**3**	**3**	**1**	**2**	**2**	**3**	**2**	**1**
1: Weakly related, 2: Moderately related and 3: Strongly related								

MODULE 1: – RETRO SYNTHESIS AND PROTECTING GROUPS	**(9L)**
Retrosynthetic Analysis: Basic principles and terminology of retrosynthesis, synthesis of aromatic compounds, one group and two group C-X disconnections, one group C-C and two group C-C disconnections, amine and alkene synthesis, important strategies of retrosynthesis, functional group transposition, important functional group interconversions Protecting groups: Protection and deprotection of hydroxy, carboxyl, carbonyl, carboxy amino groups and carbon-carbon multiple bonds; chemo- and regioselective protection and deprotection; illustration of protection and deprotection in synthesis. **Suggested Reading:** Chemical bonding and chemistry of functional groups	**CO-1** **BTL-4**
MODULE 2: OXIDATIONS	**(9L)**
Oxidation: Metal based and non-metal-based oxidations of (a) alcohols to carbonyls (Chromium, Manganese, aluminium, silver, ruthenium. DMSO, hypervalent iodine and TEMPO based reagents). (b) phenols (Fremy's salt, silver carbonate) (c) alkenes to epoxides (peroxides/per acids based), Sharpless asymmetric epoxidation, Jacobsen epoxidation, Shi epoxidation.(d) alkenes to diols (Manganese, Osmium based), Sharpless asymmetric dihydroxylation, Prevost reaction and Woodward modification, (e) alkenes to carbonyls with bond cleavage (Manganese, Osmium, Ruthenium and lead based, ozonolysis) (f) alkenes to alcohols/carbonyls without bond cleavage (hydroboration-oxidation, Wacker oxidation, selenium, chromium based allylic oxidation) (g) ketones to ester/lactones (Baeyer-Villiger). **Suggested Reading:** Role of transition metals in oxidation reactions.	**CO-2** **BTL-2**
MODULE 3: REDUCTIONS	**(9L)**
Reduction: (a) Catalytic hydrogenation (Heterogeneous: Palladium / Platinum / Rhodium / Nickel etc; Homogeneous: Wilkinson). Noyori asymmetric hydrogenation. (b) Metal based reductions using Li/Na/Ca in liquid ammonia, Sodium, Magnesium, Zinc, Titanium and	**CO-3** **BTL-3**

Samarium (Birch, Pinacol formation, McMurry, Acyloin formation, dehalgenation and deoxygenations) (c) Hydride transfer reagents from Group III and Group IV in reductions. (i) $NaBH_4$ triacetoxyborohydride, L-selectride, K-selectride, Luche reduction; $LiAlH_4$, DIBAL-H, and Red-Al, Trialkylsilanes and Trialkylstannane, Meerwein-Pondorff-Verley reduction) (ii) Stereo/enantioselectiviey reductions (Chiral Boranes, Corey-Bakshi-Shibata). **Suggested Reading:** Catalytic and non-catalytic reductions.	
MODULE 4: CURRENT SYNTHETIC METHODS	**(9L)**
Baylis-Hillman reaction, Henry reaction, Nef reaction, Kulinkovich reaction, Ritter reaction, Sakurai reaction, Tishchenko reaction and Ugi reaction. Brook rearrangement; Tebbe olefination. Metal mediated C-C and C-X coupling reactions: Heck, Stille, Suzuki, Negishi and Sonogashira, Nozaki-Hiyama, Buchwald-Hartwig, Ullmann coupling reactions, directed ortho metalation. Aza-Cope rearrangement (Overman rearrangement), ene reaction (metallocene; Coniaene); Prin's reaction. **Suggested Reading:** Conventional Name reactions in organic synthesis.	**CO-4 BTL-2**
MODULE 5: TERPENOIDS AND STEROIDS	**(9L)**
Classification – isolation of terpenes – isoprene rule- methods of structural elucidation - synthesis and structure of monoterpines and sesquiterpenes- bisabolene, transchrysantha-mic acid, logifolene, taxines, caryophyilene – Steroids- Structural elucidation and stereochemistry - cholestrol, ergosterol, estrone, progestereone, androstereone, cortisone - Prostaglandins, F21 and E2, thromboxane Tx, B2. **Suggested Reading:** Nomenclature and synthesis of terpenoids	**CO-5 BTL-2**

TEXT BOOKS	
1.	Norman, R.O.C. (2017). *Principles of Organic Synthesis*, CRC Press, 3rd Edition.
2.	Carey, F., Giuliano, R. (2016). *Organic Chemistry*, McGraw-Hill Education, 10th Edition.
REFERENCE BOOKS	
1.	Taber Douglass, F. (2015). *Organic Synthesis*, Oxford University Press Inc.
2.	Smith, M. (2016). *Organic Synthesis*, Academic Press, 4th Edition.
E BOOKS	
1.	https://www.amazon.in/Organic-Synthesis-Michael-B-Smith-ebook/dp/B007SU9QN2
2.	https://www.amazon.in/Catalyst-free-Organic-Synthesis-Green-Chemistry-ebook/dp/B078BV4Y9T
MOOC	

1.	https://www.udemy.com/topic/organic-chemistry/

COURSE TITLE	ORGANIC CHEMISTRY PRACTICAL			CREDITS	3
COURSE CODE	ACT32402	COURSE CATEGORY	PC	L-T-P-S	0-0-6-0
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4

ASSESSMENT SCHEME

Experimental	Calculation	Result	Viva	Record	ESE
20%	10%	10%	5%	5%	50%

Course Description	**This course comprises of technical aspects of organic chemistry involving characterization by qualitative analysis and spectroscopy, hands on training on the multi-step organic synthesis. In addition, this course also describes a few name reactions of synthetic importance.**
Course Objective	1. To make the students, learn on qualitative analysis of mixture of organic substances. 2. To expose the students and train them on multi-step organic synthesis and a few organic reactions. 3. To make the students characterize the compounds by spectroscopy and interpret the results.
Course Outcome	Upon completion of this course, the students will be able to 1. analyze mixture of organic substances and employ suitable separation technique. 2. perform individually, various types of organic reactions. 3. interpret the results obtained in spectroscopic analysis of organic compounds and identify them.

Prerequisites: Knowledge of Chemistry at undergraduate level.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	3	1	1
CO-2	3	3	1	1	1	3	1	1
CO-3	3	3	1	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related		
MODULE 1: LAB / MINI PROJECT/FIELD WORK		**(45L)**
1. Analysis of two component mixtures; separation andCharacterization of compounds.		**CO-1 BTL-4**
2. Preparations involving two or three stages comprising of the following processes.		**CO-2 BTL-4**
a) Nitration b) Halogenation	c) Hydrolysis d) Reduction e) Oxidation	
3. Preparations illustrating the following.		**CO-2 BTL-4**
a) Cannizaro reaction b) Perkin reaction	c) Reimer-Tiemann reaction d) Sandmeyer reaction	
4. Determination of melting point- boiling point 5. Purification and separation techniques- Recrystallisation, Distillation, Thin layer andcolumn chromatography. 6. Identification and structural elucidation of simple organic compounds by spectral Analysis.		**CO-3 BTL-4**
TEXT BOOKS		
1.	Leonard, J., Lygo, B., Procter, G. (2013). *Advanced Practical Organic Chemistry*, CRC Press, 3rd Edition.	
2.	Afonso, C.A.M., Candeias, N.R., Simão, D.P., Trindade, A.F., Coelho, J.A.S. (2016). *Comprehensive Organic Chemistry Experiments for the Laboratory Classroom*, Royal society of Chemistry.	
REFERENCE BOOKS		
1.	Pirrung, M.C. (2016). *Hand book of Synthetic Organic Chemistry*, Academic Press, 2nd Edition.	
2.	Fumiss, B.S., Hannaford, A,J., Rogers, V., Smith, P.W.G., Tatchell, A.R. (2009). *Vogel's Text book of Practical Organic Chemistry*, ELBS, 5th Edition.	
E BOOKS		
1.	http://www.springer.com/gp/book/9780412282300	
MOOC		
1.	https://www.mooc-list.com/course/organic-chemistry-i-saylororg	

