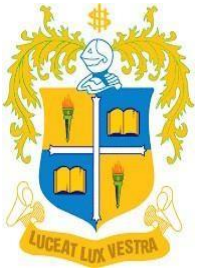
LEARNING OUTCOMES BASED CURRICULUM FRAMEWORK (LOCF) FOR POSTGRADUATE PROGRAMMES

(with effect from 2022-23)

M.Sc. Chemistry

DEPARTMENT OF CHEMISTRY



LOYOLA COLLEGE (AUTONOMOUS)

CHENNAI 600034

PREFACE

The outcome-based curriculum for post graduate courses in chemistry is focused on the advanced level of learning fields such as inorganic, physical, organic and analytical chemistry. The curriculum is designed to include scientific research methodology and project as components of research along with the necessary provision for employability and entrepreneurship. The periodical restructuring of the syllabi is carried out to fulfill the requirements of graduate attributes, qualification descriptors, program learning outcomes and course-level learning outcomes. The purpose of the outcome-based education is meant to provide an exposure to the fundamental and advanced concepts in different branches of chemistry and its applications keeping in mind the growing needs for higher education, employability, entrepreneurship and social responsibility.

The outcome-based education enriches the curriculum to achieve self-learning module, minor projects and industrial internship to enable students to get equipped for higher studies and employment.

The program also includes training to students for seminar presentation preparation of internship reports, hands-on training in lab courses, skills to handle instruments, synthesis and analysis of compounds, developing leadership qualities, organization and participation in the inter-collegiate academic competitions. The papers studied under different categories such as subject elective, cross-disciplinary, value-added course, life skill training etc. provide additional strength to augment students' interest in related fields.

The outcome-based curriculum is intended to enrich the learning pedagogy to global standards. ICT enabled teaching learning methodology seminar invited lectures endowment lectures provide ample opportunities to students for interactions with industrialists, entrepreneurs, academics, researchers, alumni, etc. to update with recent trends in different fields of chemistry.The exposure to the academic/industrial internship and MOUs with industries can open an avenue for a start-up and its progress would be followed regularly. The OBE based evaluation methods will reflect the true cognitive levels of the students as the curriculum is designed with course outcomes and cognitive level correlations as per BLOOM's Taxonomy.

CONTENTS

VISION AND MISSION OF LOYOLA COLLEGE

VISION

Towards holistic formation of youth, grounded in excellence, through accompaniment to serve the humanity.

MISSION

- To provide inclusive education through an integral and holistic formative pedagogy.
- To promote skills that prepare them for the future.
- To kindle in young minds the spirit of social and environmental justice with a blend of academic excellence and empathy.
- To stimulate critical and conscientious scholarship leading to meaningful and innovative human capital.

CORE VALUES

- *Cura Personalis*
- Pursuit of Excellence
- Moral Rectitude
- Social Equity
- Fostering solidarity
- Global Vision
- Spiritual Quotient

VISION AND MISSION OF THE DEPARTMENT

VISION

To strive with excellence in teaching and research in Chemistry to empower students with values for the society.

MISSION

To render competent and empathetic educational service to meet global standards in academia/industry through commitment, dedication and continuous learning.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)
(School of Physical Sciences)

PEO 1	**Professional Skill Development** To provide professional training and skill development to students in physical sciences, related disciplines and nurture them to become responsible persons in the society.
PEO 2	**Core Competency Development** To augment their core-competencies and knowledge levels in science, humanities and inter-disciplinary areas by imparting education of high standards and advanced technological tools with specialized research orientation.
PEO 3	**Innovative Curriculum of Global Relevance** To upgrade the curriculum periodically based on scientific advancements, innovations and societal relevance, so as to cater to the shifting global demands as cited by University Grants Commission, CSIR, etc.
PEO 4	**Environmental Sensitivity and Sustainability** To infuse environmental sensitivity in students through academic activities and hence equip them with technical skills and scientific knowledge required to protect and safeguard the environment for a sustainable future by respecting ecological balance of the globe.
PEO 5	**Ethical Principles and Holistic Development** To promote ethical values and special focus on the holistic development of students to become proficient, skilled, competent and socially responsible people.
PEO 6	**Accessibility and Academic Excellence** To provide an accessible learning environment of excellence and equal opportunity to students, enabling them to develop their creativity, critical thinking, leadership, employability skills and making them competent for job market.

PROGRAMME OUTCOMES (POs)
(School of Physical Sciences)

PO 1	**Disciplinary and Inter-disciplinary Knowledge for Capacity Building** Students will acquire required knowledge of the laws governing nature through classroom teaching and experimenting in the laboratories. They will develop a sense of interdisciplinary approach to identify and resolve issues through project, seminars, field work, internships and industrial visits related to their curriculum.
PO 2	**Skills for Effective and Efficient Communication** Students will be able to improve and enhance their communication skills such as reading, writing, listening and speaking. This will help them to express their ideas clearly and effectively and subsequently empower them to become agents of social change and hence pave the way for betterment of the society at large.
PO 3	**Sense of Inquiry and Problem-solving Skills** Students will demonstrate the core competencies of their discipline through analytical reasoning, problem solving and research related skills, cooperation, team work, scientific reasoning and thinking that would make them emerge as entrepreneurs or administrative personnel.
PO 4	**Skills to Impact Society** Students will develop leadership, team spirit and other psychomotor skills which will help them to identify, approach and analyze the existing societal problems with an eye to look beyond gender, age, caste, creed or nationality and work for the emancipation and empowerment of humanity.
PO 5	**Energy, Ethics and Environment** They will be able to involve themselves in framing policies of social relevance and develop scientific temper to harness energy and work on alternate resources scientifically.
PO 6	**Self-directed and Lifelong Learning** Through digital literacy, students will engage in self-paced and curious learning with necessary knowledge acquisition and hence develop motivation for a sustained lifelong learning capability. Students will accumulate knowledge by continuous activity centered learning and leverage the past knowledge to solve the problems in the future.
PO 7	**National and International-priorities Preferences and Perspectives** Students will be able to prioritize national and global issues with an aim to build a nation and an integrated world through contributions that imbibe the spirit of multicultural competency, creative thinking, critical analysis, political awareness and the much-needed awareness on international policies.

PROGRAMME SPECIFIC OUTCOMES (PSOs)
(Department of Chemistry)

PSO 1	Recall the various concepts of chemistry and apply them suitably to find solutions for the challenges in academics, industry, environment and society.
PSO 2	Propose solutions through scientific research for issues in public health, safety and hygiene.
PSO 3	Transform the acquired knowledge to become successful in competitive exams for higher studies/research/administration in private/public sectors.
PSO 4	Familiarize with the different branches of chemistry such as analytical, organic, inorganic, physical, food, medicinal, polymer, biochemistry, etc., and become suitable for a career in these fields.
PSO 5	Rationalize the societal importance of chemistry to develop leadership and entrepreneurship skills to create job opportunities nationally.
PSO 6	Interpret and contribute significantly to update/modify/improve/simplify the course contents of undergraduate and post graduate levels globally.
PSO 7	Impart a broad foundation in chemistry and enable them to evaluate and analyze critically the scientific facts.

Correlation Rubrics

High	Moderate	Low	No Correlation
3	2	1	0

Mapping of PEOs with Vision and Mission

	PEO1	PEO2	PEO3	PEO4	PEO5	PEO6
Vision	3	3	3	3	3	3
Mission	3	3	3	3	3	3

Mapping of POs with PEOs

	PEO1	PEO2	PEO3	PEO4	PEO5	PEO6
PO1	3	3	3	3	3	3
PO2	3	3	3	2	3	3
PO3	3	3	3	3	3	3
PO4	3	3	3	3	3	3
PO5	3	3	3	3	2	3
PO6	3	2	3	3	3	3
PO7	3	3	3	3	3	2

Mapping of PSOs with PEOs

	PEO1	PEO2	PEO3	PEO4	PEO5	PEO6
PSO1	3	3	3	3	3	3
PSO2	3	3	2	3	3	3
PSO3	3	3	3	2	3	3
PSO4	3	3	3	3	3	3
PSO5	3	3	3	3	3	3
PSO6	3	3	3	3	3	3
PSO7	3	3	3	3	3	3

Mapping of PSOs with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
PSO1	3	3	3	3	3	3	3
PSO2	3	2	3	3	3	2	3
PSO3	3	3	3	3	3	3	3
PSO4	3	3	3	3	3	3	3
PSO5	3	3	3	3	3	3	3
PSO6	3	3	3	3	3	3	3
PSO7	3	3	3	3	3	3	3

DEPARTMENT OF CHEMISTRY
PG RESTRUCTURING 2022-23
OVERALL COURSE STRUCTURE

Sem	Code	Subject Name	T/L/P	Cate	Hours	Credits
I	PCH1MC01	Organic Reaction Mechanism and Stereochemistry	T	MC	6	7
	PCH1MC02	Concepts in Inorganic Chemistry	T	MC	5	6
	PCH1MC03	Quantum Chemistry and Group Theory	T	MC	6	6
	PCH1MC04	Analytical Chemistry	T	MC	5	5
	PCH1MC05	Organic Laboratory Techniques-I	L	MC	4	2
	PCH1MC06	Inorganic Quantitative Analysis and Preparations	L	MC	4	2
II	PCH2MC01	Organic Reaction Mech. & Heterocyclic compounds	T	MC	5	5
	PCH2MC02	Coordination Chemistry	T	MC	6	6
	PCH2MC03	Scientific Research Methodology and Communications	T	MC	4	3
	PCH2MC04	Organic Laboratory Techniques-II	L	MC	4	2
	PCH2MC05	Inorganic Semi-micro Qualitative Analysis	L	MC	4	2
	PCH2ME01	Biomolecules and Natural Products	L	ME	4	2
	PCH2ME02	Surface Chemistry and Catalysis	T	ME	4	2
		MOOC Courses	T	MO	2##	2
		Life Skills		LS	2#	1
	PCH2CD01	Chemistry of Consumer products	T/L	CD	3	1
		Summer Internship		SI	3 to 4 Weeks#	1
III	PCH3MC01	Main Group Elements and Nuclear Chemistry	T	MC	5	5
	PCH3MC02	Thermodynamics & Chemical Kinetics	T	MC	6	6
	PCH3MC03	Molecular Spectroscopy	T	MC	5	5
	PCH3MC04	Physical Chemistry Practical-I	L	MC	4	2
	PCH3ME01	Applied Organic Chemistry	T	ME	4	2
	PCH3ME02	Organometallic Chemistry	T	ME	4	2
	PCH3ID01	Material Science (ID)	T	ID	6	3
		Soft Skills		SK	2#	1
	PCH3VA01	Herbal products development and formulation		VA	2#	1
		Service Learning (LEAP)		SL	2#	1
IV	PCH4MC01	Organic Synthesis and Photochemistry	T	MC	5	6

	PCH4MC02	Electrochemistry	T	MC	6	7
	PCH4MC03	Physical Chemistry Practical-II	L	MC	4	2
	PCH4MC04	Project	P	MC	15	5

MC – Major Core; **ME**-Major Elective; **ID**-Inter-Disciplinary; **MO**-MOOC; **LS**-Life Skills; **SK**-Soft Skills;

CD-Cross Disciplinary; **VA**- Value Added; **SI**-Summer Internship; **SL**-Service Learning; **PJ**-Project

Outside the Class Hours

Additional Credits

M.Sc. Chemistry - Restructured LOCF Curriculum (effective from June, 2022)

PART	SEMESTER I	SEMESTER II	SEMESTER III	SEMESTER IV
MAJOR CORE (MC)	Analytical Chemistry (5h/5c)	Coordination Chemistry (6h/7c)	Main Group Elements and Nuclear Chemistry (5h/6c)	Electrochemistry (6h/7c)
	Concepts in Inorganic Chemistry (5h/6c)	Organic Reaction Mechanism and Heterocyclic Compounds (5h/6c)	Molecular Spectroscopy (5h/6c)	Organic Synthesis and Photochemistry (5h/6c)
	Organic Reaction Mechanism and Stereochemistry (6h/7c)	Scientific Research Methodology and Communications (4h/4c)	Thermodynamics and Chemical Kinetics (6h/7c)	Physical Chemistry Practical-II (4h/2c)
	Quantum Chemistry and Group Theory (6h/6c)	Inorganic Semi-micro Qualitative Analysis (4h/2c)	Physical Chemistry Practical-I (4h/2c)	-
	Inorganic Quantitative Analysis and Preparations (4h/2c)	Organic Lab Techniques -II (4h/2c)	-	-
	Organic Lab Techniques-I (4h/2c)	-	-	-
SUBJECT ELECTIVE (SE)	-	Biomolecules and Natural Products (4h/2c)	Applied Organic Chemistry (4h/2c)	-
	-	Surface Chemistry and Catalysis (4h/2c)	Organometallic Chemistry (4h/2c)	-
INTER-DISCIPLINARY (ID)	-	-	Material Science (6h/3c)	-

ADDITIONAL CREDIT (MOOCs) (MO)	-	(2h#/2c##) (outside class hours)	-	-
LIFE SKILLS (LS)	-	(2h/1c) (outside class hours)	-	-
SOFT SKILLS (SK)	-	-	(2h/1c) (outside class hours)	-
CROSS-DISCIPLINARY (CD)	-	Chemistry of Consumer Products (3h/1c)	-	-
VALUE - ADDED COURSES (VA)	-	-	Herbal Products Development and Formulation (2h/1c) (outside class hours)	-
SUMMER INTERNSHIP (SI)	-	(3 to 4 Weeks/1c)	-	-
SERVICE LEARNING (SL-LEAP)	-	-	(2h/1c) (outside class hours)	-
PROJECT (PJ)	-	-	-	Project (15h/5c)
Total	30h/28c	32h/23c (2h#/2c## Additional)	36h/26c	30h/20c

Note: A Theory paper shall have 3 to 6 contact hours and a practical session shall have 2 to 4 contact hours

COURSE DESCRIPTORS

Course Code	**PCH1MC01**
Course Title	**ORGANIC REACTION MECHANISM AND STEREOCHEMISTRY**
Credits	7
Hours/Week	6
Category	Major Course (MC) - Theory
Semester	I
Regulation	2022

Course Overview

1. The aim of the course is to explain the concepts of advanced organic chemistry with mechanistic approach.
2. The course gives a detailed discussion about the methods of determining the reaction mechanism and stereochemistry.
3. The importance of this course is to explain the evidences in favour of the mechanism of organic reactions and rearrangements.
4. The stereochemical aspects of organic reaction mechanisms are discussed in detail.
5. The course describes the important aspects involved in the preparation of various functional organic compounds.

Course Objectives

1. To understand the path, feasibility and the mechanism of various organic reactions.
2. To comprehend the techniques in the determination of reaction mechanisms
3. To understand the concept of stereochemistry involved in organic compounds.
4. To correlate and appreciate the differences involved in the synthetic applications of oxidising and reducing agents.
5. To design feasible synthetic routes for the preparation of organic compounds.

Prerequisites	Basic knowledge of organic chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Mechanisms and Methods** 1.1 Thermodynamic and kinetic requirements of reactions: Hammond postulate, microscopic reversibility, potential energy diagrams, transition states and intermediates. 1.2 Methods of determining mechanism: Non-kinetic methods- product analysis, determination of intermediates-isolation, detection and trapping. Cross-over experiments, isotopic labelling, isotope effects and stereo chemical evidences. Kinetic methods - relation of rate and mechanism. 1.3 Effect of structure on reactivity: Hammett and Taft equations. Linear free energy relationship, partial rate factor, substituent and reaction constants.	18	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**Rearrangements** 2.1 Rearrangements to electron deficient carbon: Pinacol-pinacolone and semi-pinacolone rearrangements - applications and stereochemistry, Wagner-Meerwein, Demjanov, Dienone-phenol, Baker-Venkataraman, Benzilic acid and Wolff rearrangements. Rearrangements to electron deficient nitrogen: Hofmann, Curtius, Schmidt, Lossen, Beckmann and abnormal Beckmann rearrangements. Rearrangements to electron deficient oxygen: Baeyer-Villiger oxidation and Dakin rearrangements. Rearrangements to electron rich atom: Favorskii, Quasi-Favorskii, Stevens, [1,2]-Wittig and [2,3]-Wittig rearrangements. 2.2 Rearrangement from heteroatom to carbon - The Orton, Hofmann Martius and Fischer-Hepp rearrangements. Bamberger, Fries and Photo Fries rearrangement. 2.3 Intramolecular rearrangements – Claisen, abnormal Claisen, aza Claisen, Claisen-Ireland, Cope, oxy-Cope and anionic oxy-Cope,	18	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	Benzidine rearrangements.			
III	**Oxidation and Reduction Reactions** 3.1 Mechanisms: Direct electron transfer, hydride transfer, hydrogen transfer, displacement, addition-elimination, oxidative and reductive coupling reactions. 3.2 Mechanism of oxidation reactions: Dehydrogenation by quinones, selenium dioxides, ferricyanide, mercuric acetate lead tetraacetate, permanganate, manganese dioxide, osmium tetroxide, oxidation of saturated hydrocarbons, alkyl groups, alcohols, halides and amines. Reactions involving cleavage of C-C bonds - cleavage of double bonds, oxidative decarboxylation, allylic oxidation, oxidation by chromium trioxide-pyridine, DMSO-Oxalyl chloride (Swern oxidation) and Corey-Kim oxidation,dimethyl sulphoxide - dicyclohexyl carbodiimide (DMSO-DCCD). 3.3 Mechanism of reduction reactions: Wolff-Kishner, Clemmenson, Rosenmund, reduction with Trialkyl and triphenyltin hydrides, McFadyen-Steven's reduction, Homogeneous hydrogenation, Hydroboration with cyclic systems, MPV and Bouveault-Blanc reduction.	18	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
IV	**Stereochemistry-I** 4.1 Introduction to molecular symmetry and chirality – axis, plane, center, alternating axis of symmetry. Optical isomerism due to asymmetric and dissymmetric molecules with C, N, S based chiral centers. Optical purity, prochirality, enantiotopic and diastereotopic atoms, groups, faces, axial and planar chirality, chirality due to helical shape, methods of determining the configuration. Racemic modifications: Racemization by thermal, anion, cation, reversible formation, epimerization,	18	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	mutarotation. 4.2 D, L system, Cram's and Prelog's rules: R, S-notations, proR, proS, side phase and re phase Cahn-Ingold-Prelog rules, absolute and relative configurations. Configurations of allenes, spiranes, biphenyls, cyclooctene, helicene, binaphthyls, ansa and cyclophanic compounds, exo-cyclic alkylidene-cycloalkanes. Topicity and prostereo isomerism, chiral shift reagents and chiral solvating reagents. Geometrical isomerism: E, Z notations, geometrical isomerism in C=C, cyclic systems and oximes. 4.3 Criteria for optical purity: Resolution of racemic modifications, asymmetric transformations, asymmetric synthesis, destruction. Stereoselective and stereospecific synthesis: Enantioselective reduction of alkenes and ketones, reduction of ketones, epoxidation of allyl alcohols, dihydroxylation of alkenes, absolute chiral synthesis, optical purity calculations.			
V	**Stereochemistry-II** 5.1 Conformation and reactivity of acyclic systems, intramolecular rearrangements, neighbouring group participation, chemical consequence of conformational equilibrium - Curtin-Hammett principle. 5.2 Stability of five and six-membered rings: mono-, di- and polysubstituted cyclohexanes, conformation and reactivity in cyclohexane systems. Fused and bridged rings: bicyclic, poly cyclic systems, decalins and Brett's rule. 5.3 Optical rotation and optical rotatory dispersion, conformational asymmetry, ORD curves, octant rule, configuration and conformation, Cotton effect, axial haloketone rule and determination of configuration.	18	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text Books

1. J. March and M. Smith, Advanced Organic Chemistry, 5th edition, John-Wiley and Sons.2001.
2. E. S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Inc., 1959.
3. P. S. Kalsi, Stereochemistry of carbon compounds, 8thedition, New Age International Publishers, 2015.
4. P. Y. Bruice, Organic Chemistry, 7thedn, Prentice Hall, 2013.
5. R. T. Morrison, R. N. Boyd, S. K. Bhattacharjee, Organic Chemistry, 7thedition, Pearson Education, 2010.
6. D. Nasipuri, Stereochemistry of Organic Compounds, 2ndedition, New Age Publishers, 2005.
7. S. M. Mukherji and S. P. Singh, Reaction Mechanism in Organic Chemistry, 3rd edition, Macmillan India Ltd., 1984.
8. J. Clayden, N. Greeves, S. Warren, Organic Compounds, 2ndedition, Oxford University Press, 2014.

Suggested Readings

1. F.A. Carey and R.J. Sundberg, Advanced Organic Chemistry Part-A and B, 5th edition, Kluwer Academic / Plenum Publishers, 2007.
2. D. G. Morris, Stereochemistry, RSC Tutorial Chemistry Text 1, 2001.
3. N.S. Isaacs, Physical Organic Chemistry, ELBS, Longman, UK, 1987.
4. E. L. Eliel, Stereochemistry of Carbon Compounds, Tata-McGraw Hill, 2000.
5. I. L. Finar, Organic chemistry, Vol-1, 6th edition, Pearson Education Asia, 2004.
6. I. L. Finar, Organic Chemistry. Vol-2, 5th edition, Pearson Education Asia, 1975.
7. T. H. Lowry K. S. Richardson, Harper and Row, Mechanism and theory in organic chemistry, 2nd edition, New York, 1981.
8. S. H. Pine, Organic Chemistry, 5th edition, McGraw Hill International Edition, 1987.
9. L. F. Fieser and M. Fieser, Organic Chemistry, Asia Publishing House, Bombay, 2000.
10. G. C. Barret, Elucidation of Organic structures by Physical and Chemical Methods Part I (Eds) K.W. Bentley and G.W. Rirty John Wiley, 1972, Chapter VIII.

Web Resources

1. https://bit.ly/3zT4PUq
2. https://www.organic-chemistry.org/
3. https://www.studyorgo.com/summary.php
4. https://www.clutchprep.com/organic-chemistry

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic principles of organic chemistry.	**K1, K2**
CO 2	To understand the formation and detection of reaction intermediates of organic reactions.	**K3**
CO 3	To predict the reaction mechanism of organic reactions and stereochemistry of organic compounds.	**K4**
CO 4	To apply the principles of kinetic and non-kinetic methods to determine the mechanism of reactions.	**K5**
CO 5	To design and synthesize new organic compounds by correlating the stereochemistry of organic compounds.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH1MC02**
Course Title	**CONCEPTS IN INORGANIC CHEMISTRY**
Credits	6
Hours/Week	5
Category	Major Course (MC) - Theory
Semester	I
Regulation	2022

Course Overview

1. This course demonstrates the fundamental concepts of types of compounds based on bonding.
2. This course makes the students conversant with the electrochemical nature and reactivity of metals and non-metals.
3. This course explains the basic theories to predict the structure of any covalent compounds.
4. This course demonstrates how the properties of the compounds are correlated to the nature of the bonding.
5. This course trains the students to recognize the nuts and bolts of stereochemistry of chiral complexes and synthesis of coordination compounds.

