Centurion
UNIVERSITY
Shaping Lives...
Empowering Communities...

B.Sc. (Chemistry) Syllabus

(Four Years Programme)

School of Applied Sciences

Centurion University of Technology & Management

2025-26

STRUCTURE OF UNDER GRADUATE PROGRAMME

Sl. No.	Board Category of Courses	Minimum Credit Requirement	
		3 Year UG	4 Year UG
01	Major (Core)	60	80
02	Multidisciplinary + Minor	34	42
03	Value added course	07/06	07/06
04	Ability Enhancement Courses (AEC) + Skill Enhancement Courses (SEC)	18	18
05	Summer Internship	02	02
06	Research Project/Domain Project	0	12
	Total	**121/120**	**161/160**

Sl. No	Code	Subject Name	Type of course	T-P-Pr (Credit)	Credits	Level
SEMESTER I						
01	-	**Value Added**	Theory + Project	**2-0-1**	**3**	-
02	CUCHE101	Environmental Science	Theory + Practice+ Project	3-0-1	4	**4.5**
03	CUTM4598	Atomic Structure and Chemical bonding	Theory + Practice+ Project	2-1-1	4	**4.5**
04	CUTM4599	States of matter and ionic equilibrium	Theory + Practice+ Project	2-1-1	4	**4.5**
05	GE-1@	Inter Disciplinary Subject	Theory + Practice	3-1-0	4	**4.5**
				TOTAL	**19**	
SEMESTER II						
06	CUTM1016	Job Readiness	Practice	0-0-2	2	-
07	CUTM4600	Basics of Hydrocarbons	Theory + Practice+ Project	2-1-1	4	**4.5**
08	CUTM4601	Chemical Thermodynamics and its application	Theory + Practice	3-1-0	4	**4.5**
09	GE-2@	Inter Disciplinary Subject	Theory + Practice	3-1-0	4	**4.5**
10		Skill		-	4	**4**
				TOTAL	**18**	
SEMESTER III						
11		Job Readiness	Practice	0-0-2	2	-
12		Value added	Theory + Project	-	3	-
13	CUTM4602	Chemistry of Main Group Elements	Theory + Practice+ Project	2-1-1	4	**5**
14	CUTM4603	Chemistry of Oxygenated Organic Compounds	Theory + Practice+ Project	2-1-1	4	**5**
15	CUTM4604	Phase Equilibria & Chemical Kinetics	Theory + Practice+ Project	2-1-1	4	**5**
16	GE-3@	Inter Disciplinary Subject	Theory + Practice	3-1-0	4	**5**
				TOTAL	**21**	
SEMESTER IV						
17		Skill			4	-
18		Job Readiness	Practice	0-0-2	2	-
19	CUTM4605	Coordination Chemistry	Theory + Practice+ Project	2-1-1	4	**5**
20	CUTM4606	Heterocyclic Chemistry	Theory + Practice	3-1-0	4	**5**
21	CUTM4607	Electrochemistry	Theory + Practice+ Project	2-1-1	4	**5**

22	GE-4@	Inter Disciplinary Subject	Theory + Practice	3-1-0	4	**5**
				TOTAL	**22**	
SEMESTER V						
23	CUTM4608	Bio-molecules	Theory + Practice	3-1-0	4	**5.5**
24	CUTM4609	Quantum Chemistry & Molecular Spectroscopy	Theory + Practice	3-1-0	4	**5.5**
25	CUTM4610	Organometallic chemistry	Theory + Practice+Project	2-1-1	4	**5.5**
26	Domain	Multidisciplinary	Theory	-	9	**5.5**
				TOTAL	**21**	
SEMESTER VI						
27	CUTM4611	Organic Spectroscopy	Theory + Practice+Project	2-1-1	4	**5.5**
28	CUTM4612	Bio Inorganic Chemistry	Theory + Practice	3-1-0	4	**5.5**
29	Domain	Multidisciplinary	Practice	-	9	**5.5**
30	Skill	-		-	4	**5**
				TOTAL	**21**	
SEMESTER VII						
31	CUTM4613	Organic Synthesis: Reaction and Reagents	Theory + Practice	3-1-0	4	**6**
32	CUTM1402	Advanced Characterization Techniques	Theory + Practice	3-1-0	4	**6**
33	CUTM1417	Polymer Chemistry	Theory + Practice	3-1-0	4	**6**
34	Domain	Multidisciplinary	Project	-	6	
35	-	Internship	-	-	2	
				TOTAL	**20**	
SEMESTER VIII						
36	CUTM1405	Synthesis and Applications of Nano Composites	Theory + Practice	3-1-0	4	**6**
37	CUTM1425	Sustainable Chemistry	Theory + Practice	3-1-0	4	**6**
38	-	Research Project / Domain Project / 3 No.s Discipline Specific Elective	-	-	12	
				TOTAL	**20**	
				GRAND TOTAL	**162**	

BASKET – I (Core Courses) 60 credits

SL. No.	Course Code	Course Name	Credit	Type [T+pr+Pj]	NCRF Level
1.	CUTM4598	Atomic Structure and Chemical bonding	4	2+1+1	4.5
2.	CUTM4599	States of matter and ionic equilibrium	4	2+1+1	4.5
3.	CUTM4600	Basics and Hydrocarbons	4	2+1+1	4.5
4.	CUTM4601	Chemical Thermodynamics and its application	4	3+1+0	4.5
5.	CUTM4602	Chemistry of Main Group Elements	4	2+1+1	4.5
6.	CUTM4603	Chemistry of Oxygenated Organic Compounds	4	2+1+1	5
7.	CUTM4604	Phase Equilibria & Chemical Kinetics	4	2+1+1	5
8.	CUTM4605	Coordination Chemistry	4	2+1+1	5
9.	CUTM4606	Heterocyclic Chemistry	4	3+1+0	5
10.	CUTM4607	Electrochemistry	4	2+1+1	5
11.	CUTM4608	Bio-molecules	4	3+1+0	5.5
12.	CUTM4609	Quantum Chemistry & Molecular Spectroscopy	4	3+1+0	5.5
13.	CUTM4610	Organometallic chemistry	4	2+1+1	5.5
14.	CUTM4611	Organic Spectroscopy	4	2+1+1	5.5
15.	CUTM4612	Bio Inorganic Chemistry	4	3+1+0	5.5
ADVANCED CORE COURSES (20 CREDITS)					
16.	CUTM4613	Organic Synthesis: Reaction and Reagents	4	3+1+0	6
17.	CUTM1402	Advanced Characterization Techniques	4	3+1+0	6
18.	CUTM1417	Polymer Chemistry	4	3+1+0	6
19.	CUTM1405	Synthesis and Applications of Nano Composites	4	3+1+0	6
20.	CUTM1425	Sustainable Chemistry	4	3+1+0	6
DISCIPLINE SPECIFIC ELECTIVES(8 CREDITS)					
21.	CUTM4614	Applications of Computers in Chemistry	4	3+1+0	
22.	CUTM4615	MOLECULAR MODELLING and DRUG DESIGN	4	3+1+0	
23.	CUTM4616	Research Methodology for Chemistry	4	3+0+1	

Course Outline

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4598	Atomic Structure and Chemical Bonding	2-1-1	

Objective

- To study and compare between various theories of atomic structure.
- To know the most common structure and hybridization observed for different compounds.
- To use periodic trend to understand the chemistry of alkali metals, alkaline earth metals, halogens, transition as well as inner transition elements.

Course outcome

COs	Course outcomes
CO1	Acquire knowledge in the structure, bonding, and hybridisation of different compounds, their periodic properties and the quantum mechanical aspect.
CO2	Solve problems of different wave functions and wave equations.
CO3	Improved experimental and theoretical knowledge by analyzing the data.
CO4	Develop problem solving aptitude related to behavior of different compounds
CO5	Develop innovative ideas to apply in journal publications.

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2			2			2	2	3	2	3
CO2	3	3	3	2	2			2			2	2	3	2	3
CO3	3	3	3	2	2			2			2	2	3	2	3
CO4	-	3	2	2	2			2			2	2	3	2	3
CO5	-	3	2	2	2			2			2	2	3	2	3

Course content

Module I

Atomic structure-I **(3h)**

Bohr's theory, its limitations and atomic spectrum of hydrogen atom, Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrodinger's wave equation, significance of Ψ and Ψ^2.

Project-1: Comparative Study of Bohr's Model and Quantum Mechanical Model of the Atom

Practice-1: Identify metal ions based on the color of flame.

Module II

Atomic structure-II **(5h)**

Quantum numbers and their significance, Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of s, p, d and f orbital's. Contour boundary and probability diagrams. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.

Project-2: Analysis of Radial and Angular Wave Functions of the Hydrogen Atom

Practice-2: Modeling Atomic Orbitals with 3D Software or Sketches

Module III

Periodic Properties-I **(4h)**

s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements with reference to s and p-block, Effective nuclear charge, shielding or

screening effect, Slater rules, variation of effective nuclear charge in periodic table, Atomic radii (van der Waals), Ionic and crystal radii, covalent radii (octahedral and tetrahedral), Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy, Applications of ionization enthalpy

Project-3: Application of effective nuclear charge

Module IV

Periodic Properties-II (3h)

Electron gain enthalpy, trends of electron gain enthalpy. Electronegativity, Pauling's/ Mulliken's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity.

Project-4: Polarizing powder and Polarizability

Module V

Chemical Bonding-I(Ionic Bonding) (3h)

Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations, Packing of ions in crystals, Born-Lande equation Madelung constant, Born-Haber cycle and its application, solvation energy.

Project -5: Radius ratio of different cubic crystal structures

Practice-3: Compare electrical conductivity of different solutions(Conductivity Test of Ionic vs Covalent Compounds).

Module VI

Chemical Bonding-II (Covalent Bonding-I) (5h)

Covalent bond: Lewis structure, Valence Bond theory (Heitler-London approach), Energetic of hybridization, equivalent and non-equivalent hybrid orbitals, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules, Formal charge, Valence shell electron pair repulsion theory (VSEPR).

Project-6: Wave mechanical treatment of covalent bond

Practice-5: Compare the melting points of various compounds.

Module VII

Chemical Bonding-III (Covalent Bonding-II) (3h)

Covalent character in ionic compounds, polarizing power and polarisability, Fajan's rules and consequences of polarization, Ionic character in covalent compounds: Bond moment and dipole moment, Percentage ionic character from dipole moment and electronegativity difference

Project-7: Term symbols for a diatomic molecule

Practice-5: Hydrogen Bonding Demonstration Using Boiling Point Trends

Practice-6: Test solubility of compounds in polar/non-polar solvents.

Book References:

- Lee, J.D. Concise Inorganic Chemistry, ELBS, 1991.
- Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, Oxford, 1970
- Atkins, P.W. & Paula, J. Physical Chemistry, Oxford Press, 2006.
- Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications 1962.

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4599	States of Matter and Ionic Equilibrium	2-1-1	

Objective

- To develop basic and advance concepts regarding the three states of matter.
- To derive the expressions for determining the physical properties of gases, liquids and solids.

Course outcome:

After completion of the course, students will be able to

COs	Course outcomes
CO1	Recall on the thermodynamic, colligative, and electrical properties of sample
CO2	Describe on the handling of pH meter and it's usage in various sample analysis
CO3	Demonstrate the concept of ionization of both weak and strong electrolytes
CO4	Analyze the behavior of different types weak acids and bases in solution phase
CO5	Develop innovative idea for synthesis of product and journal publications.

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2	3	2	2	3	1	2	1	3	2	1
CO2	3	2	3	1	2	1	2	3	1	1	3	2	3	1	2
CO3	2	3	1	2	2	2	1	1	2	3	2	1	2	2	2
CO4	2	2	3	2	1	1	2	1	1	3	2	2	1	3	2
CO5	2	2	1	3	1	2	3	2	3	2	2	3	2	2	3

Course content

Module I

Gaseous state-I **(4 hrs)**

Empirical Gas Laws, Ideal gas equation, Deviation of real gases from ideal behaviour, compressibility factor, causes of deviation. Van der Waals equation of state for real gases, Boyle temperature (derivation not required), Critical phenomena, critical constants and their calculation from van der Waals equation.

Module II

Gaseous state-II **(4 hrs)**

Maxwell Boltzmann distribution laws of molecular velocities and their importance, Temperature dependence of these distributions. Most probable, average and root mean square velocities, Collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules, Liquefaction of gases.

Module III

Liquid state **(4 hrs)**

Qualitative treatment of the structure of the liquid state, Physical properties of liquids; intermolecular forces in solution, vapour pressure, surface tension and coefficient of viscosity, and their determination, Effect of addition of various solutes on surface tension and viscosity. Temperature variation of viscosity of liquids.