COURSE TITLE	SUMMER INTERNSHIP			CREDITS	4
COURSE CODE	ACT32800	COURSE CATEGORY	SI	L-T-P-S	0-0-0-0
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-6

ASSESSMENT SCHEME

First Review	Second Review	Third Review	ESE
20%	20%	10%	50%

Course Description	**The Summer Internship provides students with an immersive, hands-on experience in a professional setting. This course is designed to bridge the gap between academic learning and practical application, offering students the opportunity to engage in real-world chemical research and industry practices. Students will work under the guidance of experienced professionals, gaining valuable insights and skills that will enhance their academic and career prospects.**
Course Objective	1. To provide practical experience in a professional chemistry environment. 2. To develop technical skills in laboratory techniques, data analysis, and chemical research. 3. To enhance problem-solving abilities and critical thinking in a research context. 4. To improve scientific communication skills through report writing and presentations. 5. To understand and apply safety protocols and ethical standards in a laboratory setting.
Course Outcome	Upon completion of this course, the students will be able to 1. develop advanced laboratory techniques and hands-on experience with scientific instruments, improving their ability to conduct independent research and experiments in chemistry. 2. gain proficiency in collecting, analysing, and interpreting experimental data, leading to stronger analytical and problem-solving skills. 3. enhance their ability to communicate scientific findings through written reports and oral presentations. 4. apply safety protocols and ethical standards in a laboratory.

	5. acquire valuable experience working in a professional environment, collaborating with multidisciplinary teams, and networking with industry experts.

Prerequisites: Knowledge of Chemistry and basic scientific exposure.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	3	1	1
CO-2	3	3	1	1	1	3	1	1
CO-3	3	3	1	1	1	3	1	1
CO-4	3	3	1	1	1	3	1	1
CO-5	3	3	1	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

COURSE TITLE	**RESEARCH PROJECT**			**CREDITS**	**20**
COURSE CODE	**ACT32801**	**COURSE CATEGORY**	**RP**	**L-T-P-S**	**0-0-40-0**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-6**

ASSESSMENT SCHEME

First Review	Second Review	Third Review	ESE
20%	20%	10%	50%

Course Description	**The project will include several of the following components: planning and carrying out a research project in chemistry, based on literature survey and preliminary results, Production of data, structuring and adequate interpretation of them; setting up and testing hypotheses; finding and making uses of new literature; writing a research project report.**

Course Objective	1. To make the students sound scientific knowledge of their selected project topic. 2. To expose the students and train them on problem identification, formulation and solution. 3. To make the students design solutions to complex problems. 4. To expose the students and train them on interpretation of the results. 5. To make the students sound knowledge in research paper writing and presentation.
Course Outcome	Upon completion of this course, the students will be able to 1. Demonstrate a sound scientific knowledge of their selected project topic. 2. Undertake problem identification, formulation and solution. 3. Design solutions to complex problems utilising a scientific approach. 4. Communicate with scientists and the community at large in written and oral forms. 5. Demonstrate the knowledge, skills and attitudes of a researcher.

Prerequisites: Knowledge of Chemistry and basic scientific exposure.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	3	1	1
CO-2	3	3	1	1	1	3	1	1
CO-3	3	3	1	1	1	3	1	1
CO-4	3	3	1	1	1	3	1	1
CO-5	3	3	1	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

COURSE TITLE	**SYNTHETIC METHODOLOGY IN ORGANIC CHEMISTRY**			**CREDITS**	**3**
COURSE CODE	**ACT32500**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-4**

ASSESSMENT SCHEME

First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment**	**ESE**

	and other assessment tools approved by Department Examination Committee (DEC)	
25%	**25%**	**50%**
Course Description	**The course aims to teach students basic synthetic organic chemistry.**	
Course Objective	1. To learn on the fundamental techniques of organic synthesis, viz., retrosynthesis, C-C bond formation, Umpolung and protection of reactive groups.	
Course Outcome	Upon completion of this course, the students will be able to 1. Analyze the synthetic methods. 2. Choose suitable reagents for nucleophilic reactions. 3. Identify umpolung reactions in organic synthesis. 4. Generate free radicals and bring about C-C bonds. 5. Protect the reactive groups during organic synthesis.	

Prerequisites: Knowledge of chemistry at an undergraduate level.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
CO-2	**3**	**2**	**1**	**1**	**1**	**3**	**2**	**1**
CO-3	**3**	**2**	**1**	**1**	**1**	**3**	**2**	**1**
CO-4	**3**	**2**	**1**	**1**	**1**	**3**	**2**	**1**
CO-5	**2**	**3**	**1**	**1**	**1**	**3**	**2**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 – BASIC RETROSYNTHETIC ANALYSIS	**(9 L)**
Terminology is associated with, pro-stereoisomerism - homo, enantio, diastereo ligands and faces, - stereoselective synthesis.	**CO-1 BTL-2**
MODULE 2 – NUCLEOPHILIC C-C BOND FORMING REACTIONS	**(9L)**
Organometallic reagents of lithium, magnesium, copper, chromium and iron - ylides of sulfur and nitrogen - Tebbe's reagent – Condensation reactions -4 Claisen, Dieckmann, Knoevenegal, Stobbe, Darzen glycidic ester.	**CO-2 BTL-2**
MODULE 3 – CHEMISTRY OF UMPOLUNG	**(9L)**
Umpolung reagents, definition of umpolung, acyl anion equivalent, equivalents of ketene, RCOCH2+, RCOCH2CH2CH2+, RCOCH2CH2CH2$^-$.	**CO-3 BTL-3**

MODULE 4 – C-C BOND FORMATION	(9L)
Methods of generation of free radicals and carbenes, reactions of free radicals, coupling, addition, substitution, fragmentation and rearrangements - C-C bond formation using tin reagents	**CO-4** **BTL-2**
MODULE 5 – PROTECTING GROUPS IN ORGANIC SYNTHESIS	**(9L)**
Protecting groups, protection of hydroxyl, carboxyl, carbonyl, amino groups - Protection of carbon-carbon multiple bonds - Illustration of protection and deprotection in synthesis.	**CO-5** **BTL-4**

TEXT BOOKS	
1.	Carey, F., Giuliano, R. (2016). Organic Chemistry, McGraw-Hill Education, 10th Edition.
2.	Smith, M. (2016). Organic Synthesis, Academic Press, 4th Edition.
REFERENCE BOOKS	
1.	Werner, H., Erker, G. (2016). Organic Synthesis, Springer.
2.	Norman, R.O.C. (2017). Principles of Organic Synthesis, CRC Press, 3rd Edition.
E BOOKS	
1.	http://www.cambridge.org/gb/academic/subjects/chemistry/organic-chemistry/modern-methods-organic-synthesis-4th-edition?format=PB
2.	Textbooks & References for Organic Synthesis - CHEM 436 - Applications of Organometallic Chemistry to Synthesis I - LibGuides at University of Rochester
MOOC	
1.	https://www.mooc-list.com/tags/organic-reactions

COURSE TITLE	ANALYTICAL CHEMISTRY			CREDITS	3
COURSE CODE	ACT32501	COURSE CATEGORY	DE	L-T-P-S	2-1-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4

ASSESSMENT SCHEME		
First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)	ESE
25%	25%	50%

Course Description	The course aims to expose students to various analytical techniques along with practical skills.
Course Objective	1. To analyse experimental data 2. To perform volumetric & gravimetric analysis 3. To analyse fuel 4. To conduct instrumentation and separation techniques.
Course Outcome	Upon completion of this course, the students will be able to 1. Apply the statistical method to assess the data quality. 2. Select suitable indicators for titrations and to estimate by gravimetry 3. Analyze varieties of fuel and grade them 4. To identify suitable techniques for analyzing cations 5. To separate reactions mixtures using chromatographic techniques.

