Syllabus Based on NEP 2020

Five Year Integrated Postgraduate (MSc) Programme
in Chemistry
(*Effective from Academic Year 2024-2025*)

Approved in the 14th Academic Council Meeting held on 5th July, 2024

Bodoland University

Department of Chemistry
Kokrajhar-783370, Assam, India

Five Year Integrated Postgraduate (PG) Programme (*Chemistry*)

Semester	Major	Minor	IDC	AEC	SEC	VAC	Internship	Dissertation	Total Credits
SEM-I	CHMMAJ101-4: Fundamentals of Chemistry-1	CHMMIN101-4: Chemistry-1	CHMIDC101-3: Chemistry in Everyday Life-1	AEC-1 (2) Language/ Regional Language	CHMSEC101-3: Basic Analytical Chemistry	VAC-1(4)			20
SEM-II	CHMMAJ102-4: Fundamentals of Chemistry-2	CHMMIN102-4: Chemistry-2	CHMIDC102-3: Chemistry in Everyday Life-2	AEC-2 (2) Language/ Regional Language	CHMSEC102-3: Fuel Chemistry	VAC-2(4)			20
Exit with a Certificate (40 Credits and Internship of 4 Credits)									
SEM-III	CHMMAJ201-4: Inorganic Chemistry-1 CHMMAJ202-4: Physical Chemistry-1	CHMMIN201-4: Chemistry-3	CHMIDC201-3: Chemistry in Everyday Life-3	AEC-1 (2) Language/ Regional Language	CHMSEC201-3: Basic Instrumental Techniques in Chemistry				20
SEM-IV	CHMMAJ203-4: Inorganic Chemistry-2 CHMMAJ204-4: Organic Chemistry-1 CHMMAJ205-4: Physical Chemistry-2	CHMMIN202-4: Chemistry-4		AEC-2 (2) Language/ Regional Language			CHMINT201-2: Internship		20
Exit with a Diploma (80 Credits and Internship of 4 Credits)									
SEM-V	CHMMAJ301-4: Inorganic Chemistry-3 CHMMAJ302-4: Organic Chemistry-2 CHMMAJ303-4: Physical Chemistry-3	CHMMIN301-4: Chemistry-5							20

	CHMMAJ304-4: Computers in Chemistry								
SEM-VI	CHMMAJ305-4: Organic Chemistry-3 CHMMAJ306-4: Spectroscopy-1 CHMMAJ307-4: Industrial Chemistry CHMMAJ308-4: Environmental Chemistry	CHMMIN302-4: Chemistry-6							20
Exit with a Bachelor Degree (Major) (120 Credits)									
SEM-VII	CHMADL 14014 CHMADL 14024 CHMADL 14034 CHMADL 14044 CHMADL 14054								20
SEM-VIII	CHMADL 14064 CHMSPL 15074 CHMSPL 15084 CHMSPL 15094 CHMSPL 15104								20
	80	**32**	**9**	**8**	**9**	**8**	**2**	**12**	**160**
Exit with a Bachelor Degree (Honours) (160 Credits)									

Important Points

- ***Theory Classes*:**

  1 Credit = 15 Classes in one semester = 15 Contact hours in one semester.

- ***Tutorial Classes*:**

  1 Credit = 15 Tutorial classes in one semester = 15 Contact hours in one semester.

- ***Practical Classes*:**

  1 Credit (2 h) = 30 Contact hours in one semester.

Abbreviations

MAJ – Major

MIN – Minor

IDC – Inter Disciplinary Course

AEC – Ability Enhancement Course

SEC – Skill Enhancement Course

VAC – Value Added Course

INT – Internship

REM – Research Methodology

DIS – Dissertation

ADL – Advanced Learning

SPL – Special Learning

Five Year Integrated Postgraduate (PG) Programme in Chemistry

Curriculum Structures

SEMESTER I						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMMAJ101-4	Fundamentals of Chemistry-1	3+0+1	4	50+20(P)	30	100
CHMMIN101-4	Chemistry-1	3+0+1	4	50+20(P)	30	100
CHMIDC101-3	Chemistry in Everyday Life-1	2+1+0	3	50	-	50
AEC-1 (2)	Language/ Regional Language	2+0+0	2	50	-	50
CHMSEC101-3	Basic Analytical Chemistry	2+1+0	3	50	-	50
VAC1014			4			100
Total		**20**	**20**			**450**

SEMESTER II						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMMAJ102-4	Fundamentals of Chemistry-2	3+0+1	4	50+20(P)	30	100
CHMMIN102-4	Chemistry-2	3+0+1	4	50+20(P)	30	100
CHMIDC102-3	Chemistry in Everyday Life-2	2+1+0	3	50	-	50
AEC-1 (2)	Language/ Regional Language	2+0+0	2	50	-	50
CHMSEC102-3	Fuel Chemistry	2+1+0	3	50	-	50
VAC			4			100
Total		**20**	**20**			**450**

SEMESTER III						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMMAJ201-4	Inorganic Chemistry-1	3+0+1	4	50+20(P)	30	100
CHMMAJ202-4	Physical Chemistry-1	3+0+1	4	50+20(P)	30	100
CHMMIN201-4	Chemistry-3	3+0+1	4	50+20(P)	30	100
CHMIDC201-3	Chemistry in Everyday Life-3	2+1+0	3	50	-	50
AEC-1 (2)	Language/ Regional Language	2+0+0	2	50	-	50
CHMSEC201-3	Basic Instrumental Techniques in Chemistry	0+0+3	3	50	-	50
Total		**20**	**20**			450

SEMESTER IV						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMMAJ203-4	Inorganic Chemistry-2	3+0+1	4	50+20(P)	30	100
CHMMAJ204-4	Organic Chemistry-1	3+0+1	4	50+20(P)	30	100
CHMMAJ205-4	Physical Chemistry-2	3+0+1	4	50+20(P)	30	100
CHMMIN202-4	Chemistry-4	3+0+1	4	50+20(P)	30	100
AEC-1 (2)	Language/ Regional Language	2+0+0	2	50	-	50
CHMINT201-2	Internship	2	2	-	-	50
Total			**20**			500

SEMESTER V						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMMAJ301-4	Inorganic Chemistry-3	3+0+1	4	50+20(P)	30	100
CHMMAJ302-4	Organic Chemistry-2	3+0+1	4	50+20(P)	30	100
CHMMAJ303-4	Physical Chemistry-3	3+0+1	4	50+20(P)	30	100
CHMMAJ304-4	Computers in Chemistry	3+0+1	4	50+20(P)	30	100
CHMMIN301-4	Chemistry-5	3+0+1	4	50+20(P)	30	100
Total		**20**	**20**			**500**

SEMESTER VI						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMMAJ305-4	Organic Chemistry-3	3+0+1	4	50+20(P)	30	100
CHMMAJ306-4	Spectroscopy-1	3+0+1	4	50+20(P)	30	100
CHMMAJ307-4	Industrial Chemistry	3+0+1	4	50+20(P)	30	100
CHMMAJ308-4	Environmental Chemistry	3+0+1	4	50+20(P)	30	100
CHMMIN302-4	Chemistry-6	3+0+1	4	50+20(P)	30	100
Total		**20**	**20**			**500**

SEMESTER VII						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMADL 14014	Physical Chemistry-4	3+0+1	4	50+20(P)	30	100
CHMADL 14024	Organic Chemistry-4	3+0+1	4	50+20(P)	30	100
CHMADL 14034	Inorganic Chemistry-4	3+0+1	4	50+20(P)	30	100
CHMADL 14044	Spectroscopy-2	3+1+0	4	70	30	100
CHMADL 14054	Research Methodology	3+0+1	4	50+20(P)	30	100
Total		**20**	**20**			**500**

SEMESTER VIII						
Course Code	**Course Title**	**L+T+P**	**Credit**	**Final Exam**	**Internal Exam**	**Total Marks**
CHMADL 14064	Nanomaterials and Green Chemistry	3+0+1	4	50+20(P)	30	100
CHMSPL 15074	Physical Chemistry-5	3+0+1	4	50+20(P)	30	100
CHMSPL 15084	Organic Chemistry-5	3+0+1	4	50+20(P)	30	100
CHMSPL 15094	Inorganic Chemistry-5	3+0+1	4	50+20(P)	30	100
CHMSPL 15104	Spectroscopy-3	3+1+0	4	70	30	100
Total		**20**	**20**			**500**

- **Students after the end of 8th Semester can choose to do (*any one*)**
  - (A) Only Coursework both in the 9th and 10th Semesters (*Total Credits: 40*), or
  - (B) Coursework in 9th Semester and Research in 10th Semester (*Total Credits: 40*), or
  - (C) Only Research both in the 9th and 10th Semesters (*Total Credits: 40*).

Option A – Only course work in the 9th and 10th semesters (*Total Credits: 40*)

SEMESTER IX

Paper Code	Courses	Credits	L+T+P	Contact Hours	Internal Exam	Final Exam	Total Marks
CHMSPL 25014	Quantum Chemistry	4	3+1+0	60	30	70	100
CHMSPL 25024	Analytical Techniques in Chemistry	4	3+1+0	60	30	70	100
CHMSPL 25034	Supramolecular Chemistry	4	3+1+0	60	30	70	100
CHMSPL 25044	Literature Survey	4	4	60	30	70	100
CHMSPL 25054	Practical	4	0+0+4	120	30	70	100

SEMESTER X

Papers	Credits	L+T+P	Contact Hours	Internal Exam	Final Exam	Total Marks
Paper 1	4	3+1+0	60	30	70	100
Paper 2	4	3+1+0	60	30	70	100
Paper 3	4	3+1+0	60	30	70	100
Paper 4	4	3+1+0	60	30	70	100
Paper 5	4	0+0+4	120	30	70	100

Elective Papers		
Paper 1	CHMSPL 25064	Reaction Dynamics and Statistical Thermodynamics
	CHMSPL 25074	Organic Synthesis and Heterocyclic Chemistry
	CHMSPL 25084	Inorganic Photochemistry
Paper 2	CHMSPL 25094	Polymer Science
	CHMSPL 25104	Natural Products Chemistry
	CHMSPL 25114	Bioinorganic Chemistry
Paper 3	CHMSPL 25124	Catalysis
	CHMSPL 25134	Medicinal and Bioorganic Chemistry
	CHMSPL 25144	Organometallic Chemistry
Paper 4	CHMSPL 25154	Computational Chemistry
	CHMSPL 25164	Advanced Topics in Organic Chemistry
	CHMSPL 25174	Group Theory and Application
Paper 5	CHMSPL 25184	Physical Chemistry Practical
	CHMSPL 25194	Organic Chemistry Practical
	CHMSPL 25204	Inorganic Chemistry Practical

Option B **– Coursework + Research *i.e.* Coursework in the 9th Semester and Research in 10th Semester (*Total Credits: 40*)**

SEMESTER IX

Paper Code	Courses	Credits	L+T+P	Contact Hours	Internal Exam	Final Exam	Total Marks
CHMSPL 25014	Quantum Chemistry	4	3+1+0	60	30	70	100
CHMSPL 25024	Analytical Techniques in Chemistry	4	3+1+0	60	30	70	100
CHMSPL 25034	Supramolecular Chemistry	4	3+1+0	60	30	70	100
CHMSPL 25044	Literature Survey	4	4	60	30	70	100
CHMSPL 25054	Practical	4	0+0+4	120	30	70	100

SEMESTER X

Dissertation (CHMDIS 250620)

- Research thesis/Project with minimum 1 conference paper. Peer reviewed research publication should be encouraged.

Option C **– Only Research i.e. only research both in the 9th and 10th semesters (*Total Credits: 40*)**

SEMESTER IX & X

Dissertation (CHMDIS 250140)

- Research thesis/Project with minimum 2 conference papers. Peer reviewed research publication should be encouraged.

SEMESTER I

Course Code: CHMMAJ101-4
Course Title: Fundamentals of Chemistry-1
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving students the theoretical understanding about the basic constituents of matter – atoms, ions and molecules in terms of their electronic structure and reactivity. Structure and bonding in these are to be dealt with basic quantum chemistry treatment. Idea of basic organic chemistry and stereo-chemistry will be discussed. This course also contains states of matter- gaseous, liquid and solid sates along with ionic equilibria. Idea about molecular and crystal symmetry will also be provided.

Course Outcomes: On successful completion, the students would have clear understanding of the concepts related to atomic and molecular structure, chemical bonding, periodic properties. They will learn about basic organic chemistry and stereo-chemistry and states of matter- gaseous, liquid and solid sates along with ionic equilibria. The students will also be able to demonstrate about the molecular and crystal symmetry.

Unit 1: Atomic Structure and Periodicity of Elements 15 Lectures

Atomic structure: Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de-Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.

Periodicity of elements: s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to s and p-block.

(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.

(b) Atomic radii (van der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.

(f) Electron gain enthalpy, trends of electron gain enthalpy.

(g) Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

Unit 2: Basics of Organic Chemistry and Stereochemistry 15 Lectures

Basics of Organic Chemistry: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electrometric, resonance and mesomeric effects, hyperconjugation and their applications; Tautomerism; Organic acids and bases; their relative strength. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, Electrophiles and Nucleophiles; Nucleophilicity and basicity; Types, shape and their relative stability of carbocations, carbanions, free radicals, carbenes, nitrenes and benzynes.

Stereochemistry: Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules. Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Diastereoisomers, meso structures, Racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations.

Unit 3: Gaseous state 15 Lectures

Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities. Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, Z, and its variation with pressure for different gases. Causes of deviation from ideal behaviour. van der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dietrici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry.* Oxford, 1970
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry,* S. Chand, 2010.
6. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry,* Orient Longman, New Delhi (1988).
7. March, J. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7th Edition. Willey & Sons.
8. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
9. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.

10. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
11. Kapoor, K.L. *Textbook of Physical Chemistry*, (Vol-1). Mc.Graw Hill Education, 6^{th} Edition.

Inorganic Chemistry-1 LAB – CHMMAJ101-4 30 Hours

(A) General experiments

(i) Calibration and use of apparatus

(ii) Preparation of solutions of different Molarity/Normality of titrants

(B) Acid-Base Titrations

(i) Estimation of carbonate and hydroxide present together in mixture.

(ii) Estimation of carbonate and bicarbonate present together in a mixture.

(iii) Estimation of free alkali present in different soaps/detergents

Recommended Books:

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis 6thEd.*, Pearson, 2009
2. Baruah, S. Practical Chemistry. Kalyani Publishers.

SEMESTER I

Course Code: CHMMIN101-4

Course Title: Chemistry-1

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving students theoretical understanding about the atomic structure. Idea of basic organic chemistry and aliphatic hydrocarbons. This course contains basics of thermodynamics.

Course Outcomes: On successful completion, students would have clear understanding of the atomic structure, basic organic chemistry and aliphatic hydrocarbons and basics of thermodynamics.

Unit 1: Atomic Structure 15 Lectures

Review of: Bohr's theory and its limitations, dual behaviour of matter and radiation, de Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a new approach to atomic structure. Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ^2, Schrödinger equation for hydrogen atom. Radial and angular parts of the hydrogenic wave functions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers m_l and m_s. Shapes of s, p and d atomic orbitals, nodal planes. Rules for filling electrons in various orbitals, electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

Unit 2: Fundamentals of organic chemistry and aliphatic hydrocarbons

15 Lectures

Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis. Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals.

Alkanes: Preparation: Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: Free radical Substitution: Halogenation.

Alkenes: Preparation: Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule). Reactions: cis-addition (alkaline $KMnO_4$) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis.

Alkynes: Preparation: Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides. Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, oxidation with hot alkaline $KMnO_4$.

Unit 3: Chemical Thermodynamics **15 Lectures**

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics. First law: Concept of heat, q, work, w, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

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

Second Law: Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry.* Oxford, 1970

3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry,* S. Chand, 2010.
6. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry,* Orient Longman, New Delhi (1988).
7. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
8. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
9. Kapoor, K.L. *Textbook of Physical Chemistry*, (Vol-2). Mc.Graw Hill Education, 6^{th} Edition.