Practice-1: Determination of surface tension

Practice-2: Determination of Viscosity of Organic Solvents

Practice-3: Determination of co-efficient of viscosity of an unknown aqueous solution

Practice-4: Study the variation of surface tension of detergent solutions with concentration

Module IV

Solid state **(4hrs)**

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, seven crystal systems and fourteen Bravais lattices. X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method, Analysis of powder diffraction patterns of NaCl, CsCl and KCl

Module V

Ionic equilibria-I **(4 hrs)**

Strong, moderate and weak electrolytes, Degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ions effect, dissociation constants of mono and diprotic acids

Practice-5: Determination of the pH scale by the method of successive dilutions

Practice-6: Study the effect of addition of HCl/NaOH on pH to the solutions of acetic acid, sodium acetate and their mixtures.

Module VI

Ionic equilibria-II **(3 hrs)**

Buffer solutions; derivation of Henderson equation and its applications, Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Module VII

Ionic equilibria-III **(3 hrs)**

Qualitative treatment of acid – base titration curves, Calculation of pH at various stages, Theory of acid–base indicators, Selection of indicators and their limitations.

Book References:

Atkins, P.W.; Paula, J.de. (2014),Atkin's Physical Chemistry Ed., 10th Edition, Oxford University Press.
Ball, D. W. (2017),Physical Chemistry, 2nd Edition,Cengage Learning, India.
Castellan, G. W. (2004),Physical Chemistry, 4th Edition, Narosa.

Kapoor, K.L. (2015),A Textbook of Physical Chemistry, Vol 1, 6th Edition, McGraw Hill Education.
Practical:
Khosla, B.D.; Garg, V.C.; Gulati, A. (2015),Senior Practical Physical Chemistry, R. Chand & Co, New Delhi.
Kapoor, K.L. (2019),A Textbook of Physical Chemistry, Vol.7, 1st Edition, McGraw Hill Education.
Garland, C. W.; Nibler, J. W.; Shoemaker, D. P.(2003),Experiments in Physical Chemistry, 8th Edition, McGraw-Hill, New York.

Course Outline

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4600	Basic of Hydrocarbon	2-1-1	

Objective

- To Understand the fundamental principles of organic chemistry.
  - To Identify and classify types of hydrocarbons, their structures, and the mechanisms of their chemical reactions.
  - To Apply laboratory techniques to analyse and purify organic compounds and study their physical properties.
  - To Interpret and differentiate stereoisomers, conformations, and aromatic character based on molecular structure.

Course Outcome

Students will be able to

COs	Course outcomes
CO1	Recall the classification, nomenclature, and basic concepts of organic molecules.
CO2	Interpret the stability and reactivity of reaction intermediates and organic mechanisms.
CO3	Apply organic reaction mechanisms such as substitution, addition, and elimination to hydrocarbons.
CO4	Analyse the aromaticity and stereochemistry of organic compounds using structural rules.
CO5	Evaluate physical and chemical properties of hydrocarbons through lab experiments.

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	3					1	2	1	1	3	3
CO2	3	2	2	2	3					3	2	3	3	2	3
CO3	2	3	1	2	3					1	3	2	2	2	3
CO4	2	2	2	1	3					2	1	3	3	1	3
CO5	2	3	3	2	2					2	2	1	2	2	3

Module -I: Basics of Organic Chemistry (5Hrs)

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules,Influence of hybridization on bond properties, Electronic Displacements: Inductive, electrometric, resonance and mesomeric effects, hyperconjugation and their applications. Dipole moment; Organic acids and bases; their relative strength.

Practice-1 : Calibration of a Thermometer

Module – II: Reaction Intermediate (4Hrs)

Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges;Electrophiles and Nucleophiles; Nucleophilicity and basicity. Types, shape and their relative stability of Carbocations, Carbanions, Free radicals and Carbenes. Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

Practice-2 :To purify organic compound by crystallization method.

Module – III : Chemistry of Aliphatic Hydrocarbons (2Hrs)

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation -relative reactivity and selectivity.

Practice-3 : Effect of impurities on the melting point - mixed melting point of two unknown organic compounds.

Module – IV : Carbon-Carbon pi bonds (6Hrs)

Formation of alkenes and alkynes by elimination reactions. Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff/ Anti-Markownikoff addition). Mechanism of oxymercurationdemercuration, hydroboration-oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation) 1,2-and 1,4-addition reactions in conjugated dienes and, DielsAlder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene. Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions.

Practice-4: Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and capillary method)
Project : Separation of Amino acids by TLC

Module – V : Aromatic Hydrocarbons (3Hrs)
Aromaticity: Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation. Electrophilic aromatic substitution: Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups.
Practice-5 : Detection of N,S,Cl,Br and I in organic compound.
Practice-6 : Test for Hydrocarbon.

Module - VI: Cycloalkanes and Conformational Analysis: (2Hrs)
Types of cycloalkanes and their relative stability, Baeyer strain theory. Conformation analysis of alkanes. Relative stability: Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms; Relative stability with energy diagrams.
Practice-7 : Preparation of Methane from sodium acetate

Module – VII : Stereochemistry (5Hrs)
Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions. Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with I.P rules. Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres. Distereoisomers, meso structures, racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations.
Practice-8 : Preparation of Ethyne from calcium carbide.
Project : Conformation analysis of alkanes,Relative stability,Fischer Projection, Newmann and Sawhorse Projection formulae and their inter conversions.

Text Books:
1. University Chemistry, Vol. II, U.N Ojha and K.K Ojha, Himalaya Publishing House
2.Modern College Chemistry, Y.R Sharma and K.D Sharma, Kalyani Publishers
Reference Books:
1.Morrison, Boyd and Bhattacharjee, Organic Chemistry, 7th Edition, Pearson.
2.Kalsi, P. S. Stereochemistry Conformation and Mechanism, New Age International, 2005.
3.Eliel, E. L. & amp; Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.

Course Outline.

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4601	Chemical Thermodynamics and its Applications	**3-1-0**	

Objective

- To develop basic and advanced concepts regarding fundamentals thermodynamics and its related phenomena.
- To explore the concept of chemical equilibrium in attaining high products by controlling various factors.
- To identify the concept of ideal and non-ideal solution along with various colligative properties.

Course outcome

After completion of the course, students will be able to,

COs	Course outcomes
CO1	Reproduce different thermodynamic laws, Chemical Equilibria and Colligative properties.
CO2	Discuss different derivations for thermodynamic equations, chemical equilibriums and their relationship among each other.
CO3	Apply the knowledge in solving problems related to thermodynamics.
CO4	Do experiments on different thermodynamic phenomenon and interpretet the results.
CO5	Appraise the ideas to apply in scientific research for journal publications.

Course Outcome to Program Outcome Mapping:

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	**2**	**3**	**3**					**2**				**1**	**2**		**1**
CO2	**2**	**3**	**2**	**2**		**2**			**1**				**2**	**2**	**1**
CO3	**2**	**3**	**3**	**2**		**2**				**2**			**3**	**3**	
CO4	**3**	**3**	**3**	**2**		**2**					**3**		**3**	**3**	
CO5	**3**	**3**	**3**	**2**	**2**			**2**					**2**		**1**

***High-3, Medium-2, Low-1**

Course content

Module I : Introduction to Thermodynamics (6h)

Intensive and extensive variables; state and path functions; isolated, closed and open systems Zeroth law of thermodynamics, First law: Concept of heat (q), work (w), internal energy (U), and statement of first law, Enthalpy (H), relation between heat capacities, Calculations of q, w, U and H for reversible condition, Calculations of q, w, U and H for irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions

Module II : Thermochemistry (6h)

Heats of reactions: standard states; Enthalpy of formation of molecules and ions and enthalpy of combustion and its applications, Effect of temperature (Kirchhoff's equations) and pressure on enthalpy of reactions, Adiabatic flame temperature, explosion temperature, Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data

Practice 1: Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).

Practice 2: Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

Practice 3: Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.

Practice 4: Determination of enthalpy of hydration of copper sulphate

Module III : Chemical Thermodynamics I (7h)

Thermodynamic scale of temperature, Statement of the second law of thermodynamics; molecular and statistical interpretation of entropy, Calculation of entropy change for reversible and irreversible processes, Third Law: Statement of third law, concept of residual entropy , calculation of absolute entropy of molecules, Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity, Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature, Thermodynamic equation of state, Gibbs-Helmholtz equation, Maxwell relations

Module IV : Chemical Thermodynamics and Open System (3h)

Partial molar quantities, dependence of thermodynamic parameters on composition, Gibbs Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases, Partial molar quantities

Module V : Chemical Equilibrium: I (5h)

Criteria of thermodynamic equilibrium, Degree of advancement of reaction, chemical equilibria in ideal gases, Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient, Concept of fugacity, Equilibrium constants and their quantitative dependence on temperature, pressure and concentration, Coupling of exoergic and endoergic reactions, Free energy of mixing and spontaneity

Practice 5: To study the shift of equilibrium between ferric ions and thiocyanate ions by increasing the concentration of either of them

Module VI : Chemical Equilibrium: II **(4h)**

Thermodynamic derivation of relations between the various equilibrium constants Kp, Kc and Kx. Le Chatelier principle (quantitative treatment), Equilibrium between ideal gases and a pure condensed phase, Introduction to dilute Solutions, Introduction to Colligative Properties

Module VII: Colligative Properties **(8h)**

Excess thermodynamic functions, Thermodynamic derivation using chemical potential to derive relations between the relative lowering of vapour pressure and amount of solute, Raoult's and Henry's Laws and their applications, Thermodynamic derivation using chemical potential to derive relations between the elevation of boiling point and amount of solute, Thermodynamic derivation using chemical potential to derive relations between Depression of freezing point and amount of solute, Thermodynamic derivation using chemical potential to derive relations between the osmotic pressure and amount of solute, Applications in calculating molar masses of normal, dissociated and associated solutes in solution

Practice 6: To find the molar mass through freezing point depression of a solution

Practice 7: To find the elevation of boiling point of a solution

Practice 8: To find the molar mass through elevation of boiling point of a solution

Text Books:

1. Atkins P. and De Paula, J. *Physical Chemistry* Tenth Ed.*,* OUP, 2014.

2. Castellan, G. W. *Physical Chemistry 4th Ed.,* Narosa, 2004.

Reference Books:

1. Engel, T. and Reid, P. *Physical Chemistry 3rd Ed.,* Prentice Hall, 2012

2. .McQuarrie, D. A. and Simon, J. D. *Molecular Thermodynamics* Viva Books, 2004.

3. Roy, B. N. Fundamentals of Classical and Statistical Thermodynamics Wiley, 2001

4. Levine, I .N. *Physical Chemistry* 6th Ed. Tata Mc Graw Hill, 2010.

Course Outline

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4602	Chemistry of Main Group Elements	2-1-1	

Objective

- To understand the characteristic reactions and properties of s- and p-block elements.
- To study the structure and reactivity of oxides, hydroxides, and halides of main group elements.
- To perform qualitative and quantitative analysis of main group compounds.

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	Demonstrate understanding of periodic trends and reactivity of main group elements.	PO1 (3)
CO2	Perform qualitative and quantitative analysis of main group compounds.	PO2(3)
CO3	Analyze the solubility, acidity, and basicity of oxides and hydroxides.	PO3(2)

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3								3	2	3
CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3
CO4													3	2	3
CO5													3	2	3

***High-3, Medium-2, Low-1**

Course content

Module I **(4h)**

Groups- 1 and 2

Differentiate the properties of Li and Be from other members of their groups. Compare the properties of Hydrides, Nitrides, Carbides and Oxides of Gr – 1, Gr – 2. Describe compounds of Gr – 1, Gr – 2 ions with Crown ether and Cryptands, Lithium carbonate, basic beryllium acetate, Alkalides and Electride, Reverse sodium hydride. Isotopes of H, ortho and para- hydrogen.

Project-1: Comparison of Hydrides, Nitrides, Carbides, Oxides (Group 1 vs Group 2)

Practice-1: Qualitative and quantitative analysis for alkali and alkaline metal ions.

Module II **(5h)**

Groups -13 and 14

Illustrate the relative acidity, amphoteric, basic characteristics of the oxides and formation of oxocations (wherever applicable); examples of compounds in all the oxidation states, hydrides, halides (including the halo complexes) and their hydrolytic behaviour; dimerization and/or polymerization through halogen bridges (wherever applicable) etc. Preparation, properties of boranes; Structure and bonding of diborane, Borazine, Boron nirides; electron deficient nature of hydrides, halides and their polymerisation. Intercalation compounds, Preparation, properties and uses of the fluorocarbons, silanes, silicates and silicones. Inert Pair Effect and stability of Tl(I) and Pb(II).