Prerequisites: Knowledge of instruments and analysis at undergraduate level.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	1	1	1	1	1
CO-2	3	2	1	1	1	3	2	1
CO-3	3	2	1	1	1	3	2	1
CO-4	3	2	1	1	1	3	2	1

CO-5	**2**	**3**	**1**	**1**	**1**	**3**	**2**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 – ERRORS IN MEASUREMENT	**(9L)**
Nature of quantitative measurements and treatment of data. Basic statistical concepts – Errors-random and systematic, mean, median, precision and accuracy, significant figures, Gaussian distribution curves, Null Hypothesis, Confidence interval of mean, Rejection of data (Q test), Student's t, F tests. Regression and correlation. Quality control and control chart. Principles of sampling methods for solid, liquids and gases. Gross sampling, Sampler's responsibility and pitfalls, hazards of sampling.	**CO-1** **BTL-2**
MODULE 2 – VOLUMETRY AND GRAVIMETRY ANALYSIS	**(9L)**
Theory of gravimetric analysis - Introduction, solubility, product-common ion effect, precipitation methods. Acid Base titrations: Mixed indicators – universal indicators -neutralization curves. Complexometric titrations: Factors influencing the stability of complexes-metal ion indicators. Precipitation titrations: Theory of precipitation reactions -determination of end points. Oxidation reduction titration: Theory-change of electrode potential during the titration of a reductant with an oxidant- detection of end points.	**CO-2** **BTL-2**
MODULE 3 – FUEL ANALYSIS	**(9L)**
Solids, liquids and gaseous fuels – sampling procedure, ultimate and proximate analysis, specific volatile index, ash content, Calorific value by bomb calorimeter and Junker's gas calorimeter. Liquid fuels – Flash point, viscosity, carbon residue, aniline point, pour point. Gaseous fuels – Analysis of producer gas, water gas and industrial gases. Chemical and physical methods of analysis.	**CO-3** **BTL-3**
MODULE 4 – INSTRUMENTATION TECHNIQUES	**(9L)**
Flame Photometry – Theory, Instrumentation and a few important applications. Emission Techniques – Theory, techniques of excitation, electrodes and their shapes, flame and plasma emission spectrometry – instrumentation and application. Atomic Absorption Spectrometry – Theory, instrumentation (flame and flameless atomization) and applications.	**CO-4** **BTL-2**
MODULE 5 – SEPARATION TECHNIQUES	**(9L)**

Classical forms of chromatography – Introduction, principle and applications of thin layer chromatography and paper chromatography. Modern chromatographic techniques – Principle and applications of Gas chromatography and High-performance liquid chromatography.	**CO-5** **BTL-4**

TEXT BOOKS	
1.	Skoog, D.A., Holler, F.J. and Crouch, S.R. (2017). *Principles of Instrumental Analysis*, Thomson Learning.
2.	Skoog, D.A., West, D.M., Holler, F.J. and Crouch, S.R. (2013). *Fundamentals of Analytical Chemistry*, 9th Edition, Brooks Cole.
REFERENCE BOOKS	
1.	Ritgen, U. (2023). *Analytical Chemistry*, Springer.
E BOOKS	
1.	http://www.freebookcentre.net/Chemistry/Analytical-Chemistry-Books.html
MOOC	
1.	https://www.mooc-list.com/tags/analytical-chemistry

COURSE TITLE	**NUCLEAR CHEMISTRY AND BIOMOLECULES**			**CREDITS**	**3**
COURSE CODE	**ACT32502**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-4**

ASSESSMENT SCHEME		
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**	**ESE**
25%	**25%**	**50%**
Course Description	**The course provides an extended knowledge of the atomic nucleus, stable and unstable, in order to master the theoretical concepts and the various applications related to isotopes, radioactivity and nuclear reactions; - give a fundamental understanding of the interactions between radiations and matter. The chemistry and**	

	structures of biomolecules like enzymes, proteins, lipids and their biological role are studied.
Course Objective	1. To make the students aware of the nucleus of the atom, its structure in detail, and properties like magnetic dipole moment, quadrupole moment, etc. 2. To educate the students about radiochemistry, emission of radiation from nucleus, etc. 3. To provide knowledge on nuclear reaction, fission and fusion reactions. 4. To educate the students about the functions of enzymes, lipids and membranes. 5. To provide sound knowledge on the basic principles of bio- inorganic chemistry, biological roles of metal ions, etc.
Course Outcome	Upon completion of this course, the students will be able to 1. Have a clear idea of the constituents of nucleus of the atom and their characteristics. 2. Identify different types of radioactive emissions and detection methods for them. 3. Identify suitable radioactive element as source for harnessing nuclear energy. 4. Suggest suitable enzyme for catalysis and understand the mechanism of biological processes occurring with lipids and protein as support. 5. Relate the deficiency of different types of minerals and heme proteins in the inhibition of biological processes.

Prerequisites: Knowledge in fundamentals of structure, properties and functions of biomolecules.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	1	1	1	1
CO-2	3	1	1	1	1	1	2	1
CO-3	3	2	1	2	1	1	2	2
CO-4	3	1	1	1	2	1	1	1
CO-5	3	2	1	1	2	1	2	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: THE NUCLEUS	**(9L)**
Structure of the atom, The subatomic particles: electron, proton, neutron, antiproton, positron, meson, quacks – Nuclear masses: isotopes, isobars, mass spectrometry-identification of isotopes-Radius of atomic nuclei- binding energy of nuclei-force between nucleons- Nuclear Structure– Nuclear models: liquid drop model, nuclear shell model.	**CO-1 BTL-2**

MODULE 2: RADIOCHEMISTRY	(9L)
Radioactive decay and basic decay equations: radioactive decay kinetics, determination of half –lives, Redionuclide dating, -Alpha decay: theory of emission, alpha-ray energy spectra-Beta-decay: decay theory, electron capture, double beta decay-Gamma decay: theory of emission, classification of decay types, internal conversion, Radiation detectors: Geiger counters, scintillation counters. Radiotracers and its applications.	**CO-2** **BTL-2**
MODULE 3: NUCLEAR REACTION	**(9L)**
Types of nuclear reactions and mechanism: reaction cross section-direct reaction, compound nucleus reaction, high energy nuclear, direct nuclear, photonuclear and thermonuclear reactions-high energy nuclear reaction, Source of nuclear bombarding particles: Charged particle accelerators, gamma ray, X ray and neutron sources- Fission: Fission products and Fission yield curve, Fission energy, theory of nuclear fission, nuclear reactor, breeder reactor - nuclear reactors in India. Fusion reactions to hydrogen bomb and energy of sun. Applications for nuclear reactions.	**CO-3** **BTL-3**
MODULE 4: LIPIDS AND ENZYMES	**(9L)**
Common class of lipids-self association of lipids-Formation of micelles-membranes-bilayer and hexagonal phases-Membrane bound proteins structure-properties and transport phenomena–Enzymes – classification – characteristics - functions- catalysis- thermodynamic and kinetic considerations -enzyme kinetics - Michelis Menton equation -inhibition of enzyme action. **Suggested Reading**: Structure and functions of lipids – membrane transport mechanism – active and passive transport – Classification and functions of enzymes.	**CO-4** **BTL-4**
MODULE 5: PHYSIOLOGICAL BIOCHEMISTRY	**(9L)**
Minerals – classification - Biological importance of minerals - calcium biochemistry-Hemoglobin –structure and functions - Cytochrome P-450 enzymes-coenzyme. Porphyrins: Nomenclature and biological importance, Structure of chlorophyll: Photosynthesis reactions and mechanism (light dependent reaction, light independent reaction) **Suggested Reading:** Oxygen transport and storage-carbonic anhydrase-carboxypeptidases-FeS proteins and non-heme iron-cytochromes of the electron transport chain- oxidative phosphorylation.	**CO-5** **BTL-4**

TEXT BOOKS	
1.	Lehninger, A.L., Nelson, D.L., Cox. M.M. (2017). *Principles of Biochemistry*, CBS Publishers and Distributors, 7th Edition.
3.	Arnikar, H.J. (2012). *Essentials of Nuclear Chemistry*, Wiley Eastern Ltd.
REFERENCE BOOKS	
1.	Satyanarayana, U., Chakrapani, U. (2015). *Biochemistry*, Books and Allied Pvt. Ltd, 4th Edition.
2.	Loveland, W.D., Morrissey, D.J., and Seaborg, G.T. (2017). *Modern Nuclear Chemistry*, Wiley.
E BOOKS	
1.	http://www.freebookcentre.net/chemistry-books-download/Macromolecules.html
2.	http://www.freebookcentre.net/chemistry-books-download/Membranes.html
MOOC	
1.	https://www.mooc-list.com/course/principles-biochemistry-edx
2.	https://www.edx.org/course/principles-biochemistry-harvardx-mcb63x-1