Chemistry-1 LAB – CHMMIN101-4 **30 Hours**

Qualitative Inorganic analysis:
Identification of not more than three radicals in a mixture. (Presence of Na^+, K^+ and CO_3^{2-} are to be ignored and not to be reported)

Recommended Books:

1. Baruah, S. Practical Chemistry. Kalyani Publishers.
2. Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7thEd.,* Prentice Hall, 1996.

SEMESTER I

Course Code: CHMIDC101-3
Course Title: Chemistry in Everyday Life-1
Credits: 2+1+0
(Theory: 30 Hours, Tutorial: 15 Hours)
Total Marks: 50 (Theory: 50)

Course Objectives: This course aims at giving students preliminary ideas of chemistry of medicine, food additives, preservatives and biomolecules.

Course Outcomes: On successful completion, students would have basic ideas of chemistry involved in medicine, sweeteners, flavours, colours and preservatives in food science and different aspects of biomolecules.

Unit 1: Chemistry in medicine **8 Lectures**
Antacid, antipyretics, analgesic, antibacterial, antibiotics, antiallergic, antidiabetic, anti-hypertensives and anaesthetics. (*Structure not necessary*)

Unit 2: Food additives and preservation **8 Lectures**

Artificial sweeteners, food flavours, food colours, food preservation with examples.
(*Structure not necessary*)

Unit 3: Biomolecules **14 Lectures**

Carbohydrates: Definition, source and uses of Glucose, Lactose, Sucrose, Starch, Cellulose.
Amino acids: Definition, essential and non-essential amino acids, and their importance.
Vitamin: Definition, classification, sources and their deficiency diseases.
(*Structure not necessary*)

Recommended Books:

1. Murray, R.K., Granner, D.K., Mayes, P.A. & Rodwell, V.W. (2009) *Harper's Illustrated Biochemistry.* XXVIII edition. Lange Medical Books/ McGraw-Hill.
2. Sen, M. (2021). Food chemistry: role of additives, preservatives, and adulteration. *Food Chemistry: The Role of Additives, Preservatives and Adulteration*. Willey & Sons.
3. Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.
4. Nelson, D. L. & Cox, M. M. *Lehninger's Principles of Bioch*emistry *7th Ed.*, W. H. Freeman.

SEMESTER I

Course Code: CHMSEC101-3
Course Title: Basic Analytical Chemistry
Credits: 2+1+0
(Theory: 30 Hours, Tutorial: 15 Hours)
Total Marks: 50 (Theory: 50)

Course Objectives: To familiarize students with different micro and semi-micro analytical techniques and help develop the ability to use modern instrumental methods for chemical analysis of food, soil, air and water.
Course Outcomes: Upon completion of this course, students shall be able to explain the basic principles of chemical analysis, design/implement microscale and semi-micro experiments, record, interpret and analyse data following scientific methodology.

Unit 1: Introduction to Analytical Chemistry and its interdisciplinary nature
8 Lectures

Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements (with problem-based examples). Presentation of experimental data and results, from the point of view of significant figures.

Unit 2: Analysis of soil **8 Lectures**

Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators. Determination of pH of soil samples.

Unit 3: Analysis of water **14 Lectures**

Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods. (a) Determination of pH, acidity and alkalinity of a water sample. (b) Determination of dissolved oxygen (DO) of a water sample.

Demonstration of

1. pH meter
2. Conductometer
3. Potentiometer
4. DO meter
5. Flame photometer
6. UV-Vis spectrophotometer

Recommended Books:

1. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of Analysis*, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA,1988.
2. Skoog, D.A., Holler, F.J. & Crouch, S. *Principles of Instrumental Analysis*, Cengage Learning India Edition, 2007.
3. Skoog, D.A.; West, D.M. & Holler, F.J. *Analytical Chemistry: An Introduction 6thEd.,* Saunders College Publishing, Fort Worth, Philadelphia (1994).
4. Harris, D.C. *Quantitative Chemical Analysis*, 9th ed. Macmillan Education, 2016.
5. Dean, J. A. *Analytical Chemistry Handbook*, McGraw Hill, 2004.
6. Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India, 1992.
7. Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7thEd.,* Prentice Hall, 1996.
8. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6thEd.,* Pearson, 2009.
9. Robinson, J.W. *Undergraduate Instrumental Analysis 5thEd.,* Marcel Dekker, Inc., New York (1995).
10. Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.

SEMESTER II

Course Code: CHMMAJ102-4
Course Title: Fundamentals of Chemistry-2
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving students theoretical understanding about the chemical bonding, liquid and solid state and hydrocarbon.
Course Outcomes: On successful completion, students would have clear understanding of the concepts related to Ionic and covalent bond. They will learn about the solid and liquid state of matter and aliphatic and aromatic hydrocarbons.

Unit 1: Chemical Bonding **14 Lectures**
(i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation. Madelung constant, Born-Haber cycle and its application, Solvation energy.
(ii) Covalent bond: Lewis structure, Valence Bond theory (Heitler-London approach). Types of hybridization (involving s, p and d orbitals). Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths. Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization. Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

Unit 2: Liquid and solid-state **14 Lectures**
Liquid state: Physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases.
Solid state: Nature of the solid state, law of constancy of interfacial angles, law of rational indices, miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Defects in crystals. Glasses and liquid crystals.

Unit 3: Hydrocarbon **17 Lectures**

Carbon-Carbon sigma bonds Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Corey-House reaction, Free radical substitutions: Halogenation - relative reactivity and selectivity.

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

Reactions of alkynes: Preparation of alkynes. Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, reduction of alkynes. Alkylation of terminal alkynes.

Cycloalkanes and Conformational Analysis: Types of cycloalkanes and their relative stability, Baeyer strain theory. Conformation analysis of alkanes, Relative stability and Energy profile diagrams. Cyclohexane: Chair, Boat and Twist boat forms, relative stability with energy profile diagrams.

Aromatic Hydrocarbons: Aromaticity: Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry.* Oxford, 1970
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry,* S. Chand, 2010.
6. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry,* Orient Longman, New Delhi (1988).
7. March, J. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7th Edition. Willey & Sons.
8. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
9. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
10. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
11. Kapoor, K.L. *Textbook of Physical Chemistry*, (Vol-1). Mc.Graw Hill Education, 6th Edition.

Organic Chemistry-1 LAB – CHMMAJ102-4 **30 Hours**

1. Preliminary investigation of organic compounds (Solubility, nature, test for saturation, aromaticity).
2. Detection of extra elements (N, S and Halogens).
3. Test for functional group containing N, S and Halogens.

Recommended Books:

1. Agarwal, O.P. Advanced Practical Organic Chemistry. Krishna Prakashan Media (P) Ltd.
2. Baruah, S. Practical Chemistry. Kalyani Publishers.

SEMESTER II

Course Code: CHMMIN102-4

Course Title: Chemistry-2

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving students theoretical understanding about the periodicity of elements, stereochemistry and kinetic theory of gases.
Course Outcomes: On successful completion, students would have clear understanding of the concepts related to periodicity of elements, stereochemistry and kinetic theory of gases.

Unit 1: Periodicity of Elements **14 Lectures**

s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to s and p-block.
(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
(b) Atomic radii (van der Waals)
(c) Ionic and crystal radii.
(d) Covalent radii (octahedral and tetrahedral)
(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
(f) Electron gain enthalpy, trends of electron gain enthalpy.
(g) Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

Unit 2: Stereochemistry **14 Lectures**

Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism, Racemic mixture and Meso compounds). Threo and erythro; D and L; cis-trans nomenclature; CIP Rules: R/S (for upto 2 chiral carbon atoms) and E/Z Nomenclature.

Unit 3: Kinetic Theory of Gases **17 Lectures**

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation. Deviation of real gases from ideal behaviour, compressibility factor, causes of deviation. van der Waals equation of state for real gases. Boyle temperature. Critical phenomena, critical constants and their calculation from van der Waals equation. Andrews isotherms of CO_2. Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance. Temperature dependence of these distributions. Most probable, average and root mean square velocities (no derivation). Collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only).

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry.* Oxford, 1970
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry,* ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
6. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
7. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
8. Kapoor, K.L. *Textbook of Physical Chemistry*, (Vol-1). Mc.Graw Hill Education, 6th Edition.

Chemistry-2 LAB – CHMMIN201-4 **30 Hours**

1. To determine the solubility of a given salt at room temperature.
2. To determine the solubility of a given salt at different temperatures and to plot solubility curve.
3. Estimation of oxalic acid by titrating it with $KMnO_4$.
4. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.

Recommended Books:

1. Yadav, J.B. Advanced Practical Physical Chemistry. Krishna Publication.
2. Baruah, S. Practical Chemistry. Kalyani Publishers

3. Pandey, O.P, Bajpai, D.N., Giri, S. Practical Chemistry. S. Cand.

SEMESTER II

Course Code: CHMIDC102-3
Course Title: Chemistry in Everyday Life-2
Credits: 2+1+0
(Theory: 30 Hours, Tutorial: 15 Hours)
Total Marks: 50 (Theory: 50)

Course Objectives: This course aims at giving students preliminary ideas of Chemistry of household materials, polymers and rubbers, chemicals used in agriculture.
Course Outcomes: On successful completion, students would have basic ideas of Household materials, Polymers and rubbers, Chemicals used in Agriculture.

Unit 1: Chemistry of Household materials 15 Lectures
Soap and detergent – definition, composition and uses. Disinfectants – antiseptic (Dettol, Savlon), hand and surface sanitizer, and surface cleaner.
LPG, CNG, Cooling gases (CFC, HFC), perfumes, deodorant, and talc.
Biogas (Gobar gas) and its production.

Unit 2: Polymers and rubbers 8 Lectures
Basic definitions and uses of polythene, PVC, nylon, Teflon, Bakelite, melamine, polyester.
Rubber – types, sources and uses.
Biodegradable and non-biodegradable polymers – definition and example.

Unit 3: Chemicals used in Agriculture 7 Lectures
Chemical Fertilizers – urea, superphosphate, ammonium nitrate, DAP, NPK.
Organic fertilizer – manure, vermicompost.
Definition, examples and uses of pesticides, insecticides, herbicides, and fungicides.

Recommended Books:

1. Handbook on Soaps, Detergents & Acid Slurry (3rd revised edition)
2. Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. *Polymer Science*, New Age International (P) Ltd. Pub.
3. *De, A.K. Environmental Chemistry*; Edition, 8; Publisher, New Age International (P) Limited.
4. Das, B.K., Hoque, M., Dhar, A. *Fuel Chemistry*. Union Book Publication, Pan Bazar, Guwahati-1.

SEMESTER II

Course Code: CHMSEC102-3
Course Title: Fuel Chemistry
Credits: 2+1+0
(Theory: 30 Hours, Tutorial: 15 Hours)
Total Marks: 50 (Theory: 50)

Course Objectives: This course discusses about the chemistry of various sources of energy. Students are expected to learn about the composition of coal and petroleum products, their extraction, purification methods and usage. A section also covers classification and applications of natural and synthetic lubricants. Students will also learn about the determination and significance of various industrially relevant physical parameters for different fuels and lubricants.

Course Outcomes: At the end of this course students will learn about the classes of renewable and non-renewable energy sources. Students will learn about the composition of coal and crude petroleum, their classification, isolation of coal and petroleum products and their usage in various industries. They will also learn to determine industrially significant physical parameters for fuels and lubricants.

Unit 1: Review of energy sources **6 Lectures**

Renewable and non-renewable. Classification of fuels and their calorific value. Numerical problems based on calorific value.

Unit 2: Coal **10 Lectures**

Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas-composition and uses. Fractionation of coal tar, uses of coal tar bases chemicals, requisites of a good metallurgical coke, Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining.

Unit 3: Petroleum, petrochemical industry and lubricants **14 Lectures**

Composition of crude petroleum, Refining and different types of petroleum products and their applications. Fractional Distillation (Principle and process), Cracking (Thermal and catalytic cracking), Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels. Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives Xylene.

Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semisolid lubricants, synthetic lubricants. Properties of lubricants (viscosity index, cloud point, pour point) and their determination.

Recommended Books:

1. Stocchi, E. *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK (1990).
2. Jain, P.C. & Jain, M. *Engineering Chemistry* Dhanpat Rai& Sons, Delhi.

3. Sharma, B.K. & Gaur, H. *Industrial Chemistry,* Goel Publishing House, Meerut (1996).
4. Das, B.K., Hoque, M., Dhar, A. *Fuel Chemistry*. Union Book Publication, Pan Bazar, Guwahati-1.

SEMESTER III

Course Code: CHMMAJ201-4
Course Title: Inorganic Chemistry-1
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** This course starts with the periodic behaviour of s and p block elements related to their electronic structure and their reactivity is included to acquaint students with the principles governing their reactivity. Concepts of protonic and non-protonic acids and bases are introduced for students to appreciate different types of chemical reactions. This course further intends to apprise students about the variety of compounds of the main group elements including oxides, hydrides, nitrides, interhalogens, noble gases and inorganic polymers.
As part of the accompanying lab course, experiments involving acid-base and redox titrations are included for the students to explore other varieties of redox titration.
***Course Outcomes*:** On successful completion of this course, students would be able to identify the variety of s and p block compounds and comprehend their preparation, structure, bonding, properties and uses. They will also be able to apply the concept of acids and bases in inorganic applications. Students will also be equipped with noble gases and inorganic polymer.
Experiments in this course will boost their quantitative estimation skills and precautions involved in titrations.

Unit 1: Chemistry of *s* and *p* Block Elements **15 Lectures**
Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Complex formation tendency of *s* and *p* block elements. Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogens and basic properties of halogens.

Unit 2: Acids and Bases **6 Lectures**
Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB). Application of HSAB principle.

Unit 3: Noble Gases **6 Lectures**

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2). Molecular shapes of noble gas compounds (VSEPR theory).

Unit 4: Inorganic Polymers **6 Lectures**

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes, and polysulphates.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry*, ELBS, 1991.
2. Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models of*
3. *Inorganic Chemistry 3rd Ed.*, John Wiley Sons, N.Y. 1994.
4. Greenwood, N.N. & Earnshaw. *Chemistry of the Elements*,
5. Butterworth-Heinemann. 1997.
6. Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.
7. Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning India
8. Edition, 2002.
9. Miessler, G. L. & Donald, A. Tarr. *Inorganic Chemistry* 4th Ed., Pearson, 2010.
10. Atkin, P. *Shriver & Atkins' Inorganic Chemistry* 5th Ed. Oxford University Press (2010).
11. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
12. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed., Pearson Education India, 2006.

Inorganic Chemistry-1 LAB – CHMMAJ201-4 **30 Hours**

(A) Titrimetric Analysis

(i) Calibration and use of apparatus

(ii) Preparation of solutions of different Molarity/Normality of titrants

(B) Acid-Base Titrations

(i) Estimation of carbonate and hydroxide present together in mixture.

(ii) Estimation of carbonate and bicarbonate present together in a mixture.

(iii) Estimation of free alkali present in different soaps/detergents

(C) Oxidation-Reduction Titrimetry

(i) Estimation of Fe (II) and oxalic acid using standardized $KMnO_4$ solution.

(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.

(iii) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books:

3. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis 6thEd.,* Pearson, 2009
4. Baruah, S. Practical Chemistry. Kalyani Publishers.

SEMESTER III

Course Code: CHMMAJ202-4

Course Title: Physical Chemistry-1

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** In this course, chemical thermodynamics, and chemical equilibrium will be taught to the students. Experiment-based knowledge of properties of solutions like surface tension, viscosity, and pH-metry will be provided.