Course Objectives

1. To understand and explain the concepts of bonding interactions and molecular topologies.
2. To predict the lattice energy and structure of various minerals.
3. To discuss the stability of compounds and its determinations.
4. To draw the structure of various molecules based on the bonding theories.
5. To explain the importance of weak bonding forces on the properties of compounds.

Prerequisites	Basic knowledge in chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Atoms, Term symbols and Electrode potential** 1.1 Modern views of atomic structure, radial and angular wave functions. Poly electronic atom: Born-Oppenheimer approximations. Quantum numbers. Computation of effective nuclear charge-applications of Slater's rule, electronic configurations. Periodicity. 1.2 Atomic and Molecular term symbols: methods of determining ground state term. Pigeon hole diagram, ground and higher states and Russel-Saunders microstate method for $p^2$and d^2 configurations-term symbol for non-equivalent electrons. Molecular term symbols: di- and poly atomic molecules - H_2O and NH_3. Walsh diagram of AH_2 molecules. 1.3 Electrode potential: concept of oxidation and reduction potentials. Periodic trends. Application of electrode potentials- interpretation of chemical behaviour. Electrode potential diagrams and uses: Latimer and Frost. 1.4 Reactivity of metals and non-metals-spontaneity of redox reactions. Masking and demasking agents. Oxidising and reducing properties of substances in aqueous solution in non-standard conditions.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Ionic compounds** 2.1 Packing of ions in crystals: ccp, hcp, bcc and fcc. Tetrahedral and octahedral voids/interstitial sites - edge length, radius, size of interstitial site and radius ratio rule. Stoichiometry and crystal structures - AB, AB_2 and ABX_3 - Perovskite, spinel and inverse spinel. 2.2 Lattice energy: Derivation of Born-Lande equation, Born-Haber cycle-thermochemical calculations, factors affecting hydration, lattice energy and solvation energy. Fajan's rule and applications.	**15**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	2.3 Defects in solids: Point defects, metal deficiency, F-center. Defects and conduction. Reactions in solid state-diffusion, diffusion coefficient, diffusion mechanism, vacancy and interstitial diffusion.			
III	**Covalent Compounds** 3.1 Molecular topologies-Lewis, Sidgwick-Powell, VB, VSEPR - Postulates, applications and drawbacks. Bent's rule and energetics of hybridisation: BF_3, CH_4, PCl_3F_2, PF_5, SF_6, IF_7, $SnCl_2$, NH_3, H_2O, SF_4, ClF_3, XeF_2, XeF_4, IF_5, CO_3^{2-}, NO_3^-, SO_4^{2-}, ClO_4-, ClO_3^- ions, I_3^- and BF_4^-. 3.2 Molecular orbital theory-LCAO-MO model, TASO, LUMO-HOMO concepts in bonding-homo diatomic molecules. 3.3 MO theory for hetero poly atomic molecules (CO, NO, HCl, CO_3^{2-},NO_3^{2-}, SO_3, O_3, NO_2, CO_2, N_3^-). Comparison between VBT and MOT.	**14**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
IV	**Metallic, Weak Chemical Forces and Acid-Base systems** 4.1 Bonding in metals: packing of atoms, band theory of metals and metallic properties, insulators, and semiconductors. 4.2 Hydrogen bonding: unique properties, structure of DNA, and molecular self-assembly. Supramolecular architectures. van der Waals forces. Weak forces of interactions- dipole-dipole, induced dipole. Inclusion compounds, clathrates- gas hydrates. 4.3 Acid-base definitions: Bronsted-Lowry, Lux-Flood, Lewis, Usanovich, steric effects on the strength of acids and bases. 4.4 Non-aqueous solvents: classification, typical reactions and applications of H_2SO_4, CH_3COOH, BrF_3 and molten salts.	**14**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

V	**Coordination Compounds** 5.1 Terminologies, nomenclature, types of ligands, - chelate, steric and macrocyclic effects. Werner's theory, isomerism. EAN rule. Thermodynamic Stability - determination of stability constants from thermodynamic data. Irving–William series. 5.2 Nomenclature of chiral complexes, study of absolute configurations of chiral complexes- ORD and CD. Stability of complexes: HSAB principle. 5.3 Synthesis of metal complexes-direct, by ligand substitution, Schiff-base condensation, ligand substitution and template methods.	**14**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Textbooks

1. K. F. Purcell and J. C. Kotz, Inorganic Chemistry; W.B. Saunders company: Philadelphia, 1977.
2. Puri, Sharma and Kalia, Principles of Inorganic Chemistry, 33rd edition, Vishal publishing company, 2019.
3. J. E. Huheey, E. A. Keiter and R. L. Keiter, Inorganic Chemistry; 4th ed.; Harper and Row: NewYork, 1983.
4. B. E. Douglas, D. H. McDaniel and J. J. Alexander, Concepts and Models of Inorganic Chemistry; 3rd ed.; John Wiley & Sons, 1994.
5. Satya Prakash, G. D. Tuli, S.K. Basu and K.D. Madan, Advanced Inorganic Chemistry, S.Chand& Company Ltd, New Delhi, 2010.
6. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, Advanced Inorganic Chemistry; 6th ed.; Wiley Interscience: New York, 1988.

Suggested Readings

1. T. Moeller, Inorganic Chemistry, A Modern Introduction; John Wiley: New York, 1982.
2. D. F. Shriver, P. W. Atkins and C.H. Langford; Inorganic Chemistry; 3rd ed.; Oxford University Press: London, 2001.
3. G. H. Stout and L. H. Jenson, X-Ray Structure Determination; 2nd ed.; John Wiley & Sons: New York, 1989.
4. Solid-state Chemistry and its application, D.K. Chakrabarty, New Age International Private Publications, 2010.

Web Resources

1. https://nptel.ac.in/
2. https://ocw.mit.edu/courses/chemistry/
3. https://swayam.gov.in

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand fundamental concepts of various bonding and reactions in inorganic compounds.	**K1, K2**
CO 2	To illustrate the chemical reactions using ionic, covalent, coordination, and weak bonding forces.	**K3**
CO 3	To analyse Slater's rule, lattice energy, molecular topologies, stability constants, and intermolecular forces.	**K4**
CO 4	To determine the defects in solid, term symbols, van der Waals forces, synthesis of metal complexes.	**K5**
CO 5	To construct various redox and half reactions, MO diagrams of molecules and to synthesise the compounds.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH1MC03**
Course Title	**QUANTUM CHEMISTRY AND GROUP THEORY**
Credits	6
Hours/Week	6
Category	Major Course (MC) – Theory
Semester	I
Regulation	2022

Course Overview

1. Quantum chemistry deals with the study of wave functions through mathematical aspects.
2. It deals with the quantum mechanical models to explore the energetics involved in the basic modes of motion and its applications to interpret spectroscopic properties of molecules.
3. The description of electron in terms of radial and angular functions for hydrogen atom and multi-electron system is dealt with quantum mechanically.
4. This course aims at exploring the symmetry aspects of molecules to understand the properties such as polarity, optical activity and mutual exclusion principle.
5. Semi-empirical method is used for conjugated systems for the calculation of delocalization/resonance energy and group theoretical approach is employed in predicting hybridization and vibrational modes.

Course Objectives

1. To understand essentially the characteristics of wave functions in terms of mathematical concepts and the need for quantum mechanics to account for the failures of classical mechanics.
2. To learn the importance of quantum mechanical models such as particle in a box, rigid rotor and harmonic oscillator
3. To apply the concept of quantum mechanics to hydrogen and poly electronic systems.
4. To make students to become aware of the importance of symmetry in molecules to predict its point group and classify the symmetry operations.
5. To interpret the application of quantum mechanical methods for chemical bonding and to predict the vibrational modes, hybridization scheme and selection rules using the concepts of group theory.

Prerequisites	Basic knowledge of chemistry and mathematics.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Fundamentals of Quantum Mechanics** 1.1 Coordinate systems, functions - real, complex, odd, even, normalized, orthogonal, orthonormal and eigen functions. Operators: linear, angular, differential, Hermitian and Hamiltonian. quantum mechanical treatment of angular momentum, significance of angular momenta and commutators: $[x, p_x]$, $[x,p_x^2]$, $[L_x,L_y]$ and $[L_{x2}, L_x]$. 1.2 Introduction to quantum mechanics: Failure of classical mechanics: black body radiation, photo electric effect, hydrogen spectrum and Compton effect. 1.3 Need and postulates of quantum mechanics. Schrodinger wave equation – Time independent and time dependent.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Quantum mechanical models** 2.1 Particle in a box (1D, 2D and 3D), degeneracy, application to linear conjugated molecular systems, free particle, ring systems, Bohr's correspondence principle. Quantum mechanical tunneling – probability of tunneling and tunneling coefficient, inversion of ammonia, electron and proton transfer reactions. 2.2 Harmonic Oscillator - wave equation and solution, anharmonicity, force constant and its significance. 2.3 Rigid Rotor - wave equation and solution, calculation of rotational constants and bond length of diatomic molecules.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5,K6**
III	**Applications to hydrogen and poly electron atoms** 3.1 Hydrogen atom and hydrogen like ions: Hamiltonian - wave equation and solution, radial and angular functions, representation of radial distribution functions.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5,K6**

	3.2 Approximation methods - variation method: trial wave functions, variation integral and application to particle in a 1D box. Perturbation method: first order and application. Qualitative features of approximation methods. 3.3 Hartree-Fock self-consistent field method, foundation of density functional theory: Hohenberg - Kohn theorem and Kohn - Sham equation. Helium atom - electron spin, Pauli's exclusion principle and Slater determinant.			
IV	**Group theory** 4.1 Group, subgroup, symmetry elements, operations, classification – axial and non-axial. Dihedral point groups: $C_{nv,}$ C_{nh}, D_n, D_{nh}, D_{nd}, $T_d$and O_h. Symmetry and polarity. 4.2 Matrix representations and classes of symmetry operations, reducible, irreducible and direct product representations. 4.3 The Great orthogonality theorem: general relationship of irreducible representations, reduction formula, construction of character table for $C_{2v,}$ C_{2h}, C_{3v} and D_{2h} point groups.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
V	**Chemical applications of quantum chemistry and group theory** 5.1 Hydrogen molecule: Molecular orbital theory and Heitler-London (VB) treatment. Energy level diagram. Hydrogen molecular ion: Use of linear variation function and LCAO methods. Calculation of overlap, resonance and coulomb integrals, bonding energy, probability density. 5.2 Electronic structure of conjugated systems: Huckel method applied to ethylene, allyl systems, butadiene, cyclopropenyl, cyclobutadiene and benzene. 5.3 Applications of group theory to molecular vibrations, electronic spectra of formaldehyde and ethylene, chemical bonding.Symmetry based	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4,K5,K6**

	selection rules.			

Text Books

1. R.K. Prasad, *Quantum Chemistry*, New Age International Publishers, New Delhi, 2010, 4th revised edition.
2. D.A. McQuarrie, *Quantum Chemistry*, Viva Books PW. Ltd, 2013, 2nd edition.
3. A. Vincent, *Molecular Symmetry and Group Theory. A Programmed Introduction to Chemical Applications*, John and Willy & Sons Ltd., 2013, 2nd Edition.
4. T. Engel & Philip Reid, *Quantum Chemistry and Spectroscopy*, Pearson, New Delhi, 2018, 4th edition.
5. Chang, Raymond. Physical Chemistry for the Biosciences. Sansalito, CA: University Science, 2005.
6. F. A. Cotton, *Chemical Applications of Group Theory*, John Wiley & Sons, 2003, 2nd edition.
7. K. V. Raman, *Group Theory and its Applications to Chemistry*, Tata McGraw-Hill, New Delhi, 1990.
8. G. K. Vemulapalli, *Physical Chemistry*, Prentice Hall of India Pvt. Ltd. 2001.

Suggested Readings:

1. N. Levine, *Quantum Chemistry*, Allyn& Bacon Inc, 1983, 4th edition.
2. D.A. McQuarrie and J. D. Simon, *Physical Chemistry, A Molecular Approach*, Viva Books Pvt. Ltd, New Delhi, 2012.
3. R. P. Rastogi & V. K. Srivastava, *An Introduction to Quantum Mechanics of Chemical Systems*, Oxford & IBH Publishing Co., New Delhi, 1999.
4. R.L. Flurry. Jr, *Symmetry Group Theory and Chemical applications*, Prentice Hall. Inc, 1980
5. J. M. Hollas, *Symmetry in Molecules*, Chapman and Hall, London, 2011, Reprint.
6. H. Eyring, J. Walter & E. Kimball, *Quantum Chemistry*, Wiley International edition, John Wiley, London, 2011.
7. W. J. Moore, *Physical Chemistry*, Longman, London, 1972, 5th edition.
8. G. W. Castellan, *Physical Chemistry*, Addison-Wesley, London, 1983, 3rd edition.

Web Resources

1. **https://nptel.ac.in/courses/104101124**
2. **https://ipc.iisc.ac.in/~kls/teaching.html**
3. **https://www.digimat.in/nptel/courses/video/104106083/L01.html**
4. **https://www.digimat.in/nptel/courses/video/111106113/L01.html**
5. **https://onlinecourses.nptel.ac.in/noc21_cy37/preview**

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To define and outline the characteristics of wave functions, the need for quantum mechanics and symmetry concepts.	**K1, K2**
CO 2	To apply the concept of quantum mechanics and group theory to predict the electronic structure and spectral properties.	**K3**
CO 3	To classify the symmetry operation and wave function for correlating the bonding and properties governed by polarity.	**K4**
CO 4	To improve the accuracy of trial wave functions using approximation methods and specify the appropriate irreducible representations for group theoretical applications.	**K5**
CO 5	To develop the analytical skills in evaluating the energies for electronic transitions, IR/Raman activities and molecular structure.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH1MC04**
Course Title	**ANALYTICAL CHEMISTRY**
Credits	5
Hours/Week	5
Category	Major Course (MC) – Theory
Semester	I
Regulation	2022

Course Overview

1. Analytical chemistry comprises of theoretical knowledge on various methods of titration, separation, thermal, electro and spectral techniques.
2. The aim of the course is to explain the principle of qualitative, quantitative and data analysis.
3. Instrumentation and applications of various analytical methods will be discussed in detail.
4. This course also covers the principle, instrumentation and applications of thermal and electro gravimetric analysis.
5. In this course, the different sampling methods and their statistical data are also examined.

Course Objectives

1. To understand the various types of separation and purification techniques.
2. To acquire the knowledge about different analytical methods and its applications.
3. To gain knowledge about the different thermal and electro analytical techniques.
4. To understand the principle and applications of atomic absorption and Emission spectroscopy.
5. To analyse the data of various samples in different sampling methods

Prerequisites	Basic undergraduate level knowledge in analytical chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Data analysis** 1.1 Statistical considerations: population and samples, sampling distributions, interference about the population mean, sampling problems. 1.2 Measures of variability (dispersion): the total range, the interquartile range, the average deviation, the variance-analysis of variance and covariance; the standard deviation; normal distributions: the normal distribution and the normal probability curve. 1.3 Statistical analysis of data: Confidence interval, Test of hypothesis -Student t-test, chi-square test, F-test. Criteria for rejection of data- Q test. Correlation and Regression – Least Square method, correlation coefficient.	13	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**Separation Techniques** 2.1 Chromatography - classification, concept of plate and rate theories, efficiency, resolution, selectivity and separation capability. Van Deemter equation and broadening of chromatographic peaks. Optimization of chromatographic conditions. 2.2 Gas chromatography: Instrumentation- sample injection systems - split/splitless, column types, solid/ liquid stationary phases, temperature programming, detectors - hot-wire, flame ionization, photo ionizationand ECD. GC-MS - determination of C, H, N and S. 2.3 High-Performance Liquid Chromatography: Instrumentation-pumping system, sample injection, column, detectors and advantages. Principles of preparative and analytical HPLC. 2.4 Electrophoresis and capillary electrophoresis - principle, instrumentation and applications.	15	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

III	**Thermoanalytical and Electroanalytical Methods** 3.1 Thermogravimetry: Principle - TGA and DTA curves of $MgC_2O_4.H_2O$ and $Ca(OOCCH_3)_2.H_2O$. Simultaneous DTA and TGA curves - $SrCO_3$ in air. DSC- Principle, Instrumentation and application. Comparison of DTA and DSC. Evolved gas analysis: TG-MS and TG-FTIR. Thermometric titrimetry – theory, instrumentation and applications. 3.2 Electrogravimetry: Principle,Instrumentation, electrogravimetric determination with constant applied voltage and at constant current. Applications -estimation of copper. 3.3 Coulometry: principles, types of coulometers, constant current coulometric analysis, coulometric titrations – principle, applications, advantages and errors. Controlled potential coulometry – Technique and applications of inorganic and organic compounds. 3.4 Entropymetry for understanding the state of health of the battery.	17	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
IV	**Titrimetric analysis** 4.1 Stoichiometry and expressions of concentrations. Principle, titration curves of a weak dibasic acid versus strong base. Redox titrations: formal and standard potentials in various media, standardization, oxidizing systems: Mn(VII), Ce(IV), Cr(VI) and V(V). Reducing systems: V(II), Ti(III), Sn(II), Fe(II) in H_3PO_4. 4.2 Acid-base titrations in non-aqueous solvents: classification, principle, auto-protolysis constant, dielectric constant and its effect. Detection of equivalence point – titrations in ethylene diamine, glacial acetic acid, methanol and ethanol. 4.3 Complexometric Titrations: Stability of complexes - stepwise formation constants, titration curves, feasibility of complexation titration. 4.4 Hydrolysis of salts – strong base *vs* weak acid,	15	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	weak base *vs* strong acid and weak acid *vs* weak base.			
V	**Spectrometry** 5.1 Spectrophotometry - principle, types, applications- determination of the pH value of an indicator, identification of complex, determination of Fe(III) by EDTA. Spectrophotometric titrations. 5.2 Atomic Absorption Spectroscopy: Principle, instrumentation. Spectral and chemical interferences, applications in qualitative and quantitative analysis, determination of metals in blood serum, lead in petrol, Mg in hard water. Principle of inductively coupled plasma (ICP) spectrometry. 5.3. Flame emission spectrometry: Principle, instrumentation and interferences, determination of alkali metals, and iron in non-ferrous alloys. 5.4 Turbidimetry and nephlometry: Principle, instrumentation - determination of sulphate and phosphate. Fluorimetry - Principle, excitation and fluorescence spectra, factors affecting fluorescence emission, determination of quinine in tonic water, codeine and morphine.	15	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text Books

1. Douglas A. Skoog, Donald M. West and F. James Holler, Fundamentals of analytical Chemistry, 9th Ed., Harcourt Asia Pvt. Ltd., 2013.
2. R. A. Day, Jr. and A.L. Underwood, Analytical Chemistry, Pearson, 6th Edition 2015.
3. H. Kaur, Instrumental methods of chemical analysis, Pragati Prakashan, 2003.
4. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis, Longman Scientific and Technical, 1989.
5. S.M. Khopkar, Basic concepts of analytical Chemistry,,3rd Edn, New age International Ltd, 2011.

Suggested Readings

1. D. A. Skoog, D. M. West and F. J. Holler, Analytical Chemistry an Introduction, Saunders College Publishers, 2000.
2. D.A. Skoog, E.J. Holler, Stanley. J. Croch, Principles of Instrumental Analysis, Cengage Learning, 6th edition, 2019.
3. J. Mendham, R. C. Denney, J. D. Barnes and M. Thomas, Vogel's Text book of Quantitative Chemical Analysis, Pearson Education Pvt. Ltd., 2004.
4. J. G. Dick, Analytical Chemistry, Sir George Williams University, McGraw-Hill Book Company, New York, 1973.
5. H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Seattle, Instrumental methods of analysis, 5th Ed., Harcourt Asia Pvt. Ltd., India, 2001.
6. E. Heftmann, Chromatography: Fundamentals and applications of chromatography and related differential migration methods - Part A: Fundamentals and techniques, Elsevier, 2004.
7. M. G. Gore, Spectrophotometry and Spectrofluorimetry: A Practical Approach, Oxford University Press, 2000.
8. Galen Ewing, Instrumental Methods & Chemical Analysis –5th ed., McGraw-Hill Publishing Company Ltd., 1985.
9. Gary D. Christian, Analytical Chemistry -, 6th ed. John Wiley and sons. Inc, New York, 1994.

Web Resources

1 https://open.umn.edu/opentextbooks/textbooks/486
2. https://www.ychem4u.com/2021/01/08/analytical-chemistry-
3. https://nptel.ac.in/courses/103/106/103106120/

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand the principle of statistical analysis and instrumentation of various analytical methods	**K1, K2**
CO 2	To apply chromatographic techniques in identifying the components, and infer the principle of coulometry, spectrophotometry, thermal methods and to compute statistical parameters to arrive at meaningful conclusions.	**K3**
CO 3	To analyse the data by statistical method and examine the significance of various analytical technique	**K4**
CO 4	To assess the importance of data analysis and choice of analytical techniques to study the chemical characteristics and	**K5**
CO 5	To develop analytical skills in thermal, electro analytical chromatographic techniques for its applications in industries and research	**K6**

COURSE DESCRIPTOR

Course Code	**PCH1MC05**
Course Title	**ORGANIC LABORATORY TECHNIQUES-I**
Credits	2
Hours/Week	4
Category	Major Course (MC) - Lab
Semester	I
Regulation	2022

Course Overview

1. The practical course deals with the separation and analysis of two and three component mixtures and two stage preparations of organic compounds.
2. The course discusses on the systematic separation of two and three component mixtures along with systematic analysis for their functional groups.
3. The course also describes the separation methodology involving ether or aqueous solvents.
4. The preparation of organic compounds involves two stages of suitable combination of synthetic methodologies.
5. In overall, the practical paper highlights the systematic separation of mixtures, qualitative analysis, derivatization of functional groups and, finally, multi-stage preparation of organic compounds.

Course Objectives

1. To understand the concept of separation, qualitative analysis and preparation of organic compounds.
2. To develop analytical skill in the handling of chemical reagents for separation of binary and ternary organic mixtures.
3. To analyze the separated organic components systematically and derivatize them suitably.
4. To construct suitable experimental setup for the organic preparations involving two stages.
5. To experiment different purification and drying techniques for the compound processing.