Project-2: Structural Analysis of Diborane and Electron Deficient Bonding

Practice-2: Synthesis of Silicone from Dichlorodimethylsilane

Module III **(3h)**

Group 18

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation, properties and reactivities of fluorides (XeFn) and oxofluorides (XeOmFn) of xenon. Describe xenon-oxygen compounds. Illustrate molecular shapes of noble gas compounds. Compare nature of bonding in noble gas compounds. Xenon-oxygen compounds. Fluorides of krypton

Project-3: Stability and Explosiveness of Xenon–Oxygen Compounds (XeO_3, XeO_4)

Practice-3: Hydrolysis of XeF_4 and Study of Reaction Products

Module IV **(5h)**

Chemical Properties

Various oxidation states and their relative stability especially for 4th and 6th period elements (redox behaviour in solution, wherever applicable), higher stability of the higher oxidation states for the heavier members; gradual changes of the ionic/covalent character of the compounds from lighter to heavier members; illustrate the relative acidity, amphoteric, basic characteristics of the oxides and formation of oxocations (wherever applicable); examples of compounds in all the oxidation states, in particular, the unusual (rare) oxidation states being stabilized through coordination; hydrides, halides (including the halo complexes) and their hydrolytic behavior.

Project-4: Hydrolysis and Reactivity Patterns of Transition Metal Halides

Practice-4: Redox Titration Using Potassium Permanganate

Module V **(3h)**

Group 15

Illustrate the presence of lone pair and basicity of trivalent compounds; trends in bond angles of hydrides, halides, preparation, properties, structures and bonding of hydrazine, hydroxylamine, hydrazoic acids, the oxides and oxyacids of N, P; discuss Phosphazene, phosphonirtilic compounds $(PNCl_2)n$. isopoly& heteropoly acids, condensed phosphates.

Project -5: Design of Eco-Friendly Detergents Using Condensed Phosphates

Practice-5: Determination of Basicity of NH_3, PH_3 by Titration Method

Module VI **(3h)**

Group 16

Preparation, properties, Ultra-pure Se; structures and bonding of the oxides, oxyacids (including the thionous, thionic and per–acids) of sulfur, halides, oxy–halides and sulfur nitrogen compounds (SN)x, photo-conductivity of Se.

Project-6: Preparation and electrical properties study of Selenium nanoparticles

Practice-6: Titration of Sodium Thiosulfate ($Na_2S_2O_3$) with Iodine

Module VII

Group 17 **(3h)**

Color of halogens in different media. Halogen hydrides, their acidity; describe preparation, properties, structures and bonding of the oxides and oxy acids; Synthesis, structures and properties of (i) the inter-halogen compounds, (ii) polyhalides and pseudohalides including their preparations, properties and structures.

Project-7: Color Changes of Halogens in Various Solvents: Polarity and Molecular Interactions

Practice-7: Preparation and Identification of Iodine Triiodide (KI_3)

Book References:

- Lee, J.D. Concise Inorganic Chemistry, ELBS, 1991.
- Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, Oxford, 2012
- Shriver and Atkins' Inorganic Chemistry, Oxford Press, 2010.
- James E. Huheey, Ellen A. Keiter, Richard L. Keiter Inorganic Chemistry Principles Of Structure And Reactivity (2017).

Course Outline

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4603	Chemistry of Oxygenated Organic Compounds	2-1-1	

Objective

- To introduce basic practical skills to synthesize organic molecules containing functional groups like alcohols, acids, acid derivatives, carbonyl compounds, ethers, etc.
- To help students understand the reaction mechanism subjects in the later stages of their study.
- To make them eligible to predict and interpret different organic reaction and mechanism.

Course outcome

After completion of the course, the students will be able to

COs	Course outcomes
CO1	Define some basic rules of organic chemistry about structure, behavior of molecules and their reactions.
CO2	Understand various organic reactions, functional group transformations and their mechanisms
CO3	Apply the knowledge to understand different phenomena in organic chemistry and it will help in troubleshooting of organic reactions
CO4	Analyze different functional groups present in a given organic compound.
CO5	Evaluate and interpret different research data in organic chemistry

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3								3	2	3
CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3

CO4													3	2	3
CO5													3	2	3

***High-3, Medium-2, Low-1**

Course content

Module – I **(4h)**

Structure and Bonding: Hybridization, bond lengths and bond angles, bond energy, localized and delocalized chemical bonding, Van der Waals interactions, inclusion compounds, clatherates, charge transfer complexes, resonances, hyperconjugation, aromaticity, inductive and field effects, hydrogen bonding.

Module II **(3h)**

Introductory Concepts : Inductive effect, electromeric effect, conjugation, resonance and resonance energy, hyperconjugation. Homolytic and heterolytic bond breaking,

Module III **(4h)**

Electrophiles and nucleophiles; carbocations, carbanions and radicals (stability andreactivity). Stereochemistry of carbon compounds: Different types of isomerism,enatiomers and diastereoisomers;Fischer,Sawhorse, and Newman Projection formulae of simple molecules containing one and twoasymmetric carbon atom (s).

Module IV **(5h)**

Stereochemistry I: Concept of isomerism, Types of isomerism; Optical isomerism – elements of symmetry, molecular chirality, enantiomers, stereogenic center, optical activity, properties of enantiomers, chiral and achiral molecules with two stereogenic centers, disasteromers, threo and erythro diastereomers, meso compounds, resolution of enantionmer, inversion, retention and recemization.

Module V **(4h)**

Stereochemistry II

Relative and absolute configuration, sequence rules, D & L and R & S systems of nomenclature. Geometric isomerism – determination of configuration of geometric isomers, E & Z system of nomenclature, geometric isomerism in oximes and alicyclic compounds.

Module VI **(4h)**

Stereochemistry III

Conformational isomerism – conformational analysis of ethane and n-butane; conformations of cyclohexane, axial and equatorial bonds, conformation of mono substituted cyclohexane derivatives, Newman projection and Sawhorse formulae, Fischer and flying wedge formulae, Difference between configuration and conformation.

Module VII **(2h)**

Aromaticity: Huckel's rule of aromaticity, Aromatic, antiaromatic and non-aromatic compounds. Electrophilic aromatic substitution reactions.

Practices

Practice 1. Functional group test for Alkyl halides
Practice 2 Preparation of benzene diazonium chloride.
Practice 3 Synthesis of chlorobenzene from aniline
Practice 4 Functional group test for alcohol
Practice5 Functional group test for Phenol
Practice 6 Functional group test for Carbonyl compounds
Practice 7 Functional group test for carboxylic acid

Project: Students will do a project based on knowledge gained, such as synthesis of any organic compound and its charactaerization, study and prediction of behavior of some chemical reaction etc.

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4604	Phase Equilibria and Chemical Kinetics	2-1-1	

Objective

- The course gives idea about the different phases of matter and their equilibria from which the stability and sustainability can be easily predicted.
- Deals with kinetics study of different processes and surface phenomenon like adsorption, chemisorptions etc.

Course outcome After completion of the course, students will be able to

COs	Course outcomes
CO1	Determine the different phases of matter and kinetics of reaction.

CO2	Explain the degrees of freedom of the systems and kinetics of chemical reaction
CO3	Demonstrate the controlling factors that affect the rate of reactions
CO4	Analyze the phase diagram and solve related problems
CO5	Fabricate the inorganic polymer-based material

Course Outcome to Program Outcome Mapping:

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	1	1	2	3	2	3	2	1	2	1	2	1
CO2	2	3	3	2	2	2	3	1	2	1	2	2	2	3	2
CO3	3	2	2	3	3	1	1	2	3	1	1	2	3	2	3
CO4	3	3	3	2	2	3	2	1	2	3	2	1	2	1	2
CO5	2	3	1	2	2	2	1	2	1	2	3	3	3	2	3

***High-3, Medium-2, Low-1**

Course content

Module 1: **Phase Equilibria-1** **(3 hrs)**

Definitions of phase, Concept of phases and Components; Degrees of freedom; Derivation of Gibbs Phase Rule for Non-reactive and reactive systems; Clausius-Clapeyron equation; Applications to solid-liquid, Liquid-vapour and Solid- vapour equilibria.

Module II: **Phase Equilibria-2** **(4 hrs)**

Definition of phase diagram; Phase diagram for one component systems – water, with applications; Liquid-vapour equilibrium for two component systems; Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions, Three component systems, water-chloroform-acetic acid system, triangular plots.

Module III: **Phase Equilibria-3** **(2 hrs)**

Azeotropes, lever rule; Partial miscibility of liquids, CST; Miscible pairs, steam distillation; Nernst distribution law: its derivation and applications.

Practice 1
Study the distribution law of Acetic acid and benzoic acid by water and carbon tetra chloride

Module IV: **Chemical Kinetics-1** **(5 hrs)**

Order and molecularity of a reaction; Rate laws in terms of the advancement of a reaction, rate constants; Differential and integrated form of rate expressions up to first order reactions; Pseudo first order reactions; Experimental methods of the determination of rate laws; Determination of order of a reaction by half-life and differential method.

Practice 2
Kinetics Study on the Reaction between Sodium Thiosulphate and Hydrochloric Acid

Practice 3
Acid hydrolysis of methyl acetate with hydrochloric acid

Module V: **Chemical Kinetics-2** **(5 hrs)**

Opposing reactions and parallel reactions; Consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms); Chain reactions; Temperature dependence of reaction rates; Arrhenius equation; activation energy; Unimolecular Reactions; Collision theory of reaction rates, Lindemann mechanism.

Practice 4
Effect of ionic strength on rate of persulphate iodide reaction

Module VI: **Catalysis** **(3 hrs)**

Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts; Enzyme catalysis, Michaelis-Menten mechanism; turn-over number.

Module VII: **Surface Chemistry** **(3 hrs)**

Physical adsorption, chemisorptions; Freundlich and Langmuir adsorption isotherms; Multilayer adsorption and BET adsorption isotherm.

Practice 5
Verify the Freundlich for adsorption of acetic acid on activated charcoal

Practice 6
Verify the Langmuir isotherm for adsorption of acetic acid on activated charcoal

Text Books:

1. Peter Atkins & Julio De Paula, Physical Chemistry 10th Ed., Oxford University Press (2014).
2. Castellan, G. W. Physical Chemistry, 4th Ed., Narosa (2004).
3. Levine, I. N. Physical Chemistry 6th Ed., Tata McGraw-Hill (2011).

Reference Books:

1. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.,* Prentice-Hall (2012).
2. Zumdhal, S.S. *Chemistry concepts and applications* Cengage India (2011).
3. Ball, D. W. *Physical Chemistry* Cengage India (2012).
4. Mortimer, R. G. *Physical Chemistry 3rd Ed.,* Elsevier: NOIDA, UP (2009).
5. Metz, C. R *Physical Chemistry 2nd Ed.,* Tata McGraw-Hill (2009).

Course Outline

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4605	Coordination Chemistry	2-1-1	

Objective

- To Know the basic of coordination chemistry, bio-inorganic chemistry and aimed at advanced knowledge in the field of industrial chemistry
- To be able to use Crystal Field Theory to understand the magnetic properties (and in simple terms the color) of coordination compounds.
- To be able to name coordination compounds and to be able to draw the structure based on its name.
- To become familiar with some applications of coordination compounds.

Course Outcome

Students will be able to

COs	Course outcomes
CO1	Understand the concepts of metal ligand bonding in transition complex compounds
CO2	Demonstrate advanced knowledge and understanding in coordination compound
CO3	Describe role of different metal ions in biological system
CO4	Recognize the biological reaction alkali and alkaline earth metals, nitrogen fixation, hemoglobin and myoglobin
CO5	Explain the role of Inorganic ―substances in living systems and the use of metal ions in medicinal therapy and diagnosis field

Course Outcome to Program Outcome Mapping:

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	3	3								3	2	3
CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3
CO4													3	2	3
CO5													3	2	3

***High-3, Medium-2, Low-1**

Course content

Module-I **(3Hours)**

Coordination Chemistry

Werner's theory, Valence bond theory (inner and outer orbital complexes), Electro neutrality principle and back bonding.

Practice -1: To Synthesis and Characterization of Metal Complexes with Schiff Base Ligands
Practice -2: Estimation of nickel (II) using Dimethylglyoxime (DMG).

Module-II **(3Hours)**

Crystal Field Theory-I

Crystal field theory, measurement of 10 Dq (Δo), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δo, Δt). Octahedral vs. tetrahedral coordination,

Module-III **(4Hours)**

Crystal Field Theory-II

Tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspect of Ligand field and MO Theory.

Practice-3: To familiar with the chromatographic method and its working principle

Module-IV **(4 Hours)**

Nomenclature of Coordination Compounds

IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Chelate effect of polynuclear complexes, Labile and inert complexes.

Practice-4: To Familiar with Kjeldahl apparatus and its operating procedure

Module-V **(4 Hours)**

Transition Elements I

Stability of various oxidation states and e.m.f. (Latimer & Bsworth diagrams General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, ability to form complexes).