***Course Outcomes*:** In this course, the students will learn laws of thermodynamics, thermochemistry, thermodynamic functions, relations between thermodynamic properties, Gibbs Helmholtz equation, Maxwell relations, etc. Moreover, the students are expected to learn ionic equilibria, the acidic and basic nature of the solution, pH measurement, buffer solution, their applications, and related numerical calculation. They will also learn about the quantitative estimation of solutions. Students are expected to gather experimental knowledge of properties of solutions like surface tension, viscosity, and pH-metry.

Unit 1: Chemical Thermodynamics 1 — 15 Lectures

Definition of thermodynamic terms, closed, open and isolated system; surroundings, energy, heat, work, internal energy. The first law, calculation of work done during expansion of gas, thermodynamic reversibility, heat capacity, enthalpy and its significance, significance of heat and work. State functions and differentials; variation of internal energy and enthalpy with temperature, Joule-Thomson experiment and liquefaction of gases; relation between Cp and C_V; Calculation of work done on adiabatic expansion; relation between P, V and T in adiabatic processes. Thermochemistry- standard enthalpy changes, derivation of Hess's law and Kirchhoff's law. Relation of reaction enthalpy with changes in internal energy. Calculation of bond dissociation energies from thermochemical data.

Unit 2: Chemical Thermodynamics 2 — 15 Lectures

The second law, entropy changes in reversible and irreversible processes. Clausius inequality, calculation of entropy changes during various processes. Helmholtz function and Gibb's function and the direction of spontaneous change. Thermodynamics of chemical reactions -

Equilibrium constant of a reaction in terms of standard Gibb's function, dependence of equilibrium constant of temperature and pressure. Standard entropy of a reaction and standard Gibbs function of formation. Maxwell's relations and derivation of thermodynamic equation of state; Gibb's-Helmholtz equation, variation of Gibb's function with pressure and temperature. A brief idea of partial molar quantity, chemical potential, and Gibb's-Duhem equation. Third law of thermodynamics – Nernst heat theorem.

Unit 3: Ionic equilibria **15 Lectures**

Strong, moderate, and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di-and triprotic acids.

Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolyte systems; hydrolysis and hydrolysis constants.

Recommended Books:

1. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
2. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
3. Kapoor, K.L. *Textbook of Physical Chemistry*. Mc.Graw Hill Education, 6^{th} Edition.
4. Negi, A. S. Anand, S. C. A Textbook of Physical Chemistry. New Age International.

Physical Chemistry-1 LAB – CHMMAJ202-4, 30 Hours

1. **Surface tension measurements**
    - a. Determine the surface tension by (i) drop number (ii) drop weight method.
    - b. Study the variation of surface tension of detergent solutions with concentration.
2. **Viscosity measurement using Ostwald's viscometer**
    - a. Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
    - b. Study the variation of viscosity of sucrose solution with the concentration of solute.
3. **pH metry**
    - a. Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
    - b. Preparation of buffer solutions of different pH
        - i. Sodium acetate-acetic acid
        - ii. Ammonium chloride-ammonium hydroxide

c. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.
d. Determination of dissociation constant of a weak acid.

Recommended Books:

1. Yadav, J.B. Advanced Practical Physical Chemistry. Krishna Publication.
2. Baruah, S. Practical Chemistry. Kalyani Publishers

SEMESTER III

Course Code: CHMMIN201-4
Course Title: Chemistry-3
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving students theoretical understanding about the chemical bonding and aromatic hydrocarbon. This course contains also basics concept of liquid and solid.
Course Outcomes: On successful completion, students would have clear understanding of the chemical bonding of compounds, electrophilic aromatic substitution, properties of liquid and structure of solid. The students will also get idea of volumetric analysis.

Unit 1: Chemical Bonding **15 Lectures**
(i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Lattice energy. Born-Haber cycle and its application, Solvation energy.
(ii) Covalent bond: Lewis structure, Valence Bond theory (Heitler-London approach). Types of hybridization (involving s, p and d orbitals). Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N_2, O_2, F_2, CO, and HCl. Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths. Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization. Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

Unite 2: Aromaticity and Aromatic Hydrocarbons **15 Lectures**
Aromaticity: Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups.
Directive influence of activating and deactivating groups in aromatic electrophilic substitution reaction.

Unit 3: Liquids and Solids **15 Lectures**

Liquid state: Physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of soap and detergents. Temperature variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of structure of water.

Solid state: Nature of the solid state, classification of crystalline solid, crystal lattice and unit cell, Miller indices, seven crystal systems and fourteen Bravais lattices; closed packed structure and packing efficiency, X-ray diffraction, Bragg's law. Defects in crystalline solids.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry.* Oxford, 1970
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
6. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
7. March, J. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7th Edition. Willey & Sons.
8. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
9. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
10. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
11. Kapoor, K.L. *Textbook of Physical Chemistry*, (Vol-1). Mc.Graw Hill Education, 6th Edition.

Chemistry-3 LAB – CHMMIN201-4 **30 Hours**

Inorganic Chemistry - Volumetric Analysis

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.
3. Estimation of Cu (II) ions iodometrically using $Na_2S_2O_3$.
4. To determine the hardness of water by EDTA titration.

Recommended Books:

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis 6thEd.*, Pearson, 2009
2. Baruah, S. Practical Chemistry. Kalyani Publishers.

SEMESTER III

Course Code: CHMIDC201-3

Course Title: Chemistry in Everyday Life-3

Credits: 2+1+0

(Theory: 30 Hours, Tutorial: 15 Hours)

Total Marks: 50

Course Objectives: This course aims at giving students preliminary ideas of Chemistry of environmental pollution and related issues including health impacts of metals on human health.
Course Outcomes: On successful completion, students would have basic ideas of the chemicals responsible for environmental pollution, dos and dons for protection of environmental related issues. They will also have the basic idea of the importance and impact of metals on human health.

Unit 1: Environmental Pollution 12 Lectures

Definition, Causes, effects and control measures of air pollution, water pollution, soil pollution, marine pollution, noise pollution, and thermal pollution.
Role of an individual in prevention of pollution. Pollution case studies. Disaster management – floods, earthquake, cyclone and landslides.

Unit 2: Issues related to Environment 12 Lectures

From Unsustainable to Sustainable development. Urban problems related to energy. Water conservation. Rain water harvesting, watershed management, Environmental ethics: issues and possible solutions. Climate change – global warming, acid rain, ozone layer depletion. nuclear accidents - case studies. Wasteland reclamation.

Unit 3: Impacts of some elements in human health 6 Lectures

Role of sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), iron (Fe), cobalt (Co), copper (Cu), and zinc (Zn) in human health.
Toxicity due to mercury (Hg), lead (Pb), cadmium (Cd), arsenic (As) and fluoride.
Importance of metal salts in diet.

Recommended Books:

1. *De, A.K. Environmental Chemistry*; Edition, 8; Publisher, New Age International (P) Limited.
2. S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi.
3. S.E. Manahan, Environmental Chemistry, CRC Press (2005).

SEMESTER III

Course Code: CHMSEC201-3

Course Title: Basic Instrumental Techniques in Chemistry

Credits: 0+0+3

(Practical: 90 Hours)

Total Marks: 50

Course Objectives: This course introduces the basic ideas about the various equipment in common chemistry laboratory. The course will also discuss about the electronic equipment's used in chemistry and as well as handling of sophisticated equipment's.

Course Outcomes: At the end of this course, students will learn about the different equipment's used in common chemistry laboratories. They will also be equipped with the knowledge of electronic equipment's used in chemistry for chemical analysis. The students will also learn about handling of sophisticated equipment's and software's used in chemistry.

Unit 1: Common Laboratory Equipment **30 Hours**

Melting point apparatus, electronic balance, viscometer, stalagmometer, pycnometer, separating funnel, distillation apparatus, Soxhlet apparatus, Kipps apparatus, centrifuge Machin, suction apparatus.

Unit 2: Basic Electronic Equipment **30 Hours**

Conductometer, pH meter, potentiometer, polarimeter, magnetic stirrer, calorimeter, hot plate, hot air oven, muffle furnace, DO meter.

Unit 3: Handling of sophisticated Equipment **30 Hours**

Flame photometer, UV-Vis spectrophotometer, IR spectrophotometer, Dean stark apparatus, Vacuum Rotary Evaporator, colorimeter, computer software (Chemdraw, origin, excel, etc.)

Recommended Books:

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis 6thEd.,* Pearson, 2009
2. Baruah, S. Practical Chemistry. Kalyani Publishers.
3. Yadav, J.B. Advanced Practical Physical Chemistry. Krishna Publication.

SEMESTER IV

Course Code: CHMMAJ203-4
Course Title: Inorganic Chemistry-2
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives**:** This course introduces students to transition elements, metallurgy of transition elements and coordination chemistry. Various aspects like nomenclature, structure, bonding, variety and reactivity of the coordination compounds are included for the students to learn.
As part of the accompanying lab course, experiments involving iodo- and iodi-metric titrations are included for the students to explore other varieties of redox titration. Preparation of simple inorganic compounds is incorporated to give hands-on experience of inorganic synthesis.
Course Outcomes**:** On successful completion, students will be able to gain the idea of general trends in the properties of transition elements in the periodic table and identify differences among the rows. The students will also learn about various aspects of metallurgy. Students will be able to name coordination compounds according to IUPAC, explain bonding in this class of compounds, understand their various properties in terms of CFSE and predict reactivity.
Through the experiments, students not only will be able to estimate and prepare inorganic compounds but also will be able to design experiments independently which they would be able to apply if and when required.

Unit 1: Transition Elements **15 Lectures**
General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Frost diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co (Chemistry of first -row transition elements) in various oxidation states as halides, oxides, hydroxides.

Unit 2: Metallurgy of elements of First Transition Series **8 Lectures**
Chief modes of occurrence of metals based on standard electrode potentials. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond’s process, Zone refining.

Unit 3: Coordination Chemistry-1 **7 Lectures**
Coordination compounds, types of ligands, Werner’s theory, IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers.

Unit 4: Coordination Chemistry-2 **15 Lectures**

Valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of 10 Dq (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δ_o, Δ_t). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspects of ligand field and MO Theory. Chelate effect, polynuclear complexes, labile and inert complexes.

Recommended Books

1. Lee, J.D. *Concise Inorganic Chemistry*, ELBS, 1991.
2. Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models of*
3. *Inorganic Chemistry 3rd Ed.*, John Wiley Sons, N.Y. 1994.
4. Greenwood, N.N. & Earnshaw. *Chemistry of the Elements*,
5. Butterworth-Heinemann. 1997.
6. Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.
7. Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning India Edition, 2002.
8. Sharpe, A.G. *Inorganic Chemistry*, 4th Indian Reprint (Pearson Education) 2005
9. Miessler, G. L. & Donald, A. Tarr. *Inorganic Chemistry* 4th Ed., Pearson, 2010.
10. Atkin, P. *Shriver & Atkins' Inorganic Chemistry* 5th Ed. Oxford University Press (2010).
11. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
12. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed., Pearson Education India, 2006.

Inorganic Chemistry-2 LAB - CHMMAJ203-4 **30 Hours**

(A) Iodo / Iodimetric Titrations

(i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).

(ii) Estimation of (i) arsenic and (ii) antimony in tartar-emetic iodimetrically

(iii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic preparations

(i) Cuprous Chloride, Cu_2Cl_2

(ii) Preparation of Manganese (III) phosphate, $MnPO_4.H_2O$

(iii) Preparation of Aluminium potassium sulphate $KAl(SO_4)_2.12H_2O$ (Potash alum) or Chrome alum.

Recommended Books:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6thEd.,* Pearson, 2009.
2. Baruah, S. Practical Chemistry. Kalyani Publishers.
3. Raj, G. Advance Practical Inorganic Chemistry. Goel Publishing House.

SEMESTER IV

Course Code: CHMMAJ204-4
Course Title: Organic Chemistry-1
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives**:** The aim of this course is to teach students the important aspects of halogenated hydrocarbons, alcohols, phenols, ethers, epoxides, carbonyl compounds and carboxylic acids.
Course Outcomes**:** The students are expected to learn preparation, properties and reactions of halogenated hydrocarbons, alcohols, phenols, ethers and epoxides, carbonyl compounds and carboxylic acids. They will also learn certain name reactions and reaction mechanisms. After attending this course, the students will be able to understand and demonstrate the concepts of organic chemistry and reactions of organic compounds. After studying the lab course of this paper, students will be able to detect of extra elements present in organic compounds, perform functional group test for nitro, amine and amide groups, and further, they will be able to perform qualitative analysis of unknown organic compounds containing simple functional groups (alcohols, carboxylic acids, phenols and carbonyl compounds).

Unit 1: Chemistry of Halogenated Hydrocarbons **10 Lectures**
Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_Ni mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.
Aryl halides: Preparation, including preparation from diazonium salts. Nucleophilic aromatic substitution; S_NAr, Benzyne mechanism. Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions. Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

Unite 2: Alcohols, Phenols, Ethers and Epoxides **10 Lectures**
Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement. *Phenols:* Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism;
Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$.

Unit 3: Carbonyl Compounds **15 Lectures**
Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer

Villiger oxidation, α-substitution reactions, Meerwein-Ponndorf-Verley Reduction, oxidations and reductions (Zn-Hg/HCl, Hydrazine /NaOH, $LiAlH_4$, $NaBH_4$, SeO_2, PDC and PCC). Michael addition. Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

Unit4: Carboxylic Acids and their Derivatives 10 Lectures

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids: succinic, malic, and phthalic, hydroxy acids: lactic, tartaric, citric, and unsaturated acids: maleic and fumaric acids. Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group - Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

Recommended Books:

1. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry,* S. Chand, 2010.
2. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry,* Orient Longman, New Delhi (1988).
3. March, J. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7th Edition. Willey & Sons.
4. Bruice, P.Y. Organic Chemistry. Pearson. 8th Edition.
5. Caruthers, W, Coldham, I. Modern Method of Organic Synthesis. Cambridge University Press; 4th edition.

Organic Chemistry-1 LAB – CHMMAJ204-4 30 Hours

1. Qualitative analysis of unknown organic compounds containing simple functional groups (alcohols, carboxylic acids, phenols and carbonyl compounds)
2. Determination of melting/boiling of organic sample.
3. Preparation of derivatives of simple organic functional group and determination of melting point.

Recommended Books:

3. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009).
4. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012).
5. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).
6. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).
7. Agarwal, O.P. Advanced Practical Organic Chemistry. Krishna Prakashan Media (P) Ltd.

SEMESTER IV

Course Code: CHMMAJ205-4
Course Title: Physical Chemistry-2
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** In this course, the chemical equilibrium, conductance, and phase equilibria will be taught to the students. Experiment based knowledge of thermochemistry will be taught in the lab course.

***Course Outcomes*:** In this course, the students are expected to learn about chemical thermodynamics, conducting properties of solution, transference number, their determination, application of conductance measurement and conductometric titrations, and hydrolysis of salts. They will also learn about phase transition and phase equilibria, the derivation of various relations related to phase equilibria, and their applications. It is also expected that the students will learn about lab-based knowledge of thermochemistry.

Unit 1: Chemical Equilibrium **15 Lectures**

Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Coupling of exoergic and endoergic reactions. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants Kp, Kc and Kx. Le Chatelier principle (quantitative treatment); equilibrium between ideal gases and a pure condensed phase.

Unit 2: Conductance **15 Lectures**

Conductance Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden’s rules. Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

Unit 4: Phase Equilibria **15 Lectures**

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications. Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions. Three component systems, water-chloroform-acetic acid system, triangular plots. Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and non-ideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation. Nernst distribution law: its derivation and applications.

Physical Chemistry-2 LAB – CHMMAJ205-4 30 Hours

Thermochemistry

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

(b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

(c) Calculation of the enthalpy of ionization of ethanoic acid.

(d) Determination of enthalpy of hydration of copper sulphate.

(e) Study of the solubility of benzoic acid in water and determination of ΔH.

Phase equilibria

(a) Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.