COURSE TITLE	**PROCESS DEVELOPMENT OF ACTIVE PHARMACEUTICAL INGREDIENTS**			**CREDITS**	**3**
COURSE CODE	**ACT32503**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-4**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**
Course Description	**This course provides basic knowledge of the process development of active pharmaceutical ingredients to the students.**				

Course Objective	1. To understand the active pharmaceutical ingredients 2. To understand the process flow diagram and various process parameters 3. To know the important features associated with process development of APIs 4. To develop technology for APIs and intermediates from lab scale to commercial batch 5. To understand the GLP, GMP and safety in API industry
Course Outcome	Upon completion of this course, the students will be able to 1. Understand the active pharmaceutical ingredients 2. Understand the process flow diagram and various process parameters 3. Know the important features associated with process development of APIs 4. Develop technology for APIs and intermediates from lab scale to commercial batch 5. Understand the GLP, GMP and safety in API industry

Prerequisites: Understanding of general principles of chemistry and spectroscopic techniques.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	1	1	1	1	1
CO-2	3	2	1	1	1	3	2	1
CO-3	3	2	1	1	1	3	2	1
CO-4	3	2	1	1	1	3	2	1
CO-5	2	3	1	1	1	3	2	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 – ACTIVE PHARMACEUTICAL INGREDIENTS (APIS)	**(9L)**
Pharmaceutical industries: Past and present; Introduction and Importance of active pharmaceutical ingredients, bulk drugs and their intermediates, Import and Export of APIs Scale-up approach of APIs: process research and development, optimization, maximization of percentage yield of the product, in-process control techniques.	**CO-1 BTL-2**
MODULE 2 – CHEMICAL TECHNOLOGY OF SELECTED APIS	**(9L)**
Case studies with special emphasis on various factors for selection of routes: availability of raw materials and intermediates, process control parameters, pollution control procedures, polymorphs, safety issues, productivity etc.	**CO-2 BTL-2**
MODULE 3- PROCESS TECHNOLOGY	**(9L)**
Overview of plant layout, plant design, utilities and process flow sheets, Raw material consumption and costing.	**CO-3 BTL-3**

MODULE 4 - REGULATORY PROFILE	(9L)
Overview of GLP, GMP and safety in API industry, Overview of Quality Assurance and Regulatory Affairs.	**CO-4** **BTL-2**
MODULE 5 – STABILITY OF PRODUCTS	**(9L)**
Drug substance – criteria, storage conditions, long term testing accelerated testing, frequency, evaluation, labeling; Drug product- selection of batches criteria, specification, conditions of storage and testing.	**CO-5** **BTL-4**

TEXT BOOKS	
1.	Dey, A. (2023). *Handbook on Active Pharmaceutical Ingredients (API), Drugs & Pharmaceutical Products*, Niir Project Consultancy Services.
2.	Hout, S.A. (2022). *Manufacturing of Quality Oral Drug Products: Processing and Safe Handling of Active Pharmaceutical Ingredients (API)*, CRC Press.
REFERENCE BOOKS	
1.	Kumar Kar, S. (2022). *Pharmaceutical Quality Management & Drug Delivery System*, Career Publications.
2.	Burke, A.J. (2018). *Active Pharmaceutical Ingredients in Synthesis: Catalytic Processes in Research and Development*, Wiley VCH.
E BOOKS	
1.	https://www.researchgate.net/publication/233699827_Process_Development_for_Active_Pharmaceutical_Ingredients_Following_a_Developmental_Cascade.
2.	https://continuing-education.ku.dk/master-of-industrial-drug-development/process-development-and-production-of-active-pharmaceutical-ingredients-api/
MOOC	
1.	https://pharmacyconsulting.co.uk/active-pharmaceutical-ingredient/
2.	https://www.usp.org/global-public-health/promoting-quality-of-medicines/gmp-online-course

COURSE TITLE	ELECTROCHEMISTRY AND ELECTRODICS			CREDITS	3
COURSE CODE	ACT32504	COURSE CATEGORY	DE	L-T-P-S	2-1-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-3
ASSESSMENT SCHEME					
First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)				ESE
25%	25%				50%
Course Description	The course describes the electrochemical cell, its measurement, corrosion and its inhibition, types of energy storage devices, energetics of transferring an electron into or out of a metal or semi-conductor surface. Understand the double layer model of ion distribution within an electrolyte near a charged metal surface. Understand the instrumentation used in electro analytical techniques and experiments.				
Course Objective	1. To understand the basics of electrochemical cell, emf measurements, corrosion and its prevention. 2. To provide knowledge on energy storage devices, like different tyes of fuel- cells and hydrogen fuel. 3. To impart basic knowledge on ionic conductions and the various factors influencing it. 4. To make the student learn about the electrodics & dynamic electrochemistry including Butler- Volmer equation. 5. To provide sound knowledge on the basic principles of electro analytical techniques, like coulometry, voltammetry and polarography.				

Course Outcome	Upon completion of this course, the students will be able to 1. explain various overpotential involved during the operation of the cell, calculate electrochemical cell parameters, amount of corrosion and its rate. 2. work on alternate energy sources, which are need of the hour, especially renewable energy sources 3. apply theories in electrochemistry to analyze electrode kinetics. 4. analyze variation of potential vs current, surface coverage vs. potential, potential vs. pH, concentration profile vs. distance from the electrode 5. work in any analytical laboratories using the knowledge gained.

Prerequisites: Basic knowledge in undergraduate level electrochemistry**.**

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-2	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-3	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-4	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
CO-5	**3**	**2**	**1**	**1**	**1**	**1**	**2**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: – CORROSION AND ITS CONTROL	**(9L)**
Corrosion: Different types of corrosion-mechanism-Galvanic corrosion-concentration cell corrosion-Galvanic series-factors influencing corrosion- corrosion control – corrosion inhibitors –design- Electrochemical methods of protection such as anodic and cathodic protection. Evans diagram, Pourbaix diagram; corrosion rate measurements; Stern Geary equation; mixed potential theory and prevention of corrosion. Protective coatings- Metallic coatings-electroplating- nonmetallic coatings- paints.	**CO-1** **BTL-2**
MODULE 2: ENERGY STORAGE DEVICES	**(9L)**
Electrochemical power sources: Principle of electrochemical energy conversion, Classification of batteries - primary and secondary systems –Alkaline battery, Nickel Cadmium battery, Li-batteries- Metal-hydride batteries- Lead acid storage battery– solar cell-fuel cells – Introduction - Types of fuel cells, construction and principle of operations and application. -Hydrogen as fuel-production – thermal, electrolysis – photolysis and photochemical methods. – Storage of Hydrogen and applications of H_2 as fuel.	**CO-2** **BTL-2**

MODULE 3: ELECTROLYTIC CONDUCTANCE	(9L)
Independent migration of ions - determination of ionic conductance, Transference numbers and its determination - solvent effect on conductance, influence of temperature and pressure of ionic conductance- Walden's equations - Abnormal ion conductance. **Suggested Reading:** Conductance, its determination and applications	**CO-3** **BTL-3**
MODULE 4: ELECTRODICS & DYNAMIC ELECTROCHEMISTRY	**(9L)**
Thermodynamics of electrified interface, Lippmann equation, electrocapillary curves, surface excess, determination of surface excess, structure of electrical double layer, Helmholtz-Perrin model, Guoy-Chapman model, Stern model. Butler Volmer equation for simple electron transfer reaction, current density, Tafel equation, Theories of overvoltage and its determination, factors affecting overvoltage, exchange current density, polarization. **Suggested Reading:** Basics in electrodics.	**CO-4** **BTL-2**
MODULE 5: ELECTRO ANALYTICAL TECHNIQUES	**(9L)**
Reference electrodes: polarizable and non-polarizable systems. Types of reference and working electrodes. Voltammetry – Polarography - DME, polarograms, currents in polarography, polarographic maxima, effect of dissolved oxygen and application to chemical analysis, amperometeric titrations, pulse polarography – normal and differential pulse, square wave polarography, stripping methods – cathodic and anodic stripping, linear sweep voltammetry, cyclic voltammetry, types of electrodes and chemically modified electrodes.	**CO-5** **BTL-2**

TEXT BOOKS

1.	Puri, B. R., Madan Pathania, S., Sharma, L. R. (2020). *Principles of Physical Chemistry*, Shoban Lal Nagin Chand and Co.
2.	Levine, I. (2011). *Physical Chemistry*, McGraw Hill Education.