Module-VI **(3 Hours)**

Transition Elements II

Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy)

Practice-5:To estimate the amount of barium in the whole of the given solution of barium chloride

Practice-6:Estimation of Iron in Hematite ore solution

Module-VII **(5 Hours)**

Lanthanoids and Actinoids:

Electronic configuration, oxidation states, colour, Spectral and magnetic properties, lanthanide contraction, separation of lanthanides (ion-exchange method only), Actinides elements and properties

Practice

- ***To separate cation and anion from an unknown mixture by ion exchange column method***
- ***Paper chromatographic separation of Ni(II) and Cu(II)***

Practice

- ***To learn the working principle of colorimeter method***

Project

Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

Recommended Books:

1. ***Purcell, K.F & Kotz, J.C. Inorganic ChemistryB. Saunders Co, 1977.***
2. ***Huheey, J.E., Inorganic Chemistry, Prentice Hall, 1993.***
3. ***Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.***
4. ***Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry Wiley-VCH, 1999***
5. ***Bassolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.***
6. ***Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.***

Recommended Books For Practice:

1.Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009

Course Outline

Heterocyclic Chemistry

Code	Course Title	T-P-P	Prerequisite
CUTM4606	**Heterocyclic Chemistry**	**3-1-0**	

Course Objectives

- To introduce students to nitrogen-containing functional groups (such as nitro compounds, amines, and amides), their structure, synthesis, and reactivity, along with their applications in organic transformations and related mechanisms.
- To provide students with a comprehensive understanding of heterocyclic compounds, focusing on both five-membered and six-membered rings, including their structure, synthesis, reactivity, and the mechanism of substitution reactions, with an emphasis on important polycyclic aromatic hydrocarbons.
- To familiarize students with naturally occurring nitrogen-based compounds, such as alkaloids and terpenoids, exploring their structural features, synthesis methods, reactivity, and biological significance, particularly in the context of their physiological actions.

After completion of the course:

COs	Course outcomes
CO1	Remember the properties and synthesis of heterocyclic compounds and basic knowledge in bio-organic chemistry
CO2	Understand the concepts and classification of different heterocyclic compounds
CO3	Apply the organic chemistry principle for trouble shooting of organic reaction
CO4	Analyze the extraction, purification and separation techniques for synthesis various organic molecules.
CO5	Fabricate different heterocyclic structures and can create new molecules in the laboratory.

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3								3	2	3
CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3
CO4		2	2	1	1								3	2	3
CO5		1	2	2	2								3	2	3

***High-3, Medium-2, Low-1**

Course Contents

Module I: Nitrogen-Containing Functional Groups (5Hours)

Structure and Preparation of Nitroalkanes and Nitroarenes, Properties and Reactions of Nitroalkanes, Properties and Reactions of Nitroarenes, Structure, Preparation, and Properties of Nitriles and Isonitriles,Important Nitro Aromatic Compounds and Their Uses

Module II: Amines (7 Hours)

Preparation of Primary Amines (Reduction of Nitro Compounds, Hoffmann's Ammonolysis, Hofmann Degradation, Gabriel Phthalimide Synthesis), Preparation of Secondary and Tertiary Amines (Aminolysis of Alkyl Halides, Reductive Amination, Ullmann Reaction), Properties of Amines (Basicity, Effect of Substituents and Solvents on Basicity), Important Reactions of Amines (Alkylation, Acylation, Carbylamine Reaction), Additional Reactions of Amines (Mannich Reaction, Hoffmann's Exhaustive Methylation, Hofmann Elimination), Diazonium Salts (Structure, Preparation, and Reactions/ Applications), Electrophilic Substitution Reactions of Aryl Amines, Distinction between 1°, 2°, and 3° Amines with Hinsberg Reagent and Nitrous Acid

Practice-1: Detection of Extra Elements (Nitrogen, Sulphur, Halogens)

Practice-2: Functional Group Tests for Nitro, Amine, and Amide Groups

Module III: Five-Membered Heterocyclic Compounds (6 Hours)

Classification, Nomenclature, and Structure of Pyrrole, Furan, Thiophene (Five-membered) and Pyridine (Six-membered), Molecular Orbital Theory and Aromaticity in Pyrrole, Furan, Thiophene, and Pyridine, Synthesis, Reactions, and Mechanism of Substitution Reactions of Furan, Synthesis of Pyrrole (Knorr

Pyrrole Synthesis, Paal-Knorr Synthesis, Hantzsch Synthesis), Reactions and Mechanism of Substitution Reactions of Pyrrole, Derivatives of Furan (Furfural and Furoic Acid), Synthesis and Properties of Thiophene, Acidic and Basic Character of Pyrrole, Furan, and Thiophene

Practice-3: Qualitative Analysis of Unknown Organic Compounds Containing Simple Functional Groups (Alcohol, Carboxylic Acids)

Module IV: Six-Membered and Condensed Heterocyclic Compounds (5 Hours)

Structure, Synthesis, and Properties of Pyridine (Hantzsch Synthesis), Pyrimidine, Structure Elucidation of Indole (Fischer Indole Synthesis, Madelung Synthesis), Structure Elucidation of Quinoline and Isoquinoline, Skraup Synthesis, Friedlander's Synthesis, Knorr Quinoline Synthesis, Doebner-Miller Synthesis, Bischler-Napieralski Reaction, Pictet-Spengler Reaction, Pomeranz Fritsch Reaction

Practice-4: Qualitative Analysis of Unknown Organic Compounds Containing Simple Functional Groups (Phenols)

Module V: Polynuclear Hydrocarbons (5 Hours)

Preparation and Structure Elucidation of Naphthalene, Reactions of Naphthalene, Important Derivatives of Naphthalene, Preparation, Structure Elucidation, and Important Derivatives of Anthracene, Preparation, Structure Elucidation, and Properties of Phenanthrene

Practice-5: Qualitative Analysis of Unknown Organic Compounds Containing Simple Functional Groups (Aldehydes)

Module VI: Alkaloids (6 Hours)

Natural Occurrence, Isolation, and Physiological Action of Alkaloids, General Structural Features, Experimental Determination of Alkaloids, Hoffmann's Exhaustive Methylation, Emde's Modification, Structure Elucidation and Synthesis of Hygrine, Structure Elucidation and Synthesis of Nicotine, Medicinal Importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine

Practice-6: Qualitative Analysis of Unknown Organic Compounds Containing Simple Functional Groups (Ketones)

Module VII: Terpenoids (5 Hours)

Occurrence, Classification, and Isoprene Rule, Elucidation of Structure and Synthesis of Citral, Neral, Elucidation of Structure and Synthesis of α-Terpineol

Textbooks:

1. **A Textbook of Organic Chemistry – III**, M. K. Jain, S. C. Sharma, Amita, Vishal Publishing Co.
2. **Kalsi, P. S.** Textbook of Organic Chemistry, 1st Ed., New Age International (P) Ltd.
3. **Morrison, R. T. & Boyd, R. N.** Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education)

4. **Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.;** Organic Chemistry, Oxford University Press.

Reference Books:

1. **Acheson, R.M.** Introduction to the Chemistry of Heterocyclic Compounds, John Wiley & Sons (1976)
2. **Joule, J. A., Mills, K., & Smith, G. F.** Heterocyclic Chemistry, 5th Ed.
3. **Singh, J.; Ali, S.M. & Singh, J.** Natural Product Chemistry, Pragati Prakashan (2010).

Course Outline

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM4607	Electrochemistry	2-1-1	

Objective

- To Know the basic of ions, electrolyte, movement of ions, electrochemistry
- To know how the ionic movements are related to different other fields such as thermodynamics.
- Also, this course will help students to garner basic knowledge on novel energy storage devices

Course outcome

After completion of the course students will be able to

COs	Course outcomes
CO1	Define the ionic, and electrical properties of sample
CO2	Explain the behavior of electrolytes in solutions
CO3	Able to gain skill on the handling of conductometer and to Interpret the results of electrolytic conductance in different solution
CO4	Differentiate the conductometric behavior of different electrolytic solution based on titration
CO5	Develop different electrochemical device for energy storage

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3								3	2	3

CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3
CO4		2	1	1	1								3	2	3
CO5		1	2	1	1								3	2	3

***High-3, Medium-2, Low-1**

Course content

Module-I: Conductance I **(6 hrs)**

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Ostwald's dilution law, Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions.

Module-II: Conductance II **(5hrs)**

Walden's rules, Debye-Huckel-Onsager equation. Ionic mobility and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods.

Module-III: Conductance III **(5 hrs)**

Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

Practice 1: Conductometric titrations of strong acid and strong base

Practice 2: Conductometric titrations of strong acid and weak base

Practice 3: Conductometric titrations of weak acid and strong base

Practice 4: Conductometric titrations of weak acid and weak base

Practice 5: Conductometric titrations of mixture of strong and weak acid with a strong base

Module-IV: Electrochemistry I **(5 hrs)**

Quantitative aspects of Faraday's laws of electrolysis, applications of electrolysis in metallurgy and industry. Electrochemical series, rules of oxidation/reduction of ions based on half-cell potentials. Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells.

Module-V: Electrochemistry II **(5 hrs)**

Electromotive force of a cell and its measurement. Chemical cells, reversible and irreversible cells with examples, Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, and glass electrodes.

Module-VI: Electrochemistry III **(5 hrs)**

Concentration cells with and without transference, liquid junction potential, Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

Module-VII: Energy Storage and Conversion(5 Hrs.)

Needs for energy storage and storage alternatives, Fundamentals on Li ion batteries, basic principle and types of fuel cells, theory of solar cells and types of solar cells, basic principles on super capacitors and types of super capacitors.

Text Books:

1. Atkins, P.W & Paula, J.D. Physical Chemistry, 10th Ed., Oxford University Press (2014).
2. Castellan, G. W. Physical Chemistry 4th Ed., Narosa (2004).
3. Mortimer, R. G. Physical Chemistry 3rd Ed., Elsevier: NOIDA, UP (2009).
4. Barrow, G. M., Physical Chemistry 5th Ed., Tata McGraw Hill: New Delhi (2006).
5. Engel, T. & Reid, P. Physical Chemistry 3rd Ed., Prentice-Hall (2012).
6. Rogers, D. W. Concise Physical Chemistry Wiley (2010).

Course Outline

Code	CourseTitle	T-P-Pj(Credit)	Prerequisite
CUTM4608	Biomolecules	3-1-0	

Objective

- To understand the fundamental structures and properties of biomolecules
- To apply biochemical techniques and synthesis in the laboratory to characterize DNA, amino acids, lipids, and pharmaceutical compounds.
- To analyze metabolic pathways and bioenergetics
- To evaluate and create knowledge on the structure–activity relationship of pharmaceutical compounds and demonstrate the ability to interpret diagnostic tools used in bio-imaging and biomedical sciences.

Course outcome

Students will be able to

COs	Course Outcomes
CO1	**Identify** the structures and components of nucleic acids.
CO2	**Explain** the properties and reactions of amino acids, peptides, and proteins.
CO3	**Perform** laboratory techniques to isolate DNA and estimate amino acids.
CO4	**Analyze**enzyme mechanisms and metabolic pathways.
CO5	**Interpret** the structure and function of pharmaceutical and bio-imaging compounds.

Course Outcome to Program Outcome Mapping:

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	-	-	-						2		3	2	3
CO2	3	2	2	1	-						2		3	2	3
CO3	-	3	2	1	2						2		3	2	3
CO4	-	3	2	1	2						2		3	2	3
CO5	-	3	2	1	2						2		3	2	3

***High-3, Medium-2, Low-1**

Coursecontent

ModuleI: Nucleic Acids **(4Hrs)**

NucleicAcids:Introduction of Nucleic Acids, Components of nucleic acids, Nucleosides and nucleotides, Structure, synthesis and reactions of Adenine, Guanine, Cytosine, Uracil and Thymine, Structure of poly nucleotides.

Practice1: Isolation and characterization of DNA from cauliflower

Practice2: Isolation and characterization of DNA from onion

ModuleII: Aminoacids, peptideandproteins **(6Hrs)**

Amino acids, peptide and proteins: Introduction to amino acid, peptide and protein, Classification of amino acid and peptides, α-Amino Acids: Synthesis, ionic properties and reactions, Zwitterions, pKa values, isoelectric point and electrophoresis, Study of peptides: determination of their primary structures-end group analysis, methods of peptide synthesis (SynthesisofpeptidesusingN-protecting,C-protectingandC-activatinggroups-Solid-phase synthesis)

Practice3: EstimationofglycinebySorenson'sformalinmethod

Practice4: StudyofthetitrationcurveofAminoacid

Module III: Enzymes **(6 Hrs)**

Enzymes: Introduction, classification and characteristics of enzymes, Salient features of active siteofenzymes,Mechanismofenzymeaction,Factorsaffectingenzymeaction, Coenzymesand Cofactors and their role in biological reactions, Enzyme inhibitors: Importance of enzyme inhibition phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition).