Prerequisites	Basic knowledge of chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	1. **Separation and analysis:** A. Two component mixtures. B. Three component mixtures	30	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	2. **Preparations:** Two stage processes involving nitration, halogenation, diazotization, deamination, rearrangements, hydrolysis, reduction, alkylation, hydroxylation, formylation, cyclisation and oxidation. Two stage preparations: a) *p*-Bromoacetanilide from aniline b) *p*-Nitroaniline from acetanilide c) 1,3,5-Tribromobenzene from aniline d) Acetyl salicyclic acid from methyl salicylate e) Benzilic acid from benzoin f) *m*-Nitroaniline from nitrobenzene g) *m*-Nitrobenzoic acid from methyl benzoate	30	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text books

1. N. S. Gnanapragasam and G. Ramamurthy, Organic Chemistry – Lab Manual, S. Viswanathan Co. Pvt. Ltd, 2009.
2. J. N. Gurtu and R. Kapoor, Advanced Experimental Chemistry, S. Chand and Co., 2011.

Suggested Readings

1. Vogel's Text book of Practical Organic Chemistry, 5th Ed, ELBS/Longman, England, 2003.

Web Resources

1. https://bit.ly/3tMt2YQ

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic principles of organic separation, qualitative analysis and preparation.	**K1, K2**
CO 2	To explain the method of separation and analysis of separated organic mixtures	**K3**

	and convert them as derivatives by suitable preparation method.	
CO 3	To determine the characteristics of separation of organic compounds by various chemical reactions.	**K4**
CO 4	To develop strategies to separate, analyze and prepare organic compounds.	**K5**
CO 5	To formulate a method of separation, analysis of organic mixtures and design suitable procedure for organic preparations.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH1MC06**
Course Title	**INORGANIC QUANTITATIVE ANALYSIS**
Credits	2
Hours/Week	4
Category	Major Course (MC) – Lab
Semester	I
Regulation	2022

Course Overview

1. This course impart the skill of the students in the quantitative estimation of ions by visual colorimetric and to prepare standard solutions by serial dilution method.
2. Illustration of the role of masking and demasking agents in the quantitative analysis would be thoroughly utilized in complexometric methods.
3. Students would be taught to identify the methodology of estimation of a metal ion in presence of another metal ion.
4. Students to understand the techniques and mechanism of determination of the presence of dissolved metal salts in water.

Course Objectives

1. To understand and enhance the visual observation as an analytical tool for the quantitative estimation of ions.
2. To recall the principle and theory in preparing standard solutions.
3. To train the students for improving their skill in estimating the amount of ion accurately present in the solution
4. To estimate metal ions present in the given solution accurately without using instruments.
5. To determine the amount of ions present in a binary mixture accurately.

Prerequisites	Basic knowledge in Chemistry

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Colorimetry (**visual**)** 1. Estimation of iron. 2. Estimation of nickel. 3. Estimation of lead 4. Estimation of ammonium ion 5. Estimation of copper	**12**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Complexometric Titration** 1. Estimation of zinc, nickel, magnesium, and calcium. 2. Estimation of mixture of metal ions-pH control, masking and demasking agents. 3. Determination of calcium and lead in a mixture (pH control). 4. Determination of manganese in the presence of iron. 5. Determination of nickel in the presence of iron.	**12**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
III	**Quantitative (Two component) Analysis**: **Gravimetry and Titrimetry** Separation and estimation of mixtures by volumetric (v) and gravimetric (G) methods. Some recommended mixtures are 1. Estimation of Copper(v) and Nickel(G) 2. Estimation of Copper (v) and Calcium(G) 3. Estimation of Fe(III)(G) and Nickel (G) 4. Estimation of Barium (G) and Calcium(v) 5. Estimation of Copper (v) and Zinc(G) 6. Estimation of Calcium(v) and Copper (G)	**30**	**CO 3** **CO 4** **CO 5**	**K3, K4, K5,K6**
IV	**Cerimetric Titrations** 1. Estimation of iron	**6**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Text Books

1. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, *Vogel's Textbook of Quantitative Chemical Analysis*; 6th ed., ELBS, 1989.
2. J. D. Woollins, *Inorganic Experiments*; VCH: Weinheim, 1995.

Suggested Readings

1. G. Pass, and H. Sutcliffe, *Practical Inorganic Chemistry*; Chapman Hall, 1965.
2. W. G. Palmer, Experimental *Inorganic Chemistry*; Cambridge University Press, 1954.

Web resources

1. https://bit.ly/3Ncpy8C

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the principle and theory in preparing standard solutions.	**K1, K2**
CO 2	To illustrate the role of EDTA in complexometric titrations in the quantitative estimation of Ca, Mg and Zn.	**K3**
CO 3	To analyze the amount of ions by selecting suitable method.	**K4**
CO 4	To determine the amount of ions present in a binary mixture accurately.	**K5**
CO 5	To construct methods and mechanism for the analysis of water for Industrial application	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2MC01**
Course Title	**ORGANIC REACTION MECHANISM AND HETEROCYCLIC COMPOUNDS**
Credits	5
Hours/Week	5
Category	Major Course (MC) - Theory
Semester	II
Regulation	2022

Course Overview

1. The aim of the course is to explain the mechanism of various types of organic reactions and heterocyclic compounds.
2. The course gives a detailed discussion on the orientation and reactivity with evidences for reaction mechanism.
3. The importance of this course is to explain the reactivity of aliphatic and aromatic substrates in different reaction conditions.
4. The advanced synthetic methods and name reactions for synthetically important heterocyclic compounds are discussed.
5. The course includes the preparation of various functional organic compounds, five and six membered heterocyclic compounds containing two and more hetero atoms.

Course Objectives

1. To understand the concept of aromaticity in benzenoid, non-benzenoid and heterocyclic compounds.
2. To understand the mechanism involved in various types of organic reactions with evidences.
3. To understand the applications of synthetically important reagents.
4. To correlate the reactivity between aliphatic and aromatic compounds.
5. To design synthetic routes for organic and heterocyclic compounds.

Prerequisites	Basic knowledge of organic chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Aromatic and Aliphatic Electrophilic Substitution** 1.1 Aromaticity: Aromaticity in benzenoid, non-benzenoid, heterocyclic compounds and annulenes. Alternant and non-alternant hydrocarbons, Huckel's rule, energy level of π-molecular orbitals, homo- aromaticity, PMO approach. NMR as a tool for aromaticity. 1.2 Aromatic electrophilic substitution: Orientation and reactivity of phenol, nitrobenzene and halobenzene. Multisubstitution reactions: Reactions involving nitrogen electrophiles - nitration, nitrosation and diazonium coupling. Sulphur electrophiles - sulphonation. Halogen electrophiles - chlorination and bromination. Carbon electrophiles - Friedel-Crafts alkylation, acylation and limitations. 1.3 Aliphatic electrophilic substitution mechanisms: SE2, SE1 and SEi. Substitution by double bond shifts, addition-elimination and cyclic mechanism. Hydrogen as electrophile: Hydrogen exchange - hydro dehydrogenation. Halogen electrophiles - halogenation of aldehydes, ketones and carboxylic acids. Nitrogen electrophiles- aliphatic diazonium coupling, direct formation of diazo compounds, direct amination, insertion by nitrenes. Sulphur electrophiles - sulphonation, sulphenylation. Carbon electrophiles: alkylation, acylation, alkoxy carbonyl alkylation, Stork-enamine reaction and insertion by carbene.	18	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**Aromatic and Aliphatic Nucleophilic Substitution** 2.1 Aromatic nucleophilic substitution: Mechanisms - S_NAr, S_N1 and benzyne mechanisms. Reactivity, effect of structure, leaving group and attacking nucleophile. 2.2 Reactions: Oxygen and Sulphur nucleophiles, Bucherer and Rosenmund, von Richter, Sommelet- Hauser and Smiles rearrangements. S_N1, ion pair, S_N2 mechanisms and evidences.	15	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	2.3 S_N1, S_N2, S_Ni, and S_E1 mechanisms, neighbouring group participation - non classical carbocations. Reactivity: Effect of substrate, attacking nucleophile, leaving group and the medium – Swain - Scott, Grunwald - Weinstein relationship and ambident nucleophiles, Aliphatic nucleophilic substitutions at an allylic carbon, aliphatic trigonal carbon and vinyl carbon.			
III	**Elimination and Free Radical Reactions** 3.1 Mechanisms: E2, E1, E1cB and syn eliminations. Orientation of the double bond: Hoffmann and Saytzeff rules and applications. Reactivity: Effect of substrate, attacking bases, leaving group and medium. Mechanisms and orientation in pyrolytic eliminations. Stereochemistry - acyclic and cyclic systems. 3.2 Long lived and short-lived radicals - Production of radicals - thermal and photochemical reactions, methods of detection, stability, characteristics. Reactions - polymerization, addition, halogenations, aromatic substitutions and rearrangements. Reactivity: aliphatic, aromatic substrates, attacking radicals, effect ofsolvent.	15	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
IV	**Addition to Carbon Multiple Bonds** 4.1 Mechanisms: Addition to carbon-carbon multiple bonds, addition reactions - electrophiles, nucleophiles, free radicals, carbenes and cyclic mechanisms. Orientation and reactivity, hydrogenation of double and triple bonds, Michael reaction, addition of oxygen and nitrogen. Addition to carbon-hetero atom multiple bonds - Mannich reaction, acids, esters, nitrites, addition of Grignard reagents, Wittig and Prins reactions. 4.2 Stereochemical aspects of addition reactions. Addition to carbon-hetero atom multiple bonds**:** Addition of Grignard reagents, organozinc and organolithium reagents to carbonyl and unsaturated carbonyl compounds.	15	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	4.3 Mechanism of condensation reactions involving enolates – Stobbe reactions. Hydrolysis of esters and amides, ammonolysis of esters.			
V	**Heterocyclic Compounds** 5.1 Nomenclature, aromaticity, basicity, reactivity and stability. Five and six membered heterocyclic compounds with two heteroatoms - 1,2 and 1,3-Azoles: Pyrazole, isothiazole, isoxazole, imidazole, thiazole and oxazole. 5.2 Diazines -pyridazine, pyrimidine, pyrazine, uracil, thymine and cytosine - synthesis and reactions. 5.3 Heterocyclic compounds with more than two heteroatoms – 1,2,3-triazole, 1,2,4-triazole, tetrazole and pentazole – synthesis and reactions.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text Books

1. J. March and M. Smith, Advanced Organic Chemistry, 5th edition, John-Wiley and Sons.2001.
2. E. S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Inc., 1959.
3. P. S. Kalsi, Stereochemistry of carbon compounds, 8thedition, New Age International Publishers, 2015.
4. P. Y. Bruice, Organic Chemistry, 7th edition, Prentice Hall, 2013.
5. R. T. Morrison, R. N. Boyd, S. K. Bhattacharjee Organic Chemistry, 7th edition, Pearson Education, 2010.
6. D. Nasipuri, Stereochemistry of Organic Compounds, 2nd edition, New Age Publishers, 2005.
7. S. M. Mukherji and S. P. Singh, Reaction Mechanism in Organic Chemistry, 3rd edition, Macmillan India Ltd.1984.
8. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, Oxford University Press, 2nd edition, 2016.

Suggested Readings

1. S. H. Pine, Organic Chemistry, 5thedn, McGraw Hill International Edition, 1987.
2. L. F. Fieser and M. Fieser, Organic Chemistry, Asia Publishing House, Bombay, 2000.
3. E.S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Inc., 1959.
4. T. L. Gilchrist, Heterocyclic Chemistry, Longman Press, 1989.
5. J. A. Joule and K. Mills, Heterocyclic Chemistry, 4thedition, John-Wiley, 2010.
6. K. S. Richardson and T. H. Lowry, Mechanisms and Theory in Organic Chemistry by 3rdedition, Joanna Cotler Books, 1981.
7. T. H. Lowry K. S. Richardson, Harper and Row, Mechanism and theory in organic chemistry, 2nd edition, New York, 1981.

8. S. H. Pine, Organic Chemistry, 5th edition, McGraw Hill International Edition, 1987.
9. L. F. Fieser and M. Fieser, Organic Chemistry, Asia Publishing House, Bombay, 2000.

Web Resources

1. https://bit.ly/3HMlFWX
2. https://www.organic-chemistry.org/
3. https://www.studyorgo.com/summary.php
4. https://www.clutchprep.com/organic-chemistry

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic principles of aromaticity of benzenoid, non-benzenoid and heterocyclic compounds.	**K1, K2**
CO 2	To understand the mechanism of various types of organic reactions and heterocyclic compounds.	**K3**
CO 3	To predict the suitable reagents for the conversion of selective organic and heterocyclic compounds.	**K4**
CO 4	To correlate the principles of substitution, elimination addition reactions and heterocyclic compounds.	**K5**
CO 5	To design new routes to synthesis organic and heterocyclic compounds.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2MC02**
Course Title	**COORDINATION CHEMISTRY**
Credits	6
Hours/Week	6
Category	Major Course (MC) - Theory
Semester	II
Regulation	2022

Course Overview

1. Coordination Chemistry comprises of modules of theories and kinetics of coordination compounds and bioinorganic chemistry.
2. The aim of the course is to impart knowledge on theories of crystal field, reaction kinetics, electronic spectroscopy and metalloproteins.
3. The other important aspects that will be discussed in the course include the distortion in the crystal field, electron transfer reactions, molecular magnetism and transport of proteins.
4. In this course, the molecular orbital theory, photochemistry, and spectral characterisation of coordination compounds are discussed.

Course Objectives

1. To understand and explain the concepts of theories and characterisation of coordination compounds.
2. To predict the distortion in the crystal field and mechanisms of electron transfer reactions.
3. To discuss the spectral characterisation techniques of molecules.
4. To draw the molecular orbital energy levels and quantification of metal-ligand interactions.
5. To explain the role of coordination compounds in the biological systems**.**

Prerequisites	Basic knowledge of coordination chemistry and spectral techniques.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Bonding in Coordination Compounds** 1.1 Theories: Valence bond theory (VB) – drawbacks - Crystal Field Theory: Crystal field splitting in T_d, O_h, square planar, square pyramid, cubic and trigonal bipyramid fields. Computation of CFSE in tetrahedral, LS and HS octahedral geometries. Crystal field stabilization parameters. Spectrochemical series. 1.2 Evidences of crystal field splitting: variation of ionic size, lattice energy, hydration energy, Octahedral site stabilization energy, prediction of spinel and inverse spinel, Jahn-Teller effect- static and dynamic- distortions in d^{1-10}low and high spin octahedral and tetrahedral complexes- consequences. 1.3 Molecular Orbital Theory: Evidences of metal-ligand covalency, TASO-MO concepts and diagram of complexes, Oh complexes with σ- and π-bonding T_d and square planar complexes.	**19**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Kinetics of coordination compounds** 2.1 Reactions-Inert or labile complexes: classification - Aquation: acid and base hydrolysis–-D, A, and S_N1CB mechanism. Substitution reactions in square planar and octahedral complexes- Trans effect- trans effect series, theories-polarization, pi bonding, sigma bonding and Cardwell's electronegativity theory and applications. 2.2 Electron transfer reactions: mechanisms of inner- and outer-sphere. Complementary and non-complementary reactions. Marcus-Husch theory. Sequence of reactions in the catalytic activity of Ziegler-Natta catalyst-Wilkinson catalyst. 2.3 Photochemistry: Photophysical processes- Florescence and phosphorescence-Charge transfer Photosubstitution: Adamson's rules–examples. Photochemistry of $[Ru(bpy)_3]^{2+}$	**19**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

III	**Characterization of Coordination Compounds-I** 3.1 Introduction to Electronic Spectroscopy. Transitions in metal complexes - Selection rules. Term states-hole formulation, calculation of number of microstates. Orgel diagrams for O_h and T_d complexes- limitations. Tanabe-Sugano diagrams. Evaluation of Dq and B values for d^2–d^8 complexes. Charge transfer spectra- LMCT, MLCT and MMCT. Lanthanides and Actinides-spectral properties. 3.2 Molecular magnetism: Classification -Van Vleck equation and magnetic moments of free metal ions. Spin only, and spin & orbital magnetic moment contribution of $d^{1\text{-}10}$, low and high spin O_h and T_d complexes with A, E and T ground terms. Thermal equilibrium between spin states-spin crossover. 3.3 Infrared spectroscopy: Effect of coordination on the stretching frequency-carboxylic acids, amides, esters, sulphato and aqua, perchlorate, linkage isomers-cyano- and isocyano-, nitro- and nitrito-, thiocyanato- and isothiocyanato complexes, terminal and bridging carbonyls.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
IV	**Characterization of Coordination Compounds-II** 4.1 Nuclear Magnetic Resonance Spectroscopy: ^{19}F, ^{31}P, and ^{15}N NMR spectra- Isomers of $Rh(PPh_3)_3Cl_3$, $[PtX_2(PR_3)_2]$, $P_3N_3Cl_4F_2$, $P_4N_4Cl_6(NHC_6H_5)_2$, P_3N_3 $(C_6H_5)_3F_3$, R_2PF_3. Nuclear Quadrupole Resonance Spectroscopy. Applications to complexes. 4.2 Electron Spin Resonance Spectroscopy: Introduction - line width, presentation of spectra, McConnel equation, 'g' and A' parameters-Kramer's rule of degeneracy-EPR spectra of transition metal complexes-bis(salicylaldimine)copper(II), $Co_3(CO)_9Se$, $[(NH_3)_5Co\text{-}O_2\text{-}Co(NH_3)_5]^{5+}$ and Mn^{2+} complexes-representative spectra of different d^n systems. 4.3 Mossbauer spectroscopy - isomer shift -	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	quadrupole splitting- Application to iron complexes-$Fe(CO)_5$, $Fe_2(CO)_9$, $Fe_3(CO)_{12}$, $K_4[Fe(CN)_6]$, $K_3[Fe(CN)_6$, $FeCl_3$, $FeSO_4.7H_2O$, $Fe[Fe(CN)_6]$, $[Fe(NO)(H_2O)_5]^{2+}$and tin complexes - R_2SnX_2 and *cis*-R_3SnX and *trans*-R_2SnX4 compounds.			
V	**Bioinorganic Chemistry** 5.1 Metalloproteins - Metal storage, proteins and bio-mineralisation - Ferritin, trans ferritin, siderophores, sodium potassium balance, Transport proteins: oxygen carriers – haemoglobin - structure, oxygenation and stereochemistry - Bohr effect. Biological redox system: Cytochromes - classification of cytochrome a, b and c, cytochrome- P450. Iron -sulphur proteins - Rubredoxins and ferredoxins, Chlorophylls and photosynthesis. 5.2 Active site and functions of metallo enzymes: zinc enzymes - carboxy peptidase, peroxidase, superperoxide dismutase and copper proteins - haemocyanin, plastocyanin, stellacyanin, azurin. 5.3 Nitrogen fixation via nitride formation, reduction of dinitrogen to ammonia. Chelate therapy-anticancer activity, mechanism of anitcancer activity of cis platinum and related metal complexes, DDP. Radioisotopes - diagnosis as radiopharmaceuticals.	**16**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Text Books

1. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry, 4th ed.; Harper and Row: New York, 1993.
2. F. A. Cotton, G. Wilkinson.; C. A. Murillo; M. Bochmann, Advanced Inorganic Chemistry, 6th ed.; Wiley Inter-science: New York, 1999.
3. K. F. Purcell, J. C. Kotz, Inorganic Chemistry; Saunders: Philadelphia, 1980.
4. R. S. Drago, PhysicaI Methods in Chemistry; Saunders: Philadelphia, 1977.
5. K. K. Rohatgi Mukherjee, Fundamentals of photochemistry (Revised edition), Wiley Eastern Ltd., 1996.

Suggested Readings

1. Basic Inorganic Chemistry, F. A. Cotton, G. Wilkinson, P. L. Guas, John Wiley, 2002, 3rd edn.
2. Concepts and Models of Inorganic Chemistry, B. Douglas, D. McDaniel, J. Alexander, John Wiley, 1994, 3rd edn.
3. Inorganic Chemistry, D. F. Shriver, P. W. Atkins, W. H. Freeman and Co, London, 2010.
4. Inorganic Chemistry: A Modern Introduction, T. Moeller, Wiley, New York, 1990.

Web Resources

1. https://nptel.ac.in/
2. https://ocw.mit.edu/courses/chemistry/
3. https://swayam.gov.in

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand the concepts of theories and characterisation of coordination compounds.	**K1, K2**
CO 2	To illustrate the distortion in the crystal field and mechanisms of electron transfer reactions.	**K3**
CO 3	To analysethe compounds using spectral characterisation techniques.	**K4**
CO 4	To determine the energy levels of molecular orbital and quantification of metal-ligand interactions.	**K5**
CO 5	To elucidate the structure of a molecule using spectral characterisation techniques and to synthesise the coordination compounds.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2MC03**
Course Title	**SCIENTIFIC RESEARCH METHODOLOGY AND COMMUNICATIONS**
Credits	3
Hours/Week	4
Category	Major Course (MC) - Theory
Semester	II
Regulation	2022

Course Overview

1. The course focuses on learning the research and its methodology.
2. The methodology gives an insight on systematic training in research work with all ethical issues being taken care of.
3. The course deals with scientific writing and gives training to write thesis, project proposals, scientific reports and research articles.
4. The course also trains a student for seminar presentations.
5. In overall, the course discusses on learning research, practicing ethical values in research, collating the results, preparing a thesis and finally trains to present it or defend the work.

Course Objectives

1. To introduce the purpose and importance of research for future development.
2. To know the various indexes and abstracts in science and technology.
3. To learn literature search for current awareness and for retrospective survey.
4. To know the methodology of writing thesis and journal articles.
5. To develop communication skills of students for seminar and paper presentations.

Prerequisites	Basic knowledge of Chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Research, Literature search and Ethics** 1.1 Research: Introduction, types, objectives, scope, and research problem: identification, selection, formulation of research objectives, research design: components, types and importance. 1.2 Literature Search: Review of literature, journals, books, periodicals, patents and abstracts. Chemical abstracts: CASSI, indexes, retrospective search. 1.3 Research ethics, Institutional ethics, Plagiarism, Copy right, intellectual property rights, royalty.	8	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**Technical Writing** 2.1 Technical communications: Technical and non-technical, outlines; documents: Full length research paper, Short/Brief communications, Letters to editor, Book chapter, Review, Conference report, Project proposal Components of research paper: Title/Topic statement, Abstract/ keywords, 2.2 Components of thesis: aim and objectives, hypothesis building, rationale of the paper, work plan, materials and methodology, results and discussion, key issues and arguments, acknowledgement, conflict of interest statement, bibliography, technical resumes and cover letters 2.3 Components of a research proposal: project summary, key words, origin of the proposal, major objectives, methodology, overview of status of research and development in the subject, importance of the proposed project in the context of current status, bibliography / references.	13	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
III	**Scientific Publications** 3.1 Literature search tools - SCOPUS, Google Scholar, PUBMED, Web of Science, Indian Citation Index. Citation and referencing. 3.2 Styles of referencing - APA, MLA, Oxford, Harvard, Chicago Annotated bibliography. Tools for citing and referencing - grammarly, Mendeelev,	5	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	endnote.			
IV	**Presentation and Communication skills** 4.1 Tables, figures, graphs and diagrams – ChemDraw, MS-Excel and PowerPoint slides. Poster preparation. 4.2 Electronic submission of manuscripts, communication skills, oral and poster presentations.	4	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
V	**Seminar Presentation** Current topics in chemistry and in applied areas.	30	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text books

1. Kothari, C. Research Methodology Methods & Techniques – New Age international Publishers, Reprint 2008.
2. Anderson, J. Thesis and Assignment Writing, Wiley Eastern Ltd., 1997.
3. Mukul Gupta, Deepa Gupta, Research Methodology – PHI Learning Private Ltd., New Delhi, 2011.
4. Rajammal, P. Devadoss and K. Kulandaivel, A Hand Book of Methodology of Research, RMM Vidyalaya press, 1976.