REFERENCE BOOKS

1.	Chatterjee, S. (2016). *Introduction to Electrochemistry*, Discovery Publishing House Pvt Ltd.
2.	Reychler, A. (2023). *Outlines of Physical Chemistry*, Legare Street Press.

E BOOKS	
1.	Free ElectroChemistry Books Download | Ebooks Online Textbooks (freebookcentre.net)
2.	An Introduction to Electrochemistry eBook by Samuel Glasstone - 9781446545461 | Rakuten Kobo United States
MOOC	
1.	https://www.my-mooc.com/en/mooc/introduction-to-physical-chemistry/
2.	Electrochemistry MOOC and Free Online Courses | MOOC List (mooc-list.com)

COURSE TITLE	**HETEROCYCLIC CHEMISTRY**			**CREDITS**	**3**
COURSE CODE	**ACT32505**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**
Course Description	**The course aims to teach students on fundamentals of heterocyclic chemistry**.				
Course Objective	1. To provide a fundamental theoretical understanding of heterocyclic chemistry. 2. To identify alternative methods for ring synthesis and application of such methods. 3. To get familiar with particular properties and reactions for the most important heterocycles 4. To deduce different systems of nomenclature.				

Course Outcome	Upon completion of this course, the students will be able to 1. To name the heterocyclic compounds. 2. Identify the reactions of 3 and 4 membered compounds 3. Suggest mechanism of reaction by 5-membered compounds 4. Prepare the 6 membered heterocyclic compounds 5. Suggest suitable application of heterocyclic compounds

Prerequisites: Knowledge of organic chemistry at undergraduate level.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	1	1	1	1	1
CO-2	3	2	1	1	1	3	2	1
CO-3	3	2	1	1	1	3	2	1
CO-4	3	2	1	1	1	3	2	1
CO-5	2	3	1	1	1	3	2	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 –STRUCTURE AND NOMENCLATURE	**(9 L)**
Structure of three, four, five, six and seven membered heterocycles - Hantsch Widman nomenclature – replacement nomenclature – systematic nomenclature – Examples.	**CO-1** **BTL-2**
MODULE 2 - THREE AND FOUR MEMBERED HETEROCYCLES	**(9L)**
Aromaticity - reactivity - synthesis – reactions – 3-membered - Oxirane – Thiirane – Aziridine, 4-membered - Oxetane – Thietane – Azetidine.	**CO-2** **BTL-2**
MODULE 3 – FIVE MEMBERED HETEROCYCLES	**(9L)**
Reactivities of Furan, Tetrahydrofuran, Thiophene, Thiolane, Pyrrole, Indole, Carbazole, Pyrrolidine.	**CO-3** **BTL-3**
MODULE 4 – SIX MEMBERED HETEROCYCLES	**(9L)**
Preparation, structure and reactivity of Chromene, Chroman, Pyridine, Quinoline, Piperidine, Pyridazine, Pyrimidine, Purine	**CO-4** **BTL-2**
MODULE 5 – APPLICATIONS OF HETEROCYCLES	**(9L)**
Natural products containing heterocycles - polymers – optical brighteners – in dye industry - pesticides – drug intermediates - antibiotics - antibacterial – antifungals- analgesics – antihypertensive.	**CO-5** **BTL-4**

TEXT BOOKS	
1.	Bansal, R.K. (2020). *Heterocyclic Chemistry*, New Age International.
2.	Jacobi, P.A. (2018). *Introduction to Heterocyclic Chemistry*, Wiley.
REFERENCE BOOKS	
1.	Joule, J. A. (2010). *Heterocyclic Chemistry*, Wiley, 5th Edition.
2.	Jovtchev, G. *et al*. (2021). *Heterocyclic Compounds and Biological Applications*, Science Publishing Group, 1st Edition.
E BOOKS	
1.	https://www.amazon.in/Heterocyclic-Chemistry-John-Joule-ebook/dp/B00D42LJ8I
2.	V.K. Ahluvalia (2016). Heterocyclic Chemistry (Paperback), Narosa Publishing House.
MOOC	
1.	http://nptel.ac.in/courses/104105034/
2.	Heterocyclic Chemistry online course video lectures by IIT Kharagpur (freevideolectures.com)

COURSE TITLE	**CHEMISTRY OF INDUSTRIALLY IMPORTANT PRODUCTS**			**CREDITS**	**3**
COURSE CODE	**ACT32506**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**
Course Description	**The course aims at giving basic knowledge of knowledge of chemistry of industrially important products to the students.**				
Course Objective	1. To an overview of industrially important products 2. To identify various process parameters associated with dyes, pigments, petrochemicals, blends, additives and polymers				

	3. To understand the important features associated with process development of industrially important compounds 4. To develop technology for of industrially important compounds 5. To solve various issues related to petrochemicals and dyes
Course Outcome	Upon completion of this course, the students will be able to 1. Overview of industrially important dyes 2. Identify various process parameters associated with pigments 3. Understand the important features associated with petrochemicals 4. Process development of polymers and fabrics 5. Develop technology for the process development of blends, additives and agrochemicals

Prerequisites: Understanding of general principles of chemistry and spectroscopic techniques in addition to synthetic aspects.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	2	2	1	1	1	3	1	1
CO-2	3	3	1	1	1	3	2	1
CO-3	3	3	1	1	1	3	2	1
CO-4	3	3	1	1	1	3	2	1
CO-5	3	2	1	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 - DYES	**(9L)**
Introduction and classification of dyes, color & constitution, different types of chromophores. Fluorescence and phosphorescence, dye intermediates, Developments of acid and basic dyes. Applications of different dyes and challenges associated with them.	**CO-1 BTL-3**
MODULE 2 – PIGMENTS	**(9L)**
Chemistry and applications of optical brightening agents and pigments. Applications of different pigments and challenges associated with them.	**CO-2 BTL-2**
MODULE 3 – PETROCHEMICALS	**(9L)**
Crude oil and natural gas, refinery operations, energy consumption, lower olefins and acetylenes, cracking processes, synthesis gas, ammonia and methanol production, acetic acid	**CO-3 BTL-3**

and acetic anhydride production, C1 products: Formic acid, hydrogen cyanide, chloromethanes, C2 products: ethanol, acetaldehyde, ethylene oxide.	
MODULE 4 – PROCESS TECHNOLOGY OF POLYMERS AND FABRICS	**(9L)**
Chemistry and Technology of chemical processing of polyester, nylon and acrylics. Dyeing machines for dyeing fiber, yarn and fabric. Mass coloration. Coloration of polypropylene.	**CO-4 BTL-2**
MODULE 5 – BLENDS, ADDITIVES AND AGROCHEMICALS	**(9L)**
Blends, antioxidants, UV stabilizers, antistatic agents, peroxides, lubricants, fire retardants, heat stabilizers, plasticizers. Agricultural Chemicals: Fertilizers, insecticides, herbicides, fungicides.	**CO-5 BTL-2**

TEXT BOOKS	
1.	Sharma, B.K. (2023). *Industrial Chemistry* -Part 1&2, Krishna Prakashan.
2.	Maqdoom, F. (2016). *A Textbook of Industrial Chemistry*, Educational Publisher and Distributor.
REFERENCE BOOKS	
1.	Nagawade, AV. (2016). *Industrial Chemistry*, Nirali Prakashan Educational Publishers.
2.	Torrens, F. (2021). *Engineering Technology and Industrial Chemistry with Applications*, CRC Press.
E BOOKS	
1.	https://link.springer.com/book/10.1007/978-94-011-0613-9
2.	https://www.researchgate.net/publication/257417805_Industrial_Chemistry
MOOC	
1.	https://onlinecourses.nptel.ac.in/noc23_cy27/preview
2.	https://www.coursera.org/learn/chemical-hazards-toxicology-and-reactivity