Module IV: Lipids **(5Hrs)**

Lipids:Introductiontooilsandfats(Propertiesandfunctions),ClassesofLipids(commonfatty acids present in oils and fats), Hydrogenation of fats and oils, Saponification value, acid value, iodine number, Reversion and rancidity

Practice6: Saponification valueof anoilorafat

practice7: Determination of Iodine number of an oil/fat.

Module V: Concept of Energy in Biosystems **(6Hrs)**

Concept of Energy in Biosystems: Introduction to metabolism (catabolism, anabolism), ATP: ATP hydrolys is and free energy change, Biological redox systems: NAD+,FAD, Conversion of food to energy, Outline of catabolic pathways of carbohydrate-glycolysis, Fermentation and Krebs cycle, Catabolic pathways of fat and protein, Metabolic pathways of protein, fat and carbohydrate

Practice8: Extraction of starchfrompotatoes

Module VI: Pharmaceutical Compounds (6Hrs)

Pharmaceutical Compounds: Structure and Importance: Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis), Antimalarials: Chloroquine, Antibiotics and detailed study of chloramphenicol, Medicinal values of curcumin (haldi), azadirachtin (neem), vitamin C and antacid (ranitidine)

Practice9: Preparation of triphenyl methanol via Grignard reaction

Practice10: Handling of Pyro phoric Materials liken-Butyl Lithium

ModuleVII: Bio-imaging and Bio-Medical science (6 Hrs)

Bio-imaging and Bio-Medical science: Introduction to basic cell biology, Optical fluorescent probe and photophysical property, Optical probe for bio-imaging application, Protein labelling, Diagnostic kit and Device fabrication

Reference Books:

1. Berg,J.M.,Tymoczko,J.L.andStryer,L.(2006)Biochemistry.VIthEdition.W.H. Freeman and Co.
2. ***Lehninger Principles of Biochemistry*** – David L. Nelson, Michael M. Cox
3. ***Biochemistry*** – Mary K. Campbell, Shawn O. Farrell
4. ***Biochemistry and Molecular Biology*** – William H. Elliott, Daphne C. Elliott

Course Outline

Nomenclature

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM4609	Quantum Chemistry and Spectroscopy	3-1-0	

Objective

- To impart knowledge about quantum mechanical principles and understanding as well as predicting different microscopic phenomena.
- To understand the covalent nature of bonding and their theoretical background and correlation to practical aspects.
- To have a sound understanding of different spectroscopic techniques and photochemistry.

Course outcome

After completion of the course students will be able to

COs	Course outcomes
CO1	Students will gain knowledge on different aspects of quantum chemistry and its applicability in different bonding behavior of atoms.
CO2	Understand different quantum mechanical phenomenon pertaining to behavior of atomic subatomic particles
CO3	Interprete different types of interactions of radiation with matter which is crucial for research purposes.
CO4	Differentiate the classical and quantum mechanics to understand behavior of microscopic objects.
CO5	Evaluate and interprete research and predict/interpret data.

Course Outcome to Program Outcome Mapping:

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	3	3								3	2	3
CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3
CO4													3	2	3
CO5													3	2	3

***High-3, Medium-2, Low-1**

Course content

Module I Quantum Chemistry (7 hours)

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment), quantization of energy levels, Heisenberg Uncertainty principle; wavefunctions, probability distribution functions, nodal properties, Extension to two and three dimensional boxes, separation of variables, degeneracy. Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wavefunctions. Vibrational energy of diatomic molecules and zero-point energy.

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component. Rigid rotator model of rotation of diatomic molecule. Schrödinger equation,

transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution. Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus.Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems(particle-in-a-box, harmonic oscillator, hydrogen atom).

Module II

Chemical bonding (6 hours)

Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+. Bonding and antibonding orbitals. Qualitative extension to H_2. Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, detailed solution not required) and their limitations.
Refinements of the two approaches (Configuration Interaction for MO, ionic terms in VB). Qualitative description of LCAO-MO treatment of homonuclear and heteronuclear diatomic molecules (HF, LiH). Localised and non-localised molecular orbitals treatment of triatomic (BeH_2, H_2O) molecules. Qualitative MO theory and its application to AH_2 type molecules.

Module III (5 hours)

Introduction to Molecular Spectroscopy:
Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation.

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Module IV

Vibrational spectroscopy (7 hours)

Classical equation of vibration, computation of force constant,amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

Module V

Raman and Electronic Spectroscopy (5 hours)

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.
Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.

Module VI **(5 hours)**

Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and low resolution spectra, different scales, spin-spin coupling and high resolution spectra, interpretation of PMR spectra of organic molecules.

Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals.

Assignment 6: Deduce the number of ESR peaks for methyl radical.

Module VII Photochemistry **(4 hours)**

Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physicalsignificance of absorption coefficients. Laws, of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, photochemical equilibrium and the differentialrate of photochemical reactions, photosensitised reactions, quenching. Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence.

Practices

Practice 1
Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J mol^{-1}, kJ mol^{-1}, cm^{-1}, eV).
Practice 2
Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$.
Practice 3
Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde,2-propanol, acetic acid) in water. Comment on the effect of structure on the UVspectra of organic compounds.
Practice 4
Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/$K_2Cr_2O_7$ in a solution of unknown concentration
Practice 5. Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.
Practice 6
Determine the amount of iron present in a sample using 1,10-phenathroline.
Practice 7
Determine the dissociation constant of an indicator (phenolphthalein).
Practice 8
Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.

Reference Books:

1. ***Quantum Chemistry*** *– Ira N. Levine*
2. ***Introduction to Quantum Mechanics in Chemistry*** *– Mark A. Ratner and George C. Schatz*
3. ***Physical Chemistry: A Molecular Approach*** *– Donald A. McQuarrie and John D. Simon*
4. ***Molecular Quantum Mechanics*** *– Peter W. Atkins and Ronald Friedman*

5. ***Fundamentals of Molecular Spectroscopy*** *– C.N. Banwell and E.M. McCash*
6. ***Molecular Spectroscopy*** *– Jeanne L. McHale*

Course Outline

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM1405	Synthesis and Application of Nanocomposites	3-0-1	

Objective

- To provide knowledge of the advantages of using different types of nanocomposites
- To make the students familiar with the mechanism of nanocomposites
- To make them aware of the manufacturing and testing methods of nanocomposites

Course outcome

After completion of the course students will be able to

COs	Course outcomes
CO1	Able to gain knowledge on the significance of the nanocomposites as an important class of materials
CO2	Learn hands-on experience on the synthesis of nanocomposites as well as its applications
CO3	Investigation and Judgments
CO4	Able to solve or identify different problems arising in nanotechnology research
CO5	This knowledge will help them to develop innovative research ideas for research and publications

Course content

Module-I

Introduction to Nanocomposite Materials

Definition, Classification, and constituents of nanocomposites, General characteristics of particle-reinforced composites and fiber-reinforced composites- classification.

Module-II

Basic Constituent Materials in Nanocomposites Role and Selection of reinforcement materials, Glass fibers, Carbon fibers, Boron Fibers, Natural fibers, Multiphase fibers

Module-III

Fabrication of various types of Nanocomposites

Ceramic/Metalnanocomposite Systems, Nanocomposites based on polymer matrix, Carbon-carbon, Carbon-metal nano composites, Bio-inspired nano composites

Module IV

Nanocomposite Processing Methods

Nanocompositeprocessing:In-situpolymerizationtechnique,Solutioncasting,Electrospinning,melt mixing, Filament Winding, Injection and compression molding, Pultrusion Process

Module V

Mechanical Properties-Stiffness and Strength

Geometrical aspects – volume and weight fraction, Unidirectional continuous fiber, Determination of stiffness and strength sofunidirectional composites, tension, compression, flexure and shear

Module VI

Application of Nanocomposites - I

Application of Nanocomposites in Aerospace, Coating, Mechanical, Electrical & Electronics, Fuel cell.

Module VII

Applications of Nanocomposites - II

Hybrid Nanocomposite materials for food packaging, graphene-carbon nano tube nano composite for energy storage applications, Nanocomposites for solar cells, Nano composite materials for Lithium-ion battery.

Recommended Textbooks:

- Composite Polymeric Materials–Sheldon
- Lubin – Hand book of composites–(VanNostrand,1982)

- CarbonNanotubeandGrapheneDevicePhysics,byH.-S.PhilipWong(Author),DejiAkinwande(Author)
- K. Chawla, Composite Materials–Science & Engg., Springer-Veslag, New York,1988.
- Mohr-SPIE Hand book of Technology and Engineering of Reinforced Plastics/Composites– (Van Nostrand,1998)

Student should be assigned different project for carrying out different synthesis and characterization of nanocomposite.

Course Outline

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4610	Organometallic Chemistry	2-1-1	

Objective

- To Understand electronic and molecular structures of organometallic compounds.
- To Learn methods to synthesize various organometallic compounds.
- To Analyze the role of organometallic compounds in industrial and organic synthesis.

Course outcome

COs	Course outcomes
CO1	Understand the Fundamental Concepts of Organometallic Chemistry and can define and Classify organometallic compounds by metal type, ligand nature, and bonding type.
CO2	Analyze the Structure and Bonding in Organometallic Complexes by applying Apply molecular orbital theory and crystal field theory .
CO3	Understand the Reactivity Patterns and Mechanisms and can apply Knowledge to real-world applications like catalysis, pharmaceuticals, and materials science.
CO4	Interpret Spectroscopic and Analytical Data of Organometallic Compounds by using IR, NMR, and UV-Vis spectroscopy to characterize metal–ligand bonding.
CO5	Can Develop Laboratory and Analytical Skills to Synthesize and handle air-sensitive organometallic compounds

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3	1	3	2				3	3	2	3
CO2	3	3	3	2	3	1	2	1				3	3	2	3
CO3	-	3	2	3	3	1	1	1				2	3	2	3
CO4	2	2	3	3	3	2	2	2				3	3	2	3
CO5	2	2	2	3	3	2	3	2					3	2	3

***High-3, Medium-2, Low-1**

Course content

Module I **(2 hrs)**

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands.

Project-1: Concept of hapticity of organic ligands

Practice-1: Estimation of Fe(II) with $K_2Cr_2O_7$

Module II **(4 hrs)**

Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series.

Project-2: Role of Organometallics in Polymerization Reactions

Practice-2: To detect the presence of a cation and anion in a given inorganic mixture.

Module III **(4 hrs)**

Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.Zeise's salt: Preparation and structure, evidences of synergic effect and comparison ofsynergic effect with that in carbonyls.

Project-3: Study of Metal-Carbonyl Complexes: IR Spectroscopy and Bonding

Practice-3: Identification of Cobalt and Nickel ions in chemistry Lab

Module IV **(4hrs)**

Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.

Project-4: Preparation and Spectral Analysis of Grignard Reagents

Practice-4: Brown ring test for nitrate ion in laboratory

Module V **(4 hrs)**

Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene. MO diagram of ferrocene and metallocene.

Project -5: Molecular Orbital Theory of Ferrocene and Related Sandwich Complexes

Practice-5: Estimation of free alkali present in different soaps/detergents

Module VI **(4 hrs)**

Organometallic reactions: Oxidative Addition, Reductive Elimination, Migratory Insertion & Elimination Reactions, Migration & Insertion Reactions, Alpha-Migratory Insertion & Alpha-Elimination Reactions, Beta-Migratory Insertion, Beta-Elimination Reaction.

Project-6: Kinetics and Thermodynamics of Organometallic Substitution Reactions

Practice-6: Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution

Module VII **(4 hrs)**

Study of the following industrial processes and their mechanism: Alkene hydrogenation (Wilkinsons Catalyst),Hydroformylation (Co salts),Wacker Process,Synthetic gasoline (Fischer Tropsch reaction).

Project-7: Organometallic Compounds in Medicine

Practice-7: Synthesis of Ferrocene from Cyclopentadiene and Iron(III) Chloride

Book References:

- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
- Sharpe, A.G. Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005
- Douglas, B. E.; McDaniel, D.H. & Alexander, J.J. Concepts and Models in Inorganic Chemistry3rd Ed., John Wiley and Sons, NY, 1994.
- Greenwood, N.N. & Earnshaw, A. Chemistry of the Elements, Elsevier 2nd Ed, 1997 (Ziegler Natta Catalyst and Equilibria in Grignard Solution).Shriver and Atkins' Inorganic Chemistry, Oxford Press, 2010.
- James E. Huheey, Ellen A. Keiter, Richard L. Keiter Inorganic Chemistry Principles Of Structure And Reactivity (2017).