(b) Construction of the phase diagram using cooling curves or ignition tube method:

a. simple eutectic and
b. congruently melting systems.

(c) Distribution of acetic/ benzoic acid between water and cyclohexane.

Recommended Books

1. Khosla, B. D.; Garg, V. C. &Gulati, A., *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Athawale, V. D. & Mathur, P. *Experimental Physical Chemistry* New Age International: New Delhi (2001).
3. Yadav, J.B. Advanced Practical Physical Chemistry. Krishna Publication.
4. Baruah, S. Practical Chemistry. Kalyani Publishers.

SEMESTER IV

Course Code: CHMMIN202-4

Course Title: Chemistry-4

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving the students theoretical knowledge about the chemistry of *s* and *p* block elements, alkyl and aryl halide, chemical kinetics and catalyst.
Course Outcomes: On successful completion, students would have clear understanding of the properties of s- and p block elements present in periodic table, halogenated hydrocarbons and kinetics of reaction and catalysis. The students will get idea on the analysis of organic compounds.

Unit 1: Chemistry of *s* and *p* Block Elements 15 Lectures

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Complex formation tendency of *s* and *p* block elements. Hydrides and their classification ionic, covalent and interstitial. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogens and basic properties of halogens.

Unit 2: Chemistry of Halogenated Hydrocarbons 15 Lectures

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_Ni mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.
Aryl halides: Preparation, including preparation from diazonium salts. Nucleophilic aromatic substitution; S_NAr, Benzyne mechanism. Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions. Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

Unit 3: Chemical Kinetics and catalysis 15 Lectures

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, derivation of zero and first order rate law equation, Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates.
Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts. Homogenous and heterogenous catalysis reactions, Enzyme catalysis, acid-base catalysis.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry.* Oxford, 1970
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry,* ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
6. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
7. March, J. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7^{th} Edition. Willey & Sons.
8. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
9. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
10. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
11. Kapoor, K.L. *Textbook of Physical Chemistry*, (Vol-1). Mc.Graw Hill Education, 6^{th} Edition.

Chemistry-4 LAB – CHMMIN202-4 **30 Hours**

1. Qualitative analysis of organic sample-

a. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing upto two extra elements).

b. Identification of functional group.

2. Purification of organic compounds by crystallization (from water and alcohol) and distillation.

Recommended Books:

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009).
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012).
3. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).
4. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).
5. Agarwal, O.P. Advanced Practical Organic Chemistry. Krishna Prakashan Media (P) Ltd.

SEMESTER IV

CHMINT201-2 (Internship)

Credit: 2

Total Marks: 50

SEMESTER V

Course Code: CHMMAJ301-4
Course Title: Inorganic Chemistry-3
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*: This course familiarizes students to the knowledge of lanthanides and actinides. Organometallic compounds are incorporated so as to apprise students about the importance of metal carbon bond to form complexes and their application as catalysts. Students are expected to learn factors leading to stability of organometallic compounds, their synthesis, reactivity and uses and catalytic behaviour. Bioinorganic chemistry is included in this course to aquatint studies on the useful and harmful aspects of metals in biological system.
Through the accompanying lab course, experiments related to gravimetric analysis, synthesis of coordination compounds and separation of metal ions using chromatography is included. This will broaden the experimental skills of the students where students will learn about various aspects of experiment design depending upon the requirements like synthesis, estimation or separation.

***Course Outcomes*:** By studying this course, the students will be expected to learn about the chemistry of lanthanides and actinides. Students will also learn about organometallic compounds, comprehend their bonding, stability, reactivity and uses. They will be familiar with the variety of catalysts based on organometallic compounds and their application in industry. The students will be familiar to the role of metals in biological system.
Through the experiments, students not only will be able to prepare, estimate or separate metal complexes/compounds but also will be able to design experiments independently which they would be able to apply if and when required.

Unit 1: Lanthanoids and Actinoids **8 Lectures**

Electronic configuration, oxidation states, colour, spectral and magnetic properties of lanthanide and actinide, lanthanide and actinide contraction, separation of lanthanides (ion-exchange method only), separation of actinides. Extraction of uranium from monazite ore.

Unit 2: Organometallic Compounds **20 Lectures**

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.

Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls. Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.
Ferrocene: Preparation and reactions (acetylation, alkylation, metalation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

Unit 3: Organometallic Compounds in catalysis 8 Lectures
Study of the following industrial processes and their mechanism:
1. Alkene hydrogenation (Wilkinsons Catalyst)
2. Hydroformylation (Co salts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes.

Unit 4: Bioinorganic Chemistry 9 Lectures
Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on the distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals.
Toxicity of metal ions (Hg, Pb, Cd and As), reasons for toxicity, Use of chelating agents in medicine.
Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

Recommended Books:
1. Purcell, K.F & Kotz, J.C. *Inorganic Chemistry* W.B. Saunders Co, 1977.
2. Huheey, J.E., *Inorganic Chemistry,* Prentice Hall, 1993.
3. Lippard, S.J. & Berg, J.M. *Principles of Bioinorganic Chemistry* Panima Publishing Company 1994.
4. Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry* Wiley-VCH, 1999.
5. Basolo, F, and Pearson, R.C. *Mechanisms of Inorganic Chemistry,* John Wiley & Sons, NY, 1967.
6. Greenwood, N.N. &Earnshaw A. *Chemistry of the Elements*, Butterworth-Heinemann, 1997.
7. Bioinorganic Chemistry by Bertini, Gray, Lippard and Valentine (Eds)
8. Principles of Bioinorganic Chemistry by S.J.Lippard and J.M.Berg

Inorganic Chemistry-3 LAB - CHMMAJ301-4 30 Hours
Gravimetric Analysis
i. Estimation of nickel (II) using Dimethylglyoxime (DMG).
ii. Estimation of copper as CuSCN.
iii. Estimation of iron as Fe_2O_3 by precipitating iron as $Fe(OH)_3$.

iv. Estimation of Al (III) by precipitating with oxine and weighing as Al(oxine)$_3$ (aluminium oxinate).

Inorganic Preparations

i. Tetraamminecopper (II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$

ii. *Cis* and *trans* $K[Cr(C_2O_4)_2.(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)

iii. Tetraamminecarbonatocobalt (III) ion

iv. Potassium tris(oxalate)ferrate(III)

Chromatography of metal ions

Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:

i. Ni (II) and Co (II)

ii. Fe (III) and Al (III)

Recommended Books:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6thEd.,* Pearson, 2009.
2. Raj, G. Advance Practical Inorganic Chemistry. Goel Publishing House.

SEMESTER V

Course Code: CHMMAJ302-4

Course Title: Organic Chemistry-2

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** The students will be taught about nitrogen and sulphur compounds, alkaloids, terpenes, dyes, and carbohydrates. They will also be introduced to organic photochemistry and its processes.

***Course Outcomes*:** At the end of the course, the students will learn about the preparation and important reactions of nitrogen and sulphur compounds. They will also learn about the occurrence, classification, properties and related aspects of alkaloids, terpenes, dyes, and carbohydrates. After attending this course, the students will be able to understand and demonstrate the basic concepts of organic photochemistry and related processes. After studying the lab course of this paper, students will be able to estimate and determine the amount of glycine, proteins, saponification value and iodine number of oil/fat, and they will also be able to do isolation and characterization of DNA from natural products.

Unit 1: Nitrogen and Sulphur Containing Functional Groups 12 Lectures

Preparation and important reactions of nitro and compounds, nitriles and isonitriles.

Amines: Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid. Diazonium Salts: Preparation and their synthetic applications.
Preparation and reactions of thiols, thioethers and sulphonic acids.

Unit 2: Molecular Rearrangement **10 Lectures**

Nucleophilic or anionotropic: Whitmore 1,2 Shift, Wagner-Meerwein, Wolff,
Hofmann, Lossen, Curtius, Schmidt, Beckman, Favorskii, Benzil- benzilic acid,
Baeyer Villiger
Free radical: Wittig
Electrophilic or cationotropic: Pinacol pinacolone
Special: Fries rearrangement (aromatic electrophilic substitution)
Stevens rearrangement (ion pairs in solvent cage/ radical pair)

Unit 3: Heterocyclic chemistry **13 Lectures**

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of: Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction.

Unit 4: Dyes **5 Lectures**

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing; Synthesis and applications of: Azo dyes – Methyl Orange and Congo Red; Triphenyl Methane Dyes - Malachite Green, Rosaniline and Crystal Violet; Phthalein Dyes – Phenolphthalein and Fluorescein; Natural dyes –structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

Unit 5: Chromatographic techniques **5 Lectures**

Introduction and basic principles of chromatography (paper, thin layer, column, gas, HPLC and GPC).

Recommended Books:

1. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Finar, I. L. *Organic Chemistry* (*Volume 2: Stereochemistry and the Chemistry of Natural Products*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

4. Acheson, R.M. *Introduction to the Chemistry of Heterocyclic compounds,* John Welly & Sons (1976).
5. Graham Solomons, T.W. *Organic Chemistry,* John Wiley & Sons, Inc. McMurry, J.E. *Fundamentals of Organic Chemistry,* 7th Ed. Cengage Lear ning India Edition, 2013.
6. Kalsi, P. S. *Textbook of Organic Chemistry 1stEd.*, New Age International (P) Ltd. Pub.
7. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry,* Oxford University Press.
8. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry,* Prajati Parakashan (2010).

Organic Chemistry-2 LAB - CHMMAJ302-4 30 Hours

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.
3. Estimation of proteins by Lowry's method.
4. Study of the action of salivary amylase on starch at optimum conditions.
5. Effect of temperature on the action of salivary amylase.
6. Saponification value of an oil or a fat.
7. Determination of Iodine number of an oil/ fat.
8. Isolation and characterization of DNA from onion/ cauliflower/peas.

Recommended Books:

1. Arthur, I. V. *Quantitative Organic Analysis,* Pearson.
2. Bansal, R.K., Laboratory Manual of Organic Chemistry, New Age International.

SEMESTER V

Course Code: CHMMAJ303-4

Course Title: Physical Chemistry-3

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives**:** The aim of this course is to teach students the important topics of physical chemistry viz. chemical kinetics, electrochemistry and quantum chemistry. Moreover, the students will be trained to handle UV-Visible spectrometers and colorimeters used in various experimental purposes.

Course Outcomes**:** The students are expected to learn chemical kinetics and its application. They will also learn the rate laws of chemical transformation, experimental methods of rate law determination, steady state approximation, etc. in the chemical kinetics unit. After attending this course, the students will be able to understand electrochemistry and various laws related to it. They will learn about theoretical chemistry i.e. quantum chemistry. After studying the lab course of this paper, students will be able the handle UV-Visible spectrometers and colorimeters for various experimental purposes.

Unit 1: Chemical Kinetics-1 15 Lectures

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates.

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

Unit 2: Electrochemistry 10 Lectures

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry. Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb_2O_3 electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

Unit 3: Quantum Chemistry-1 20 Lectures

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment), quantization of energy levels, zero-point energy and Heisenberg Uncertainty principle; wave functions, probability distribution functions, nodal properties, Extension to two- and three-dimensional boxes, separation of variables, degeneracy. Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wave functions. Vibrational energy of diatomic molecules and zero-point energy. Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component. Rigid rotator model of rotation of diatomic molecule. Schrödinger equation, transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution. Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus. Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom). Chemical bonding: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+. Bonding and antibonding orbitals.

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

Recommended Books:

1. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
2. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
3. Kapoor, K.L. *Textbook of Physical Chemistry*. Mc.Graw Hill Education, 6^{th} Edition.
4. Negi, A. S. Anand, S. C. A Textbook of Physical Chemistry. New Age International.
5. Chandra, A. K. *Introductory Quantum Chemistry* Tata McGraw-Hill (2001).
6. House, J. E. *Fundamentals of Quantum Chemistry* 2nd Ed. Elsevier: USA (2004).
7. Sen, B. K. Quantum Chemistry- Including Spectroscopy, Kalyani Publishers; 4th edition (2011).
8. Choudhury, H.K., *Physical Chemistry-V*, Kalyani Publishers.

Physical Chemistry-3 LAB - CHMMAJ303-4 30 Hours

UV/Visible spectroscopy

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).
2. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$.
3. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.

Colorimetry

1. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/$K_2Cr_2O_7$ in a solution of unknown concentration
2. Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.
3. Study the kinetics of iodination of propanone in acidic medium.
4. Determine the amount of iron present in a sample using 1,10-phenathroline.
5. Determine the dissociation constant of an indicator (phenolphthalein).
6. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.
7. Analysis of the given vibration-rotation spectrum of HCl(g).

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).

2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.;* McGraw-Hill: New York (2003).
3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rdEd.;* W.H. Freeman & Co.: New York (2003).

SEMESTER V

Course Code: CHMMAJ304-4

Course Title: Computers in Chemistry

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** This course intends to make learners familiar with the basics of computer language, computer programming, handling of experimental data, curve fitting, etc to analyse experimental results. This basic knowledge will help the students to perform and interpret the results of various chemistry practical.

***Course Outcomes*:** After the completion of this course, it will help the student to interpret laboratory data, curve fitting of experimental work, and also to perform quantum mechanical calculations for various molecular models.

Unit 1: Introduction to Computers 20 Lectures

Definition of computer, computer program, components of a computer – input unit and output units. Secondary storage devices – magnetic disks, floppy disks, hard disks, optical disks.

The general idea of hardware and software.

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

Unit 2: Numerical methods 15 Lecture

Roots of equations: Numerical methods for roots of equations: Quadratic formula, iterative method, Newton-Raphson method, Binary bisection and Regula-Falsi. Differential calculus: Numerical differentiation. Integral calculus: Numerical integration (Trapezoidal and Simpson's rule), probability distributions and mean values. Simultaneous equations: Matrix manipulation: addition, multiplication. Gauss-Siedal method. Interpolation, extrapolation and curve fitting: Handling of experimental data.

Unit 3: BASIC Programming Applications in Chemistry 15 Lectures

Determination of empirical formula of hydrocarbons, Program to determine molecular weights of organic compounds.

Determination of electronegativity of an atom from bond energy data using Pauling's relation, determination of lattice energy of a crystal using Born-Lende Equation.

Recommended Books:

1. Raman, K. V., Computers in chemistry. Tata McGraw-Hill Company Limited.
2. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.
3. De Levie R. How to Use Excel® in Analytical Chemistry: And in General Scientific Data Analysis. Cambridge University Press; 2001.
4. Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).
5. Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996)

Computers in Chemistry LAB - CHMMAJ304-4 30 Hours

Computer programs based on numerical methods for

1. Roots of equations: (e.g., the volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).
2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).
3. Use of software (Chem-Draw etc.) to draw simple molecular structure.
4. Use of software (Origin, Excel etc.) to draw graph.

Recommended Books:

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

SEMESTER V

Course Code: CHMMIN301-4

Course Title: Chemistry-5

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving the students theoretical knowledge about the d-block elements and coordination chemistry; preparation and reactions of alcohols, phenols and ethers; and chemical and ionic equilibrium.

Course Outcomes: On successful completion, students would have clear understanding of the properties of d- block elements and its bonding in complexes; preparation, physical and chemical properties of alcohols, phenols and ethers; and equilibrium. From the laboratory course, the students will get idea on the determination of solubility and paper chromatography to separate sugar from a mixture.

Unit 1: Coordination Chemistry — 15 Lectures

Study of transition elements (electronic configuration, characteristics and important compounds of transition elements). Werner's theory, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of 10 Dq (o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq.

Unite 2: Alcohols, Phenols, Ethers and Epoxides — 15 Lectures

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement. *Phenols:* Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism.

Ethers and Epoxides: Preparation and chemical reactions of ethers with HI. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$.