COURSE TITLE	**POLYMER CHEMISTRY**			**CREDITS**	**3**
COURSE CODE	**ACT32507**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-4**
ASSESSMENT SCHEME					

First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)	ESE
25%	25%	50%
Course Description	**This course mainly includes study of polymers synthesis, polymer properties, polymer processing, polymer testing, polymer degradation, polymer reaction, composites and applications.**	
Course Objective	1. To understand the importance of the chemical approach to polymers and the subject provides an introduction to polymer science with respect to synthesis, polymerization kinetics and network formation/gelation of macromolecules formed by step-growth and chain-growth polymerization. 2. To Study the methods of measuring molecular weight, polymerization kinetics and Copolymerization and polymer processing technologies. 3. To understand radical and ionic polymerization and techniques of polymer analysis 4. To study mechanical properties and applications of polymers 5. To study the molecular weight and its distribution	
Course Outcome	Upon completion of this course, the students will be able to 6. Classify polymers based on different titles. 7. Deduce rate equation and mechanism of chain polymerization. 8. Characterize step-growth polymer using instruments. 9. Suggest suitable polymerization techniques for preparation of polymer 10. Determine molecular weight of a polymer.	
Prerequisites: Fundamentals of organic reactions along with spectroscopy.		

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	1	1	1	1	1
CO-2	3	2	1	1	1	3	2	1
CO-3	3	2	1	1	1	3	2	1
CO-4	3	2	1	1	1	3	2	1
CO-5	2	3	1	1	1	3	2	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 – BASIC CONCEPTS OF POLYMERS	(9L)
Introduction – Basic definitions – Classification of polymers based on occurrence, structure and end use – Thermoplastic and thermosetting polymers – Tacticity - Structure and property relationship of polymers - Glass transition temperature and its determination by dilatometric, thermomechanical and calorimetric methods.	**CO-1 BTL-2**
MODULE 2 – CHAIN POLYMERISATION	**(9L)**
Kinetics and mechanism of free radical polymerization, ionic polymerisation – cationic and anionic polymerization - Coordination polymerisation – Ziegler-Natta catalysts – Alfin polymerization.	**CO-2 BTL-2**
MODULE 3 – STEP GROWTH POLYMERSIATION	**(9L)**
Kinetics and mechanism of polycondensation, polyaddition and ring-opening polymerisation – Copolymerization – The copolymer equation – Monomer reactivity ratios- Mayo-Lewis and Fineman-Ross methods – Reactivity ratios and copolymerization behaviour- Miscellaneous polymerisation reactions – Electrochemical, Metathetical and Group transfer polymerisation.	**CO-3 BTL-3**
MODULE 4 –POLYMERISATION TECHNIQUES	**(9L)**
Homogeneous and heterogeneous polymerization – Bulk, Solution, Suspension and Emulsion polymerisation - Merits and demerits – Melt polycondensation – Solution polycondensation – Interfacial condensation – Solid and gas phase polymerisation.	**CO-4 BTL-2**
MODULE 5 – MOLECULAR WEIGHT AND ITS DISTRIBUTION	**(9L)**
Number, weight and viscosity average molecular weights – Polydispersity and molecular weight distribution in polymers – Determination of molecular weight by GPC and viscometry methods- Polymer solutions - Thermodynamics of polymer dissolution – Isolation and purification of polymers – Polymer fractionation - Fractional precipitation and Partial dissolution techniques.	**CO-5 BTL-4**

TEXT BOOKS

1. Gowarikar, V.R., Viswanathan, N.V., Sreedhar, J. (2015). *Polymer Science*, New Age International Publishers.
2. Mishra, A., Ahluwalia, V.K. (2008). *Polymer Science: A Textbook*, CRC Press.

REFERENCE BOOKS

1. Bhatnagar, M.S. (2012). *A Textbook of Polymer Chemistry*. S. Chand.
2. Kumar, U. (2013). *Textbook of Polymer Chemistry*, Centrum Press.

E BOOKS

1.	https://bookboon.com/en/introduction-to-polymer-science-and-technology
2.	Polymer Chemistry, Sixth Edition (earthwormexpress.com)
MOOC	
1.	http://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-0
2.	Introduction to polymers - OpenLearn - Open University - T838_1

COURSE TITLE	**MOLECULAR SPECTROSCOPY**			**CREDITS**	**3**
COURSE CODE	**ACT32508**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-4**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**
Course Description	**Molecular Spectroscopy provides an introduction to the knowledge of the spectroscopy methods, their principles and applications. Identification of structure of the chemistry compounds, as well as experimental usage of chosen methods (IR, NMR, UV- VIS & Mass).**				
Course Objective	1. To make the students understand the interaction of radiation with matter, different energy levels, transition taking place due to absorption, etc. 2. To educate the students about quantum mechanics principle to understand the molecular spectra. 3. To provide knowledge on the rotational and vibrational spectroscopy, degrees of freedom, IR and Raman spectroscopy. 4. To provide sound knowledge on the NMR spectroscopy, its fundamentals, requirements for nucleus to be active, its applications.				

	5. To make the students learn about the principle-ionization methods, isotope abundance, molecular ions, fragmentation processes of organic molecules.
Course Outcome	Upon completion of this course, the students will be able to 1. Gain knowledge in the interaction of radiation with matter. 2. Use quantum mechanics and group theory principle to understand the molecular spectra. 3. Acquire knowledge on the principle and application of NMR. 4. Determine the structure of compounds based on the spectra. 5. Find the molecular mass and identify the structure of compound using mass spectroscopy.

Prerequisites: Basic knowledge of spectroscopy in undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-2	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-3	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-4	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-5	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: INTERACTION OF ELECTROMAGNETIC RADIATION WITH MATTER (9L)

Interaction of matter with radiation-time dependent perturbation theory-Einstein Coefficients-Energy levels and transition probabilities for the rigid rotor harmonic oscillator model -Potential energy surfaces in the ground and excited electronic states-Franck Condon principle. **Suggested Reading:** C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., Tata McGraw Hill, New Delhi, 2000.	**CO-1** **BTL-2**

MODULE 2: ROTATIONAL AND VIBRATIONAL SPECTROSCOPY (9L)

Rotational and vibrational spectroscopy of polyatomic molecules-angular momentum operator matrix elements, energy levels and transition probabilities for symmetric and asymmetric top molecules-normal modes of vibration and their classification by group theory-Coupling between rotational and vibrational degrees of freedom-Elementary introduction-Electronic spectra of poly-atomic molecules-absorption and emission spectroscopy-charge transfer spectra-effect of solvent-Raman Spectroscopy. **Suggested Reading**: C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., Tata McGraw Hill, New Delhi, 2000.	**CO-2** **BTL-2**
MODULE 3: NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY	**(9L)**
General introduction and definition − Chemical shift, spin-spin interaction, shielding mechanism, chemical shift values and correlation for protons bonded to carbon complex spin-spin interaction between two, three, four and five nuclei (first order spectra), spin Fourier transform technique. Carbon-13 NMR Spectroscopy – General considerations, chemical shift - coupling constants. nuclear overhauser effect (NOE). **Suggested Reading**: C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., Tata McGraw Hill, New Delhi, 2000.	**CO-3** **BTL-4**
MODULE 4: ELECTRON SPIN RESONANCE SPECTROSCOPY	**(9L)**
Electronic Zeeman and hyperfine interactions-hydrogen atom in a magnetic field-election rules in ESR-anisotropy and hyperfine constants-hybridization-ESR of organic free radicals in solution-McConnel's relations. **Suggested Reading**: K. V. Raman, R. Gopalan and P. S. Raghavan, Molecular Spectroscopy, Thomson and Vijay Nicole, Singapore, 2004.	**CO-4** **BTL-4**
MODULE 5: MASS SPECTROMETRY	**(9L)**
Basic principle-ionization methods, isotope abundance, molecular ions, fragmentation processes of organic molecules and deduction of structural information-high resolution MS-introduction to soft ionization techniques and illustrative examples in Macromolecular and supra molecular chemistry. **Suggested Reading**: I. N. Levine, Molecular Spectroscopy, John Wiley & Sons, New York, 1974.	**CO-5** **BTL-4**