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4611	**Organic Spectroscopy**	**2-1-1**	

1. Objective

- To learn proper sample handling procedures for acquiring infrared **spectra**.
- To determine the percentage composition of a liquid sample mixture Recognize and draw particular carbohydrate structures
- To train the students for identification of unknown compounds

2. Course outcome

After the completion of the course students will be able to

COs	Course outcomes
CO1	Recall the basic concepts of spectroscopy
CO2	Understand the problem-solving techniques of organic spectroscopy
CO3	Employ the knowledge in deducing the structure of molecules based on spectroscopic data
CO4	Analyze different patterns of peaks and their origin and hence the deduction of structure of organic species.
CO5	Judge the various spectroscopic patterns for organic molecules

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3	1	3	2				3	3	2	3
CO2	3	3	3	3	3	1	2	1				3	3	2	3
CO3	-	3	2	3	3	1	2	1				2	3	2	3
CO4	2	3	3	3	3	2	2	2				3	3	2	3
CO5	2	2	2	3	3	2	3	2					3	2	3

***High-3, Medium-2, Low-1**

Course Content

Module I **(4 hrs)**

Introduction to UV spectroscopy, Theory and principles, Types of electronic transitions, Tmax, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; of Application Woodward rules for calculation of λmax for the following systems: α,β unsaturated aldehydes, ketones, carboxylic acids and esters; Conjugated dienes: distinction between cis and trans isomers.

Module II **(2 hrs)**

IR Spectroscopy:
Fundamental and non-fundamental molecular vibrations; IR absorption positions of O, N and S containing functional groups;

Module III **(4 hrs)**

IR Spectroscopy-II
Effect of hydrogen bonding and solvent effect on vibrational frequencies; overtones; FT-IR of gaseous; solids and polymeric materials.

Module IV **(4 hrs)**

Nuclear Magnetic Resonance Spectroscopy-I
The nature of spinning particles, interaction between spin and a magnetic field. Population of energy levels, the larmor precession. Relaxation times. The meaning of resonance and the resonance condition.

Module V **(4 hrs)**

Nuclear Magnetic Resonance Spectroscopy-II
NMR experiment, significance of shielding constants and chemical shift. The origin and effect spin - spin coupling, factors affecting chemical shift, chemical analysis by NMR. double resonance and nuclear-overhauser effect.

Module VI **(4 hrs)**

Mass Spectrometry I:
Introduction, ion production, factors affecting fragmentation, ion analysis, ion abundance. Mass spectral fragmentation of organic compounds, common functional groups, molecular ion peak, metastable peak.

Module VII (4 hrs)
Mass Spectrometry II:
McLafferty rearrangement, nitrogen rule. High-resolution mass spectrometry. Examples of mass spectral fragmentation of organic compounds with respect to their structure determination.

Practices

Practise-1: To study the UV-Visible Spectroscopy of Conjugated Molecules
Practise-2: Solvent Effects on the UV-visible Absorption Spectra
Practise-3: To Determine of the Molar Absorptivity of a Light Absorbing Molecule by using Lambert-Beer's law
Practice 4: Verification of Beer-Lambert's law and determination of concentration of a given $KMnO_4$ solution.
Practice 5: Determination of concentration of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture solution.

Project: Students will do a project in the field of spectroscopy such as structural elucidation, determination of structure, obtaining the reaction rate etc.

Reference Books:

1. Organic spectroscopy by William Kemp
2. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India)Pvt. Ltd. (Pearson Education
3. Spectrophotometric identification of Organic Compounds by Silverstein
4. Billmeyer, F. W. Textbook of Polymer Science, John Wiley & Sons, Inc.4. Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. Polymer Science, New Age International (P) Ltd. Pub.
5. 4. Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. 5. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press.
7. Pavia, D. L. et al. Introduction to Spectroscopy 5th Ed. Cengage Course India Ed. (2015).

CourseOutline

5.

Code	CourseTitle	T-P-Pj(Credit)	Prerequisite
CUTM4612	Bio Inorganic Chemistry	3-1-0	

6.

Objective

- Identify metal-containing biomolecules such as hemoglobin, ferritin, and transferrin
- Describe the function of metalloenzymes in intracellular biochemical processes
- Apply the concept of metal-ligand interactions in explaining siderophore function.
- Evaluate the impact of metal deficiency or toxicity in physiological systems.

Course Outcome

Students will be able to

COs	Course outcomes
CO1	Explain the biological significance of essential and trace elements
CO2	Demonstrate the mechanisms of metal ion transport and storage in biological systems
CO3	Analyse the roles of metalloenzymes and metal complexes in intracellular processes
CO4	Assess the effects of metal ion imbalances on healthand the application of metals
CO5	Design models or conceptual frameworks to simulate metal-nucleic acid interactions

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1		2		1					3	2	
CO2	3	3	2	2		2		2					3	3	2
CO3	3	3	2	2		2	1	2					2	3	2
CO4	2	3	2	1	2	3	2	2					2	2	
CO5	2	3	3	2		3	2	2					2	3	2

***High-3, Medium-2, Low-1**

Module-I **(3h)**

Essential and trace elements in biological processes, Biological role of alkali and alkaline earth metal ions, transport and regulation.

Module-II **(3h)**

Metal Storage and Transport: Ferritin, transferrin, and siderophores, ionophores, cellular transport of Fe, Ca, Na and K, ionophores and ions channels

Module-III **(4h)**

Function and Transport of Alkali and Alkaline earth metals: Uptake, transport and storage of metal ions by organisms - structure and functions of biological membranes - the generation of concentration gradients (the Na+ -K+ pump) – mechanisms of ion-transport across cell membranes

Module-IV **(4h)**

Bleomycin - siderophores (e.g. Enterobactin and desferrioxamine) - transport of iron by transferring - storage of iron by ferritin - bio chemistry of calcium as hormonal messenger. Metals at the Center of Photosynthesis: Primary Processes in Photosynthesis – Photosystems I and II.

Module-V **(5h)**

Molecular aspects of intracellular processes. Metalloenzymes, Iron enzymes, Mn, Ni, Zn and Cu containing Enzymes, SODs, Molybdenum/Tungsten containing enzymes, Coenzyme vitamin B12, Zinc in transcription and regulation.

Module-VI **(4h)**

Photosynthesis, Oxygen Evolution Complex (OEC), Oxygen Binding and transport: Biological Dioxygen carriers: Hemoglobin, hemerythrin, hemocyanin, allosteric regulation, artificial dioxygen carriers, metallo porphyrins, Electron-transfer proteins, long distance electron transfer.

Module-VII **(3h)**

Metal-Nucleic Acid Interactions: Metals in Medicine, Metal deficiency and disease, toxic effects of metals, metals used for diagnosis and chemotherapy with particular reference to anticancer drugs

Practice

1. Estimation of Calcium and Magnesium in Water Samples
2. Colorimetric Determination of Iron in Ferritin or Supplements
3. Demonstration of Ion Exchange Using Sodium and Potassium Ions
4. Preparation and Characterization of a Metal-EDTA Complex (e.g., Cu-EDTA)
5. Qualitative Test for Metal Ions in Biological Samples (e.g., plant ash or supplements)
6. Model Demonstration of Na^+/K^+ Pump Using Diffusion Cells
7. UV-Visible Spectral Study of any Model Iron Complexes

Reference Books

1. Purcell, K. F. and Kotz, J. C., Inorganic Chemistry, Cengage Learning, 2012.
2. Cotton, F. A., Wilkinson, G., Carlos A. Murillo, Manfred Bochmann, Advanced Inorganic Chemistry, 6th ed., A Wiley - Interscience Publication, John –Wiley & Sons, USA, 2007. Chem. Education, 62, No. 11, Bioinorganic Chemistry, State of the Art. 1985.
3. Eichorn, G. L., Inorganic Biochemistry, Volumes 1 & 2, 2nd ed., Elsevier Scientific Publishing Company, New York, 1973.
4. Atkins, P., Overton, T., Rourke, J., Weller M., and Armstrong, F., Inorganic Chemistry, 5th edition, Oxford University Press, 2010.
5. Lehninger, A., Nelson, D. L., Cox, M. M, Principles of Biochemistry, 5th edition, W.H Freeman, 2008.
6. Alessio, E., Bioinorganic Medicinal Chemistry, 1st Edition, Wiley-VCH Verlag GmbH Co. KGaA, 2012.

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM4613	Organic Synthesis: Reaction and Reagents	3-1-0	

Objective

- The course gives idea about the different phases of matter and their equilibria from which the stability and sustainability can be easily predicted.
- Deals with kinetics study of different processes and surface phenomenon like adsorption, chemisorptions etc.

Course outcome After completion of the course, students will be able to

COs	Course outcomes
CO1	Determine the different phases of matter and kinetics of reaction.
CO2	Explain the degrees of freedom of the systems and kinetics of chemical reaction
CO3	Demonstrate the controlling factors that affect the rate of reactions
CO4	Analyze the phase diagram and solve related problems
CO5	Fabricate the inorganic polymer-based material

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	1								3	2	
CO2	3	3	2	1	2								3	3	
CO3	3	3	2	1	3								3	3	
CO4	3	3	2	2	2								3	3	
CO5	3	2	2	1	2								3	3	

***High-3, Medium-2, Low-1**

Course content

Module I

Introductory concept **(6 Hrs)**

Inductive effect, electromeric effect, conjugation, resonance and resonance energy, hyperconjugation. Homolytic and heterolytic bond breaking,Electrophiles and nucleophiles; carbocations, carbanions and radicals (stability andreactivity).

Module II Stereochemistry (4Hrs)

Stereochemistry of carbon compounds: Different types of isomerism, enantiomers, and diastereoisomers; Fischer, Sawhorse, and Newman Projection formulae of simple molecules containing one and twoasymmetric carbon atoms.

Module III

Chemistry of Alkanes (5Hrs)

Classification of carbon atom in alkanes, General methods of preparation, physical and chemical properties of alkanes: Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation -relative reactivity and selectivity.

Module IV

Chemistry of Alkenes (7Hrs)

Methods of formation of alkenes, Addition to C=C: mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenation, hydrohalogenation, hydration.oxymercuration demercuration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch);

Practice 1: Differentiation between alkanes, alkenes.
Practice 2: Cis-trans isomerism of alkene.

Module V

Chemistry of Alcohols (7 Hrs)

Classification and nomenclature, Monohydric alcohols – nomenclature, methods of formation by reduction of Aldehydes, Ketones, Carboxylic acids and Esters, Hydrogen bonding, Acidic nature, Reactions of alcohols.

Practice 3: Identification of organic compounds through the functional group analysis -ignition test.

Module VI

Chemistry of Aromatic compounds (6 Hrs)

Nomenclature of benzene derivatives, MO picture of benzene, Aromaticity: Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their Mechanism.

Practice 4: Differentiation between aliphatic and aromaticcompounds using chemical and physical tests.

Practice 5: Aromatic electrophilic substitution: Nitration: Preparation of nitro benzene and m-dinitro benzene.

Module VII

Organic Reagents (4 Hrs)

Oxidising agents, Reducing agents,Grignard reagent, Bayer's reagent, potassium dichromate, potassiumpermanganate, Raney Ni, silver nitrate, sodium borohydride.

References Books:

1. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

2. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.

3. Carey, F. A., Guiliano, R. M.Organic Chemistry, Eighth edition, McGraw Hill Education, 2012.

4. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press, 2008.

5. Clayden, J., Greeves, N. &Warren, S. Organic Chemistry, 2nd edition, Oxford University Press, 2012.

Nomenclature

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM1402	Advanced Characterization Techniques	3-0-1	

Objective

- To acquire knowledge of the different existing experimental techniques for the microstructural and physicochemical characterizations of materials.
- To understand about the principles of various techniques.
- To be able to interpret the instrumentation/research data.

Course outcome

After completion of the course students will be able to

COs	Course outcomes
CO1	Student will be able to Explain the principles and operation of a range of advanced techniques such as X-ay, spectroscopic, microscopic, thermal and electro analytical, currently used in characterization of various materials and compounds.
CO2	Learn Hand on experience of operation of some these instruments at labs and interpretation of results.
CO3	Apply the skills gained in future course of research in materials science
CO4	Perform simple and routine operations on the experimental setups and interpret the experimental data.
CO5	These knowledges will help students to do advanced research and publish articles as well as develop products.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	-	1	3	-	-	-	-	1	-	2	3	2	
CO2	3	3	2	3	3	-	-	-	-	2	-	2	3	3	
CO3	2	3	2	3	2	-	-	-	-	2	-	2	3	3	
CO4	2	3	3	3	3	2	2	-	2	2	1	3	3	3	
CO5	2	1	1	1	1	2	3	2	1	2	-	3	2	1	

Course content

Module-I **(5h)**

Compositional and Structural Characterization

X-ray diffraction (XRD), Small-angle XRD, Powder diffraction, Lattice parameters, Structureanalysis, Strain analysis, Phase identification, Particle size analysis using - Scherer's formula

Module-II **(5h)**

Advanced Microscopy Techniques for Nanomaterials

Field emission scanning electron microscope (FESEM), Transmission electron microscopy (TEM), High-resolution transmission electron microscopy (HRTEM).