Unit 3: Equilibria — 15 Lectures

Kp, Kc and *Kx* for reactions involving ideal gases and their relations. Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Le Chatelier's principle and its application (Synthesis of ammonia as an example). Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect. Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry.* Oxford, 1970
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
6. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry,* Orient Longman, New Delhi (1988).
7. March, J. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. 7th Edition. Willey & Sons.
8. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
9. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
10. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
11. Kapoor, K.L. *Textbook of Physical Chemistry*. Mc.Graw Hill Education, 6th Edition.

Chemistry-5 LAB - CHMMIN301-4 **30 Hours**

1. To determine the solubility of a given salt at room temperature.
2. To determine the solubility of a given salt at different temperatures and to plot solubility curve.
3. To determine water of crystallization of hydrated salt by ignition and weighing.
4. Determinations of the concentrations of sodium carbonate and sodium hydroxide in a given mixture.
5. To study the kinetics of the reaction between H_2O_2 and iodide ion.
6. Paper chromatographic separation and identification of sugars.

Recommended Books:

1. Yadav, J.B. Advanced Practical Physical Chemistry. Krishna Publication.
2. Baruah, S. Practical Chemistry. Kalyani Publishers

SEMESTER VI

Course Code: CHMMAJ305-4
Course Title: Organic Chemistry-3
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** This course introduces students to the knowledge about various aspects of biochemistry and pharmaceutical compounds. Students will be taught about classification, nomenclature, structure, and reactions of heterocyclic compounds. Students will also be familiarized about aromaticity and stereoelectronic factors.
***Course Outcomes*:** Students will be able to explain/describe the important features of biochemistry and pharmaceutical compounds. They will also be able to explain/describe the features of nucleic acids, amino acids and enzymes and develop their ability to examine their properties and applications. After attending this course, the students will be able to demonstrate the concepts of heterocyclic compounds, aromaticity and stereoelectronic factors of organic reactions. After studying the lab course of this paper, students will get exposure and be able to extract analyse and prepare organic compounds and be able to interpret IR and NMR spectra of certain organic compounds.

Unit 1: Organic reaction mechanism 15 Lectures
Reaction intermediates *vs*. transition state, thermodynamic product *vs*. kinetic product; factors affecting mechanism and reactivity in nucleophilic substitution reactions; factors affecting mechanism and reactivity in elimination reactions, and competition with substitution reactions. Kinetic & non-kinetic methods; kinetic isotope labelling studies; significance of rate limiting step in multi-step reactions; from rate law to mechanism and from mechanism to rate law. Hammett & Taft equation; partial rate factor.

Unit 2: Biochemistry 15 Lectures
Lipids and structure of cell membrane; membrane transport
Carbohydrates, proteins, nucleic acids.
Amino acids, peptides and polypeptides: Primary, secondary, tertiary and quaternary structure of proteins. Structure and functions of haemoglobin and myoglobin.
Enzymes and their function as catalysts: chymotrypsin and lysozyme. Metalloenzymes, carboxypeptidase and peptide hydrolysis. Coenzymes and vitamins.
Structure and hydrogen bonding in purines and pyrimidines.
Structure of nucleotides and nucleosides. Structure of RNA and DNA.
Gene and genetic code: biosynthesis of DNA (replication), RNA (transcription) and proteins (translation)
Fundamentals of biological energy production-Glycolysis, Krebs cycle, Photosynthesis, respiration, oxidative phosphorylation and ATP synthesis.

Unit 3: Pharmaceutical chemistry 10 Lectures
Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis), Antimalarials: Chloroquine (with synthesis). An

elementary treatment of Antibiotics and detailed study of chloramphenicol, Medicinal values of curcumin (turmeric), azadirachtin (neem), vitamin C and antacid (ranitidine).
Drugs-physiological effect of their structure. Classification Chiral drugs and asymmetric synthesis. Antibiotics and their action. Anticancer and antimalarial drugs. Immunity and AIDS. Sulpha drugs- their mechanism of action.
Preparation of aspirin, quinine, chloroquine, paracetamol, phenacetine, sulphanilamide and other sulpha drugs.
Anti-cancer drugs: Cisplatin.

Unit 4: Aromaticity and Stereoelectronic factors 8 Lectures

Aromaticity and antiaromaticity– nonclassical concepts should be emphasized; HSAB concepts and their applications; symbiosis. Stereoelectronic effects on reactivity– effect through bonds, through space; conformation and reactivity.

Recommended Books:

1. Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.
2. Nelson, D. L. & Cox, M. M. *Lehninger's Principles of Bioch*emistry *7thEd.*, W. H. Freeman.
3. Freifelder, D. Physical Biochemistry 2nd Ed., W.H. Freeman and Co., N.Y. USA (1982).
4. Cooper, T.G. The Tools of Biochemistry, John Wiley and Sons, N.Y. USA. 16(1977).
5. Rastogi, S.C. Biochemistry, McGraw Hill Education; 3rd edition

Organic Chemistry-3 LAB - CHMMAJ305-4 30 Hours

1. Extraction of caffeine from tea leaves.
2. Preparation of sodium polyacrylate.
3. Preparation of urea formaldehyde resin.
4. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars.
5. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, for e.g. salicylic acid, cinnamic acid, nitrophenols, etc.
6. Identification of simple organic compounds by IR spectroscopy and NMR spectroscopy (Spectra to be provided).
7. Preparation of methyl orange.

Recommended Books:

1. Vogel, A.I. *Quantitative Organic Analysis,* Part 3, Pearson (2012).
2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009).
3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012).
4. Ahluwalia, V.K. &Aggarwal, R. *Comprehensive Practical Organic Chemistry:*
5. *Preparation and Quantitative Analysis,* University Press (2000).

6. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).

SEMESTER VI

Course Code: CHMMAJ306-4

Course Title: Spectroscopy-1

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** Students will be introduced to the fundamental principles of spectroscopy with special emphasis on rotational, vibrational, Raman, electronic spectroscopies, spin resonance and mass spectroscopy.

***Course Outcomes*:** Students will be able to identify/explain the theoretical basis of different spectroscopic techniques, and show their application in analyzing/interpreting experimental data.

Unit 1: Introduction to Spectroscopy — 5 Lectures

The nature of electromagnetic radiation. The regions of spectrum. Mechanism of interaction of electromagnetic radiation with matter. Absorption and emission spectroscopy. Basic elements of practical spectroscopy. Representation of spectrum – the width of spectral line. Intensity of spectral lines. Selection rules for various transitions. The Beer-Lambert law, molar absorption coefficient and absorbance. Molecular motion and energy – degree of freedom. Moment of inertia.

Unit 2: Rotational Spectroscopy — 5 Lectures

Rotational spectra of diatomic molecules – rigid rotator concept – determination of bond length – effect of isotopic substitution – spectra of non-rigid rotator.

Unit 3: Vibrational and Raman Spectroscopy — 10 Lectures

Vibrational spectra of diatomic molecules – harmonic and anharmonic oscillator model – Morse potential - calculation of force constants – effect of isotope - vibrations of polyatomic molecules, fundamental modes of vibration of H_2O & CO_2 molecules. Diatomic vibrating rotor – vibration rotation spectrum of CO. Basic principles of IR spectroscopy.

Principle of Raman spectroscopy – rotational and vibrational Raman spectra of linear molecules, stokes and anti-stokes lines, rule of mutual exclusion. Symmetry and IR/Raman activity of normal modes of vibration. Interpretation of IR and Raman spectra of simple inorganic and coordination compounds.

Unit 4. Electronic spectroscopy **5 Lectures**

Basic principles. Electronic transitions and selection rule - spectrum of atomic hydrogen – fine structure, spectra of H-like atoms. Electronic transitions in diatomic molecules – Selection rule - Born Oppenheimer approximation – vibrational coarse structure - Frank Condon principle – electronic transitions in polyatomic molecules. chromophore, auxochrome – absorption due to ethylenic chromophore. Effect of solvents on electronic transition, quantitative estimation by spectrophotometry.

Unit 5. Spin resonance spectroscopy **12 Lectures**

Basic principle of NMR. Interaction between spin and magnetic field, equivalent and non-equivalent proton, ^{1}H NMR – presentation of the spectrum - chemical shift and its unit, factors affecting chemical shift – chemical shifts for simple organic molecules (alkane, alkene, alkyne, arenas, aldehydes, carboxylic acids and esters). Splitting patterns of signals, coupling constant and its distinction from chemical shift - use of coupling constant in structural elucidation Spin-spin coupling and high resolution ^{1}H NMR spectra of ethanol, ethyl benzoate, 2-iodopropane, cyanohydrin.

Basic concept of electron spin resonance spectroscopy – presentation of the spectrum – hyperfine structure – ESR of H- atom, deuterium atom and methyl radical.

Unit 6. Basics of Mass spectroscopy **5 Lectures**

Mass spectroscopy, principle, idea of mass spectrometer, fragmentation pattern, base peak, molecular ion peak and metastable ion, nitrogen rule.

Spectroscopy LAB - CHMMAJ306-4 **30 Hours**

1. Determination of pKa values of indicator using spectrophotometry.
2. Structural characterization of compounds by infrared spectroscopy.
3. Determination of a Mixture of Cobalt and Nickel by UV/Vis spectrophotometer.
4. Determination of concentration of Na and K in water by Flame Photometer.

Recommended Books:

1. Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Ed.
2. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of Analysis*,
3. 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.
4. Drago, R. S. Physical Methods in Chemistry, (Saunders College Publishing, 1992).
5. Hollas, J. M. Modern Spectroscopy, (John Wiley, 1996).

SEMESTER VI

Course Code: CHMMAJ307-4
Course: Industrial Chemistry
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: The aim is to teach the students about fertilizers, surface coating, silicate industries, batteries, etc. They will also be provided with knowledge of the characterization of some industrial compounds and their preparations.

Course Outcomes: Students will gain an understanding of

- Properties and the types of different glasses, ceramics, and cement.
- Different types and manufacture of fertilizers, and composition of paint pigments.
- Working principle of different batteries, elements present in alloys, different types of steel, etc.
- They will be able to prepare some industrial chemical compounds.

Unit 1: Silicate Industries **15 Lectures**

Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

Ceramics: Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fibre.

Cements: Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cements.

Unit 2: Fertilizers **7 Lectures**

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

Unit 3: Surface Coatings **8 Lectures**

Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings, metal spraying and anodizing.

Unit 4: Batteries **4 Lectures**

Primary and secondary batteries, battery components and their role, Characteristics of Battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

Unit 5: Alloys **11 Lectures**

Classification of alloys, ferrous and non-ferrous alloys, and Specific properties of elements in alloys. Manufacture of Steel (removal of silicon, decarbonization, demanganization, desulphurization, dephosphorisation) and surface treatment (argon treatment, heat treatment, nitriding, carburizing). Composition and properties of different types of steels.

Recommended Books:

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.
4. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
5. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.
6. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas Publications, New Delhi.
7. B. K. Sharma: Engineering Chemistry, Goel Publishing House, Meerut.

Industrial Chemistry LAB - CHMMAJ307-4 **30 Hours**

1. Determination of free acidity in ammonium sulphate fertilizer.
2. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
3. Estimation of phosphoric acid in superphosphate fertilizer.
4. Electroless metallic coatings on ceramic and plastic material.
5. Determination of composition of dolomite (by complexometric titration).
6. Analysis of (Cu, Ni); (Cu, Zn) in alloy or synthetic samples.
7. Analysis of Cement.
8. Preparation of pigment (zinc oxide).

Recommended Books:

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.
4. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
5. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.
6. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas Publications, New Delhi.
7. B. K. Sharma: Engineering Chemistry, Goel Publishing House, Meerut.

SEMESTER VI

Course Code: CHMMAJ308-4
Course Title: Environmental Chemistry
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** Students will be introduced to the various aspects of environmental chemistry, the chemistry of the atmosphere, and water. It is also aimed to provide knowledge of environmental sources of energy and biocatalysts. They will be taught about the large-scale production, uses, storage, and hazards in handling industrial gases and compounds.
***Course Outcomes*:** Students will be able to demonstrate an understanding of environmental chemistry, viz. air, and water chemistry, and identify the relationships between atmosphere, solar radiation, and ozone formation. They will learn about the environmental source of energy, application of biocatalysts, large-scale production, uses, storage, and hazards in handling industrial gases and compounds.

Unit 1: Environment and its segments Ecosystems **20 Lectures**

Biogeochemical cycles of carbon, nitrogen and sulphur.
Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution. Pollution by SO_2, CO_2, CO, NOx, H_2S and other foul-smelling gases. Methods of estimation of CO, NOx, SOx and control procedures. Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.
Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems. Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal. Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

Unit 2: Energy & Environment Sources of energy **10 Lectures**

Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.
Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

Unit 3: Biocatalysis **5 Lectures**

Introduction to biocatalysis: Importance in “Green Chemistry” and Chemical Industry.

Unit 4: Industrial Gases and Inorganic Chemicals 10 Lectures

Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene. Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

Recommended Books:

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. R.M. Felder, R.W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
3. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
4. S. S. Dara: A Textbook of Engineering Chemistry, S. Chand & Company Ltd. New Delhi.
5. K. De, Environmental Chemistry: New Age International Pvt., Ltd, New Delhi.
6. S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi.
7. S.E. Manahan, Environmental Chemistry, CRC Press (2005).
8. G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).
9. A. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).

Environmental Chemistry LAB - CHMMAJ308-4 30 Hours

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Determination of Biological Oxygen Demand (BOD)
4. Percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by simple titration method ($AgNO_3$ and potassium chromate).
6. Estimation of total alkalinity of water samples (CO_3^{2-}, HCO_3^-) using double titration method.
7. Measurement of dissolved CO_2.
8. Study of some of the common bio-indicators of pollution.
9. Estimation of SPM in air samples.
10. Preparation of borax/ boric acid.

Recommended Books:

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. R.M. Felder, R.W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
3. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
4. S. S. Dara: A Textbook of Engineering Chemistry, S. Chand & Company Ltd. New Delhi.
5. K. De, Environmental Chemistry: New Age International Pvt., Ltd, New Delhi.
6. S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi.

SEMESTER VI

Course Code: CHMMIN302-4
Course Title: Chemistry-6
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: This course aims at giving the students theoretical knowledge about the acid - base chemistry; preparation and reactions of carbonyl compounds; and surface and colloidal chemistry.

Course Outcomes: On successful completion, students would have clear understanding of the different concept of acid base chemistry; preparation, physical and chemical properties of aldehyde, ketone and carboxylic acid; and colloidal chemistry and its application. In the laboratory course, the students will get idea on semimicro qualitative analysis of inorganic mixture containing six radicals. Moreover, the students will get exposure on the preparation of coordination compounds.

Unit 1: Acids and Bases **10 Lectures**

Brönsted-Lowry concept of acid and base, conjugate acid-base, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Hard and Soft Acids and Bases (HSAB). Application of HSAB principle.

Unit 2: Redox reaction **5 Lectures**

Redox equations, Standard Electrode Potential and its application to inorganic reactions. Principles involved in volumetric analysis to be carried out in class.

Unit 3: Carbonyl Compounds and Carboxylic Acids **15 Lectures**

Structure, reactivity and preparation; Nucleophilic addition reactions, Mechanisms of Aldol condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, haloform reaction and α-substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$). Addition reactions of unsaturated carbonyl compounds: Michael addition.

Preparation, physical properties and reactions of monocarboxylic acids. Preparation and reactions of acid chlorides, anhydrides, esters and amides; Claisen condensation, Dieckmann and Reformatsky reactions, Hoffmann bromamide degradation and Curtius rearrangement.

Unit 4: Surface chemistry and colloids **15 Lectures**

Introduction to solid surfaces, adsorption on surfaces – physisorption and chemisorption. Adsorption isotherms – Langmuir, Freundlich, BET equation. Determination of surface area, Catalytic activity at surface with examples.

Colloids: Definition, sols, lyophobic and lyophilic colloids. Structure, surface and stability of colloids. Surface-active agents, micelle formation, critical micellar concentration, electrical double layer and Electrokinetic phenomena.