TEXT BOOKS	
1.	Sindhu, P.S. (2011). *Fundamentals of Molecular Spectroscopy.* New Age Publishers.
2.	Banwell, C.N., McCash, E.M. (2016). *Fundamentals of Molecular Spectroscopy*, Tata McGraw Hill, 5th Edition.
REFERENCE BOOKS	
1.	Banwell, C.N., Mc Cash, E.M. (2017). *Fundamentals of Molecular Spectroscopy*, Mcgraw Hill College, 4th Edition.
2.	Jain, V.K. (2011*). Introduction to Atomic and Molecular Spectroscopy*, Narosa Publisher.
E BOOKS	
1.	https://www.mooc-list.com/course/introduction-molecular-spectroscopy-coursera
2.	www.ewingdigital.com/text_content/215880813875ea832ebce4bf.pdf
MOOC	
1.	https://www.mooc-list.com/course/introduction-molecular-spectroscopy-coursera
2.	Introduction to Molecular Spectroscopy | My Mooc (my-mooc.com)

COURSE TITLE	**HOMOGENEOUS & HETEROGENEOUS CATALYSIS**			**CREDITS**	**3**
COURSE CODE	**ACT32509**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-1**
Version	**1.0**	**Approval Details**	**42 ACM, 26.10.2024**	**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)**				**ESE**
25%	**25%**				**50%**
Course Description	**The course focuses on the study of the basic concepts of catalysis, the different types of catalysts, their mechanism of action and their applications. The course is divided into different titles like basic concepts in catalysis, applications and mechanisms, principles, classification and applications of heterogeneous catalysts.**				

Course Objective	1. To define the principles and mechanisms of catalysis 2. To calculate the constant in the rate expression 3. To develop internal and external diffusion mechanisms between solid surface and the fluid surface. 4. Develops adsorption, surface reaction and desorption mechanisms.
Course Outcome	Upon completion of this course, the students will be able to 1. To propose suitable model for adsorption over the catalyst surface. 2. To prepare catalyst at lab scale using suitable techniques. 3. To identify suitable catalyst for the Bio-Photo-Polymer reactions. 4. To choose the appropriate method to analyze the given catalyst. 5. To calculate kinetics of homogeneous catalyzed reactions.

Prerequisites: Knowledge of chemistry in under graduate level.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**2**	**1**	**2**	**1**	**3**	**2**	**2**
CO-2	**3**	**2**	**1**	**2**	**1**	**3**	**2**	**2**
CO-3	**3**	**2**	**1**	**2**	**1**	**3**	**2**	**2**
CO-4	**3**	**2**	**1**	**2**	**1**	**3**	**2**	**2**
CO-5	**3**	**2**	**1**	**2**	**1**	**3**	**2**	**2**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 – INTRODUCTION TO CATALYSIS	**(9L)**
Introduction – advantages - disadvantages of catalysts – acidity – basicity, stepwise and concerted reactions, catalyst activation - deactivation and regeneration. Adsorptions: Physical and chemical adsorption, Langmuir adsorption, the BET adsorption isotherm.	**CO-1** **BTL-2**
MODULE 2 – CATALYST PREPARATION AND ZEOLITES	**(9L)**
Preparation of catalyst by solid state, precipitation, co-precipitation, SHS, sol-gel, CVD, impregnation, hydrothermal methods. Structure of zeolites - families of zeolites -adsorption and diffusion in zeolites –cracking - reactions of olefins - catalysis by zeolites containing metal complexes and clusters -non zeolite molecular sieves - clays.	**CO-2** **BTL-2**

MODULE 3 – BIO-PHOTO-POLYMER CATALYSTS	(9L)
Enzyme catalysis reactions (selected few examples), Immobilized enzymes and cells, catalytic antibodies. Porphyrins, phthalocyanes and semiconductor as photo catalysts in photolysis reactions Generation of hydrogen by photo catalysts, photocatalytic break down of water and harnessing solar energy. Ziegler – Natta catalyst in is polymerizations reactions	**CO-3** **BTL-3**
MODULE 4 – CHARACTERIZATION OF CATALYSTS	**(9L)**
Surface area, structure and surface morphology, porosity, pore volume and diameter, particle size, X-ray diffraction, SEM, TEM, XPS and Anger Spectroscopy to surface studies, TPD, TPR, TG/DTA/DTG.	**CO-4** **BTL-2**
MODULE 5 – HOMOGENEOUS CATALYSIS	**(9L)**
Inter mediate stages in homogenous Catalysis, energy profile diagram, general scheme for calculating kinetics of reactions, decomposition of hydrogen peroxide, acid-base catalysis, hydrogenation, hydroformulation, isomerization and Wacker reaction, C-C bond forming reactions and asymmetric oxidations.	**CO-5** **BTL-2**

TEXT BOOKS	
1.	Hanefeld, U., Lefferts, L. (2018). *Catalysis: An Integrated Textbook for Students*, Wiley.
2.	Prins, R., Wang, A., Li, X., Sapountzi, F. (2022). *Introduction to Heterogeneous Catalysis*, World Scientific.
REFERENCE BOOKS	
1.	Hanefeld, U., Lefferts, L. (2017). *Catalysis: An Integrated Textbook for Students*, Wiley.
2.	Hagen, J. (2015). *Industrial Catalysis: A Practical Approach*, Wiley, 3rd Edition.
E BOOKS	
1.	https://www.kobo.com/us/en/ebook/catalysis-2
2.	Chemical Catalysts & Catalysis, Chemistry, eBooks & NOOK | Barnes & Noble® (barnesandnoble.com)
MOOC	
1.	https://www.mooc-list.com/university-entity/catalyst
2.	Catalyst MOOC and Free Online Courses | MOOC List (mooc-list.com)

<table>
<tr><td>COURSE TITLE</td><td colspan="3">COORDINATION AND ORGANOMETALLIC CHEMISTRY</td><td>CREDITS</td><td>3</td></tr>
<tr><td>COURSE CODE</td><td>ACT32510</td><td>COURSE CATEGORY</td><td>DE</td><td>L-T-P-S</td><td>2-1-0-1</td></tr>
<tr><td>Version</td><td>1.0</td><td>Approval Details</td><td>42 ACM, 26.10.2024</td><td>LEARNING LEVEL</td><td>BTL-4</td></tr>
<tr><td colspan="6">ASSESSMENT SCHEME</td></tr>
<tr><td>First Periodical Assessment</td><td colspan="4">Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)</td><td>ESE</td></tr>
<tr><td>25%</td><td colspan="4">25%</td><td>50%</td></tr>
<tr><td>Course Description</td><td colspan="5">The coordinate bond is a covalent bond between two atoms where one of the atoms provides both electrons that form the bond. The chapter also describes the various classes of ligands and attached groups that occur in organometallic compounds.</td></tr>
<tr><td>Course Objective</td><td colspan="5">1. To make the students aware of chemistry of coordination compounds and to understand the periodicity of the elements and the chemistry of d and f lock elements.
2. To educate the students about the theories of metal – ligand bond, and CFT, crystal field splitting and bonding involved.
3. To provide knowledge on spectral characterization of coordination compounds
4. To make the student learn about reactivity of coordination compounds, like substitution, electron transfer, photochemical reactions, etc.
5. To provide knowledge on the role of Inorganic materials in biological systems.</td></tr>
<tr><td>Course Outcome</td><td colspan="5">Upon completion of this course, the students will be able to
1. employ the knowledge on the chemistry of coordination compounds in analyzing their stability and suggesting suitable analytical methods.
2. propose probable mechanism and design new complexes for special applications.
3. analyze spectral characteristics of coordination compounds to analyze complexes and relate to their stabilities.
4. suggest active coordination compounds for the synthesis of very important drugs to cure specific diseases.
5. understand the role of inorganic materials in biological systems.</td></tr>
<tr><td colspan="6">Prerequisites: Knowledge in chemical bonding and molecular geometry.</td></tr>
</table>