Suggested Readings

1. John Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (Hardcover), 2008
2. John W. Creswell, Qualitative Research & Evaluation Methods, 2008.

Web Resources

1. https://bit.ly/3tLCETu
2. https://bit.ly/2Jc1qm5
3. https://bit.ly/3OLOvJx

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic requirements to start research.	**K1, K2**
CO 2	To identify suitable research areas and perform a successful research work.	**K3**
CO 3	To collect the data, collate them suitably and come out with a successful thesis.	**K4**
CO 4	To appraise suitably and defend the work by delivering a seminar.	**K5**
CO 5	To publish the work in the form of research publications and proposal for the society.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2MC04**
Course Title	**ORGANIC LABORATORY TECHNIQUES-II**
Credits	2
Hours/Week	4
Category	Major Course (MC) - Lab
Semester	II
Regulation	2022

Course Overview

1. This course explains the functional group estimation and extraction methodologies of organic compounds.
2. The estimation technique provides the quantitative skill of analysis of various organic compounds.
3. This course explores the extraction of active natural products from food materials.
4. The course also demonstrates the separation of organic mixtures by a suitable chromatographic technique.
5. Overall, this practical course gives a complete training of estimation of organic compounds, extraction of natural products and explores the chromatographic separation of organic mixtures.

Course Objectives

1. To develop the analytical skills in organic quantitative analysis.
2. To explore the techniques involved in estimation of organic compounds.
3. To identify suitable method for the extraction of active components from the natural products.
4. To demonstrate the different chromatographic techniques to separate various organic mixtures.
5. To understand the different separation methods and estimation procedures of organic compounds.

Prerequisites	Basic knowledge of organic chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**1. Estimations** a) Estimation of Phenol (bromination) b) Estimation of Aniline (bromination) c) Estimation of Ethyl methyl ketone (iodimetry) d) Estimation of Glucose (redox) e) Estimation of Ascorbic acid (iodimetry) f) Estimation of Aromatic nitro groups (reduction) g) Estimation of Glycine (acidimetry) h) Estimation of Formalin (iodimetry) i) Estimation of Acetyl group in ester (alkalimetry) j) Estimation of Hydroxyl group (acetylation) k) Estimation of Amino group (acetylation)	25	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**2. Extraction** a) Caffeine from tealeaves b) Nicotine from tobacco leaves c) Citric acid from citrus fruits d) Lycopene from tomatoes e) Lactose from milk f) Piperine from black pepper	25	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
III	**3. Separation of components of a mixture** (Demonstration) a) Thin layer chromatography b) Column chromatography c) Paper chromatography. d) Ion-exchange chromatography	10	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text books

1. N. S. Gnanapragasam and G. Ramamurthy, Organic Chemistry – Labmanual, S. Viswanathan Co. Pvt. Ltd, 2009.
2. J. N. Gurtu and R. Kapoor, Advanced Experimental Chemistry, S. Chand and Co., 2011.

Suggested Readings

1. Vogel's Text book of Practical Organic Chemistry, 5th Ed, ELBS/Longman, England, 2003.

Web Resources 1. https://bit.ly/3tMt2YQ

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic principles of estimation and extraction of organic compounds.	**K1, K2**
CO 2	To develop the skills of quantitative analysis and the extraction of natural products.	**K3**
CO 3	To illustrate the reactivity of various functional groups for estimations and to apply a suitable technique for the separation of organic compounds from a mixture.	**K4**
CO 4	To formulate a suitable estimation method for a functional organic compound and a possible extraction procedure for natural products.	**K5**
CO 5	To design a suitable estimation method for any functional organic compound and a suitable extraction and separation procedure for any organic mixture.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2MC05**
Course Title	**INORGANIC QUALITATIVE ANALYSIS AND PREPARATIONS**
Credits	2
Hours/Week	4
Category	Major Course (MC) – Lab
Semester	II
Regulation	2022

Course Overview

1. This course is with two modules of qualitative analysis as well as preparation of complexes with purity checking that involves quantitative estimation.
2. The students are taught with the technique and elementary idea of detection of cations as common and rare cations in a mixture.
3. The students are able to qualitatively identify several cations based on the knowledge of solubility product, ionic product and precipitating agents.
4. Identification of metals using spot reagents is of analytical importance to the students for applying these techniques in analytical labs of food processing and dairy products.
5. The various techniques learnt in quantitative analysis can be applied to determine the purity of any synthesized compound.

Course Objectives

1. To understand the characteristic reactions of individual cations as well as in the mixture that enhances the influence of one cation on another cations.
2. To adhere the classification of cations based on solubility.
3. To train the students for improving their skill in maintaining suitable pH to get the characteristic precipitate based on solubilty product.
4. To estimate the amount of ion accurately present in the complex to prove the purity.
5. To enhance the skill of doing yield percentage calculations.

Prerequisites	Basic knowledge in Chemistry

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
1	**Principles of Analysis of mixture of cations** Classification of cations into groups and preparation of salt solution and reagents, Inter group and intragroup separations and confirmatory test for cations.	4	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
2	**Analysis of mixture of cations** Analysis of a mixture of four cations containing two common cations and two rare cations. Cations to be tested. Group-I : W, Tl and Pb. Group-II : Se, Te, Mo, Cu, Bi and Cd. Group-III : Tl, Ce, Th, Zr, V, Cr, Fe, Tiand U. Group-IV : Zn, Ni, Co and Mn. Group-V : Ca, Ba and Sr. Group-VI : Li and Mg.	40	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
3	**Preparation of metal complexes and Purity checking:** Preparation of inorganic complexes: a. Preparation of tristhioureacopper(I)sulphate b. Preparation of potassium trioxalatechromate(III) c. Preparation of tetramminecopper(II) sulphate d. Preparation of Reineck's salt e. Preparation of hexathioureacopper(I) chloridedihydrate f. Preparation of *cis*-Potassium tri oxalate diaquachromate(III) g. Preparation of sodium trioxalatoferrate(III) h. Preparation of hexathiourealead(II) nitrate **Purity Checking:** **Preparations and estimation of one metal ion in the complex (only for internal test or demo experiments)** a. Potassium tris(oxalato)ferrate(III) - iron by colorimetry or oxalate by permanganometry calculation of percentage of Fe in $K_3[Fe(C_2O_4)_3]$	16	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	b. Hexaamminenickel(II) tetrafluoroborate - Ni by colorimetric or gravimetric analysis c. Potassium tetrachlorocuprate(II) – Cu by colouri metric / gravimetric analysis. d. Tris(thiourea)(sulfato)zinc(II) – Zn by complex metric analysis.			

Text Books

1. A. Jeya Rajendran, Microanalytical Techniques in Chemistry: Inorganic Qualitative Analysis, United global publishers, 2021.
2. V. V. Ramanujam, *Inorganic Semimicro Qualitative Analysis*; 3rd ed., The National Publishing Company, Chennai, 1974.
3. *Vogel's Text book of Inorganic Qualitative Analysis,* 4th ed., ELBS, London.

Suggested Readings

1. G. Pass, and H. Sutcliffe, *Practical Inorganic Chemistry*; Chapman Hall, 1965.
2. W. G. Palmer, Experimental *Inorganic Chemistry*; Cambridge University Press, 1954.

Web resources

1. https://bit.ly/3Ncpy8C

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To identify the anions and cations present in a mixture of salts.	**K1, K2**
CO 2	To apply the principles of semi micro qualitative analysis to categorize acid radicals and basic radicals.	**K3**
CO 3	To acquire the qualitative analytical skills by selecting suitable confirmatory tests and spot tests.	**K4**
CO 4	To choose the appropriate chemical reagents for the detection of anions and cations.	**K5**
CO 5	To synthesize coordination compounds in good quality	**K6**

COURSE DESCRIPTOR

Course Code	**PCH3MC01**
Course Title	**MAIN GROUP ELEMENTS AND NUCLEAR CHEMISTRY**
Credits	5
Hours/Week	5
Category	Major Course (MC) - Theory
Semester	III
Regulation	2022

Course Overview

1. This course illustrates the structure and bonding in inorganic chains, rings, and cages.
2. The conceptualization of structural features enables to identify the chemical properties and uses of main group elements.
3. This subject provides the cognitive mapping of various functional inorganic compounds along with the synthesis, theoretical description of symmetry concepts and characterization.
4. This course builds up a systematic learning of nuclear chemistry to understand the theory of radioactivity and applications of radioisotopes.
5. The numerical calculations involved in nuclear chemistry and computation of electron counts in a frame work of cluster compounds of main group elements are explicitly imparted by learning this course.

Course Objectives

1. To demonstrate the basic principles of rings, cages and clusters.
2. To explain the structure of inorganic compounds by applying VSEPR theory.
3. To illustrate the different types of non -valence forces and their influence on the physical and chemical properties.
4. To describe the various types of nuclear reactions and nuclear models to account for the properties of nuclei.
5. To acquire knowledge to predict the structure of cluster compounds of main group elements.

Prerequisites	Basic knowledge of inorganic chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Inorganic Cages and clusters** 1.1 Hydrides: Classification, Boranes–classification, synthesis, reactions, structure of diborane (MOT) and higher boranes. Prediction of STYX - number of framework electrons, valence electrons count, chemical equation method from formulae. Structure of polyhedral frameworks of boranes-PSEPT (Wade's rule) and Lipscomb's structure of B_4H_{10}, B_5H_9, B_5H_{11}, $B_6H_{10}$and $B_{10}H_{14}$. 1.2 Carboranes: classification, structure, synthesis, properties and applications of $C_2B_{10}H_{12}$. Metallocarboranes – synthesis, Wade's rule and PSEPT. Nomenclature, structures of CB_5H_9, $C_2B_4H_8$, $C_3B_3H_7$and $C_4B_2H_6$. Silanes and cyclopolysilanes. Hydrometallation-hydroboration and hydrosilylation. 1.3 Alkali and alkaline earth metal complexes: α-diketones and crown ether complexes. Phase transfer catalyst, biological role of metal ions and ionophores. Valinomycin-Na^+-K^+ pump action.	**13**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Inorganic Chains, Clusters and Selected Compounds of p-block elements** 2.1 Boron-nitrogen compounds: azaboranes, pyrazaboles, borazines, and B-N clusters. Preparation, structure, reactivity and uses of poly- and cyclophosphazenes, phosphorus-oxide and phosphorus-sulfide cages. Cyclic sulfur-nitrogen compounds, tetrasulfurtetranitride, polythiazyl, and S_xN_y ($x=y$, $x\neq y$) compounds. Nitrides-classification and properties. 2.2 Catenation: allotropes of carbon-graphite, diamond, fullerenes, CNTs and graphene. Chemistry of carbides. Hetero catenation-cyclic silicon and phosphorous compounds. 2.3 Silicates: classification-ortho- and disilicates.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	Pyroxene and amphibole minerals. Structural silicates-sheet, 3D, ultramarine, zeolites. Molecular sieve structure and water treatment, feldspar, silicones- classifications, preparation, properties and uses. 2.4 Poly acids and haloclusters: Classification, structure of isopoly and heteropoly anions of W and Mo. Keggin Structure. Chemistry of low molecularity metal clusters – di and trinuclear metal clusters; metal-metal multiple bonds – $[Re_2Cl_8]^{2-}$, $[W_2Cl_9]^{3-}$, $[Cr_2Cl_2]^{3-}$, Re_3Cl_9, Cu^{2+} and Cr^{2+} acetate complexes, $Mo_2Cl_8^{4-}$. Chalcogenides, Chevral Phases.			
III	**Halogen and Noble Gas Chemistry** 3.1 Halogen compounds of nitrogen: Preparation, structure, reactivities and uses of nitrogen trifluoride, tetrafluoro hydrazine, dinitrogen difluoride, haloamines, oxohalides, and nitrogen trifluoride oxide. 3.2 Halogen oxides and oxo compounds: Preparation, structure, reactivities and uses of dichlorine monoxide, chlorine dioxide, dibromine monoxide, and iodine pentoxide, oxyfluorides trioxohalo fluorides and ionic oxyhalogen species. Sulfur fluorides: Synthesis and reactivity of disulfur difluoride, sulfur tetrafluoride. Structure of oxides of halogen and halogen oxo compounds with VSEPR model. 3.3 Reactivity of the halides: Fluorinating agent-moderate - SF_4, SbF_3, SbF_5, harsh -ClF, ClF_3, and BrF_3. Molecular Orbitals for Cluster Compounds. 3.4 Xenon oxides and fluorides: Preparation, structure with the aid of VSEPR model, reactivities and uses of xenon trioxide, difluoride, tetrafluoride, hexafluoride, xenon oxofluoride. Applications of Xe compounds.	**13**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
IV	**Nuclear Chemistry** 4.1 Nuclear Reactions: Properties of nucleus-calculation of size, density and atomic mass. Types of nuclear reactions- natural and artificial	**13**	**CO 1** **CO 2** **CO 3** **CO 4**	**K1, K2, K3, K4, K5, K6**

	radioactive nuclear reactions, Soddy - Fajans group displacement law,: Bethe's notation,Natural radioactive series, calculation of α and β particles emitted-Geiger- Nuttal law, types of nuclei-isotope, isobar, isotone, nuclear isomers, nuclear stability- N/P ratio, mass defect, packing fraction, binding energy. 4.2 Nuclear models: liquid drop model, semi-empirical mass equation and shell model - calculation of spin and parity of magnetic moment. Magic number - Femi gas and collective model. Reaction cross section and reaction rate. Compound Nucleus Theory: excitation energy, line widths and life times of excited states - experimental verification. 4.3 Transuranides -synthesis of transuranic elements, photonuclear and thermonuclear reactions. Spallation, fusion, fission- Bohr yield curve. Atom bomb and hydrogen bomb -Nuclear reactors – conventional and breeder reactors. Fission energy *vs* Fission Barrier. 4.4 Kinetics of nuclear reaction – half-life of radioactive substances, amount of radioactive substances left undisintegrated, relation between $t_{1/2}$ and decay constant, average life, carbon dating, rock dating –principle, determination of age of earth and minerals by various dating techniques.		**CO 5**	
V	**Radioactivity and Radiation Chemistry** 5.1 Radiochemistry - Measurement of radioactivity: ionization chamber, GM counters, scintillation counters, particle accelerators, linear accelerators, cyclotron synchrotron and Geiger-Muller counter. 5.2 Types of reactors-Breeder nuclear reactors and its components. Nuclear power plant in India.Applications-neutron activation analysis, isotopic dilution, labelling studies and nuclear medicine ^{99m}Tc, radiopharmaceuticals. 5.3 Hot atom chemistry-Radiolysis of water, solvated electron - properties and identification of reactions - Hart and Boag's experiment. Pulse-radiolysis – Actinometry. Reprocessing of spent	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	fuels: Nuclear waste, sequestering agents for radioisotopes, solvent extraction and ionic liquid technology.\			

Text Books

1. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, *Advanced Inorganic Chemistry*; 6th ed.; Wiley Interscience: New York, 1988.
2. J. E. Huheey, E. A. Keiter and R. L. Keiter, *Inorganic Chemistry*; 4th ed.; Harper and Row: New York, 1983.
3. D. F. Shriver, P.W. Atkins and C.H. Langford, *Inorganic Chemistry*; 3rd ed.; Oxford University Press: London, 2001.
4. K. F. Purcell and J. C. Kotz, *Inorganic Chemistry*, Saunders: Philadelphia, 1976.
5. H. J. Arnikar, *Essentials of Nuclear Chemistry*; 4th ed., New Age International, New Delhi, 1995.
6. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models of Inorganic Chemistry*, 3rd edition, John Wiley & Sons, 2010.
7. Gary Wulfsberg, Inorganic Chemistry, Viva Books, New Delhi, 2010.

Suggested Readings

1. T. Moeller, *Inorganic Chemistry, A Modern Introduction*; John Wiley: New York, 1982.
2. A. K. Srivatsava and P. Jain, P. *Essential of Nuclear Chemistry*; S. Chand, New Delhi, 1989.
3. G. Friedlander, G.; Kennedy, W. and J. M. Miller, *Nuclear and Radiochemistry*; 2nd ed.; John Wiley and Sons Inc., 1964.
4. S. Glasstone, *Source Book on Atomic Energy*; 2nd ed.; Van Nostr and Co. Inc., New Jersey, 1958.
5. A. F.Wells, *Structural Inorganic Chemistry*, Clarendon Press, Oxford, U.K.1984
6. Hari Jeevan Arnikar and Nilima Shivadatta Rajkumar, *Nuclear Chemistry Through Problems*, New Age International Publishers, New Delhi, 2018
7. R.D. Madan, *Satya Prakash's Modern Inorganic Chemistry*, Third Edition S. Chand Publication, New Delhi,1986
8. R. Sarkar, *General and Inorganic Chemistry*, Part II, New Central Book Agency, Kolkatta, 20056.
9. Radiation Chemistry, G .Hughes – Oxford Chemistry Series, Editors P.W. Atkins, J. S. E Holker and A. K. Holiday, Clarendon press, Oxford (1973)

Web Resources

1. https://bit.ly/3OtepkR
2. https://bit.ly/3zSu8pu

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall concepts, laws, relationships, structures of cluster compounds in chemical bonding, solid state, main group elements, uses of P–N, P–S and S–N compounds and nuclear reactions.	**K1, K2**
CO 2	To explain the bonding, synthesis, reactions of main group compounds and nuclear reactions.	**K3**
CO 3	To predict STYX numbers of polyhedral structures based on PSEPT and classify nuclear reactions.	**K4**
CO 4	To discuss the chemistry of halogen, noble gas B, N, P, S-based compounds and nuclear process.	**K5**
CO 5	To develop the structure-property correlation in allotrope of C, S and P and calculate the number of skeletal electron pairs using Wade's rule and to nuclear reactions.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH3MC02**
Course Title	**THERMODYNAMICS AND CHEMICAL KINETICS**
Credits	6
Hours/Week	6
Category	Major Course (MC) – Theory
Semester	III
Regulation	2022

Course Overview

1. This course provides an insight for the interpretation of Ellingham's plot in terms of free energy and highlights the deviation from ideality through fugacity, activity and activity coefficient.
2. This course illustrates the significance of irreversible thermodynamics through Onsager theory and its applications to biological and non-linear systems.
3. Statistical approach to thermodynamic properties such as ΔG, ΔH, ΔS, and ΔU in terms of partition functions is dealt with.
4. A detailed treatment of the theories of chemical kinetics and the factors affecting the rates of ionic reactions in solution phase is covered through a unit.
5. This course deals with the kinetics of chain reactions and the methods to find the rate of fast reactions.
6. Aim of this course is also to impart mechanistic approach to the kinetics of polymerization. Molecular mass determination by different techniques is also taught.

Course Objectives

1. To learn the principle associated with the thermodynamic systems of variable composition and partial molal properties.
2. To understand the application of phase rule to ternary systems and calculate the phase changes during isothermal and isobaric evaporation process.
3. To compare Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics and interpret its significance.
4. To familiarize with the theories of reaction rate to study the factors affecting the rates of the reactions for the evaluation of thermodynamic parameters.
5. To comprehend the mechanism and study the kinetics of chain and polymerization reactions.

Prerequisites	Knowledge of Thermodynamics and Chemical Kinetics

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Classical Thermodynamics** 1.1 Thermodynamic systems of variable composition: Partial molal quantities - Chemical potential. Gibbs Duhem equation - binary and ternary systems. Determination of partial molal quantities. Ellingham diagram and its significances. 1.2 Thermodynamics of real gases and real solutions: Fugacity- determination by graphical and equation of state methods - dependence on temperature, pressure and composition. Activity and activity coefficient - standard states, determination - vapour pressure, emf and freezing point methods. 1.3 Phase equilibria involving ternary systems: liquid - liquid equilibria- formation of one and two pairs of partial miscibility. Solid-liquid equilibria: formation of double salt and salt hydrates.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Irreversible Thermodynamics** 2.1 Near equilibrium process: General theory- conservation of mass and energy- entropy production in open system by heat, matter and current flow, force and flux concepts. 2.2 Onsager theory: Validity and verification – Principle of microscopic reversibility, Onsager reciprocal relations. 2.3 Thermoelectricity –Seeback and Peltier effects - Electro kinetic and thermo mechanical effects. Application of irreversible thermodynamics to biological and non-linear systems.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
III	**Statistical Thermodynamics** 3.1 Macro and micro states: Distribution of particles in different energy levels. Stirling's approximation, Derivation of Maxwell-Boltzmann statistics. Comparison of Maxwell-	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	Boltzmann, Fermi-Dirac and Bose-Einstein statistics. 3.2 Partition functions: Canonical and molecular partition functions. Separation, multiplication theorem, thermodynamic probability. Translational, rotational, vibrational and electronic partition functions and interpretations. 3.3 Statistical approach to Thermodynamic properties: pressure, internal energy, entropy, enthalpy, Gibbs function, Helmholtz function, residual entropy, equilibrium constant, average energies and equipartition principle. Heat capacity of mono and diatomic gases - *ortho* and *para* hydrogen. Heat capacity of solids- Einstein and Debye models.			
IV	**Kinetics of reactions in gas and solutions phases** 4.1 Theories of reaction rates - Kinetic theory of collisions - bimolecular, unimolecular - Lindemann - Christiansen hypothesis, Lindemann - Hinshelwood, RRK and Rice Ramsperger-Kassel-Marcus (RRKM) theories. Bimolecular reactions in gas phase - atoms and free radicals, potential energy surfaces. Conventional transition state theory - evaluation of thermodynamic parameters of activation, application of ARRT to reactions between atoms, molecules and atoms and molecules- time and true order, evaluation of kinetic parameters. 4.2 Factors determining reaction rates in solution – solvation- ionic strength - primary and secondary salt effects, dielectric constant–concept of electrostriction, hydrostatic pressure - volume of activation. 4.3 Enzyme catalysis – one and two substrates - Michaelis-Menten equation-evaluation of kinetic parameters - Lineweaver-Burk, Eadie-Hofstee and Hanes-Woolf plots. Turn over number.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

V	**Kinetics of complex and fast reactions** 5.1 Rate expressions for opposing, parallel and consecutive reactions; Chain reactions – chain length, Rice-Herzfeld pyrolysis of acetaldehyde, hydrogen-halogen (thermal and photochemical) reaction, Gas phase auto oxidation; explosion and explosion limits. Oscillatory reactions-Belousov-Zhabotinsky reactions. 5.2 Kinetics of polymerization – Free-Radical, cationic, anionic polymerizations – polycondensation. 5.3 Flow techniques - relaxation theory and relaxation techniques - Temperature, Pressure, electric field and magnetic field jump methods, flash photolysis and pulse radiolysis.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Text Books

1. J. Rajaram and J.C. Kuriacose, Thermodynamics For Students of Chemistry, 2nd edition, S.L.N. Chand and Co., Jalandhar, 1986.
2. I.M. Klotz and R.M. Rosenberg, Chemical thermodynamics, 6th edition, W.A. Benjamin Publishers, California, 1972.
3. M.C. Gupta, Statistical Thermodynamics, New Age International, Pvt. Ltd., New Delhi, 1995.
4. K.J. Laidler, Chemical Kinetics, 3rd edition, Pearson, Reprint - 2013.
5. J. Rajaram and J.C. Kuriokose, Kinetics and Mechanisms of chemical transformation, Macmillan India Ltd, Reprint - 2011.
6. V.R. Gowariker, Polymer Science, Wiley Eastern, 1995.