Recommended Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry*. Oxford, 1970
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Puri, B.R., Sharma, L.R., Kalia, K.C. *Principles of Inorganic Chemistry*, Vishal Publishing Co.
5. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
6. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
7. Atkins, P.W. & Paula, J. *Physical Chemistry*, 10th Ed., Oxford University Press, 2014.
8. Puri, B.R., Sharma, L.R., Pathania, M.S. *Principles of Physical Chemistry*. Vishal Publishing Co.
9. Kapoor, K.L. *Textbook of Physical Chemistry*, (Vol-2). Mc.Graw Hill Education, 6th Edition.

Chemistry-6 LAB - CHMMIN302-4 **30 Hours**

1. Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested:
   CO_3^{2-}, NO_2^-, S_2^-, SO_3^{2-}, SO_4^{2-}, NO_3^-, Cl^-, Br^-, BO_3^{3-}, NH_4^+, K^+, Pb^{2+}, Sn^{2+}, Cu^{2+}, Cd^{2+}, Fe^{3+}, Fe^{2+}, Zn^{2+}, Al^{3+}, Ca^{2+}, Ba^{2+}, Mg^{2+}.
2. **Inorganic Preparations**
   i. Tetraamminecopper (II) sulphate
   ii. Tetraamminecarbonatocobalt (III) ion
   iii. Potassium tris(oxalate)ferrate(III)

Recommended Books:

1. Raj, G. Advance Practical Inorganic Chemistry. Goel Publishing House.
2. Vogel's *Qualitative Inorganic Analysis*, Revised by G. Svehla. Pearson Education, 2002.
3. Marr & Rockett *Practical Inorganic Chemistry*. John Wiley & Sons 1972.

SEMESTER VII

Course Code: CHMADL 14014
Course Title: Physical Chemistry-4
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives**:** The aim of this course is to teach students the important topics of physical chemistry viz. chemical thermodynamics and electrochemistry. Moreover, the students will acquire the knowledge of experimental thermodynamics and electrochemistry.

Course Outcomes**:** The students are expected to learn some advanced topics of chemical thermodynamics and its application. They will also learn about various aspects of dynamic electrochemistry and their applications. After attending this course, the students will be able to understand thermodynamics and electrochemistry. After studying the lab course of this paper, students will be able to know the practical aspects of thermochemistry and electrochemistry.

Unit 1. Chemical Thermodynamics **17 Lectures**

Brief review of thermodynamic functions and laws of thermodynamics: Temperature dependence of thermodynamic functions; Experimental determination of thermodynamic functions; Thermodynamic description of mixtures, Gibbs-Duhem equation; Chemical equilibrium; Thermodynamic description of phase transitions, Clapeyron-Claussius equation, Phase diagrams; Thermodynamics of non-ideal systems– fugacity and activity concepts, excess properties.

Thermodynamics of real gases and gas mixtures, fugacity and its determination. Nonideal solutions, activity and activity coefficient- different scales of activity coefficients, electrolytic activity coefficients.

Thermodynamic criteria of phase equilibrium, Gibbs phase rule and its application to three-component systems- triangular plots- water-acetic acid chloroform and ammonium chloride-ammonium sulphate-water system.

Unit 2. Non-equilibrium Thermodynamics **14 Lectures**

Difference between equilibrium and non-equilibrium thermodynamics, Criteria of nonequilibrium thermodynamics; uncompensated heat and its relation to other thermodynamic functions, Fluxes and forces- relation between these two quantities, Entropy production in heat transfer, mass transfer in flow of current, in mixing of gases, and in chemical reaction; phenomenological relation: Onsager relation, microscopic reversibility and Onsager reciprocity. Coupled reaction. Thermoelectric effects: Seebeck, Peltier and Thompson effect.

Unit 3. Dynamic Electrochemistry **14 Lectures**

Ion-solvent interactions: The Born model-thermodynamic parameters of ion-solvent interactions -structural treatment; the ion-dipole model – its modifications, ion-quadrupole and ion-induced dipole interactions.

Primary solution – determination of hydration number, compressibility method and Viscosity mobility method.
Debye-Húckel theory of ion-ion interactions – derivation, validity and limitations; extended Debye-Húckel-Onsager equation.
The random walk model of ionic diffusion - Einstein-Smoluchowski relation. Electro catalysis-influence of various parameters.

Physical Chemistry-4 LAB – CHMADL 14014 30 Hours

Unit 1. Thermochemistry

- (i) Determination of the heat capacity of a calorimeter and hence determination of the enthalpy of solution of NH_4Cl.
- (ii) Determination of heat of hydration of hydrated salt.
- (iii) Determination of integral heat of solution of a salt at two concentrations and hence the heat of dilution
- (iv) Determination of the integral heat of dilution of sulphuric acid.
- (v) Determination of heat of precipitation of $BaSO_4$.
- (vi) Determination of heat of transition.

Unit 2. Electrochemistry

- (i) Determine the equivalent conductivity of acetic acid at infinite dilution by Kohlrausch's method and hence find the degree of dissociation constant of the acid.
- (ii) Compare the relative strength of acetic acid and monochloroacetic acid by conductance measurement.
- (iii) Determine the solubility and the solubility product of a sparingly soluble salt like $PbSO_4$ or PbI_2 at room temperature by conductance measurement.
- (iv) Determine the degree of hydrolysis and the hydrolysis constant of aniline hydrochloride/sodium acetate.
- (v) Determine the strength of the components of the following mixtures by conductometric titration.
  - (a) Hydrochloric acid and acetic acid.
  - (b) Sulphuric acid and copper sulphate.
  - (c) Hydrochloric acid and potassium chloride.

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER VII

Course Code: CHMADL 14024
Course Title: Organic Chemistry-4
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives**:** The It is aimed to teach students the important concepts of stereochemistry, stereoselective reactions and reactivity and selectivity principles. Moreover, the students will be taught the organic photochemistry.
Course Outcome**:** Students will be able to demonstrate/explain the unique features of stereochemistry, stereoselective reactions and reactivity and selectivity principles and will be able to solve related problems. After learning the course, students will acquire the detailed knowledge on organic photochemistry. After studying the lab course of this paper, students will be able to analyse and identify binary organic mixtures and will be able to estimate organic compounds.

Unit 1. Stereochemistry **20 Lectures**
Chirality: Concept of chirality, symmetry elements, relative and absolute configuration and their stability.
Two or more chiral centres: Constitutionally unsymmetrical molecules: erythro-threo and syn-anti systems of nomenclature. Constitutionally symmetrical molecules with odd and even number of chiral centers: enantiomeric and meso forms, concept of stereogenic, chirotopic, and pseudoasymmetric centres. R-S nomenclature for chiral centres in acyclic and cyclic compounds.
Axial and planar chirality: Principles of axial and planar chirality. Stereochemical features and configurational descriptors (R, S) for the following classes of compounds: allenes, alkylidene cycloalkanes, spirans, biaryls (buttressing effect) (including BINOLs and BINAPs), ansa compounds, cyclophanes, trans-cyclooctenes.
Prochirality: Chiral and prochiralcentres; prochiral axis and prochiral plane. Homotopic, heterotopic (enantiotopic and diastereotopic) ligands and faces. Identification using substitution and symmetry criteria. Nomenclature of stereoheterotopic ligands and faces. Symbols for stereoheterotopic ligands in molecules with i) one or more prochiralcentres ii) a chiral as well as a prochiralcentre, iii) a prochiral axis iv) a prochiral plane v) pro-pseudoasymmetric centre. Symbols for enantiotopic and diastereotopic face.

Unit 2. Reactivity & Selectivity principles **5 Lectures**
Reactivity- selectivity principle– product selectivity, substrate selectivity, chemoselectivity, regioselectivity, stereoselectivity & stereospecificity in substitution, elimination and addition reactions; steric acceleration and steric retardation.

Unit 3. Stereoselective synthesis **8 Lectures**

Classification of stereoselective synthesis– diastereoselective, enantioselective & double stereodifferentiating reactions; nucleophilic addition to aldehyde and acyclic ketones- Cram, Felkin and Felkin-Anh model; nucleophilic addition to cyclic ketones.
Asymmetric synthesis– use of chiral reagent, chiral catalyst and chiral auxiliary.

Unit 4. Organic Photochemistry **12 Lectures**

General principles of photochemistry; excited state, and photosensitization, photochemical processes–chemiluminescence, Jablonski diagram, chemical and photochemical method of producing singlet oxygen, reactions of singlet oxygen- photooxidation, photostereomutation of cis-trans isomers.
Photochemistry of carbonyl compounds–representation of the excited states of ketones, Norrish type-I and Norrish type-II reactions. Photoreduction of saturated, arylalkyl and *α,β*-unsaturated ketones and *p*-benzoquinone; Paterno-Buchi reaction.

Organic Chemistry-4 LAB – CHMADL 14024 **30 Hours**

A. Qualitative Organic Analysis **22 Hours**

Binary mixtures of organic compounds, covering compounds with major functional groups, should be given with an objective to train students in qualitative separation by physico-chemical methods and identifying the compounds by chemical analysis.

B. Organic Estimation **8 Hours**

I. Number of hydroxy groups in a disaccharide by acetylation.
II. Percentage purity of carbonyl compounds by 2,4 dinitrophenylhydrazine.
III. Carboxylic acid by Ag-salt method.
IV. Glucose & sucrose in a mixture.

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER VII

Course Code: CHMADL 14034
Course Title: Inorganic Chemistry-4
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course objectives: The aim of this course is to teach students the important topics of chemical bonding, group theory, structure of simple solids, and supramolecular chemistry.

Course outcome: Students will be able to develop a comprehensive understanding of chemical bonding principles, applying them to predict molecular structures and reactivity. Master symmetry concepts in group theory, analysing molecular properties and extending knowledge to the structure of crystalline solids. Gain proficiency in understanding crystal structures and diffraction techniques, correlating structural characteristics with solid properties. Students will get the idea of supramolecular chemistry for a wide range of applications. After studying the lab course of this paper, students will be able to prepare inorganic complexes.

Unit 1. Chemical bonding **17 Lectures**

Chemical bonding of simple inorganic covalent compounds-molecular orbital treatments, hybridization; understanding molecular properties from bonding. Molecular orbital theory of homo-and hetero nuclear diatomics, molecular orbitals of Polyatomic molecules, molecular shape in terms of molecular orbitals- Walsh diagrams. Atomic and ionic radii-bond length and bond strength, vanderWaals forces. Hydrogen bonding interactions,effects of hydrogen bonding and other chemical Forces on melting and boiling points and solubility.

Unit 2. Group Theory **8 Lectures**

Symmetry elements, symmetry operations, point groups and molecular symmetry, Mulliken's symbol, reducible and irreducible representations, character tables.

Unit 3. Structure of simple solids **12 Lectures**

Packing of spheres-hexagonal and cubic close-packing, tetrahedral and octahedral Holes in close-packed structures-metals and alloys, solid solutions. The ionic model for the description of bonding in ionic solids. Characteristic structures of ionic solids -the NaCl and CsCI types, the sphalerite and wurtzite types of ZnS, the NiAs Structure type, Structures of compounds of the type: AB [zinc sulfide (ZnS), nickel arsenide (NiAs)], AB_2 [fluorite (CaF_2), antifluorite (Na_2O), rutile (TiO_2) and layer structures viz., cadmium chloride ($CdCl_2$) and cadmium iodide, (CdI_2)], the perovskite and spinel structure types of mixed-metal oxides. Importance of ionic radii and the radius ratios in determining structure type among ionic solids. Lattice energy considerations, thermal stability and solubility-of inorganic solids.

Unit 4. Supramolecular Chemistry **8 Lectures**

Introduction to supramolecular chemistry, concepts of host guest chemistry, classification, thermodynamics and kinetic stability, non-covalent interactions, molecular recognition,

recognition of anionic substrates, Molecular receptors for different types of molecules: Crown ethers, cryptands, cyclodextrins, Calixarenes.

Inorganic Chemistry-4 LAB - CHMADL 14034 **30 Hours**

Preparation and characterization

Preparation of selected inorganic compounds and their physicochemical characterization by elemental analysis, IR and electronic spectrophotometry, magnetic susceptibility measurements, magnetic resonance spectroscopy, solution conductivity measurements, wherever appropriate and possible.

(i) *Complexes with O-donor ligands*

(a) $A_3M(C_2O_4)_3$ –M = Al, Cr, Fe; A = alkali metal

(b) $VO(acac)_2$

(c) $Cu_2(OAc)_4(H_2O)_2$

(d) $Cu(acac)_2$

(ii) *Complexes with N donor ligands*

(a) $[Co(NH_3)_5Cl]Cl_2$, $[Co(NH_3)_5(ONO)]Cl_2$, $[Co(NH_3)_5(NO_2)]Cl_2$

(b) $Hg[Co(NCS)_4]$

(c) $Ni(dmg)_2$

(d) $NH_4[Cr(NH_3)_2(SCN)_4]$

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER VII

Course Code: CHMADL 14044

Course Title: Spectroscopy–2

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: The aim of this course is to teach students the important concepts and ideas of rotational, vibrational-rotational, IR, NMR, optical and electronic spectroscopy.

Course Outcome**:** On completion of the course, students will be able to understand and identify/elucidate the basis of different spectroscopic techniques, and demonstrate their various applications in analyzing and interpreting experimental data.

Unit 1. Rotational (microwave) spectroscopy **10 Lectures**

(a) Classification of molecules according to their moments of inertia, rotational energy levels of HCl. Determination of molecular geometry by isotopic substitution effects on pure rotational spectrum. Stark effect, estimation of molecular dipole moments. Spectra of symmetric top and asymmetric top type molecules.

(b) Rotational Raman spectra - anisotropic polarizability. Specific selection rule in Raman spectroscopy. Interpretation of IR and Raman spectra of simple inorganic and organic compounds.

Unit 2. Vibrational-rotational spectroscopy **15 Lecture**

(a) Diatomic molecules - force constants. Fundamental vibration frequencies. The anharmonicity of molecular vibrations and its effect on vibrational frequencies, second and high harmonics.

(b) Vibration-rotation spectrum of HCI - P, Q and R branches. Vibrational Raman spectra of diatomic molecules, Overtone and combination bands (H_2O, CO_2).

(c) Polyatomic molecules *(e.g.* CO_2, NH_3) - normal modes vibrations, symmetry of vibrations - group theoretical treatment. Elements of normal coordinate analysis for the CO_2 molecule.

Unit 3. IR spectroscopy **8 Lectures**

IR spectroscopy – Characteristic bands for different functional groups, change in band frequency due to FGI. Effects of hydrogen bonding on band frequency. Structure elucidation by IR spectroscopy – finger print region and group frequencies – effect of hydrogen bonding (alcohol, keto-enol) and coordination to metal. Problem solving.

Unit 4. NMR spectroscopy **15 Lectures**

Chemical shifts and splitting patterns of signals, coupling constant and its distinction from chemical shift - use of coupling constant in structural elucidation. Simplification of spectra by use of shift reagents and high magnetic fields, integration and its use in proton count and molecular ratios - determination of enantiomeric excess. Deuterium exchange technique in the determination of labile hydrogen, spin-decoupling and NOE, ^{13}C NMR (DEPT), Complexity of ^{13}C NMR spectra and use of spin decoupling in its simplification, CINDP and its applications. Worked out examples using application of NMR. Introduction to Magnetic Resonance Imaging (MRI).

Unit 5. Optical and electronic spectroscopy **12 Lectures**

Chiroptical properties: Introduction to CD (Circular Dichroism), ORD (Optical Rotatory Dispersion) and CPE. Applications of CD and ORD - octant rule.

Study of metal-ligand equilibria and Job's method, CD, ORD and MCD of inorganic compounds.