CO, PO AND PSO MAPPING								
CO	**PO-1**	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PSO-1**	**PSO-2**	**PSO-3**
CO-1	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-2	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-3	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**
CO-4	**3**	**2**	**1**	**1**	**2**	**3**	**1**	**1**
CO-5	**3**	**2**	**1**	**1**	**2**	**3**	**1**	**1**
1: Weakly related, 2: Moderately related and 3: Strongly related								

MODULE 1: – COORDINATION COMPOUNDS	**(9L)**
Nomenclature; coordination geometry and isomerism – structural and stereoisomerisms-absolute configuration – ORD and CD spectra -stability of complexes – successive and overall formation constants -experimental methods – polarography and potentiometry-thermodynamic aspects. **Suggested Reading**: Molecular Compounds – Ligands or Coordinating Groups – Coordination number - Chelation.	**CO-1** **BTL-2**
MODULE 2: THEORIES OF METAL COMPLEXES	**(9L)**
Valence bond theory – hybridization-crystal field theory – crystal field splitting-crystal field stabilization energy – thermodynamic, structural, spectral and magnetic characteristics-Jahn-Teller effect-ligand field theory-molecular orbital theory – pi bonding. **Suggested Reading**: Stability of complex compounds in aqueous solution.	**CO-2** **BTL-2**
MODULE 3: MAGNETIC PROPERTIES OF METAL COMPLEXES	**(9L)**
Basic definitions in magneto chemistry – thermal energy and magnetic properties-magnetism on the basis of crystal field model. Zeeman effect – second order Zeeman effect on Sm(III) Spin pairing – applications anomalous magnetic moments – reasons - Co-operative magnetism – antiferro magnetism – direct M- M interaction – super exchange – examples – ferro magnetism (Concept only).	**CO-3** **BTL-4**
MODULE 4: REACTIVITY OF COORDINATION COMPOUNDS	**(9L)**
Inert and labile complexes-substitution reactions in square-planar and octahedral complexes – factors affecting reactivities - electron transfer reactions-outer sphere and inner sphere mechanisms-photochemical reactions of coordination compounds – substitution, redox and rearrangement reactions.	**CO-4** **BTL-4**

Suggested Reading: Ligand substitution reaction – redox reactions – photochemical reactions.	
MODULE 5: BIOINORGANIC CHEMISTRY	**(9L)**
Transport proteins: Oxygen carriers, metalloenzymes, carboxy peptidase, carbonic anhydrase, redox process, iron-sulphur proteins, chlorophyll, salient features of the photo synthetic process, vitamin B12 role of sodium, potassium, calcium, zinc and copper; fixation of nitrogen, nitrogen cycle. Anti-cancer drugs and their mechanism of action, Natural and manmade radio isotopes and their application. **Suggested Reading**: Storage and transportation of O_2 and CO_2 by hemoglobin - electron transport chain- oxidative phosphorylation.	**CO-5** **BTL-4**
TEXT BOOKS	
1.	Keemti, L., Agarwal, S.K. (2017). Advanced Inorganic Chemistry, Pragati Prakashan Meerut.
2.	Nakazawa, H., Koe, J. (2021). *Organometallic Chemistry*, Volume 1, RSC.
REFERENCE BOOKS	
1.	Weller, M., Overton, T., Rourke, J., Armstrong, F. (2015). *Inorganic Chemistry*, Oxford University Press India.
2.	Devender, S. (2018). *Comprehensive Coordination & Organometallic Chemistry*, Ane Books Pvt Ltd.
E BOOKS	
1.	http://www.freebookcentre.net/chemistry-books-download/A-text-book-of-inorganic-chemistry.html
2.	http://www.freebookcentre.net/chemistry-books-download/Introduction-to-Inorganic-chemistry.html
MOOC	
1.	https://swayam.gov.in/courses/249-inorganic-chemistry-ii
2.	https://www.mooc-list.com/course/inorganic-chemistry-saylororg

COURSE TITLE	COMPUTATIONAL CHEMISTRY			CREDITS	3
COURSE CODE	ACT32511	COURSE CATEGORY	DE	L-T-P-S	2-1-0-1
Version	1.0	Approval Details	42 ACM, 26.10.2024	LEARNING LEVEL	BTL-4

ASSESSMENT SCHEME

First Periodical Assessment	Assignment, Seminar, Quiz, Group Discussion, Role Play, Field Visit, Scrap Book, Open Book Test, Working Model, Practical Lab Assessment and other assessment tools approved by Department Examination Committee (DEC)	ESE
25%	25%	50%

Course Description	**This course mainly includes study of various parameters and software involved in computational Chemistry and its application towards understanding the stability of molecules and proposing its reaction mechanism.**
Course Objective	1. To understand computational chemistry 2. To identify computational methods 3. To use computational software to analyse polyatomic molecules 4. To analyse the stability of molecules and visualization of transition states 5. To propose the new molecules
Course Outcome	Upon completion of this course, the students will be able to 1. Understand the computational chemistry and scope of computational chemistry 2. Identify computational methods 3. Use computational software to analyse polyatomic molecules 4. Analyzing the stability of molecules and visualization of transition states 5. Propose the new molecules

Prerequisites: Basic understanding of ab-initio methods, DFT, basis sets and potential energy map.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	1	1	1	1	1
CO-2	3	2	1	1	1	3	2	1
CO-3	3	2	1	1	1	3	2	1

CO-4	**3**	**2**	**1**	**1**	**1**	**3**	**2**	**1**
CO-5	**2**	**3**	**1**	**1**	**1**	**3**	**2**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1 – INTRODUCTION TO COMPUTATIONAL CHEMISTRY	**(9L)**
Computational chemistry map, scope of computational chemistry, Born-Oppenheimer approximation, idea of self-consistency, Hartree-Fock theory, restricted HF calculations; open shell systems, ROHF and UHF calculations, HF limit and electron correlation, semi empirical methods.	**CO-1 BTL-2**
MODULE 2 – DENSITY FUNCTIONAL THEORY	**(9L)**
Electron density, exchange-correlation functional, local Density approximation, generalized gradient approximation, hybrid density functional methods, self-Interaction corrections.	**CO-2 BTL-2**
MODULE 3 – BASIS SETS	**(9L)**
Definition of basis sets, Slater and Gaussian type orbitals, minimal, double-zeta, split-valence, core-valence, Pople style basis Sets, polarization and diffuse functions, calculation of basic functions, pseudopotentials or effective core potentials, choice of basis bets.	**CO-3 BTL-3**
MODULE 4 - BASIC CONCEPTS OF POTENTIAL ENERGY SURFACES	**(9L)**
Z-matrix construction, Stationary Points, geometry optimization, local and global minima, and transition state theory. Computations of single point energy, optimizations and transition states of polyatomic molecules, intrinsic reaction coordinate analysis.	**CO-4 BTL-2**
MODULE 5 – APPLICATIONS	**(9L)**
Geometry optimization, frequency calculation, location of transition state, intrinsic reaction co-ordinates, molecular orbitals and population analysis, natural bond orbital analysis, calculation of equilibrium constants and rate constants.	**CO-5 BTL-4**

TEXT BOOKS

1.	Foresman, J.B. and Frisch, A. (2015). *Exploring Chemistry with Electronic Structure Methods*, 2nd Edition, Gaussian Inc.
2.	Ul-Haq, Z and Wilson, A. K. (2020). *Frontiers in Computational Chemistry*, Bentham.

REFERENCE BOOKS

1.	Frank Jensen, (2017). *Introduction to Computational Chemistry*, John Wiley & Sons.
2.	Leszczynski, J and Shukla, M.K. (2022). *Practical Aspects of Computational Chemistry*, Vol. 5, Springer.

E BOOKS	
1.	Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics | SpringerLink
2.	Introduction to Computational Chemistry, 3rd Edition | Wiley
MOOC	
1.	https://nptel.ac.in/courses/104101002
2.	https://www.coursera.org/specializations/computational-social-science-ucdavis

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