Suggested Readings:

1. D.A. Mcqurrie And J.D. Simon, Physical Chemistry - A Molecular Approach, Viva Books Pvt. Ltd., New Delhi, 1999.
2. R.P. Rastogi and R.R. Misra, Classical Thermodynamics, Vikas Publishing, Pvt. Ltd., New Delhi, 1990.
3. S.H. Maron And J.B. Lando, Fundamentals of Physical Chemistry, Macmillan Publishers, New York, 1974
4. K.B. Ytsiimiriski, "Kinetic Methods of Analysis", Pergamom Press,1996.
5. Gurdeep Raj, Phase rule, Goel Publishing House, 2011.

Web Resources

1. https://nptel.ac.in/courses/104/103/104103112/
2. https://bit.ly/3tL3GdN

3. https://bit.ly/39IWesL
4. https://bit.ly/3OmPvne
5. https://nptel.ac.in/courses/104103112

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To define and explain the classical and statistical concepts of thermodynamics and chemical kinetics.	**K1, K2**
CO 2	To apply and relate the classical and statistical concepts of thermodynamics to study the kinetics of chemical reactions.	**K3**
CO 3	To deduce various expressions for the determination of thermodynamic and kinetic parameters.	**K4**
CO 4	To compare the thermodynamic properties of the system and predict the mechanism of chemical reactions.	**K5**
CO 5	To formulate and calculate the thermodynamic and kinetic parameters for real gases, real solutions and chemical reactions.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH3MC03**
Course Title	**MOLECULAR SPECTROSCOPY**
Credits	5
Hours/Week	5
Category	Major Course (MC) – Theory
Semester	III
Regulation	2022

Course Overview

1. Molecular spectroscopy course deals with the interaction of molecules with various regions of electromagnetic spectrum.
2. Computation of wavelength maximum, rotational and vibrational parameters from the respective absorption spectra.
3. The interpretation of first and second order NMR spectra of compounds and an introduction to 2D NMR such as COSY, NOESY is also covered.
4. This course explores the structural elucidation of compounds by means of combined spectral techniques such UV, VIS, IR, Mass and NMR.
5. This course deals with the interaction of quadrupole moment and electric field gradient. The oxidation state of high spin and low spin Fe and Sn compounds is determined through the interpretation of Mossbauer spectra.

Course Objectives

1. To understand the influence of rotation and vibrations on the spectra of the polyatomic molecules.
2. To study the principle of Raman spectroscopy and fragmentation patterns in Mass spectroscopy.
3. To highlight the significance of Franck-Condon principle to interpret the selection rule, intensity and types of electronic transitions and the aspects of fluorescence spectroscopy.
4. To interpret the first and second order NMR spectra in terms of splitting and coupling patterns using correlation techniques such as COSY, HETCOR, NOESY.
5. To carry out the structural elucidation of molecules using different spectral techniques.

Prerequisites	Basic knowledge of chemistry

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Rotational and Vibrational Spectroscopy** 1.1 Diatomic molecules as rigid rotors -intensity of spectral lines, selection rules, effect ofisotopic substitution. Diatomic molecules as non-rigid rotors -rotational spectra of linear and symmetric top polyatomic molecules. 1.2 Vibrating diatomic molecule -energy of diatomic molecules, simple harmonic and anharmonic oscillator –energylevels, transitions. Diatomic vibrating rotator - P, Q, R branches. 1.3 Vibrations of polyatomic molecules -Symmetry and fundamental vibrations, overtones, combination, difference bands. Influence of rotations on the spectra of polyatomic molecules - parallel and perpendicular vibrations in linear and symmetric top molecules. Interpretation of IR spectra of organic compounds.	**16**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Raman and Mass spectroscopy** 2.1 Principle of Raman spectroscopy, selection rules. Rotational and vibrational Raman spectra. Resonance-enhanced Raman spectroscopy: Principle and applications. 2.2 Mass Spectrometry (MS): Principle, basic fragmentation types and rules. Ionisation techniques - Principle of Electron spray ionisation (ESI)-MS, Matrix-assisted laser desorption / ionisation (MALDI)-MS. Tandem mass spectrometry – spectral patterns – protein, DNA, RNA and polymers.	**14**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
III	**Absorption and emission spectroscopy** 3.1 Electronic spectra of diatomic molecules: Born-Oppenheimer approximation, Franck Condon Principle, selection rules, intensity and types of electronic transition. Factors affecting electronic	**15**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	transitions. 3.2 Characterization of organic compounds: application of Woodward-Fieser rules to conjugated dienes, α, β - unsaturated carbonyl compounds, benzene and its substituted derivatives, polycyclic aromatic hydrocarbons. 3.3 Fluorescence spectroscopy – Jablonski diagram, fluorophores, spectral, time-resolved fluorescence and quenching.			
IV	**NMR and EPR spectroscopy** 4.1 Basic concepts, Bloch equations, chemical shift, spin-spin coupling, Chemical and magnetic equivalence. Relaxation mechanisms. Applications of T1 and T2 measurements, NMR of paramagnetic compounds: isotropic, contact and pseudo contact shift. Shift reagents in NMR. 4.2 Coupling constants: mechanism of coupling, first order and second order effects, Notation for spin systems. Fourier Transform (FT) and 2D NMR spectroscopy: Principle, Free induction decay (FID). Correlation spectroscopy (COSY), Hetero-COSY (HETCOR) and Nuclear Overhauser effect spectroscopy (NOESY). ^{13}C, ^{19}F and ^{31}P NMR spectra of typical examples. Principle of solid-state NMR. 4.3 EPR spectra of anisotropic systems - anisotropy in g-value, causes of anisotropy, anisotropy in hyperfine coupling, hyperfine splitting caused by quadrupole nuclei. Zero-field splitting (ZFS) and Kramer's degeneracy. Applications of EPR to organic and inorganic systems. 4.4 Structural elucidation of organic compounds by combined spectral techniques.	**16**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
V	**NQR and Mossbauer Spectroscopy** 5.1 Principle of Nuclear quadrupole resonance (NQR) spectroscopy - quadrupole nucleus and its interaction with electric field gradient, nuclear orientations, asymmetry parameter, quadrupole	**14**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	energy levels, transitions in spherical axial and non-axial symmetric fields, effect of magnetic field. 5.2 Applications of NQR spectroscopy: quadrupole coupling constant and its interpretation, structural information from NQR spectra of haloorganic compounds, point group symmetry and hydrogen bonding. 5.3 Principle of Mossbauer spectroscopy: Doppler shift, recoil energy. Isomer shift, quadrupole splitting, magnetic interactions. Applications: Mossbauer spectra of high and low-spin Fe and Sn compounds.			

Text Books

1. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed., Tata McGraw Hill, New Delhi, 2000.
2. R. M. Silverstein and F. X. Webster, *Spectroscopic Identification of Organic Compounds*, 6th Ed., John Wiley & Sons, New York, 2003.
3. W. Kemp, *Applications of Spectroscopy*, English Language Book Society, 1987.
4. D. H. Williams and I. Fleming, *Spectroscopic Methods in Organic Chemistry,* 4th Ed., Tata McGraw-Hill Publishing Company, New Delhi, 1988.
5. D. Pavia, G. M. Lampman, and G.S. Kriz, *Introduction to Spectroscopy*, 3rd Ed., John Vondeling, Florida, 2006.
6. K. V. Raman, R. Gopalan and P. S. Raghavan, *Molecular Spectroscopy*, Thomson and Vijay Nicole, Singapore, 2004.
7. R. S. Drago, *Physical Methods in Chemistry*; Saunders: Philadelphia, 1992.
8. G. M. Bancroft, *Mössbauer spectroscopy*, McGraw Hill, London, 1973.
9. Harald Günther, NMR Spectroscopy, John Wiley & Sons, Second edition, 2010.

Suggested Readings:

1. P.W. Atkins and J. de Paula, *Physical Chemistry*, 7th Ed., Oxford University Press, Oxford, 2002.
2. I. N. Levine, *Molecular Spectroscopy*, John Wiley & Sons, New York, 1974.
3. A. Rahman, *Nuclear Magnetic Resonance-Basic Principles*, Springer-Verlag, New York, 1986.
4. K. Nakamoto, *Infrared and Raman Spectra of Inorganic and coordination Compounds*, PartB: 5th ed., John Wiley& Sons Inc., New York, 1997.
5. J. A. Weil, J. R. Bolton and J. E. Wertz, *Electron Paramagnetic Resonance*; Wiley Interscience, 1994.
6. L.D. Field, S. Sternhell, and J. R. Kalman, *Organic Structures from Spectra*, 3rd Ed., John Wiley & Sons Ltd England, 2003.
7. J. W. Akitt, *NMR and Chemistry*, 3rd,ed., Chapman & Hall, London,1992.

8. Jack K. Becconsall, *Basic one and two dimensional NMR Spectroscopy*, 4th Ed., Wiley – VCH,2005.
9. R. V. Parish, *NMR, NQR, EPR, and Mossbauer Spectroscopy in inorganic chemistry*, Ellis Horwood, London.
10. A. Abragam, B. Bleaney, *Electron Paramagnetic Resonance of Transition Metal ions*, Oxford University Press, 1970.
11. Horst Friebolin, Basic One and Two dimensional NMR spectroscopy, Wiley –VCH, Fourth edition, 2005.

Web Resources

1. https://bit.ly/3Oqo24t
2. https://bit.ly/3HDfeW6
3. https://bit.ly/3tPf08P
4. https://nptel.ac.in/courses/104101117

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand the importance of various branches of electromagnetic spectrum and its applications in the determination of spectroscopic properties.	**K1, K2**
CO 2	To apply the spectral data such as vibrational frequencies, absorption maxima, chemical shifts, coupling constants and splitting patterns for structural elucidation of compounds.	**K3**
CO 3	To calculate the various spectral parameters and illustrate the types of transitions, splitting and interactions for structural determination.	**K4**
CO 4	To outline spectral/splitting patterns using the principles of different branches of spectroscopy to predict the plausible structural elucidation of compounds.	**K5**
CO 5	To develop the analytical skills in elucidating the structure of compounds using combined spectral techniques such as UV-Visible, IR, Mass and NMR.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH3MC04**
Course Title	**PHYSICAL CHEMISTRY PRACTICALS - I**
Credits	2
Hours/Week	4
Category	Major Course (MC) – Lab
Semester	III
Regulation	2022

Course Overview

1. This practical paper involves the aspects of thermodynamics, equilibria, and kinetics.
2. This paper deals with the determination of rate constant, order and Arrhenius parameters of a chemical reaction.
3. The influence of temperature, ionic strength and concentration that affect the rates of chemical reactions is studied kinetically.
4. The experimental determination of Nernst distribution coefficient, equilibrium constant and verification of Freundlich adsorption isotherm are performed in this course.
5. The application of phase rule to two component system is studied experimentally by constructing phase diagram.

Course Objectives

1. To verify Freundlich adsorption isotherm and Bronsted-Bjerrum equations.
2. To evaluate the rate constant, energy of activation and pre-exponential factor for a reaction following pseudo first order kinetics.
3. To compare the strength of acids by studying the kinetics of acid catalyzed ester hydrolysis.
4. To construct the phase diagram of two component system forming congruent melting solid and find its eutectic temperatures and compositions.
5. To determine the order of iodination of acetone and persulphate oxidation reactions.

Prerequisites	Basic knowledge on Physical Chemistry

EXPT	CONTENT	HOURS	COs	COGNITIVE LEVEL
1	1. Verification of Freundlich adsorption isotherm – Study of adsorption acetic acid or oxalic acid on charcoal and determination of concentration of the given acid. 2. Construction of Phase diagram for two components – Compound forming systems: Diphenylamine – Benzophenone. 3. Determination of Nernst distribution coefficient, equilibrium constant for the formation of potassium triiodide from iodine and KI and the concentration of unknown potassium iodide solution. 4. Comparison of acid strengths of two acids using acid catalysed hydrolysis of methyl acetate. 5. Kinetic study of acetone and iodine in acidic medium and the determination of order with respect to acetone and iodine. 6. Determination of order of saponification of ethyl acetate by sodium hydroxide. 7. Determination of order of autocatalytic reaction between potassium permanganate and oxalic acid. 8. Study of primary salt effect on the kinetics of ionic reactions and verification of the Bronsted relationship (iodide ion is oxidized by persulphate ion). 9. Determination of energy of activation, Arrhenius frequency factor and activation parameters ($\Delta H^{\#}$, $\Delta S^{\#}$ and $\Delta G^{\#}$) for the acid catalysed hydrolysis of an ester. 10. Determination of the pseudo first order rate constant for the kinetics of inversion of cane sugar using polarimeter. 11. Polarimetric study of the effect of solvent on the optical rotation of camphor. 12. Determination of molar refractions of pure	60	**CO1** **CO2** **CO3** **CO4** **CO5**	**K1, K2, K3, K4, K5, K6**

	liquids and estimation of concentration of glucose using Abbe's refractometer. 13. Determination of the molecular weight of polymer by viscometer. 14. Study of enzyme catalysis using uv-visible spectrophotometer.			

Text Books

1. B. Viswanathan and P.S.Raghavan, Practical Physical Chemistry, Viva Books, New Delhi, 2009.
2. Sundaram, Krishnan, Raghavan, Practical Chemistry (Part II), S. Viswanathan Co. Pvt., 1996.
3. V.D. Athawale and Parul Mathur, Experimental Physical Chemistry, New Age International (P) Ltd., New Delhi, 2008.

Suggested Readings

1. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
2. G.W. Garland, J.W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8th edition, McGraw Hill, 2009.
3. J. N. Gurthu and R. Kapoor, Advanced Experimental Chemistry, S. Chand and Co., 1987.
4. Shailendra K Sinha, Physical Chemistry: A laboratory Manual, Narosa Publishing House Pvt, Ltd., New Delhi, 2014.

Web Resources

1. https://bit.ly/3QESF7t
2. https://bit.ly/3QANOnX

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the principles associated with various physical chemistry experiments.	**K1, K2**
CO 2	To scientifically plan and perform all the experiments	**K3**
CO 3	To observe and record systematically the readings in all the experiments.	**K4**
CO 4	To calculate and process the experimentally measured values and compare with graphical data.	**K5**
CO 5	To interpret the experimental data scientifically to improve students efficiency for societal developments.	**K6**

Course Code	**PCH4MC01**
Course Title	**ORGANIC SYNTHESIS AND PHOTOCHEMISTRY**
Credits	6
Hours/Week	5
Category	Major Course (MC) – Theory
Semester	IV
Regulation	2022

Course Overview

1. Organic synthesis covers the fields of advanced organic chemistry involving natural products and medicinal chemistry.
2. The course provides a detailed exposure on special reagents and special types of reactions in organic chemistry.
3. The course aims at providing advanced knowledge in planning the synthesis of organic molecules from simple starting materials.
4. This course also reviews the photochemistry of various types of organic reactions.
5. The overall focus of the course is the planning of synthesis of any chosen target molecule, use of various selected reagents, and their application in the organic synthesis of medicinal compounds and natural products.

Course Objectives

1. To understand the molecular complexity of carbon skeletons and the presence of functional groups and their relative positions.
2. To study various synthetically important reagents for any successful organic synthesis.
3. To apply disconnection approach and identifying suitable synthons to effect successful organic synthesis.
4. To learn the concepts of pericyclic reaction mechanisms.
5. To gain the knowledge of photochemical organic reactions.

Prerequisites	Knowledge on Organic Chemistry

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Reagents for Organic Synthesis** 1.1 Lithium diisopropylamine (LDA), Azobisisobutyronitrile (AIBN), Sodium cyanoborohydride ($NaBH_3CN$), *meta*-Chloroperbenzoic acid (m-CPBA), Dimethyl aminiopyridine (DMAP), n-Bu_3SnD, Triethylamine (TEA), Diazobicyclo[5.4.0]undec-7-ene (DBU), Diisopropylazodicarboxylate (DIAD), Diethylazodicarboxylate (DEAD), *N*-bromosuccinimide (NBS), Trifluoroacetic acid (TFA), Tetramethyl piperiridin-1-oxyl (TEMPO), Phenyltrimethylammonium tribromide (PTAB). 1.2 Diazomethane and Zn-Cu, Diethyl maleate (DEM), Copper diacetylacetonate ($Cu(acac)_2$), $TiCl_3$, $NaIO_4$, Pyridinium chlorochromate (PCC), Pyridinium dichromate (PDC), Meisenheimer complex**.**	13	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**Modern Synthetic Reactions** 2.1 Suzuki coupling, Heck reaction, Negishi reaction. Baylis-Hillman reaction, Henry reaction Nef reaction, Kulikovich reaction, Ritter reaction, Sakurai reaction, Tishchenko reaction, Ugi reaction. Brook rearrangement, Tebbe olefination, Click reactions. Metal mediated C-C and C-X coupling reactions: Stille, Sonogashira, Nozaki Hiyama, Buchwald-Hartwig, Ullmann coupling reactions, directed orthometalation. 2.2 Electro-organic synthesis: Electro-oxidation and -reduction reactions.	11	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
III	**Organic Synthetic Methodology** 3.1 Retrosynthetic analysis; Alternate synthetic routes. Synthesis of organic mono and bifunctional compounds via disconnection approach. Key intermediates, available starting materials and resulting yields of alternative	22	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	methods. 3.2 Convergent and divergent synthesis, Synthesis based on umpolung concepts of Seebach. Protection of hydroxyl, carboxyl, carbonyl, thiol and amino groups. Illustration of protection and deprotection in synthesis. 3.3 Control elements: Regiospecific control elements. Use of protective groups, activating groups, and bridging elements. Stereospecific control elements. Functional group alterations and transposition.			
IV	**Pericyclic Reactions** 4.1 Woodward Hoffmann rules; The Mobius and Huckel concept, FMO, PMO method and correlation diagrams. 4.2 Cycloaddition and retrocycloaddition reactions; [2+2], [2+4], [4+4, Cationic, anionic, and 1,3-dipolar cycloadditions. Cheletropic reactions. ; Electrocyclization and ring opening reactions of conjugated dienes and trienes. Sigmatropic rearrangements: (1,3), (1,5), (3,3) and (5,5)-carbon migrations, degenerate rearrangements. Ionic sigmatropic rearrangements. Group transfer reactions. Regioselectivity, stereoselectivity and periselectivity in pericyclic reactions.	17	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
V	**Organic Photochemistry** 5.1 Photochemical excitation: Experimental techniques; electronic transitions; Jablonskii diagrams; intersystem crossings; energy transfer processes; Stern Volmer equation. 5.2 Reactions of electronically excited ketones; $\pi \rightarrow \pi^*$ triplets; Norrish type-I and type-II cleavage reactions; photo reductions; Paterno-Buchi reactions; photochemistry of α,β-unsaturated ketones; cis-trans isomerisation. 5.3 Photon energy transfer reactions, Photo cycloadditions, Photochemistry of aromatic compounds; photochemical rearrangements;	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5. K6

	photo-stationery state; di-π-methane rearrangement; Reaction of conjugated cyclohexadienone to 3,4-diphenyl phenols; Barton's reactions.			

Text Books

1. F. A. Carey and Sundberg, Advanced Organic Chemistry, 5thed, Tata McGraw-Hill, New York, 2003.
2. J. March and M. Smith, Advanced Organic Chemistry, 5th ed., John-Wiley and sons, 2007.
3. R. E. Ireland, Organic synthesis, Prentice Hall India, Goel publishing house, 1990.
4. Clayden, Greeves, Warren, Organic Chemistry, Oxford University Press, Second Edition, 2016.
5. M. B. Smith, Organic Synthesis 3rd edn, McGraw Hill International Edition, 2011.
6. V.K. Ahluwalia and Renu Aggarwal, Organic Synthesis: Special Techniques, Narosa Publishing House, 2001.
7. Ian Fleming, Pericyclic Reactions 2nd edn, Oxford Science Publications, 2015.
8. R. K. Kar, Frontier Orbital and symmetry controlled pericyclic reactions, Books and Allied (P) Ltd, Kolkotta, 2010.
9. K. K. Rohatgi-Mukerjee, Fundamentals of Photochemistry, Revised Edition, New Age International Pvt Ltd, New Delhi.

Suggested Readings

1. Gill and Wills, Pericyclic Reactions, Chapman Hall, London, 1974.
2. J.A. Joule, G.F. Smith, Heterocyclic Chemistry, Garden City Press, Great Britain, 2004.
3. W. Caruthers, Some Modern Methods of Organic Synthesis 4thedn, Cambridge University Press, Cambridge, 2007.
4. H. O. House. Modern Synthetic reactions, W.A. Benjamin Inc, 1972.
5. Jagdamba Singh and Jaya Singh, Photochemistry and Pericyclic Reactions, New Age International Publishers, New Delhi, 2012.