Module-III **(6h)**

Advanced techniques of chromatography

Separating and analyzing complex mixtures, including high-performance liquid chromatography (HPLC), gas chromatography (GC), and their variations like ultra-performance liquid chromatography (UPLC) and supercritical fluid chromatography (SFC)

Module-IV **(5h)**

Nanomaterials Electrical and Magnetic Characterization Techniques

Measurement of resistivity by 4-probe method, Hall measurement, Measurement of magnetic of properties of nanomaterials, Vibrating sample magnetometer.

Module-V **(6h)**

Mechanical Characterization Techniques

Elastic and plastic deformation-mechanical properties of materials, models for interpretation of nano indentation load-displacement curves, Nano indentation data analysis methods-Hardness testing of thin films and coatings, Mechanical properties evaluation by universal testing machine(UTM),Dynamic mechanical analysis.

Module-VI **(6h)**

Physical and Optical Characterizations of Nanostructured Materials

Introduction to particle size characterization, Zeta potential measurement–Particle size analysis, specific surface area by BET analysis

Module-VII **(6h)**

Thermal and Electro chemical Characterization

Differential scanning calorimeter (DSC), Differential thermal analyzer (DTA),Thermo gravimetric analysis (TGA), Electro chemical analysis (Charging-discharging cyclic voltammetry).

Reference Books:

2. ASMHandbook:MaterialsCharacterization,ASMInternational,2008.
3. YangLeng:MaterialsCharacterization-IntroductiontoMicroscopicandSpectroscopicMethods,John Wiley &Sons(Asia) PteLtd., 2008.
4. RobertF.Speyer:ThermalAnalysisofMaterials,MarcelDekkerInc.,NewYork,1994.
Nanotechnology-BasicScienceandEmergingTechnologies,MickWilson,KamaliKannangraGeoffSmith, MichelleSimons and Burkhard Raguse, Overseas Press.

Students should be assigned different project for carrying out different characterizationsof materials like UV, IR, XPS as well as chromatographic techniques.

Course Outline

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM1417	Polymer Chemistry	3-1-0	

Objective

- To understand the importance of the chemical approach to polymer, radical, and ionic polymerization, and polymer analysis techniques.
- To study the methods of measuring the molecular weight, polymerization kinetics, co-polymerization, and polymer processing technologies.
- To understand about mechanical properties and applications of polymers.

Course outcome

After completion of the course, students will be able to

COs	Course outcomes
CO1	Able to gain knowledge about the basics of polymer and the differences between crystalline melting temperature and glass transition temperature, as well as the effect of kinetics on both.
CO2	Students will develop specific skills, competencies, and thought processes sufficient to support further study or work in this field of Polymer Chemistry.
CO3	Students will be able to evaluate the effect of factors such as polymer structure, molecular weight, branching and diluents on crystallinity.
CO4	Able to solve different environmental problems caused due to use of plastics
CO5	This knowledge will help students to do advanced research and publish articles as well as develop products.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	-	-	-	-	-	-	-	2	3	2	
CO2	3	3	2	2	1	-	-	-	-	1	-	2	3	3	
CO3	3	3	2	3	2	-	2	-	-	1	-	2	3	3	
CO4	2	2	3	3	3	1	2	-	1	2	-	3	3	3	
CO5	2	1	2	1	1	2	3	2	1	2	1	3	2	1	

Course content

Module I: Fundamental **(5 hrs)**

Introduction and history of polymeric materials, Classification of polymers, configuration and conformation of polymers, nature of molecular interactions in polymers, various structures of co-polymers such as linear, branched, crosslinked polymers, and their types.

Practice1

Determine the melting point of a crystalline polymer.

Practice2

Synthesis of Cellulose from Natural Cotton.

Module II: Crystal Morphology of polymer **(6hrs)**

Extended chain crystal, chain folding, crystallization, crystallinity, determination of melting point, and degree of crystallinity

Module III: Properties of Polymer **(6hrs)**

Properties (Physical, thermal and mechanical) of polymer, Glass transition temperature (Tg) and measurement of Tg. Factors affecting the glass transition

Practice3

Determine the viscosity by Red-Wood Viscometer.

Practice4

Preparation of Polyvinyl Chloride

Module IV: Preparation of polymer **(5hrs)**

Methods of preparation, properties, and applications of Polystyrene, Polyvinyl Chloride, Polybenzimidazole, Polyethylene, etc.

Practice5

Preparation of Polylactic Acid.

Module V: Polymerization Process **(6hrs)**

Basic methods of Polymerization and their mechanism. Addition, condensation, emulsion, and solution processes, polymer formation by step-growth and chain-growth polymerization.

Module VI: Co-polymerization **(6hrs)**

Kinetics of Co-polymerization, Zeigler-Natta Catalyst, Mayo's equation, Cage-effect, auto-acceleration, inhibition and retardation.

Practice6

Synthesis of Polymer Nanoparticles

Module VII: Adhesives **(5hrs)**

Introduction, Classification, Adhesive action, Development of action and strength, factors affecting adhesive action, Applications of adhesives.

Textbooks:

1. Principles of Polymerization, Fourth Edition –George Odian
2. GeddeUlf.W. Polymer Physics, Chapman & Hall London(1995)
3. Rodriguez, Ferdinand, Principles of Polymer Systems Mc. Craw – Hill, InternationalBookCo.InternationalStudentEdn.1985.

ReferenceBooks:

1. Cowie;JMGPolymers:Chemistry&PhysicsofModernMaterials,NelsonThornesltd. Chelterham,2001
2. Hiemenz;PaulC.PolymerChemistry-TheBasicConcepts;Marcell&Deckker,Inc.New York(1984)
3. PolymerSciencebyV.R. Gowarikar,N.V. viswanathanandJ. Sreedhar,NewAgeInternational.
4. TextbookofPolymerscience:F.M. Billmeyer,Johnwileyandsons.

Course Outline

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM1405	Synthesis and Application of Nanocomposites	3-0-1	

Objective

- To provide knowledge of the advantages of using different types of nano composites
- To make the students familiar with the mechanism of nano composites
- To make them aware of the manufacturing and testing methods of nano composites

Course outcome

After completion of the course students will be able to

COs	Course outcomes
CO1	Able to gain knowledge on the significance of the nanocomposites as an important class of materials
CO2	Learn hands-on experience on the synthesis of nanocomposites as well as its applications
CO3	Investigation and Judgments
CO4	Able to solve or identify different problems arising in nanotechnology research
CO5	This knowledge will help them to develop innovative research ideas for research and publications

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	-	-	-	-	-	-	-	-	-	1	3	-	
CO2	3	3	2	2	2	-	-	-	-	-	-	1	3	2	
CO3	3	3	2	3	2	-	-	-	-	-	-	1	3	3	
CO4	2	3	3	2	3	2	2	-	-	-	-	2	3	3	
CO5	2	-	2	-	1	2	3	2	1	2	-	3	2	1	

Course content

Module-I **(5 hrs)**

Introduction to Nano composite Materials

Definition, Classification, and constituents of nano composites, General characteristics of particle-reinforced composites and fiber-reinforced composites- classification.

Module II **(5hrs)**

Basic Constituent Materials in Nanocomposites

Role and Selection of reinforcement materials, Glass fibers, Carbon fibers, Boron Fibers, Natural fibers, Multi phase fibers

Module III **(5 hrs)**

Fabrication of various types of Nanocomposites

Ceramic/Metal nanocomposite Systems,Nano composites based on polymer matrix,Carbon-carbon,Carbon-metal nanocomposites, Bio-inspired nanocomposites

Module IV **(6 hrs)**

Nanocomposite Processing Methods

Nano composite processing: In-situpolymerization technique, Solution casting, Electrospinning, melt mixing, Filament Winding, Injection and compression molding, Pultrusion Process

Module V **(6 hrs)**

Mechanical Properties-Stiffness and Strength

Geometrical aspects – volume and weight fraction, Unidirectional continuous fiber, Determination of stiffness and strengths of unidirectional composites, tension, compression, flexure and shear

Module VI **(6 hrs)**

Application of Nano composites I

ApplicationofNanocompositesinAerospace,Coating,Mechanical,Electrical&Electronics,Fuelcell.

Module VII **(6 hrs)**

Applications of Nanocomposites II

Hybrid Nano composite materials for food packaging, graphene-carbon nano tube nano composite for energy storage applications, Nanocomposites for solarcells, Nanocomposite materials for Lithium-ion battery.

Recommended Textbooks:

- CompositePolymericMaterials–Sheldon
- Lubin-Handbookofcomposites–(VanNostrand,1982)
- CarbonNanotubeandGrapheneDevicePhysics,byH.-S.PhilipWong(Author),DejiAkinwande(Author)
- K.Chawla,CompositeMaterials–Science&Engg.,Springer-Veslag,New York,1988.
- Mohr-SPIEHandbookofTechnologyandEngineeringofReinforcedPlastics/Composites– (Van Nostrand,1998)

Student should be assigned different project for carrying out different synthesis and characterization of nanocomposite.

Course Outline

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM1425	Sustainable Chemistry	3-1-0	

Objective

- To learn the fundamental philosophy and the latest developments in sustainable chemistry.
- To understand why solvent replacements are being sought.
- To familiarize with different green reaction alternatives of conventional reaction procedures with real world applications.
- To understand how waste biomass can be converted to wealth.
- To understand importance of recycling and its application in circular economy

Course outcome

After completion of the course students will be able to

COs	Course outcomes
CO1	Will gain knowledge about the responsibility of a chemist towards the solution of various environmental issues
CO2	Able to observe and differentiate the environmental friendly chemicals to fulfill our requirements in life
CO3	Able to judge in every step of life to select sustainably viable options starting from personal to professional front
CO4	Will be equipped to be part of problem solving endeavor related to environmental issues
CO5	Can plana synthesis with less hazardous chemicals and processes.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	**3**	**2**	**2**	**3**	**2**								**3**	**2**	
CO2	**2**	**3**	**3**	**3**	**2**								**3**	**3**	
CO3	**3**	**3**	**3**	**3**	**3**								**3**	**3**	

CO4	**2**	**3**	**3**	**3**	**3**								**2**	**3**	
CO5	**2**	**3**	**2**	**2**	**3**								**2**	**3**	

Course content

ModuleI **(6Hrs.)**

Fundamental:

BasicConceptsofSustainableChemistry;Sustainabilityassessment;Essentialsofsustainablechemistry; Role of chemistry in sustainability.

ModuleII **(5Hrs.)**

GreenChemistry: Principles of green chemistry: Designing safer chemicals, predicting the properties and environmental aspects before synthesis

ModuleIII **(5Hrs.)**

GreenSolvents: Atom economy, metathesis; Ionic liquids, classification, synthesis & applications; Deep eutecticsolvents, classification, synthesis & applications.

Practice1: Ionic liquid synthesis

Practice2: Deep eutectic solvents preparation

Practice3: Supercritical fluids

ModuleIV **(6Hrs.)**

Green Synthetic Methods:

Safer Chemical Design; Green Chemistry Molecular design pyramid, Example of failed chemicaldesign(thalidomide),SaferChemicalDesignexamples.Greenalternativeofconventionalsynthetic methods; Green catalysis (Phase Transfer Catalysts, Chitosan, enzymes), solvent freereactions,Microwaveassistedreactions,ExamplesofGreenSynthesis-Ibuprofen.

Practice4: Greensynthesisofnanoparticles(Au/Ag/Cu)usingleafextracts.

Practice5: GreensynthesisofNylonprecursoradipicacid

Practice6: Solvent-FreeWittigReaction

ModuleV **(5Hrs.)**

Value addition toWaste Biomass:

Renewable Feed stocks; Types of biomass derived fuels & energy, biogas, bioethanol, biodiesel;Thermochemical conversion, gasification pathway, pyrolysis pathway; Biochemical Conversion, anaerobic digestion, fermentation.

ModuleVI **(6Hrs.)**

Sustainablematerials:

ApplicationofRenewableRawMaterialsinorganicsynthesis:Historicaldevelopments-Alizarine, Indigo and Coniine synthesis. Application of Renewable Raw Materials in synthesis:Synthesis of (±)-Usnic acid from lignin, tetracyclin antibiotics from Chitin derived L-Rednose,(−)-Bissetone and (−)-palythazine from cellulose derived glucose.

ModuleVII **(6Hrs.)**

Recycling and circular economy:

Plastic recycling in circular economy. Sustainable packaging. Life Cycle Analysis (LCA), Cradle to grave and Cradle to Cradle design.