Fluorescence and phosphorescence, Jablonski diagram. Electronic spectra of conjugated, aromatic and coordination compounds - d-d and charge-transfer spectra. Change of molecular shape upon electronic excitation.

UV-visible spectroscopy: λ_{max} and molar absorptivity, factors affecting them. Calculation of λ_{max} - Woodward Fieser's rules.

Photoelectron spectroscopy: Basic principles and applications of PES (O_2, N_2 and N_3^-) only, chemical information from ESCA.

SEMESTER VII

Course Code: CHMADL 14054

Course Title: Research Methodology

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*: ** This course is introduced to impart knowledge about the basic concepts of research and to provide a road map for conducting research.

***Learning Outcomes*: ** After completing this course, students are expected to identify, explain and apply basic concepts of research; acquire information, recognize various issues related to research, lab safety and software/computer-based applications for research.

Unit 1. Research methodology 15 Lectures

Definitions, Purpose of Research, Types of research, Research approaches, Research Methods, Stages of the research process, Background reading & information gathering: Literature survey (different sources of literature survey including online databases), Hypothesis: Identification of Research Problem; Ethical issues in research, Data collection, Data recording and reproducibility, Importance of documentation.

Unit 2. Research ethics and Publication 7 Lectures

Presentation of research findings: Elements of research publications; Seminar presentation; Patent; Paper writing; Journal impact factor, h-index; review process.

Unit 3. Laboratory safety 8 Lectures

General health and safety concerns; What to do after splash/cut, Chemical hazards, commonly used hazardous laboratory chemicals (azide, perchlorate, nBuLi, acid chlorides, bromine, cyanide, mercury, etc), Personal protective equipment, Environmental safety issues: Fume hood safety, Safety data sheet, Waste handling, Disposal of chemical and plastic-waste; precautionary measure for the maintenance of laboratory equipment.

Unit 4. Statistical Methods and Computer Applications in Chemistry 15 Lectures

Errors, precision and accuracy; Average Mean Deviation, Standard Deviation, Variance, f-test, t-test, Chi-square Test. Applications of Curve Fitting, Straight Line Fitting, Interpolation in solving chemical problems. Applications of commonly used Computer Softwares, such as Chemdraw, Chemoffice, Mercury, Origin, Excel, X'Pert HighScore, ImageJ, etc.

Research Methodology LAB – CHMADL 14054 30 Hours

1. Use of Chemdraw for drawing chemical structure, Reaction and Reaction Scheme.
2. Use of Origin software, Preparation of tables, figures, flowchart, and PowerPoint presentation.
3. Application of f-test, t-test, Chi-square Test in data analysis.
4. Applications of Curve Fitting, Straight Line Fitting, Interpolation in solving chemical problems.

SEMESTER VIII

Course Code: CHMADL 14064

Course Title: Nanomaterials and Green Chemistry

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: Students will be introduced to the nanochemistry and green chemistry.
***Course outcome*:** Students will be able to understand the nanochemistry and its various properties and applications. Moreover, students will be able to explain and compare relationships between Green Chemistry and chemical laboratory and industry for the design of safer processes and chemicals. After studying the lab course of this paper, students will be able to prepare nanomaterials/nanocomposites using different methods, and also will be able to apply green methods for the preparation/synthesis of materials and compounds.

Unit 1. Nanochemistry 25 Lectures

Introduction to Nanoscience and Nanotechnology, influence of nano over micro/macro. 1D, 2D and 3D nanostructured materials, Quantum Dots shell structures, mechanical- physical-chemical properties, Quantum confinement effect and Surface plasmon resonance. Synthesis and modification of nanoparticles: Top-Down and Bottom-Up approach, experimental procedure (coprecipitation, Sol-gel, Hydrothermal, colloidal etc.), Properties of precipitates and precipitating reagents: Colloidal and Crystalline Precipitates, nucleation (homogeneous and heterogeneous), crystal growth, morphology dependence properties. Introduction to surface active agents, types of surfactants. Basic characterizations for structural purity and morphology study. Applications of metal oxide and semiconductor nanoparticles in catalysis (photocatalysis, electrocatalysis etc.) and energy.
Carbon nanoclusters and nanotubes, application of CNT in fuel cell, catalysis, computer and as chemical sensors. Polymeric nanofibers, supramolecular structures; nanoparticles organized in/on polymer surfaces. Quantum wells, wires and dots. Fullerenes in nanochemistry.
Application of nanomaterials in green reactions and green energy production.

Unit 2. Green Chemistry **20 Lectures**

Evolution of Green Chemistry–the background, Tools of green chemistry, Principles of green chemistry. Concept of Atom Economy. Green starting materials, Green reagents, Green solvents (Water, Ionic liquid, Polyethylene glycol, Super Critical Fluids etc.), Green reaction conditions and Green chemical products; solvent free reactions; microwave assisted reactions, sonication.

Waste: production, problems and prevention.

Green chemistry in Catalysis, Health and Environment.

Water oxidation; Conversion of CO_2, Utilising CO_2 as reactant.

Feedstock chemicals, Chemicals from Biomass, Concept of platform molecules. Conversion of biomass to value-added products.

Real World Solutions: Designing for Materials and Energy Efficiency; Designing for Degradation.

Introduction to Sustainability; Aspects of Sustainability Ethics; Designing Sustainable Solutions.

Challenges of Green Chemistry.

Nanomaterials and Green Chemistry LAB – CHMADL 14064 **30 Hours**

1. Synthesis of nanoparticles/nanocomposites by coprecipitation, Sol-gel, Hydrothermal, and colloidal methods and their characterization.
2. Green synthesis of metal oxide nanoparticles and their characterization.
3. Synthesis of organic compounds by solvent free method, ionic liquid medium and microwave assisted synthesis.
4. Mechanochemical method for Hantzsch Pyridine synthesis, Begeneli reaction, Schiff Base reaction, etc.

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER VIII

Course Code: CHMSPL 15074
Course Title: Physical Chemistry-5
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives**:** The aim of this course is to teach students the important topics of physical chemistry viz. adsorption & surface chemistry and solid-state chemistry. Moreover, the students will acquire the knowledge of and solid-state reactions as well.
Course Outcomes**:** The students are expected to learn some advanced topics of adsorption & surface chemistry and solid-state chemistry. After attending this course, the students will be able to learn about adsorption isotherms and defects in solids. They will also learn about various techniques for characterization of solid substances. After studying the lab course of this paper, students will be able to know the practical aspects of adsorption and solid-state chemistry.

Unit 1. Adsorption and Surface Chemistry 15 Lectures
Adsorption of gases on solid surfaces - Langmuir's theory and its limitations. Derivation of BET equation - determination of surface area of an adsorbent, thermodynamics of adsorption processes. Capillary condensation - adsorption in micropores, hysteresis loop. Kinetics of heterogeneous catalysis - Langmuir-Hinshelwood model and Riedel-Eley model. Electrical aspects of surface chemistry, Electro kinetic phenomena, the structure of electrical double layer, Zeta potential and colloidal stability, Measurement of zeta potential. Surfactants – definition and classification, micelle formation and determination of critical micelle concentration. Reverse micelle and its application, solubilization, microemulsion.

Unit 2. Solid State Reactions 15 Lectures
Preparative Methods: Vapour phase transport, preparation of thin films – electrochemical methods, chemical vapour deposition; Crystal growth - Bridgman & Stokbarger methods, zone melting.
Characterization of Solids: Crystal diffraction of X-rays, X-ray diffraction method; Powder method– principles and uses; Scattering of X-rays by crystals – systematic absences; Electron diffraction; Neutron diffraction.

Unit 3. Powder Compact Reactions and Solid-State Defects 15 Lectures
Diffusion Model: Parabolic rate law, Jander's rate equation, Kroger-Zeigler equation, Ginstling- Brounshtein rate equation.
Stoichiometric Defects: Equilibrium concentration of point defects in crystals - Schottky defects, Frenkel defects; The photographic process - light sensitive crystals, mechanism of latent image formation, lithium iodide battery.
Non-Stoichiometric Defects: Origin of non-stoichiometry, consequences of non-stoichiometry; Equilibria in non-stoichiometric solids, Color centers: F-centre, electron and hole centre; colour centre and information storage.

Physical Chemistry-5 LAB – CHMSPL 15074 **30 Hours**

Unit 1. Adsorption and Surface Chemistry

(i) Investigation of the adsorption of oxalic acid from aqueous solution by activated charcoal, examine the validity of Freundlich and Langmuir isotherm, determination of Q_{max} value.

(ii) Removal of trace metals from aqueous medium using adsorption phenomena.

(iii) Study of adsorption of iodine from alcoholic solution by charcoal.

Unit 2. Solid State

(i) Determination of dipole moment of a liquid such as chlorobenzene, chloroform, nitrobenzene etc.

(ii) Determination of magnetic susceptibility of Mohr's salt at room temperature and hence the magnetic moment.

(iii) Analysis of a solid sample for determination of interplanar spacing by PXRD studies.

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER VIII

Course Code: CHMSPL 15084

Course Title: Organic Chemistry–5

Credits: 3+0+1

(Theory: 45 Hours, Practical: 30 Hours)

Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

***Course Objectives*:** The aim of this course is to teach students the important topics of oxidation, reduction, and pericyclic reactions and will be introduced about retrosynthetic analysis.

***Course outcome*:** After learning the course, students will acquire the detailed knowledge on oxidation, reduction reactions, and pericyclic reactions. Students will be able to understand the important concepts of retrosynthesis of organic compounds. After studying the lab course of this paper, students will be able to know the practical aspects of organic preparation, chromatographic techniques for analytical purpose and will be able to know the extraction and isolation techniques of natural products.

Unit 1. Oxidation reactions **10 Lectures**

Allylic oxidation of alkenes– use of chromium trioxide-pyridine complex (Collin's reagent) and selenium dioxide.

Oxidation of alcohols– use of PCC, PDC, Swern oxidation, Mn (IV) oxide, silver carbonate, tetrapropylammonium perruthenate (VII). Oxidation of 1,2-diols - use of periodic acid and Pb-tetraacetate.
Oxidation of carbon-carbon double bonds– perhydroxylation by $KMnO_4$, OsO_4 (including Sharpless dihydroxylation & epoxidation), oxidation with iodine, silver carboxylate and peroxy acids; introduction to electrooxidation– oxidation of tertiary amines, alkenes and carboxylates.

Unit 2. Reduction reactions **8 Lectures**

Use of H_2/Pd-C, LAH, $NaBH_4$, $NaCNBH_3$, 9-BBN, Lindlar's catalyst, DIBAL, diimide, alkali metals in liquid ammonia, super hydride and selectrides; chiral reducing agents; Electroreduction- reduction of carbonyl compounds, alkyl halides and nitro compounds.

Unit 3. Pericyclic reactions **15 Lectures**

Introduction of pericyclic reactions, MO symmetry; FMO of conjugated polyenes. Woodward-Hoffmann principle of conservation of orbital symmetry, allowed and forbidden reactions, stereochemistry of pericyclic reactions. Cycloaddition reactions |2+2|, |4+2|, |6+2| cycloadditions, stereoselectivity of the reactions. Sigmatropic rearrangements of hydrogen and chiral alkyl group - fluxional molecules, stereoselectivity in Cope and Claisen rearrangements.

1, 3 - dipolar cycloadditions–stereochemistry of the reactions. Electrocyclic reactions and cyclo reversions–stereochemistry of the reactions.
Cheletropic reactions–linear and nonlinear cheletropic rearrangement; theories of cheletropic reactions, stereochemistry of the reactions.
The ene reactions–ene reactions of 1,7–dienes, carbonyl enophiles, retro-ene reaction.

Unit 4. Retrosynthetic analysis **12 Lectures**

Basic principles and terminology of retrosynthesis, linear, convergent and divergent synthesis, synthons and synthetic equivalents, synthesis of aromatic compounds, one group and two group C -X disconnections, One group C-C and two group C-C disconnections, amine and alkene synthesis, important strategies of retrosynthesis, functional group transposition, important functional group interconversions, Umpolung of reactivity.
Protection and deprotection of hydroxy, carboxyl, carbonyl, carboxy amino groups and carbon-carbon multiple bonds; chemo- and regioselective protection and deprotection Illustration of protection and deprotection in peptide and carbohydrate synthesis.

Organic Chemistry-5 LAB – CHMSPL 15084 **30 Hours**

A. Organic Preparation **10 Hours**

One-step preparation and analysis with spectroscopic techniques.

I. Benzyhdrol from benzophenone by reduction in alkaline medium.
II. Anthraquinone from anthrancene by oxidation with chromium trioxide.
III. Preparation of *m*-nitro aniline from *m*-dinitro benzene.

IV. Preparation of methyl orange from aniline.
V. Preparation of bakelite from phenol.

B. Chromatographic Application **10 Hours**

I. Separation and identification of aromatic nitro compounds present in a binary mixture by TLC.
II. Separation and identification of amino acids present in a ternary mixture by paper chromatography.

C. Experiments on Natural Products **10 Hours**

I. Soxhlet extraction of carotenoids/chlorophyll from carrot/tomato/papaya/ spinach and determination of R_f values by TLC.
II. Isolation of nicotine from tobacco.
III. Extraction of milk proteins.
IV. Extraction of essential oils from orange peels/rose petals/clove/ginger.

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER VIII

Course Code: CHMSPL 15094
Course Title: Inorganic Chemistry-5
Credits: 3+0+1
(Theory: 45 Hours, Practical: 30 Hours)
Total Marks: 100 (Theory: 50, Practical: 20, Internal Assessment: 30)

Course Objectives: Students will be taught about the principles of coordination chemistry, structures and bonding in coordination compounds, synthesis and reactivity of organometallic complexes, and redox chemistry of coordination compounds.
Course Outcomes: Students will be able to demonstrate/explain the unique features of Coordination chemistry, Complexes of π-acceptor ligands and organometallic chemistry, Reactivity of complexes, Redox chemistry and will be able to solve related problems. By the end of the lab course, students will be able to perform qualitative and quantitative analysis of inorganic compounds confidently. They will be able to demonstrate proficiency in qualitative analysis, accurately identifying unknown ions or functional groups based on characteristic reactions and instrumental techniques.

Unit 1. Coordination Chemistry **15 Lectures**

General properties of transition elements, coordination compounds - types of ligands and complexes. Mononuclear complexes - commonly observed coordination geometries and their symmetry properties. Tetragonal, rhombic and trigonal distortions in octahedral complexes. Crystal field theory of bonding in octahedral, tetrahedral and square planar transition metal complexes. Factors affecting crystal field splitting, crystal field stabilization energy, spectrochemical series. Qualitative aspect of Ligand field and MO Theory (for octahedral σ-donor, π- acceptor and π- donor complexes)- electronic spectra– d-d spectra interpretation of spectral behaviour of octahedral and tetrahedral complexes. Charge transfer spectra.

Unit 2. Complexes of π-acceptor ligands and organometallic chemistry 15 Lectures

Synthesis, structure, bonding, and reactivity of transition-metal complexes of π–accepting ligands such as CO, NO, PPh_3. Metal carbonyl hydrides and metal carbonyl clusters. Metal-metal bonding in $Re_2Cl_8^{2-}$. Complexes containing alkenes and alkynes as ligands- Ferrocene-synthesis, structure, bonding and reactivity, Zeise's salt and comparison of synergic effect with that in carbonyls

Unit 3. Reactivity of complexes 8 Lectures

Stability constants, the chelate effect, labile and inert complexes, mechanism of Substitution reactions in octahedral complexes and associated stereochemical changes, isomerization and racemization of tris-chelate complexes. The trans effect. Electron transfer reactions-outer and inner sphere mechanism.

Unit 4. Redox Chemistry 7 Lectures

Standard electrode potentials, pH dependence of electrode potentials. Redox stability of metal ions in water, oxidation by atmospheric oxygen. Applications of Latimer and Frost diagrams, redox behavior of non-transition elements based on electrode Potential data.