Web Resources

1. https://rushim.ru/books/praktikum/Monson.pdf
2. https://bit.ly/3QBkNso
3. https://bit.ly/39FKo2x
4. https://bit.ly/3b5cRz4

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic principles of organic chemistry and to understand the various reactions of organic compounds with reaction mechanisms.	**K1, K2**
CO 2	To understand the versatility of various special reagents and to correlate their reactivity with various reaction conditions.	**K3**
CO 3	To implement the synthetic strategies in the preparation of various organic compounds.	**K4**
CO 4	To predict the suitability of reaction conditions in the preparation of tailor made organic compounds.	**K5**
CO 5	To design and synthesize novel organic compounds with the methodologies learnt during the course.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH4MC02**
Course Title	**ELECTROCHEMISTRY**
Credits	7
Hours/Week	6
Category	Major Course (MC) - Theory
Semester	IV
Regulation	2022

Course Overview

1. This course describes various aspects of electrochemistry such as theories of electrolytes, structure of double layer, electrodics of elementary and multi electron systems.
2. It highlights the evaluation of thermodynamic parameters, importance of bio electrochemistry, electroanalytical techniques, fuel cells and batteries.
3. This course explains the derivation and the applications of Nernst, Butler-Volmer and Tafel equations for electrochemical systems.
4. The vital role of rate determining step, stoichiometric number and transfer coefficients in proposing the mechanism for electrochemical reactions is also covered.
5. The significance of Pourbiax and Evan's diagram in corrosion studies and passivation of metals is dealt with.

Course Objectives

1. To understand the behavior of electrolytes in solution in terms of conductance, ionic atmosphere, interactions, dissociations, etc.
2. To familiarize with the structure of the electrical double layer of different models with its applications and limitations.
3. To distinguish between Ohmic and non-Ohmic behavior of electrodes in terms of the relationship between current density and over potential.
4. To offer a plausible mechanism for electrochemical reactions based on anodic and cathodic symmetry factors and predict the order of electrochemical reactions.
5. To infer the importance of the different types of over voltages and its applications in electroanalytical techniques.

Prerequisites	Knowledge in electrochemistry

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Ionics** 1.1. Arrhenius theory -limitations, van't Hoff factor and its relation to colligative properties. Deviation from ideal behavior. Ionic activity, ion solvent and ion-ion interactions. Born equation. Debye-Huckel theory of strong electrolytes. Debye-Huckel length and potential around a central ion, its interpretation. Debye-Huckel-Bjerrum model. Debye-Huckel limiting law – derivation, modifications and applications. 1.2. Electrolytic conduction-Debye-Huckel-Onsager treatment of strong electrolyte-experimental verification and limitations. Evidence for ionic atmosphere. Ion association and triple ion formations. Anomalous conductance of non-aqueous electrolytic solution. Abnormal mobility of hydrogen and hydroxyl ions. 1.3 Evaluation of thermodynamic quantities–ΔG, ΔH and ΔS. Calculation of K_a, K_b, K_{sp}, K_w, K_h and pH using emf data.	**20**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Electrical Double Layer and Bio- electrochemistry** 2.1 Interfacial phenomena -Evidences for electrical double layer, polarisable and non-polarisable interfaces. Electrocapillarity -Lipmann's equation,electro capillary curves. Electro-kinetic phenomena electro-osmosis, electrophoresis, streaming and sedimentation potentials, mention of colloidal and poly electrolytes. 2.2 Structure of electrical double layer: Helmholtz-Perrin, Guoy-Chapmann, Stern model and Jellium models of electrical double layer-Applications and limitations. 2.3 Bio-electrochemistry: Introduction, cells and membranes, membrane potentials, theory, interfacial electron transfer in biological systems, adsorption of proteins onto metals from solution,	**17**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	electron transfer from modified metals to dissolved protein in solution, enzymes as electrodes, electrochemical enzyme-catalysed oxidation of styrene. Goldmann equation.			
III	**Electrodics of Elementary Electrode Reactions** 3.1 Behavior of electrodes: Standard electrodes and electrodes at equilibrium. IUPAC convention for anodic and cathodic currents, condition for the discharge of ions. Ohmic behavior of electrodes. Study of electrode reaction. Kinetic expression of Faraday's law. Nernst equation. Reaction resistance-polarisable and non-polarisable electrodes. The model of three electrode system, over potential. Electron transfer- under zero field, at an interface and under electric field. 3.2. Rate of electro chemical reactions: Rates of simple elementary reactions (eg. Hydrogen evolution). Butler-Volmer(B-V) equation-exchange current density, net current density and symmetry factor. Influence of over potential on current density, modifications of B-V equation – Ohmic equation, sine hyperbolic function, Faradic rectification, Low and high field approximations. Tafel equations and Tafel plots.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
IV	**Electrodics of Multistep Multi Electron System** 4.1 Rates of multi-step electrode reactions, Butler - Volmer equation for a multi-step reaction. Rate determining step, electrode polarization and depolarization. Transfer coefficients, its significance, determination, its relation with symmetry factors – elementary and multi-step reactions. Low and high field approximations. Stoichiometric number. 4.2 Elucidation of electro-chemical reaction mechanisms-rate expressions, order, and surface coverage. Reduction of I^{3-}, Fe^{2+}, and dissolution of Fe to Fe^{2+}. 4.3. Overvoltage- Chemical and electro chemical,	**20**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	Phase, activation and concentration over potentials. Evolution of oxygen and hydrogen at different pH. Corrosion and passivation of metals-rate, polarization curves, Pourbiax and Evan's diagrams.			
V	**Concentration Polarization and Electroanalytical Techniques** 5.1 Modes of Transport of electro active species - Diffusion, migration and hydrodynamic modes. The role of supporting electrolytes. Polarography- principle and applications. Principle of square wave polarography. Cyclic voltammetry- anodic and cathodic stripping voltammetry and differential pulse voltammetry. 5.2 Electrochemical processes as source of energy storage: Batteries - types, capacity, charging/discharging profile, efficiency calculations (coulombic, voltage and energy). Ragone plot comparing power density vs. energy density of batteries. Lead-acid battery, Metal-air batteries, Sodium and lithium ion batteries and redox flow batteries.Mechanism of charge storage: intercalation/deintercalation, conversion and alloying. Capacitors- mechanism of energy storage, charging at constant current and constant voltage. 5.3 Energy production systems: Fuel Cells: classification, alkaline fuel cells, phosphoric acid fuel cells, high temperature fuel cells, Solid Oxide Fuel Cells (SOFC) and solid polymer electrolyte fuel cells.	**15**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Text Books

1. D. R. Crow, Principles and applications of electrochemistry, 4thedition, Chapman & Hall/CRC, 2014.
2. J. Rajaram and J.C. Kuriakose, Kinetics and Mechanism of chemical transformations Macmillan India Ltd., New Delhi, 2011.
3. S. Glasstone, Electro chemistry, Affiliated East-West Press, Pvt., Ltd., New Delhi, 2008.
4. B. Viswanathan, S. Sundaram, R. Venkataraman, K. Rengarajan and P.S. Raghavan,

Electrochemistry-Principles and applications, S. Viswanathan Printers, Chennai,2007.
5. Joseph Wang, Analytical Electrochemistry, 2nd edition, Wiley, 2004.
6. H. K. Moudgil, Text book of Physical Chemistry, PHI Learning Pvt Ltd, 2010

Suggested Readings

1. J.O.M. Bockris and A.K.N. Reddy, Modern Electro chemistry,vol.1 and2B, Springer, Plenum Press, New York, 2008.
2. J.O.M. Bockris, A.K.N. Reddy and M.G. Aldeco Morden Electro chemistry, vol. 2A,Springer, Plenum Press , New York, 2008.
3. Philip H. Rieger, Electrochemistry, 2nd edition, Springer, New York, 2010.
4. L.I. Antropov, Theoretical electrochemistry, Mir Publishers, 1977.
5. K.L. Kapoor, A Text book of Physical chemistry, volume-3, Macmillan, 2001.
6. Allen J. Bard and Larry R. Faulkner, Electrochemical Methods, 2nd edition, John Wiley & Sons, INC

Web Resources

1. https://bit.ly/3zWfT34
2. https://bit.ly/3y4FDsO
3. https://bit.ly/3bjCWuA
4. https://youtu.be/kDt8Hzr9ZnU
5. https://nptel.ac.in/courses/104/106/104106129/
6. https://nptel.ac.in/courses/103/102/103102015/

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand the behaviour of electrolytes in solution, importance of electrode kinetics and compare the structures of electrical double layer of different models.	**K1, K2**
CO 2	To apply the Butler-Volmer and Tafel equations to predict the kinetics of electrode reactions and to classify different electroanalytical techniques.	**K3**
CO 3	To evaluate different thermodynamic parameters and illustrate the types of batteries, mechanism of corrosion, and theory of membrane potentials.	**K4**
CO 4	To outline the theories of electrolytes, importance of electrical double layer, electrodics of elementary and multistep multi electron system and to evaluate the activity coefficient of electrolytes	**K5**
CO 5	To develop the knowledge on novel energy storage devices and formulate the structure of electrical double layer and infer the electrochemical reaction mechanism.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH4MC03**
Course Title	**PHYSICAL CHEMISTRY PRACTICALS - II**
Credits	2
Hours/Week	4
Category	Major Course (MC) – Lab
Semester	IV
Regulation	2022

Course Overview

1. This course involves the determination of K_a and verification of the validity of Onsager's theory of limiting law.
2. Experimental determination of solubility product and acid strength by conductometric titrations are performed in this course.
3. Potentiometric method is adopted for the determination of the strength of Fe(II), dissociation constants of weak acids and thermodynamic functions using emf data.
4. The course deals with the measurements of pH of solutions by pH metry and colorimetry.
5. This course provides an opportunity to perform experiments using analytical instruments such as UV-VIS, FT-IR and cyclic voltammetry and interpret the results scientifically.

Course Objectives:

1. To determine the amount of chloride and iodide present in a mixture of halides by potentiometric method and solubility product of a sparingly soluble salt by conductance method.
2. To carry out the determination of the dissociation constants of mono basic and dibasic acids potentiometrically.
3. To perform redox titrations potentiometrically and acid – base titrations conductometrically.
4. To calibrate pH meter and measure pH of various buffer solutions.
5. To have hands on training on analytical instruments such as UV-VIS, FT-IR and cyclic voltammetry.

Prerequisites	Basic knowledge on Physical Chemistry

EXPERIMENTS	CONTENT	HOURS	COs	COGNITIVE LEVEL
Conductometry **Potentiometry**	1. Determination of the equivalent conductance at different concentrations and to examine the validity of the Onsager's theory as limiting law at high dilutions for a strong electrolyte. 2. Determination of the amount of HCl and CH_3COOH present in a mixture by conductometric titration using standard NaOH solution. 3. Comparison of the relative strengths of weak acids by conductance method. 4. Determination of solubility product of inorganic compounds by conductric precipitation titration. 5. Determination of hydrolysis constant of freshly prepared and dried aniline hydrochloride by conductometry. 1. Determination of the amount of KCl and KI present in a mixture by potentiometric titration. 2. Determination of pK_{a1} and pK_{a2} of a weak dibasic acid by potentiometry. 3. Determination of dissociation constant of weak acid by potentiometry. 4. Determination of the amount of KI using $KMnO_4$ by potentiometric redox titration. 5. Estimation of thermodynamic functions from EMF data. 1. Calibration of a pH meter and measurement of pH of different buffer solutions. 2. Determination of pH of the given solution with the help of indicators using buffer solutions and by colorimetric method. 1. Determination of metal to ligand ratio of	**60**	**CO1** **CO2** **CO3** **CO4** **CO5**	**K1, K2, K3, K4, K5, K6**

pH and Colorimetry **Demonstration**	complexes by Job's method using UV-visible Spectrophotometer. 2. Identification of Organic compounds using FT-IR spectrometer. 3. Determination of the concentration of a redox active material via Cyclic voltammetry and differential pulse voltammetry.			

Text Books

1. B. Viswanathan and P.S. Raghavan, Practical Physical Chemistry, Viva Books, New Delhi, 2009.
2. Sundaram, Krishnan, Raghavan, Practical Chemistry (Part II), S. Viswanathan Co. Pvt., 1996.
3. Renu Gupta, Practical Physical Chemistry, New Age International (P) Ltd., New Delhi, 2018.

Suggested Readings

1. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
2. G.W. Garland, J.W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8th edition, McGraw Hill, 2009.
3. J. N. Gurthu and R. Kapoor, Advanced Experimental Chemistry, S. Chand and Co., 1987.
4. V.D. Athawale and Parul Mathur, Experimental Physical Chemistry, New Age International (P) Ltd., New Delhi, 2008.
5. Shailendra K. Sinha, Physical Chemistry-A laboratory manual, Narosa Publishing House Pvt. Ltd., 2014.

Web Resources

1. https://bit.ly/3y8FpAU
2. https://bit.ly/3xIMKpl
3. https://bit.ly/3xOxaJ4

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the principles and concepts such as the dissociation of electrolytes, conductance, solubility product, etc.	**K1, K2**
CO 2	To scientifically perform the procedure of experiments relating to the determination of pH, pKa, strength of acids, relative strength of acids, amount of halides and salts.	**K3**

CO 3	To observe and record systematically the readings in all the experiments.	**K4**
CO 4	To calculate and process the experimentally measured values and compare with graphical data.	**K5**
CO 5	To interpret the experimental data scientifically to improve the analytical skill for a position in an industry/research laboratory.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH4PJ01**
Course Title	**PROJECT**
Credits	5
Hours/Week	15
Category	Project (PJ)
Semester	IV
Regulation	2022

Course Overview

1. This course provides an opportunity to students to carry out literature search thoroughly on a specific topic following the principles of scientific research methodology.
2. This course helps the students to write a project proposal relevant to the topic based on the literature review.
3. A systematic and scientific approach to synthesize compounds/complexes and to characterize them using sophisticated analytical techniques can be learnt in this course.
4. Analytical skills required to perform experiments, interpret the data and to present the report with a meaningful summary and conclusion can also be acquired in this course.
5. This course trains the students to harness soft skill for presenting their research findings in front of a panel of subject experts.

Course Objectives

1. To review literature on a specified topic using scientific research methodology.
2. To write the project proposal scientifically with the mention of its industrial and commercial relevance also.
3. To carry out the synthesis of compounds/complexes and characterize them using various analytical instruments for its applications.
4. To learn the scientific methodology to collect and interpret the experimental data for the presentation of the report.
5. To handle sponsored research projects of social and environmental importance.

Prerequisites	Advanced knowledge in Chemistry

SYLLABUS				
EXPT	**CONTENT**	**HOURS**	**COs**	**COGNITIVE LEVEL**
1	Performing experiments related to industrially and socially relevant projects.	**225**	**CO1 CO2 CO3**	**K1, K2, K3, K4, K5, K6**

			CO4 **CO5**	

Testing

1. The student will be tested both in subject matter of the report and the mode of presentation in a review meeting to be held in the middle of the semester, with a panel of HOD, Supervisor and two staff of the department. This progress reporting will carry 25% marks.
2. Upon submission of the project to the office of the controller of examinations at the end of the semester, the viva-voce examination will be conducted by the supervisor and the external expert suggested by the supervisor. The project report and the viva-voce will be evaluated for 75% marks.

Project Report **50 Marks**

Standard of the subject and plan
Preparation and mastery
Originality and logical development
Summary, conclusions and references

Viva-voce **25 marks**

Use of power point, teaching aids, blackboard etc.
Language, Communication and diction
Economy of time
Answer to questions

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Descriptions	**Cognitive Level**
CO 1	To recall and comprehend the concepts of scientific research methodology for literature survey.	**K1, K2**
CO 2	To characterize the synthesized compounds/complexes and to interpret the experimental data systematically.	**K3**
CO 3	To explain and infer the chemical, biological, medicinal, industrial and commercial applications of the product obtained.	**K4**
CO 4	To report and summarize the findings of their project with respect to its social and environmental importance.	**K4, K5**
CO 5	To invent and adopt novel methodologies to solve interdisciplinary projects scientifically at national and international levels.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2ME01**
Course Title	**BIOMOLECULES AND NATURAL PRODUCTS**
Credits	2
Hours/Week	4
Category	Major Elective (ME) - Theory
Semester	II
Regulation	2022

Course overview

1. The aim of the course is to explain the importance of biomolecules and the chemistry of natural products.
2. This course deals with selected biomolecules which play vital roles in primary and secondary metabolism.
3. Natural products with strong pharmacological activity and physiological effects are discussed in detail.
4. The study of biomolecules and natural products describe the involvement in various biological processes.
5. This course also focusses on the extraction and isolation of biomolecules and natural products.

Course Objectives

1. To learn the basic concepts and biological importance of biomolecules and natural products.
2. To explain various functions of carbohydrates, proteins, nucleic acids, steroids and hormones.
3. To understand the functions of alkaloids and terpenoids.
4. To elucidate the structure determination of biomolecules and natural products.
5. To extract and construct the structure of new alkaloids and terpenoids from different methods.

Prerequisites	Basic knowledge of organic chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Chemistry and metabolism of carbohydrates** 1.1 Definition, classification and biological role of carbohydrates. Monosaccharides: Linear and ring structures (Haworth formula) of ribose, glucose, fructose and mannose (structure determination not required), physical and chemical properties of glucose and fructose. 1.2 Disaccharides: Ring structures (Haworth formula) –occurrence, physical and chemical properties of maltose, lactose and sucrose. 1.3 Polysaccharides: Starch, glycogen and cellulose – structure and properties, glycolysis of carbohydrates.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**Steroids and Hormones** 2.1 Steroids-Introduction, occurrence, nomenclature, configuration of substituents. 2.2 Diels' hydrocarbon, stereochemistry, classification, Diels' hydrocarbon, biological importance, colour reactions of sterols, cholesterol-occurrence, tests, physiological activity, biosynthesis of cholesterol from squalene. 2.3 Hormones-Introduction, classification, functions of sex hormones- androgens and estrogens, adrenocortical hormones-cortisone and cortisol structure and functions of non-steroidal hormones-adrenaline and thyroxin.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
III	**Proteins and nucleic acids** 3.1 Separation and purification of proteins – dialysis, gel filtration and electrophoresis. Catabolism of amino acids - transamination, oxidative deamination and decarboxylation. Biosynthesis of proteins: Role of nucleic acids. Amino acid metabolism and urea cycle. 3.2 Structure, methods for the synthesis of nucleosides - direct combination, formation of	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	heterocyclic base and nucleoside modification, conversion of nucleoside to nucleotides. 3.3 Primary and secondary structure of RNA and DNA, Watson-Crick model, solid phase synthesis of oligonucleotides.			
IV	**Alkaloids** 4.1 Introduction, classification and isolation, biological functions, characteristic tests. 4.2 General methods of structural elucidation of alkaloids. 4.3 Chemical methods of structure determination of Atropine, Quinine, Belladine, Cocaine, Heptaphylline, Papaverine, Morphine (Synthesis and biological functions).	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
V	**Terpenoids and carotenoids** 5.1 Introduction, special isoprene rule, classification, isolation and characteristics. 5.2 General methods of structural elucidation of terpenoid and carotenoids. 5.3 Chemical methods of structure determination of Abietic acid, Camphor, Cadinene, β-Carotene, Squalene, Vitamin A, Zingiberine.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text Books

1. T. K Lindhorst, Essentials of Carbohydrate Chemistry and Biochemistry, Wiley VCH,North America,2007.
2. G. K. Chatwal, Organic Chemistry on Natural Products, Vol. 1, Himalaya Publishing House, Mumbai, 2009.
3. G. K. Chatwal, Organic Chemistry on Natural Products, Vol. 2, Himalaya Publishing House, Mumbai, 2009.
4. O. P. Agarwal, Chemistry of Organic Natural Products, Vol. 1, Goel Publishing House, Meerut, 1997.
5. O. P. Agarwal, Chemistry of Organic Natural Products, Vol. 2, Goel Publishing House, Meerut, 1997.
6. I. L. Finar, Organic Chemistry Vol-2, 5th edition, Pearson Education Asia, 1975.
7. V. K. Ahluwalia and M. Goyal, Textbook of Organic Chemistry, Narosa Publishing, New Delhi, 2000.
8. M. K. Jain and S. C. Sharma, Modern Organic Chemistry, Vishal Publishing Co., Jalandhar,

Delhi, 2014.

Suggested Readings

1. I. L. Finar, Organic Chemistry Vol-1, 6th edition, Pearson Education Asia, 2004.
2. Pelletier, Chemistry of Alkaloids, Van Nostrand Reinhold Co, 2000.
3. Shoppe, Chemistry of the steroids, Butterworthes, 1994.
4. I. A. Khan, and A. Khanum. Role of Biotechnology in medicinal & aromatic plants, Vol 1 and Vol 10, Ukkaz Publications, Hyderabad, 2004.
5. M. P. Singh and H. Panda, Medicinal Herbs with their formulations, Daya Publishing House, Delhi, 2005.
6. V. K. Ahluwalia, Steroids and Hormones, Ane books pub., New Delhi, 2009.

Web Resources

1. https://bit.ly/39LXStz
2. https://www.organic-chemistry.org/
3. https://www.studyorgo.com/summary.php
4. https://www.clutchprep.com/organic-chemistry

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand the basic concepts of biomolecules and natural products.	**K1, K2**
CO 2	To integrate and assess the different methods of preparation of structurally different biomolecules and natural products.	**K3**
CO 3	To illustrate the applications of biomolecules and their functions in the metabolism of living organisms.	**K4**
CO 4	To analyse and rationalise the structure determination of alkaloids, terpenoids and carotenoids.	**K5**
CO 5	To develop the structure of biologically important natural products by different methods	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2ME02**
Course Title	**SURFACE CHEMISTRY AND CATALYSIS**
Credits	2
Hours/Week	4
Category	Major Elective (ME) – Theory
Semester	II
Regulation	2022

Course Overview

1. Surface chemistry describes the basic properties of solid surface which includes interfacial phenomena. It deals with particle dispersions, surfactant, emulsions and micelle formation.
2. This course explores the mechanism and the applications of homogeneous, heterogeneous and micellar catalysis.
3. It provides fundamental characteristics of various colloidal systems with an in-depth understanding of the physicochemical mechanisms that govern nanoscopic and microscopic particles.
4. One of the modules in this course focuses on the concepts of photo catalysis, electrocatalysis and biocatalysis with industrial applications.
5. It presents the types, preparation and different surface characterization techniques of catalysts.

Course Objectives

1. To develop an understanding of the concept of homogeneous catalysis and its significance.
2. To understand and use adsorption isotherms for mono and multilayer adsorption on porous solid surfaces.
3. To learn the formation and characterization of surfactants, micelles and emulsion.
4. To explain the mechanism and industrial applications of photocatalysis, electrocatalysis and bio-catalysis.
5. To describe the fundamentals behind the operation of surface analytical tools such as Auger, XPS, Ion scattering and the limitation of each method.