Textbooks:

1. New trends in green chemistry:V.K.Ahluwalia,M.KidwaiAnamayaPublishers
2. Introduction to Green Chemistry:AlbertS.Matlack,2ndedition,CRCPress
3. Waste to Wealth-The circular economy advantage:PeterLacy and Jakob Rutqvist, Ma Editions
4. GreenSolvents-IonicLiquids:PaulT.Anastas(SeriesEditor),PeterWasserscheid,AnnegretStark, Wiley-VCH
5. Sustainable chemistry: G.Reniers andC.ABrebbia,WITPress
6. Valorization of biomass to value added commodities: Daramola, Michael, Ayeni, and Augustine(Eds), Springer

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM4614	APPLICATIONS OF COMPUTERS IN CHEMISTRY	3-1-0	

Course Objectives:

- To encourage understanding of fundamental concepts and practical applications of computers in chemistry.
- To expose students to developing computational skills for data analysis, molecular modeling, chemical structure drawing, simulation techniques, and database management.
- To grow skills in software tools and computational methods to solve chemical problems, interpret results, and support research.
- To develop the students to accept the challenges by enhancing their understanding of theoretical and experimental chemistry.

Course Outcomes:

COs	Course outcomes
CO1	To demonstrate understanding of the role of computers in chemistry, including data processing, chemical databases, and computational techniques.
CO2	To apply appropriate software tools for chemical structure drawing, molecular modeling, and visualization of chemical systems.
CO3	To utilize computational methods for solving chemical problems such as thermodynamic calculations, quantum chemical studies, and molecular simulations
CO4	To analyze and interpret experimental and theoretical data using statistical and graphical tools.
CO5	To integrate computational approaches with experimental chemistry to design, predict, and optimize chemical processes and reactions.

CO,PO,PSO MappingMatrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	2		3	3	1	2			3	2	2
CO2	2	3	2	2	3		2	2	2	2			2	3	2
CO3	2	3	2	3	3		2	3	2	2			3	3	3
CO4	2	3	3	3	3		3	2	1	2			3	3	2
CO5	2	3	2	3	3		2	2	2	3			3	3	3

Content

Basics: Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis. Numerical methods: Roots of equations: Numerical methods for roots of equations: Quadratic formula, iterative method, Newton-Raphson method, Binary bisection and Regula-Falsi. Differential calculus: Numerical differentiation. Integral calculus: Numerical integration (Trapezoidal and Simpson's rule), probability distributions and mean values. Simultaneous equations: Matrix manipulation: addition, multiplication. Gauss-Siedal method. Interpolation, extrapolation and curve fitting: Handling of experimental data. Conceptual background of molecular modelling: Potential energy surfaces. Elementary ideas of molecular mechanics and practical MO methods.

Reference Books:

- Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.
- Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.
- Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).
- Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

PRACTICAL-DSE LAB: APPLICATIONS OF COMPUTERS IN CHEMISTRY

1. Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).

2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

3. Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values.

4. Matrix operations. Application of Gauss-Siedel method in colourimetry.

5. Simple exercises using molecular visualization software.

Reference Books:

- McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008). Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).
- Steiner, E. The Chemical Maths Book Oxford University Press (1996).
- Yates, P. Chemical Calculations. 2nd Ed. CRC Press (2007).
- Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.
- Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.
- Noggle, J. H. Physical Chemistry on a Microcomputer. Little Brown & Co. (1985).
- Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

Code	**Course Title**	**T-P-P (Credit)**	**Prerequisite**
CUTM4615	MOLECULAR MODELLING & DRUG DESIGN	3-1-0	

Course Objectives:

- To provide fundamental knowledge of molecular modeling techniques, molecular mechanics, and quantum chemical methods in drug discovery.
- To develop understanding of ligand-based and structure-based drug design approaches, including docking, QSAR, and pharmacophore modeling.
- To train students in the application of computational tools and software for molecular visualization, modeling, and prediction of drug–target interactions.
- To enable application of molecular modeling in rational drug design, optimization of lead compounds, and evaluation of ADMET properties.

Course Outcomes:

COs	Course outcomes
CO1	Understand the principles of molecular modeling, molecular mechanics, and quantum chemical methods.
CO2	Apply ligand-based and structure-based drug design approaches, including docking, QSAR, and pharmacophore modeling.

CO3	Use computational tools and software for molecular visualization, simulation, and drug–target interaction studies.
CO4	Analyze and predict physicochemical, pharmacokinetic, and ADMET properties of drug candidates.
CO5	Demonstrate problem-solving skills by designing and optimizing potential lead compounds using molecular modeling techniques.

CO,PO,PSO MappingMatrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	1	3		2			2	3	2	2
CO2	2	3	3	2	2	2	2		1			3	3	3	1
CO3	2	3	2	3	3	2	1		2			2	2	3	2
CO4	2	2	3	2	2	3	2		2			3	3	2	2
CO5	3	3	3	2	3	1	1		1			2	3	3	2

Introduction to Molecular Modelling:

Introduction. Useful Concepts in Molecular Modelling: Coordinate Systems. Potential Energy Surfaces. Molecular Graphics. Surfaces. Computer Hardware and Software. The Molecular Modelling Literature. (6 Lectures)

Force Fields: Fields. Bond Stretching. Angle Bending. Introduction to nonbonded interactions. Electrostatic interactions. van der Waals Interactions. Hydrogen bonding in Molecular Mechanics. Force Field Models for the Simulation of Liquid Water. (6 Lectures)

Energy Minimization and Computer Simulation: Minimization and related methods for exploring the energy surface. Non-derivative method, First and second order minimization methods. Computer simulation methods. Simple thermodynamic properties and Phase Space. Boundaries. Analyzing the results of a simulation and estimating Errors.(6 Lectures)

Molecular Dynamics & Monte Carlo Simulation:

Molecular Dynamics Simulation Methods. Molecular Dynamics using simple models. Molecular Dynamics with continuous potentials. Molecular Dynamics at constant temperature and pressure. Metropolis method. Monte Carlo simulation of molecules. Models used in Monte Carlo simulations of polymers. (6 Lectures)

Structure Prediction and Drug Design: Structure prediction - Introduction to comparative Modeling. Sequence alignment. Constructing and evaluating a comparative model. Predicting protein structures by 'Threading', Molecular docking. Structure based de novo ligand design, Drug Discovery – Chemoinformatics – QSAR.(6 Lectures)

Reference Books:

- A.R. Leach, Molecular Modelling Principles and Application, Longman, 2001.
- J.M. Haile, Molecular Dynamics Simulation Elementary Methods, John Wiley and Sons, 1997.
- Satya Prakash Gupta, QSAR and Molecular Modeling, Springer - Anamaya Publishers, 2008

PRACTICAL- DSE LAB: MOLECULAR MODELLING & DRUG DESIGN

i.Compare the optimized C-C bond lengths in ethane, ethene, ethyne and benzene. Visualize the molecular orbitals of the ethane σ bonds and ethene, ethyne, benzene and pyridine π bonds.

ii. (a) Perform a conformational analysis of butane. (b) Determine the enthalpy of isomerization of cis and trans 2-butene.

iii. Visualize the electron density and electrostatic potential maps for LiH, HF, N2, NO and CO and comment. Relate to the dipole moments. Animate the vibrations of these molecules.

iv. (a) Relate the charge on the hydrogen atom in hydrogen halides with their acid character. (b) Compare the basicities of the nitrogen atoms in ammonia, methylamine, dimethylamine and trimethylamine.

v. (a) Compare the shapes of the molecules: 1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2-propanol. Note the dipole moment of each molecule. (b) Show how the shapes affect the trend in boiling points: (118 ºC, 100 ºC, 108 ºC, 82 ºC, respectively).

vi. Build and minimize organic compounds of your choice containing the following functional groups. Note the dipole moment of each compound: (a) alkyl halide (b) aldehyde (c) ketone (d) amine (e) ether (f) nitrile (g) thiol (h) carboxylic acid (i) ester (j) amide.

vii. (a) Determine the heat of hydration of ethylene. (b) Compute the resonance energy of benzene by comparison of its enthalpy of hydrogenation with that of cyclohexene.

viii. Arrange 1-hexene, 2-methyl-2-pentene, (E)-3-methyl-2-pentene, (Z)-3-methyl-2- pentene, and 2,3-dimethyl-2-butene in order of increasing stability.

ix. (a) Compare the optimized bond angles H2O, H2S, H2Se. (b) Compare the HAH bond angles for the second row dihydrides and compare with the results from qualitative MO theory

Note: Software: ChemSketch, ArgusLab (www.planaria-software.com), TINKER 6.2 (dasher.wustl.edu/ffe), WebLab Viewer, Hyperchem, or any similar software.

Reference Books:

- A.R. Leach, Molecular Modelling Principles and Application, Longman, 2001.
- J.M. Haile, Molecular Dynamics Simulation Elementary Methods, John Wiley and Sons, 1997.
- Gupta, S.P. QSAR and Molecular Modeling, Springer - Anamaya Publishers, 2008.

Code	Course Title	T-P-P (Credit)	Prerequisite
CUTM4616	RESEARCH METHODOLOGY FOR CHEMISTRY	3-0-1	

Course Objectives:

- To provide a fundamental understanding of research design, methods, and ethics in chemical sciences.
- To develop skills in literature review, scientific writing, data collection, and data analysis for chemistry research.
- To train students in the use of modern analytical tools, instrumentation, and software relevant to chemical research.
- To enable students to plan, execute, and present independent research projects with critical thinking and problem-solving abilities.

Course Outcomes:

COs	Course outcomes
CO1	Understand the fundamental concepts of research design, methodology, and ethics in chemical sciences.
CO2	Conduct a systematic literature review and identify research gaps using scientific databases.
CO3	Apply appropriate data collection, analysis, and statistical methods in chemical research.
CO4	Demonstrate proficiency in scientific writing, referencing, and preparation of research reports/articles.
CO5	Develop the ability to design, execute, and present independent research projects with critical evaluation skills.

CO,PO,PSO MappingMatrix															
CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO3
CO1	3	2	2	1	1	–							3	2	
CO2	2	3	3	2	2	–							3	3	
CO3	2	3	2	3	3	–							2	3	
CO4	2	2	3	2	2	–							3	2	
CO5	3	3	3	2	3	1							3	3	

Module-1: Offline Literature Survey: (6 hrs)

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal, abbreviations,abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples.

Module-2: Online Literature Survey (6 hrs)

Digital: Web resources, E-journals, Journal access, TOC alerts, Hot articles, Citation index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and communities, Blogs, Preprint servers, Search engines, Scirus, Google Scholar, Chem Industry, Wiki- Databases, ChemSpider, Science Direct, SciFinder, Scopus.

Module-3: Information Technology and Library Resources: (3hrs)

The Internet and World Wide Web. Internet resources for chemistry. Finding and citing published information.

Module-4: Methods of Scientific Research and Writing Scientific Papers: (5hrs)

Reporting practical and project work. Writing literature surveys and reviews. Organizing a poster display. Giving an oral presentation. Writing scientific papers – justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work. Writing ethics. Avoiding plagiarism.

Module-5: Chemical Safety and Ethical Handling of Chemicals: (7hrs)

Safe working procedure and protective environment, protective apparel, emergency procedure and first aid, laboratory ventilation. Safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric – safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals.

Module-6: Data Analysis (7hrs)

The Investigative Approach: Making and Recording Measurements. SI Units and their use.Scientific method and design of experiments.

Analysis and Presentation of Data: Descriptive statistics. Choosing and using statistical tests. Chemometrics. Analysis of variance (ANOVA), Correlation and regression, Curve fitting, fitting of

linear equations, simple linear cases, weighted linear case, analysis of residuals, General polynomial fitting, linearizing transformations, exponential function fit, *r* and its abuse. Basic aspects of multiple linear regression analysis.

Module-7: Electronics **(5hrs)**

Basic fundamentals of electronic circuits and their components used in circuits of common instruments like spectrophotometers, typical circuits involving operational amplifiers for electrochemical instruments. Elementary aspects of digital electronics.

Reference Books

- Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J. & Jones, A. (2011) *Practical skills in chemistry*. 2nd Ed. Prentice-Hall, Harlow.
- Hibbert, D. B. & Gooding, J. J. (2006) *Data analysis for chemistry*. Oxford University Press.
- Topping, J. (1984) *Errors of observation and their treatment.* Fourth Ed., Chapman Hall, London.
- Harris, D. C. *Quantitative chemical analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
- Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis.* Cambridge Univ. Press (2001) 487 pages.
- Chemical safety matters – IUPAC – IPCS, Cambridge University Press, 1992.
- OSU safety manual 1.01.

Project: (12.5 hrs) every student has to write a review article