Prerequisites	Basic knowledge of chemical kinetics.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Homogeneous catalysis** 1.1 Catalysis - Catalytic activity, promoters, inhibitors, stabilisers, catalyst supports, selectivity, kinetic and thermodynamic interpretations. Catalyst deactivation - poisoning, fouling and thermal degradation. Green catalysis, nano catalysis, phase transfer catalysis and shape selective catalysis. 1.2 Homogeneous catalysis - general mechanism, Arrhenius and van't Hoff intermediates, activation energy. Acid-base catalysis - mechanism. Acidity function - rates of acid catalyzed reactions. Bronsted catalysis law - catalytic power and acidity-base strength. 1.3 Polymerization of olefins, oxidative dehydrogenation - ethyl benzene to styrene.	**13**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Heterogeneous catalysis** 2.1 Heterogeneous catalysis - general mechanism, preparation of catalysts - precipitation and impregnation methods. 2.2 Adsorption- types, factors affecting adsorption, adsorption isotherms. Unimolecular adsorption - Freundlich, Langmuir - simple, dissociation, competitive and non-ideal adsorption. Adsorption coefficient. Multimolecular adsorption – Brunauer, Emmett and Teller, Harkins-Jura equations. Adsorption from solution - Gibbs adsorption isotherm, surface films. 2.3 Adsorption on porous solid - pore distribution and rate of the reaction, pore size and specificity of catalyst. Geometric	**13**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5,K6**

	requirements of catalysis. Heterogeneous catalysts for catalytic cracking and Fischer-Tropsch synthesis. Electrochemical hydrogen production by electrolysis.			
III	**Colloids** 3.1 Surfactants - classification, anionic, cationic and amphoteric, hydrophile-lipophile balance. 3.2 Micelles - (Micellization) formation, shape, and structure of micelles, Micellar aggregation number, critical micellar concentration (CMC), factors affecting CMC, thermodynamics of micellization - entropy change and hydrophobic effect. Micellar catalysis - electrolyte inhibition, reverse micelles and its uses. Synthesis of mesoporous materials-Liquid crystal template (LCT) mechanism 3.3 Emulsions - macro and micro emulsion, formation, phase diagram and applications. Theories of emulsion, selection of surfactants as emulsifiers, preparation, elastic and non-elastic gels.	**11**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
IV	**Photo and Biocatalysis** 4.1 Photocatalysis – Types-Homo and hetero semiconductors - TiO_2 and ZnO. Applications - degradation of dyes, solar energy conversion, electrochemical cells, photoelectrolysis of water, organic reactions - oxidation, reduction, polymerization, substitution and isomerization reaction using TiO_2. 4.2 Electrocatalysis: Mechanism of hydrogen and oxygen electrode reactions 4.3 Biocatalysis – enzyme classification, characteristics, factors affecting enzyme catalysis, enzyme inhibition - irreversible	**12**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	and reversible. Kinetics of enzyme inhibition - competitive, uncompetitive, non-competitive and degree of inhibition.			
V	**Surface Characterization Techniques** 5.1 Brunauer-Emmett-Teller (BET) surface area analysis, Barrett-Joyner-Halenda (BJH) pore size, volume analysis and de Boer t-plot method. 5.2 Thermal methods – temperature programmed desorption and reduction. 5.3 Spectroscopic techniques - Auger electron spectroscopy, Ion scattering spectroscopy, X-ray photoelectron spectroscopy.	**11**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Text Books

1. B. Viswanathan, S. Sivasanker and A.V. Ramaswamy, Catalysis: Principles and Applications, Narosa Publishing House, New Delhi, 2010.
2. B. Viswanathan, S. Kannan and R.C Deka, Catalysts and surfaces characterization techniques, Narosa Publishing House, New Delhi, 2004.
3. D. K. Chakrabarthy and B. Viswanathan, Heterogeneous catalysis, New Age International (P) Limited, Publishers, New Delhi, 2011.
4. J C Kuriacose, Catalysis, Macmillan India Limited, New Delhi, 1991.

Suggested Readings

1. J. Rajaram and J.C. Kuriacose, Kinetics and Mechanisms of chemical transformation, Macmillan India Limited, New Delhi, 2011.
2. G.C. Bond, Heterogeneous catalysis: Principles and applications, Oxford University Press, Ely House, London W.I, 1974.
3. V. Murugesan, A. Banumathi and M. Palanichamy, Recent Trends in Catalysis, Narosa Publishing House, New Delhi, 1999.
4. D. K. Chakrabarthy, Adsorption and catalysis by solids, New Age International (P) Limited, Publishers, New Delhi, 2008.
5. B Imelik and Jacques C Védrine, Catalyst characterization: physical techniques for solid materials, Plenum Press, New York, 1994.

Web Resources

1. https://bit.ly/3HDzsPz
2. https://go.nasa.gov/3y9WBWU
3. https://bit.ly/3bgprLW
4. https://bit.ly/3n5y9zj
5. https://nptel.ac.in/courses/113/104/113104004/
6. https://bit.ly/3Oc1Dr9

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand and recall definitions, basics of surface, interfacial phenomena, catalysis, colloids and surface characterization.	**K1, K2**
CO 2	To differentiate homogeneous and heterogeneous catalysis, photo and bio catalysis, express the properties of colloids and classify surface analytical tools.	**K3**
CO 3	To illustrate the mechanism involved in various catalysis and principles of conventional and spectroscopic surface characterization techniques.	**K4**
CO 4	To outline the importance of the characteristics of surface, interfacial phenomena, colloids and limitations of surface analytical techniques.	**K5**
CO 5	To develop analytical skills in interpreting the results of surface analytical tools and to choose the appropriate among homogeneous, heterogeneous, photo and bio catalyst for industrial applications and research.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH3ME01**
Course Title	**APPLIED ORGANIC CHEMISTRY**
Credits	2
Hours/Week	4
Category	Major Elective (ME) - Theory
Semester	III
Regulation	2022

Course Overview

1. The aim of the course is to impart knowledge about the techniques adopted various chemical industries.
2. The course gives a detailed account on industrial methods of chemical processes and their applications.
3. The consequences of chemical accidents and the need for green synthesis are discussed in detail.
4. The emerging methods of synthesis of various organic compounds are also discussed.
5. This course highlights the advantages and drawbacks of renewable and non-renewable energy sources towards the organic synthesis.

Course Objectives

1. To learn the techniques of chemical processes of various industries.
2. To understand the concepts of organic chemical technology and green synthesis.
3. To understand the types and functions of various catalysts used in green synthesis.
4. To correlate the advantages of microwave and ultrasonic assisted synthesis with conventional methods.
5. To design new routes to synthesize drugs.

Prerequisites	Basic knowledge of organic chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Organic Chemical Technology** 1.1 Unit operations in chemical engineering - Fluid flow, Reynold's number, Bernoulli's equation, turbulent flow, mass transfer. Distillation - two and three component systems, leaching and extraction, stirrers and driers. 1.2 Factors affecting chemical process kinetics, scaling up of reactions from laboratory to pilot plant to main plant; Materials of construction. 1.3 Study of industrial scale nitration, sulphonation and halogenation reactions, quality control, R & D and standardization.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
II	**Organometallic Compounds** 2.1 Synthesis and reactions involving organolithium (n-BuLi, PhLi), organocadmium, organomagnesium, organopalladium, organoselenium, organocobalt, organoaluminium, organosilicon- *tert*-butyldimethylsilyl chloride, and organocopper. 2.2 Organo rhodium and ruthenium compounds: Pauson-Kand reaction, olefin metathesis, Grubb's catalyst. 2.3 Reactions promoted by samarium diiodide and dicyclopentadienyl samarium - Barbier type reaction, ketyl-alkene coupling reactions, pinacolic coupling reactions, acyl anion reactions and McMurray olefination.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
III	**Polymer supported Reagents in Organic Synthesis** 3.1 Introduction, choice of polymers, properties, advantages of polymer support and reagents. 3.2 Intramolecular cyclization reactions, bromination by using poly-N-bromosuccinimide, use of polystyrene carbodiimide. 3.3 Acylation with polystyrene anhydride, diazo transfer reaction, Wittig reactions, alkylation,	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

	oxidation with peracid and chromic acid. Use of polymer supported photosensitizers.			
IV	**Green Chemistry and Phase Transfer Catalysts** 4.1 Chemical accidents, terminologies and twelve principles. Designing green synthesis-green reagents: dimethyl carbonate. Green solvents: Water, Ionic liquids-criteria, general methods of preparation, effect on organic reaction. 4.2 Supercritical carbon dioxide- properties, advantages, drawbacks and a few examples of organic reactions in $scCO_2$. Green synthesis-adipic acid and catechol. 4.3 Phase transfer catalysts - types, mechanism, advantages, preparation of quaternary ammonium salts. Synthetic applications - substitution, esterification, addition, condensation and polymerization reactions.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6
V	**Microwave Synthesis and Sonochemistry** 5.1 Microwave assisted synthesis - Principle, types, limitations and precautions. 5.2 Applications - Esterification, deprotection of esters and ethers, C- and N-alkylation and condensation of active methylene compounds, rearrangements, synthesis of enamino-ketones and electrophilic alkenes. 5.3 Sonochemistry - Principle, types and precautions. Applications - Esterification, hydrolysis, substitution, addition, oxidation, reduction and coupling reactions.	12	CO 1 CO 2 CO 3 CO 4 CO 5	K1, K2, K3, K4, K5, K6

Text Books

1. W. L. McCabe, J.C. Smith and P. Harriott, Unit Operations of Chemical Engineering, 7thedition, McGraw-Hill, NewDelhi,2005.
2. J. M. Swan and D. St. C. Black, Organometallics in Organic Synthesis, Chapman Hall,1974.
3. V. K. Ahluwalia and R. Aggarwal, Organic Synthesis: Special Techniques, Narosa Publishing House, New Delhi,2001.
4. K. Tanaka, Solvent Free Organic Synthesis, Wiley VCH, Weinheim,2003.
5. Asim K. Das, Environmental Chemistry with Green Chemistry, Books and Allied (P) Ltd, 2010.

6. A. K. De, Environmental Chemistry, New Age Publications, 2017.
7. Chandrakanta Bandyopadhyay, An Insight into Green Chemistry, Books and Allied (P) Ltd, 2019.
8. Francis.A. Carey and Robert. M. Giuliano, Organic Chemistry, 8th edition, McGraw Hill education, 2012.
9. Robert Whyman, Applied Organometallic Chemistry and Catalysis, Oxford Chemistry Primers, Indian edition, 2005.
10. Manfred Bochmann, Organometaalics-1 Complexes with Transition Metal-Carbon σ-bonds, Oxford Chemistry Primers, Indian edition, 2005.
11. B. D. Gupta and A. J. Elias, Basic organometallic chemistry, 2nd edition, universities press, 2013.
12. Robert H. Crabtree, Organometallic Chemistry, Wiley, 6th edition, 2014.

Suggested Readings

1. P. H. Groggins, Unit Processes in Organic Synthesis, 5th edition, Tata McGraw Hill, New York, 1995.
2. C. E. Dridens, Outlines of Chemical Technology, Affiliated East-West Press Pvt. Ltd, 2001.
3. C. A. Clausen and G. Matson, Principles of Industrial Chemistry, John Willey & Sons, New York, 1978.
4. M. Larhed, and K. Olofsson, Topics in current chemistry, Springer, 266, 2006
5. R. Sanghi and M. M. Srivastava, Green chemistry, Environment Friendly Alternatives, Narosa Publishing House, 2007.
6. V. K. Ahluwalia, Green Chemistry, Ane Books Pvt. Ltd., 2006.
7. B. Michael Smith, Organic synthesis, McGraw Hill International Edition, 1994.
8. Methods and Reagents in Green Chemistry, Edited by P. Tundo, A. Perosa and F. Zacchini, Wiley-Interscience, 2007.

Web Resources

1. https://bit.ly/3zOzJ0c
2. https://www.organic-chemistry.org/
3. https://www.studyorgo.com/summary.php
4. https://www.clutchprep.com/organic-chemistry

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic chemical techniques used in conventional industrial preparations and in green innovations.	**K1, K2**
CO 2	To understand the various techniques used in chemical industries and in laboratory.	**K3**

CO 3	To compare the advantages of organic reactions assisted by renewable energy sources and non-renewable energy sources.	**K4**
CO 4	To apply the principles of PTC, ionic liquid, microwave and ultrasonic assisted organic synthesis.	**K5**
CO 5	To design and synthesize new organic compounds by green methods.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH3ME02**
Course Title	**ORGANOMETALLIC CHEMISTRY**
Credits	2
Hours/Week	4
Category	Major Elective (ME) - Theory
Semester	III
Regulation	2022

Course Overview

1. This course comprises of the basic concepts of organometallic, supramolecular and bio-organometallic chemistry.
2. The aim of the course is to apply the basic concepts to understand the reactive mechanism of organometallic compounds as catalysts.
3. This course also explains the nature of bonds, types and various theories of organometallic compounds.
4. In this course, different types of reactions in metal carbonyls, cluster and polymers are also explained.
5. The other important aspects of this paper are to understand the chemistry of organometallic compounds and supramolecules in the biosystems.

Course Objectives

1. To recall the basic concepts of organometallic, supramolecular and bio-organometallic chemistry.
2. To predict the properties and applications of various organometallic compounds.
3. To construct MO diagram to predict the structure of metal carbonyls using 18- electron rule.
4. To apply the knowledge of reaction and bonding of supramolecules.
5. To formulate methods of reactions involved in the bio-organometallic chemistry.

Prerequisites	Basic knowledge of coordination chemistry.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Organometallic compounds** 1.1 Introduction: Classification, hapticity. Nomenclature, 14-, 16- and 18-electron rule-counting electrons in ligands. Preparation, structure and properties of organometallics of alkali (Li) and alkaline earth metals (Grignard reagents), group 13-15 elements and comparison with Group-12 elements. 1.2 □□bonded organometallics of transition elements: Synthesis, carbanion exchange, transmetalation, elimination, cyclo-metalation and metal atom reactions. M-C bond cleavage (Ti and Zr complexes), alkene elimination and proton abstraction, adduct formation and insertion reactions. 1.3 π□bonded organometallics of transition elements: Classification of ligands, synthesis, reactions, structure and bonding-metal carbene, carbyne complexes, Fischer and Schrock carbine complexes and Zeise's salt. 1.4 Enyl complexes: Classification, Allyl(η^3) complexes–synthesis, reactions, structure and bonding-stereoisomerism, fluxional behaviour. Cyclopentadienyl (η^5) complexes: Metallocene-synthesis, properties, structure, bonding (*MOT*) in ferrocene, nickelocene, cobaltocene, uranocene and vanadocene. Reactions of ferrocene.	**16**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Reactions and Catalysis** 2.1 Reactions: Nucleophilic substitution– dissociative and associative mechanisms, photochemical reactions of metal carbonyls, insertion and deinsertion, carbonylation and decarbonylation reactions. Mechanism and stereochemistry of oxidative addition, reductive elimination, transmetalation, carbometalation, migratory insertion, *β*–hydride elimination.	**16**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	2.2 Organometallics as catalyst: Hydrogenation of alkene-Wilkinson's catalyst, oxo process, Wacker process, monsanto acetic acid synthesis, Ziegler-Natta catalyst-polymerization of olefin. 2.3 Preparation of synthesis and water gas shift reactions, synthetic gasoline-ZSM-5 catalyst and Fischer–Tropsch process. Palladium metal based coupling reactions: Heck reaction, Suzuki coupling, Sonogashira coupling, Stille coupling, Negishi coupling reactions.			
III	**Metal Carbonyls, Clusters and Polymers** 3.1 Metal carbonyls: Introduction, metal–metal bonding, preparation, structure and bonding (*MOT*) of CO, evidence of π–back bonding, spectral distinction of bridging and terminal. Nucleophilic and electrophilic additions, Collman's reagent and migratory insertion. 3.2 Transition metal clusters: Introduction, classification, structural characteristics, cluster geometries, tri-, tetra-, penta-, hexanuclear. Bonding: polyhedral skeletal electron pair theory, isolobal relationships, reactivity and catalysis. 3.3 Mixed clusters: Structure and bonding in hydride and carbide clusters. Wade's rule, halide cluster, Chevrel phases, zintel ions, capping and Mingo's rule. 3.4 Organometallic polymers: Introduction, ferrocene based condensation polymers.	**16**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
IV	**Supramolecular chemistry** 4.1 Host-guest chemistry: Classifications, thermodynamics and kinetic stability, lock and key model, macrocyclic systems-crown ethers. 4.2 Molecular recognition: Role of crown ether, rodents, cryptands, spherands, calixarenes and siderophores. 4.3 Dendrimers: Synthesis–divergent and convergent, dendrimeric photochemical device. Molecular wires, switches and rectifiers-	**6**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	Applications.			
V	**Bio-organometallic Chemistry** 5.1 Organometallic enzymes: coenzymes, vitamin B_{12}.correnoid-reactions, mimic compounds of vitamin B_{12}. 5.2 Heavy metal poisoning–mercury and arsenic. 5.3 Organometallic drugs: anticancer (Ru) and ferrocifen-mechanism, antimalarial drug-ferroquine, radiopharmaceuticals, tracers, ionophores and sensors.	**6**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Textbooks

1. R. Gopalan, V. Ramalingam, *Concise Coordination Chemistry*, S. Chand, 2001.
2. F. A. Cotton and G. W. Wilkinson, *Advanced Inorganic Chemistry*, 5th edn, John Wiley & Sons, 1988.
3. K. F. Purcell and J. C. Kotz, *Inorganic Chemistry*; Saunders: Philadelphia, 1976.
4. Ajai Kumar, *Coordination Chemistry*, 6th edn., Aaryush Education, 2020.
5. B. D Gupta and A.J Elias, *Basic Organometallic Chemistry*, 2nd edn., Universities Press, 2013.
6. Puri, Sharma and Kalia, *Principles of Inorganic Chemistry*, 33rd edn., Vishal Publishing Co., 2017.
7. C. E. Housecraft and A. G. Sharpe, *Inorganic Chemistry*, 4th edn., Pearson, 2012.
8. R. H. Crabtree, *Organometallic Chemistry of the Transition Metals*, 2nd edn., John Wiley, 1993.
9. J. W. Steed and J. L. Atwood, *Supramolecular chemistry*, Wiley, New York, 2000.
10. S. J. Lippard and J. M. Berg, *Principle of Bioinorganic Chemistry*, University Science Books, 1994.

Suggested Readings

1. J. E. Huheey, E. A. Keiter and R. L. Keiter, *Inorganic Chemistry, Principle, structure and reactivity*, 4th edn., Harper Collins, 1993.
2. D. F. Shriver and P. W. Atkins, *Inorganic Chemistry*, 3rd edn., Oxford, 2008.
3. B. E. Douglas, D. H. McDaniel and J. J. Alexander, *Concepts and Models of Inorganic Chemistry*, 3rd edn., John Wiley, 1993.
4. A. Yamamoto, *Organotransition Metal Chemistry: Fundamental Concepts and Applications*, John Wiley 1986.
5. T.P. Fehlner, J. Halet, J. Saillard, *Molecular clusters: a bridge to solid-state chemistry* Cambridge University Press, 2007.
6. F. A. Cotton, C. A. Murillo and R. A. Walton (Eds.), *Multiple Bonds between Metal Atoms,* Springer Science and Business Media, Inc. 2005.
7. W.L. Jolly, *Modern Inorganic Chemistry*, 2ndedn, McGraw–Hill, Inc., 1991.
8. H. J. Schneider and A. Yatsimirsky, *Principles and methods in Supramolecular chemistry*, Wiley,

New York, 2000.
9. J. M. Lehn, *Supramolecular chemistry: Concepts and Perspectives*, VCH, Weinheim, 1995.

Web Resources

1. https://bit.ly/3OxwNt5
2. https://bit.ly/3n7weum
3. https://bit.ly/3bhcJwG

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To recall the basic concepts of the organometallic, supramolecular and bio-organometallic chemistry.	**K1, K2**
CO 2	To predict the properties and applications of various organometallic compounds.	**K3**
CO 3	To construct MO diagram to predict the structure of metal carbonyls using 18-electron rule.	**K4**
CO 4	To apply the knowledge of reaction and bonding of supramolecules.	**K5**
CO 5	To formulate methods to synthesise novel organometallic compounds as industrial catalyst.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH3ID01**
Course Title	**MATERIALS SCIENCE**
Credits	3
Hours/Week	6
Category	Interdisciplinary (ID) - Theory
Semester	III
Regulation	2022

Course Overview

1. Materials science is an interdisciplinary subject, covering the physics and chemistry of matter, engineering applications and industrial manufacturing processes.
2. Materials science enables to design and develop competitive products.
3. In this course, correlations between structure and properties of crystals are also established.
4. It also explains developments in the field of crystallography, special materials, nanotechnology and renewable energy conversion materials.
5. Structure-property relationships discussed in this course will give an exposure to develop new materials for energy conversion and devices.

Course Objectives

1. To understand the crystal structure, growth methods and X-ray scattering.
2. To explain the optical, dielectric and diffusion properties of crystals.
3. To recognize the basis of semiconductors, superconductivity materials and magnets.
4. To study the synthesis, classification and applications of nanomaterials.
5. To learn about the importance of materials used for renewable energy conversion.

Prerequisites	Basic knowledge of physics and chemistry of materials.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**Crystallography** 1.1 Crystallography: symmetry - unit cell and Miller indices -crystal systems - Bravais lattices - point groups and space groups - X-ray diffraction-Laue equations-Bragg's law-reciprocal lattice and its application to geometrical crystallography. 1.2 Crystal structure–powder and single crystal-applications. Electron charge density maps, neutron diffraction-method and applications. 1.3 Crystal growth methods - nucleation–equilibrium stability and metastable state. Single crystal –Low and high temperature, solution growth– Gel and sol-gel. Melt growth – Bridgeman - Stockbarger, Czochralski methods. Flux technique, physical and chemical vapour transport. Lorentz and polarization factor - primary and secondary extinctions. 1.4 X-ray scattering: Atomic scattering factor - diffraction by a space lattice structure factor equation -electron density and Fourier series – Fourier Transform and crystal diffraction - diffraction by real crystals - Lorentz and polarization factor - primary and secondary extinctions.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**Properties of crystals** 2.1 Optical studies - Electromagnetic spectrum (qualitative) refractive index – reflectance – transparency, translucency and opacity. Types of luminescence – photo-, electro-, and injection luminescence 2.2 LEDs – organic, Inorganic and polymer LED materials - Applications. 2.3 Dielectric studies- Polarisation - electronic, ionic, orientation, and space charge polarisation. Effect of temperature. dielectric constant, dielectric loss. Types of dielectric breakdown–intrinsic, thermal,	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	discharge, electrochemical and defect breakdown. 2.4 Optical fibers-composition-types-manufacturing of the fibers. Phosphor, LASER, Nd laser, Garnet Lasers, Photonics-laser skin resurfacing-CO_2 laser - lasers in dermatology.			
III	**Nanomaterials** 3.1 Introduction-role of size, classification - 0D, 1D, 2D, 3D. Synthesis - Bottom–Up, Top–Down, consolidation of Nano powders. 3.2 Synthesis- Physical and chemical methods - inert gas condensation, arc discharge, laser ablation, sol-gel, solvo-thermal and hydrothermal - CVD-types, metallo organic, plasma enhanced, and low-pressure CVD. Microwave assisted and electrochemical synthesis. 3.3 Nanoparticles: gold and silver, metal oxides: silica, iron oxide and alumina – synthesis and properties. Core-shell nanoparticles-types, synthesis, and properties. Nanocomposites-metal-, ceramic- and polymer-matrix composites-applications. 3.4 Characterization – SEM, TEM and AFM-principle, instrumentation and applications.	**18**	**CO1** **CO2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5,K6**
IV	**Special Materials** 4.1 Semiconductor materials – classification-Ge, Si, GaAs, SiC, GaN, GaP, CdS,PbS. Identification of materials as p and n –type semiconductor-Hall effect - quantum and anomalous, Hall voltage - interpretation of charge carrier density. Applications of semiconductors: p-n junction as transistors and rectifiers, photovoltaic and photogalvanic cell. 4.2 Superconductivity: Meissner effect, Critical temperature and critical magnetic Field, Type I and II superconductors, BCS theory-Cooper pair, Applications. 4.3 Soft and hard magnets – Domain theory-Hysteresis Loop-Applications. Magneto resistance	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	and gian magneto resistance. Ferro, ferri and antiferromagnetic materials-applications, magnetic parameters for recording applications. 4.4 Ferro-, Piezo-, and pyro electric materials – properties and applications. Shape memory Alloys-characteristics and applications, Non-linear optics-Second Harmonic Generators, mixing of Laser wavelengths by quartz, ruby and $LiNbO_3$.			
V	**Materials for Renewable Energy Conversion** 5.1 Solar Cells: Organic, bilayer, bulk heterojunction, polymer, perovskite based, hybrid solar cells. Efficiency and limiting factors. 5.2 Solar energy conversion: lamellar solids and thin films, dye-sensitized photo voltaic cells, coordination compounds anchored onto semiconductor surfaces - Ru(II) and Os(II) polypyridyl complexes. 5.3 Photochemical activation and splitting of water, CO_2 and N_2. Manganese based photo systems for water-splitting. Complexes of Rh, Ru, Pd and Pt - photochemical generation of hydrogen from alcohol.	**18**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

Text Books

1. S. Mohan and V. Arjunan, Principles of Materials Science, MJP Publishers, 2016.
2. Arumugam, Materials Science, Anuradha Publications, 2007.
3. Giacavazzo et. al., Fundamentals of Crystallography, International Union of Crystallography. Oxford Science Publications, 2010
4. Woolfson, An Introduction to Crystallography, Cambridge University Press, 2012.
5. James F. Shackelford and Madanapalli K. Muralidhara, Introduction to Materials Science for Engineers. 6th ed., PEARSON Press, 2007.
6. P.K. Palanisamy, Materials Science, Scitech Publications, India, 2002.
7. T. Balachandran, Materials Science, Charulatha Publications, India, 2003.
8. Charles P. Poole, Jr., Frank J. Owens, Introduction to nanotechnology, Wiley-India, 2009.
9. T. Pradeep, Nano: The Essentials, Tata McGraw-Hill Publishing Company Limited, 2007.
10. T. Pradeep, A Text book of nanoscience and nanotechnology, Tata Mc-Graw Hill, New Delhi, 2012.
11. B.K. Hodge, Alternate Energy Systems and Applications, John Wiley & sons, Inc., 2010.
12. N. Armaroli, V. Balzani and N. Serpone, Powering Planet Earth – Energy Solutions for the Future, Wiley, 2012.

13. Alan J. Heeger, Niyazi Serdar Sariciftci and Ebinazar B. Namdas, Semiconducting and Metallic Polymers, Oxford Univ Press 2010.
14. Sukhatme S.P, Nayak J.K, "Solar Energy", Tata McGraw Hill Education Private Limited, New Delhi, 2010.
15. George W. Sutton: "Direct Energy Conversion", McGraw Hill, 1996.
16. Solar Photovoltaics: Fundamentals, Technologies and Applications, C. S. Solanki, Prentice Hall of India, 2011.

Suggested Readings

1. M.G. Arora, Solid State Chemistry, Anmol Publications, New Delhi, 2001.
2. R.K. Puri and V.K. Babbar, Solid State Physics, S Chand and Company Ltd, 2001.
3. C. Kittel, Solid State Physics, John-Wiley and sons, NY, 1966.
4. H.P. Meyers, Introductory Solid State Physics, Viva Books Private Limited, 1998.
5. A.R. West, Solid State Chemistry and Applications, John-Wiley and sons, 1987.
6. B. Viswanathan, Nanomaterials, Narosa Publishing House Pvt. Ltd., New Delhi, 2009.
7. Sulabha K. Kulkarni, Nanotechnology - Principles and Practices, Capital Publishing Company, New Delhi, 2007.
8. S. Shanmugam, Nanotechnology, MJP Publishers, Chennai, 2010.
9. P. M. Sivakumar, V.I. Kodolov, G. E. Zakie, A. K. Haghi, Nanostructure, Nanosystems, and Nanostructured Materials: Theory-Production and Development, Technology 2013.
10. L. Liu and S. Bashir, Advanced Nanomaterials and their Applications in Renewable Energy, Elsevier Science, 2015.
11. Elaine A. Moore, Lesley E. Smart, "Solid State Chemistry - An Introduction", 5th Edition, ISBN 9780367135720, 2020 by CRC Press.

Web Resources

1. http://xrayweb.chem.ou.edu/notes/symmetry.html.
2. http://www.uptti.ac.in/classroom-content/data/unit%20cell.pdf.
3. https://bit.ly/3QyVg2R
4. https://www.mdpi.com/journal/nanomaterials.
5. https://www.vssut.ac.in/lecture_notes/lecture1428910296.pdf

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive Level
CO 1	To understand and recall the synthesis and characteristics of crystal structures, semiconductors, magnets, nanomaterials and renewable energy materials.	**K1, K2**
CO 2	To integrate and assess the structure of different materials and their properties.	**K3**
CO 3	To analyse and identify new materials for energy applications.	**K4**
CO 4	To explain the importance of crystal structures, piezoelectric and pyroelectric materials, nanomaterials, hard and soft magnets, superconductors, solar cells, electrodes, LEDs uses, structures and synthesis.	**K5**
CO 5	To design and develop new materials with improved property for energy applications.	**K6**

COURSE DESCRIPTOR

Course Code	**PCH2CD01**
Course Title	**CHEMISTRY OF CONSUMER PRODUCTS**
Credits	1
Hours/Week	3
Category	Cross Disciplinary (CD) - Theory
Semester	II
Regulation	2022

COURSE OVERVIEW

1. This course intends to provide fundamental aspects of chemistry of consumer products.
2. It also highlights the applications of consumer products.
3. This paper explores the various analytical techniques used to study the standard of consumer products.
4. The course covers the hygiene and usage of food additives.
5. The course also describes the various components of manufacture of consumer products.

COURSE OBJECTIVES

1. To understand the scientific bases for common consumer products.
2. To study the functions and applications of consumer products.
3. To estimate the standard of various consumer products.
4. To justify the usage of additives in modern food components.
5. To compile the various components in the manufacture of soaps, detergents, perfumes and cosmetics.

PREREQUISITES	Basic knowledge of science.

UNIT	CONTENT	HOURS	COs	COGNITIVE LEVEL
I	**SOAPS** 1.1 Definition, Saponification of oils and fats, Mechanism of action of soap. 1.2 Manufacture of soaps, formulation of toilet soaps. Different ingredients used and their functions. 1.3 Types: Medicated, herbal, hard, soft, shaving soaps and creams - examples. ISI specifications, testing procedures and limits.	**9**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
II	**DETERGENTS** 2.1 Mechanism of action and types. 2.2 Anionic detergents: Manufacture of LAB (linear alkyl benzene), sulphonation of LAB – preparation of acid slurry, different ingredients in the formulation of detergent powders and soaps, liquid detergents, foam boosters. 2.3 Cationic and non–ionic detergents: examples. Manufacture and applications - ethylene oxide condensate. 2.4 Comparison of soaps and detergents, biodegradation–environmental effects, BIS specifications / limits.	**9**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
III	**PERFUMES** 3.1 Introduction, components of a perfume: vehicle, perfumery substances, fixatives. 3.2 Groups of odorous substances: essential oils, isolates, synthetics and semi-synthetics - alcohols, esters, ketones. Methods of extraction from essential oils: expression method, steam distillation, using volatile solvents, adsorption on purified fats and prickling	**9**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	process. 3.3 Types of fixatives: animal, resinous, essential oil and synthetic.			
IV	**SKIN PREPARATIONS** 4.1 Face and skin powders – Ingredients and functions, types, snow and face creams. 4.2 Antiperspirants, sun-screen – preparations. UV absorbers, skin bleaching agents, depilatories, turmeric and neem powder preparation, vitamin oil. 4.3 Nail polishes - preparation, nail polish removers, article removers, lipsticks, roughages, eyebrow pencils - ingredients and functions, hazards, ISI specifications.	**9**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**
V	**FOOD ADULTERATION AND HYGIENE** 5.1 Adulterants: Common adulterants in different foods–milk and milk products, vegetable oils and fats, spices and condiments, cereal, pulses, sweetening agents and beverages, contamination with toxic chemicals–pesticides and insecticides, principles involved in the analysis of detection and prevention of food adulteration. 5.2 Methods of food preservation and processing, food deterioration. 5.3 Quality Control: Specifications and standards: FSSAI, Portable Format for Analytics (PFA), Fruit Product Order (FPO), Food and Drug Administration (FDA), drug license, World Health Organisation (WHO) standards, Indian Standards Institution (ISI) specifications, packing and label requirements, essential commodities act, consumer protection	**9**	**CO 1** **CO 2** **CO 3** **CO 4** **CO 5**	**K1, K2, K3, K4, K5, K6**

	act, Agricultural Marketing (AGMARK).			

Text Books

1. S. Gobala Rao, 1998, Outlines of chemical technology, 2nd Edition, Affiliated East West press.
2. W. Sawyer, 2000, Experimental cosmetics, 1st Edition, Dover publishers, New York
3. P. Romanowski and R. Schueller, 2009, Beginning Cosmetic Chemistry, 3rd Edition, Allured Books Media, USA
4. M. Swaminathan, 1993, Advanced Text Book on Food and Nutrition, Vol. I & II, 2nd Edition, Printing and Publishing Co., Ltd., Bangalore
5. N. Norman Potter, 1994, Food Science, 5th Edition, CBS publishers and distributors, New Delhi.
6. L.H. Meyer, 1994, Food Chemistry, Latest Edition, CBS publishers and distributors, New Delhi.
7. H.K. Chopra and P.S. Panesar, 2010, Food Chemistry, Latest Edition, Narosa Publishing House.
8. M. Vimaladevi, 2019, Text Book of Cosmetics, New Edition, CBS publishers and distributors, New Delhi.

Suggested Readings

1. K. Bagavathi Sundari, 2006, Applied chemistry, 1st Edition, MJP Publishers.
2. V.K. Ahluwalia, 2010, Organic chemistry, Narosa Publications house.
3. Owen R Fennema, 1996, Food Chemistry, 1st Edition, Marcel Decker Inc, NewYork.
4. B. Srilakshmi, 2003, Food Science, 3rd Edition, New Age International Pvt. Ltd.
5. B. Siva Sankar, 2002, Food Processing and Preservation, 1st Edition, Prentice–Hall of India Pvt .Ltd. New Delhi.
6. S. Ramakrishnan, K.G. Prasannam and R. Rajan, 2001, Text book of Medical biochemistry, 2nd Edition, Orient Longman Ltd.
7. N. Shakuntala Manay and M. Shadaksharaswamy, 2002, FOODS: Facts and Principles, 2nd Edition, New age International pvt. Ltd.
8. John Emsely, Chemistry at Home, 2015, Royal Society of Chemistry.
9. André O. Barel, Marc Paye, Howard I. Maibach: Handbook of Cosmetic Science and Technology, 2014, Fourth Edition: 4th Edition, CRC Press.
10. G. R. Chatwal, Synthetic organic chemistry, 3rd edition, Himalaya Publishing House, New Delhi, 2016.

Web Resources

1. https://bit.ly/3ya27J6
2. https://bit.ly/3b42Vpx
3. https://bit.ly/3OLZyT1

4. https://bit.ly/3bdd5UY
5. https://bit.ly/3N8IkOc

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO DESCRIPTION	Cognitive Level
CO1	To understand the scientific bases of consumer products.	K1, K2
CO2	To apply the basic concepts in interpreting the functions of consumer products.	K3
CO3	To analyze and recommend various analytical techniques to assess the standard of various consumer products.	K4
CO4	To appraise the adverse impact of adulterants used in the food materials and consumer products.	K5
CO5	To summarize and validate the effect of various chemical constituents used in consumer products.	K6

COURSE DESCRIPTOR

Course Code	**PCH3VA01**
Course Title	**HERBAL PRODUCT DEVELOPMENT AND FORMULATION**
Credits	1
Hours/Week	2
Category	Value Added Course (VAC) - Theory
Semester	III
Regulation	2022

Course Overview

1. This course intend to provide the fundamental aspects of chemistry of herbal medicine
2. It also highlights the applications of compounds of plants origin.
3. This paper explores the various analytical techniques used to study the standard of herbal medicinal products.
4. The course covers the hygiene and usage of herbal products
5. The course also describes the various components of manufacture of herbal medicines and their medicinal applications.

Course Objectives

1. To understand the indigenous tradition of herbal medicinal practice and to impart awareness regarding the vitality of herbal product development
2. To train the students to develop entrepreneurial skill in herbal product production and marketing
3. To familiarize the medicinal uses to herbals and to scientifically validate and standardize crude drugs.
4. To justify the usage of herbs in modern medicinal formulation.
5. To compile the various components in the manufacture of medicine

Prerequisites	Basics of Chemistry

UNIT	CONTENT	HOURS
I	**Introduction to Herbs and Herbal Medicines** 1.1 Importance of Herbs in human life - Medicinal properties of Herbal plants - Chronic diseases and Herbs - Traditional medicines and its worldwide applications 1.2 Herbal Based industry: Scope, study of infrastructure, staff requirements, project profiles, equipment, processing, regulatory requirements, research and development. 1.3 Role of natural products in herbal medicines. General status and importance of herbal medicines in the chronic diseases. Safety of herbals/herbal pharmacovigilance. W.H.O Policy on herbal medicines.	6
II	**Herbal Processing and Extraction Process** 2.1 Definition of herb, herbal extraction, herbal medicines and herbal drug preparations - Process of phytochemical/Bioactive compounds extraction and isolation - Extraction techniques - Maceration, Percolation, Soxhlet, etc - Isolation of potential bioactive compounds through TLC, column chromatography and prep-HPLC techniques 2.2 Preparation of Kuzhi Thailam, Kashayam, Suranam, etc. - Synthetic approach for the identified active compounds to ease the cost effective herbal drug product availability. 2.3 Source, selection, identification and authentication of herbal materials - Drying and processing of herbal raw materials. Packing and labelling of finished products.	6
III	**Standardization of Herbal Extracts as per WHO/cGMP Guidelines** 3.1 Physical, chemical, spectral and toxicological standardization - Chromatographic and Spectrometric - Qualitative and quantitative estimations exemplified by the methods of preparation of at least two standardized extracts. 3.2 Stability studies for the different types of extracts and its secondary metabolites. Predictable chemical and galenical changes. 3.3 Structure based Drug Design Approach: Enhancement of bioactivity through structural modification on the identified phytoconstituents - Isomeric compounds and its specificity in bioactivity.	6

IV	**Herbal Product Development** 4.1 Preparation of liquid orals, tablets, capsules, ointments, creams and cosmetics Methods involved in monoherbal and polyherbal formulation with their merits and demerits. Excipients used in herbal formulation - Synergistic effects of combined Herbal medicines 4.2 Study of Drugability: Compatibility studies, Stability studies, Bioavailability and Pharmacokinetic aspects for herbal drugs with examples of well-known documented and clinically used herbal drugs - Drugability comparison with the existing standard drugs. 4.3 Quality Control of finished herbal medicinal products.	**6**
V	**Screening of Natural Products for the Following Biological Activities** 5.1 Method for the identification and screening of potential bioactive compounds through TLC, HPLC, GC and Mass Spectrometry. 5.2 Thermal stability of secondary metabolites present in the Herbal plants during the initial screening - Identification of Active Principals, Examples of any five bioactive compounds and their medicinal uses. 5.3 Screening of natural products for the following biological activities (a) Antidiabetic (b) Anticancer (c) Antihypertensive (d) Antiarrhythmics (e) Antipyretics (f) Antioxidants (g) Antibacterial (h)Antifungal (i) Antiepileptic (j) Osteoporosis (k) Nephroprotective (l) Immunomodulators (m) Alzheimers (n) Antifertility	**6**

Text Books

1. Trease, G.E. and Evans, W.C., Pharmacognosy. 13th Edition, Baillière Tindall, London, 1989.
2. Wallis T.E., Textbook of Pharmacognosy, 5th Edition, New Delhi: CBS, 2005.
3. AC Moffat, Clarke's Isolation and Identification of Drugs. 2nd ed. The Pharmaceutical Press. 1986.
4. C.K. Kokate, Purohit, Ghokhale, Text book of Pharmacognosy 5th edn, Nirali Prakassan., 1996.
5. Harborne, J.B., Phytochemical Methods. Chapman and Hall Ltd., London, 1973.

Suggested Readings

1. A.A. Farooqui and B.S. Shreeramu, Cultivation of medicinal and aromatic crops, 1st edn, University press, 2001.
2. S.N. Yoganarasimhan, Medicinal plants of India, 1st edn, Interline publication Pvt. Ltd., 2000.
3. Paul M. Dewick, Medicinal natural products (a biosynthetic approach), 1st edn, John Wiley and sons Ltd., England 1998.
4. Peter B. Kaufman, Natural Products from plants, 1st edn, CRC press, New York, 1998.

5. P. Pushpangadam, UIF Nyman, V. George, Glimpses of Indian Ethanopharmacology, Tropical botanic Gardon and research institute, 1995.
6. Raphael Ikan, Natural Products, A lab guide, 2nd edn, academic press, 1991.

Web Resources

1. https://pubmed.ncbi.nlm.nih.gov/24290486/
2. https://wholisticmatters.com/
3. https://www.ncbi.nlm.nih.gov/
4. https://www.hopkinsmedicine.org/
5. https://cdri.res.in/Herbal.aspx

Course Outcomes (COs) and Cognitive Level Mapping

COs	CO DESCRIPTION	Cognitive Level
CO1	Understand the scientific bases of herbal medicinal products.	K1, K2
CO2	To apply the basic concepts in interpreting the functions of herbal medicinal products.	K3
CO3	To analyse and recommend various analytical techniques to assess the standard of various herbal medicinal products.	K4
CO4	Appraise the adverse impact of adulterants used in the herbal medicinal products.	K5
CO5	Summarize and validate the effect of various chemical constituents used in herbal medicinal products.	K6

LOCF BASED DIRECT ASSESSMENTS

COGNITIVE LEVEL (CL) AND COURSE OUTCOME (CO) BASED CIA QUESTION PAPER FORMAT (PG)

SECTION		Q. NO	COGNITIVE LEVEL (CL)					
			K1	K2	K3	K4	K5	K6
A	(5 x 1 = 5) Answer ALL	1(a)	+					
		(b)	+					
		(c)	+					
		(d)	+					
		(e)	+					
	(5 x 1 = 5) Answer ALL	2(a)		+				
		(b)		+				
		(c)		+				
		(d)		+				
		(e)		+				
B	(1 x 8 = 8) Answer 1 out of 2	3			+			
		4			+			
C	(1 x 8 = 8) Answer 1 out of 2	5				+		
		6				+		
D	(1 x 12 = 12) Answer 1 out of 2	7					+	
		8					+	
E	(1 x 12 = 12) Answer 1 out of 2	9						+
		10						+
No. of CL based Questions with Max. marks			5 (5)	5 (5)	1 (8)	1 (8)	1 (12)	1 (12)
No. of CO based Questions with Max. marks			CO1		CO2	CO3	CO4	CO5
			10 (10)		1 (8)	1 (8)	1 (12)	1 (12)

Forms of questions of **Section A** shall be MCQ, Fill in the blanks, True or False, Match the following, Definition, Missing letters. Questions of **Sections B, C, D and E** could be Open Choice/ built in choice/with sub sections. Component III shall be exclusively for cognitive levels K5 and K5 with 20 marks each. CIA shall be conducted for 50 marks with 90 min duration.

COGNITIVE LEVEL (CL) AND COURSE OUTCOME (CO) BASED END SEMESTER EXAMINATION QUESTION PAPER FORMAT (PG)

SECTION		Q. NO	COGNITIVE LEVEL (CL)					
			K1	K2	K3	K4	K5	K6
A	(5 x 1 = 5) Answer ALL	1(a)	+					
		(b)	+					
		(c)	+					
		(d)	+					
		(e)	+					
	(5 x 1 = 5) Answer ALL	2(a)		+				
		(b)		+				
		(c)		+				
		(d)		+				
		(e)		+				
B	(3 x 10 = 30) Answer 3 out of 5	3			+			
		4			+			
		5			+			
		6			+			
		7			+			
C	(2 x 12.5 = 25) Answer 2 out of 4	8				+		
		9				+		
		10				+		
		11				+		
D	(1 x 15 = 15) Answer 1 out of 2	12					+	
		13					+	
E	(1 x 20 = 20) Answer 1 out of 2	14						+
		15						+
No. of CL based Questions with Max. marks			5 (5)	5 (5)	3 (30)	2 (25)	1 (15)	1 (20)
No. of CO based Questions with Max. marks			CO1		CO2	CO3	CO4	CO5
			10 (10)		3 (30)	2 (25)	1 (15)	1 (20)

IMPORTANT

- Forms of questions of **Section A** shall be MCQ, Fill in the blanks, True or False, Match the following, Definition, Missing letters.
- Questions of **Sections B, C, D and E** could be Open Choice/ built in choice/questions with sub divisions.
- Maximum sub divisions in questions of Sections B, C shall be 2 and 4 in Sections D, E).

TOTAL MARKS DISTRIBUTION OF DIRECT ASSESSMENTS BASED ON CL AND CO (PG)

Course Outcome	**CO1**		**CO2**	**CO3**	**CO4**	**CO5**	**TOTAL**
Cognitive Levels	**K1**	**K2**	**K3**	**K4**	**K5**	**K6**	
CIA 1	5	5	8	8	12	12	50
CIA 2	5	5	8	8	12	12	50
Comp III	-	-	-	-	20	20	40
Semester	5	5	30	25	15	20	100
Total Marks (CL)	**15 (6%)**	**15 (6%)**	**46 (19%)**	**41 (17%)**	**59 (25%)**	**64 (27%)**	**240**
Total Marks (CO)	**30 (12%)**		**46 (19%)**	**41 (17%)**	**59 (25%)**	**64 (27%)**	**240**