Inorganic Chemistry-5 LAB – CHMSPL 15094 30 Hours

Qualitative and Quantitative Analysis

(a) Separation and determination of two metal ions Cu-Ni, Ni-Zn, Cu-Fe, Mn-Fe *etc*. involving volumetric and gravimetric methods.

(b) Analysis of ores/alloys, cement and steel, etc.
Ores: Hematite, Limestone, Dolomite, Cement, Pyrolusite, and other ores.
Alloys: Brass, Gunmetal, cupronickel, Solder, Bronze, Phosphor Bronze, Steel, Copper concentrate, steel nickel alloy and other alloys.

(c) Determination of hardness of water.

(d) Determination of stability constant of $[Zn(NH_3)_4]^{2+}$ and $[Ag (en)]^+$ by Potentiometry.

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER VIII

Course Code: CHMSPL 15104
Course Title: Spectroscopy-3
Credits: 3+1+0
(Theory: 45 Hours, Tutorials: 15 Hours)
Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: Students will be taught about spectroscopic techniques for the purpose of identification of various compounds.
***Course Outcomes*:** Students will be able to understand and apply Mass, NMR including 2-D techniques, ESR, and Mössbauer spectroscopic techniques analytical purposes, interpretation of data, and finally identification of organic and inorganic compounds.

Unit 1. Mass spectrometry **10 Lectures**
Mass spectrometry: ionization techniques, isotope abundance, molecular ion, fragmentation processes of different organic molecules, McLafferty rearrangement, deduction of structure through mass spectral fragmentation. Applications of ESI-MS and MALDI-MS. Problem solving.

Unit 2. ESR and Mössbauer spectroscopy **12 Lectures**
ESR spectroscopy: Basic principles, factors effecting g-tensors, Dragos rule and Kramers degeneracy, hyperfine splitting in inorganic free radicals and metal complexes, zero field splitting. Applications of ESR to d^1 and d^9 complexes of various symmetry.
Mössbauer: Basic principles, isomer shift, quadruple splitting, and effect of magnetic field. Application to the study of high-spin and low-spin iron compounds and Sn compounds in various oxidation states and coordination geometries.

Unit 3. NMR spectroscopy **16 Lectures**
NMR spectroscopy: Simple application to diamagnetic inorganic compounds, NMR paramagnetic shifts, simple application to paramagnetic compounds. NMR of ^{11}B, ^{31}P and ^{19}F in inorganic compounds.
2D–NMR. Assignment of ^{1}H and ^{13}C chemical shifts by using 2D COSY, HSQC and HMBC spectra for simple organic molecules and natural products.

Unit 4. Characterization of inorganic molecules **10 Lectures**
Applications of IR, Raman, NMR, EPR, Mössbauer, UV-visible, NQR, MS, electron spectroscopy and microscopy in the determination of structure and physical properties of inorganic compounds.

Unit 5. Structure elucidation using various spectroscopic techniques **12 Lectures**
Determination of chemical structure of organic compounds by analysing UV-Vis, IR, NMR and Mass Spectrometry data.

SEMESTER IX

Course Code: CHMSPL 25014
Course Title: Quantum Chemistry
Credits: 3+1+0
(Theory: 45 Hours, Tutorials: 15 Hours)
Total Marks: 100 (Theory: 70, Internal Assessment: 30)

***Course Objectives*:** The aim of this course is to teach students about quantum mechanics and quantum chemistry. Moreover, the students will acquire the knowledge of applications of quantum mechanics in chemistry.

***Course Outcomes*:** The students are expected to learn different approximation techniques and theories used in quantum mechanics. After attending this course, the students will be able to understand the applications of quantum mechanics in chemistry with respect to chemical bonding. They will also learn about Ab initio calculations and self-consistent field theory.

Unit 1. Basic Principles of Quantum Mechanics 16 Lectures

Wave functions of one-particle and many-particle systems: Born interpretation. Well behaved functions and normalized functions. Schwartz inequality (without derivation). Dynamical variables and quantum mechanical operators- Hermitian operators and their properties.

Eigenvalues and eigenfunctions of quantum mechanical operators, their physical significance. Schrodinger's wave equation. Orthogonal functions - Schmidt's orthogonalization technique. Expectation values of observable properties. Compatible observables and compatibility theorem.

Incompatible observables and the (generalized) uncertainty principle from Schwartz inequality. Basic ideas about the theory of angular momenta– spin and orbital angular momenta, conservation of angular momenta. General angular momentum operators Jx, Jy, Jz, step-up and step-down operators. Eigenvalues of J2 and Jz operators. Coupling of orbital and spin angular momenta-theoretical basis of the L-S and j-j coupling schemes.

Unit 2. Approximate Methods of Quantum Mechanics 10 Lectures

Time-independent first-order perturbation theory for (i) non-degenerate and (ii) degenerate systems; applications to the ground and first -excited states of the helium atom. The Variation theorem, linear variation function - Secular equation.

Unit 3. General Theorems in Molecular Quantum Mechanics 10 Lectures

Born-Oppenheimer approximation, separation of electronic and nuclear motion. Hellmann-Feynmann theorem and its chemical applications. The electrostatic theorem and the force field concept in chemistry. Introduction to the molecular electronic Virial theorem. Elementary ideas about Density Functional Theory.

Unit 4. Chemical Bonding **12 Lectures**

Term symbols for molecular electronic states, their symmetry classification- ligand field terms. Correlation diagrams and the non-crossing rule.
LCAO-MO theory of simple polyatomic molecules (e.g. BeH_2, H_2O molecule).
Electron theory- Huckel molecular orbital (HMO) method for unsaturated carbon compounds showing chain and ring structures, introduction to extended Huckel theory. HMO treatment of infinite linear polyenes, elements of band theory.

Unit 5. Ab initio and Semi-empirical SCF Theories **12 Lectures**

The self-consistent field method, Hartree-Fock theory of closed shell electronic configurations of atoms and molecules. Coulomb and exchange integrals, canonical Hartree-Fock equations, Koopman's theorem (without derivation).
SCF LCAO-MO theory of molecules - Roothan equation.
Semi-empirical SCF theory: Parriser–Parr-Pople approximation.

SEMESTER IX

Paper Code: CHMSPL 25024
Paper Title: Analytical Techniques in Chemistry
Credits: 3+1+0
(Theory: 45 Hours, Tutorials: 15 Hours)
Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: Students will be taught about various analytical techniques in chemistry for the purpose of identification of various compounds/materials.
Course Outcomes**:** Students will be able to understand and apply various analytical and instrumental techniques in chemistry for analytical purposes, interpretation of data, and finally identification of organic/inorganic materials.

Unit 1. Chromatographic methods **18 Lectures**

Adsorption, liquid-liquid partition, ion–exchange, paper and thin-layer chromatography (TLC), effect of solvent polarity on retention factor, reagents commonly used in the detection of TLC spots, HPLC, HPTLC, gel permeation chromatography, gas chromatography, flash chromatography, GC-MS and LC-MS.

Unit 2. Electrochemical, Thermal and X-ray diffraction methods **20 Lectures**

Electrochemical methods: Coulometry, Polarography, anode-stripping voltammetry, pulse techniques, cyclic voltammetry, electrogravimetry, spectroelectrochemistry.

Thermal methods: TGA, DTA, DTG, DSC: Techniques, Instrumentation, Applications
X-ray methods: Techniques, Instrumentations, and Applications of Powder XRD and Single Crystal XRD.

Unit 3. Microscopy 14 Lectures

Development of Microscopy, Optical microscopy, Reflectance, Transmittance, Fluorescence Microscopy, CLSM, Ultra-high-resolution microscopy.
Electron Microscopy: Scanning Electron Microscopy (SEM, FESEM) and Transmission Electron Microscopy (TEM, HRTEM): Technique, instrumentation, and applications, EDX, SAED.
Scanning Probe Microscopy (SPM): Atomic Force Microscopy (AFM), STM: Techniques, instrumentation and applications.

Unit 4. Analysis of Metals 8 Lectures

Preparation of sample for trace metal analysis in water, air, soil and plants, Extraction and dissolution techniques, Microwave digestion, Atomic absorption spectroscopy, Inductively coupled Plasma- mass spectroscopy (ICP-MS), Atomic Emission Spectroscopy (ICP-AES), Optical Emission Spectroscopy (ICP-OES).

SEMESTER IX

Paper Code: CHMSPL 25034
Paper Title: Supramolecular Chemistry
Credits: 3+1+0
(Theory: 45 Hours, Tutorials: 15 Hours)
Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: Students will be taught about the concepts of supramolecular chemistry.
Course outcome: The students will acquire the detailed knowledge and will be able to demonstrate principles, structures, properties and applications of supramolecular chemistry.

Unit 1. Supramolecular Chemistry–I 25 Lectures

Introduction to supramolecular chemistry, concepts of host guest chemistry, classification, thermodynamics and kinetic stability.
Properties of covalent bonds - bond length, inter-bond angles, force constant, bond and molecular dipole moments. Molecular and bond polarizability, bond dissociation enthalpy, entropy, intermolecular forces, hydrophobic effects. Electrostatic, induction, dispersion and resonance energy. Magnetic interactions, magnitude of interaction energy, forces between macroscopic bodies, medium effects. Hydrogen bond, non-covalent interactions, molecular recognition, recognition of anionic substrates.
Principles of molecular association and organization as exemplified in biological macromolecules like enzymes, nucleic acids, membranes and model systems like micelles and

vesicles. Molecular receptors and design principles. Crown ethers, Cryptands, cyclophanes, calixeranes, cyclodextrins (CD). CD mediated reactions.

Unit 2. Supramolecular Chemistry–II **15 Lectures**

(a) Molecular recognition: Molecular receptors for different types of molecules including arisonic substrates, design and synthesis of coreceptor molecules and multiple recognition.
(b) Supramolecular reactivity and catalysis.
(c) Transport processes and carrier design.
(d) Supramolecular devices. Supramolecular photochemistry, supramolecular electronic, ionic and switching devices.

Unit 3. Dendrimers **20 Lectures**

(a) Introduction, synthesis and characterization of macromolecular materials, including linear, branched, dedrimetric and star polymers.
(b) Synthetic strategies and stuctural variations. Mechanical and physiochemical properties of polymer types, Kinetics of living polymerization; applications to nanostructures, templates and advanced devices.
(c) Host-guest assembly and supramolecular assembly.
(d) Competitive binding of guest molecules on the surface or in the interior of dendrimers.
(e) Supramolecular structure of dendrimer/surfactant aggregates.

Biomedical applications, biosensing, photodynamic theory, dendrimer-based MRI contrasts.

SEMESTER IX

Paper Code: CHMSPL 25044

Paper Title: Literature Survey

Credits: 4

Total Marks: 100

{Report (40) + Presentation (10) + Viva voce (20) + Internal Assessment (30)}

***Course objective*: ** Students will be introduced to the concepts of literature review on published works.

***Learning outcome*: ** Students will be able to understand how to perform literature review on published works and will be able to find out the research gap on a particular area including synopsis writing and solve related issues.

LITERATURE SURVEY OF PUBLISHED RESEARCH IN THE RELEVANT FIELD

Each student will carry out literature survey on an assigned topic under the supervision of a faculty member and shall submit three hardbound copies of a report of **Literature Survey** separately based on published works in one of the following broad fields based on at least 50 relevant up-to-date references for evaluation.

1. Inorganic Chemistry
2. Organic Chemistry
3. Physical Chemistry
4. Analytical Chemistry

SEMESTER IX

Course Code: CHMSPL 25054
Course Title: Practical
Credits: 0+0+4
(Practical: 120 Hours)
Total Marks: 100 (Practical: 70, Internal Assessment: 30)

Course outcomes: By the end of this lab course, students will be able to demonstrate advanced proficiency in synthesis/preparation and characterization organic/inorganic compounds using a variety of analytical techniques. They will be able to apply theoretical knowledge to design experiments, interpret data accurately, and communicate findings effectively. Additionally, students will develop critical thinking skills, adhere to safety protocols, and collaborate effectively with peers, preparing them for successful careers in the field of chemistry.

Unit 1. Organic Chemistry Lab **40 Hours**

Two-step preparation, purification using chromatography and analysis with spectroscopic techniques

I. Benzanilide from benzophenone.
II. Benzilic acid from benzoin.
III. Dibenzyl from benzoin.
IV. Anthranilic acid from phthalic anhydride.

Unit 2. Inorganic Chemistry Lab **40 Hours**

(a) Determine the composition of Fe(III) salicylic acid complex solutions by Job's Method.
(b) Bioinorganic chemistry- Separate pigments, viz., chlorophyll 'a' and 'b', carotene and xanthophylls from green leaves by paper chromatography and column chromatography
(c) Analysis of talcum powder for Mg by complexometric titration
(d) Paper Chromatography: Separation of Group II and III metal ions (Cu^{2+}& Fe^{3+}) by 1(N) $K_4[Fe(CN)_6]$ solution
(e) Determination of amount of chlorine in bleaching powder by iodometric method

Unit 3. Physical Chemistry Lab **40 Hours**

Students have to perform at least one experiment from section 1 to 6 and two experiments from section 7:

1. Distribution Methods

i. To determine the formula of copper ammonia complex.
ii. To determine the formula of silver ammonia complex.

2. Phase Equilibrium

i. To determine the freezing point curve of two component simple eutectic system.
ii. To determine the freezing point curve of two component compound forming system.

3. **Reaction Kinetics**

i. To study the kinetics of hydrolysis of methyl acetate catalyzed by hydrochloric acid at different temperatures and to determine the thermodynamic parameters.

ii. To study the influence of ionic strength on the rate of reaction between potassium persulphate and potassium iodide in solution.

iii. To study the kinetics of reaction between potassium persulphate and potassium iodide in solution at different temperatures and determine the thermodynamic parameters.

4. Viscosity Measurements

i. To determine limiting viscosity number of polystyrene.

ii. To determine chain linkage in polyvinyl alcohol from viscosity measurements.

iii. To determine relative molecular mass of polystyrene from viscosity measurements.

5. Surface Chemistry

i. To determine the critical micelle concentration (CMC) of sodium lauryl sulphate/N-cetyl N,N,N-trimethyl ammonium bromide (CTAB) from measurements of conductivities at different concentrations.

ii. To determine the critical micelle concentration (CMC) of sodium lauryl sulphate/ N-cetyl-N,N,N-trimethyl ammonium bromide (CTAB) from measurements of surface tensions at different concentrations.

6. Potentiometry / pH metry

i. To determine the stability constant of the silver-ammonia complex.

ii. To determine the transport number of silver and nitrate ions in aqueous solution from the cell potential of the concentration cell with liquid junction potential.

iii. To determine the substitution constants in Hammett equation for 3-aminobenzoic acid/4-aminobenzoic acid and 3-nitrobenzoic acid/4-nitrobenzoic acid.

7. Spectrophotometry: Interpretation of spectra/data

i. Interpretation of vibrational-rotational spectra of rigid and non-rigid diatomic molecules.

ii. Interpretation of electronic spectra of diatomic molecules.

iii. Interpretation of electronic spectra of simple polyatomic molecules.

iv. Analysis of XRD pattern of cubic system.

v. Structure elucidation with a given set of spectra,

vi. Determination of the degree of un-saturation from molecular formula.

vii. Systematic interpretation of set of UV-Vis and IR spectra (Identification of the compound based on systematic interpretation of spectral data would be preferred).

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER X

Course Code: CHMSPL 25064

Course Title: Reaction Dynamics and Statistical Thermodynamics

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

***Course objective*:** Students will be introduced to the concepts of chemical kinetics, molecular dynamics and fast reaction kinetics. This course is also introduced to impart students with the knowledge of terms and concepts used in statistical thermodynamics, partition functions and theories.

***Course outcome*:** After completion of this course students will be able to describe/examine the concepts and theories of chemical kinetics, the applications of molecular dynamics, fast reactions and the fundamentals of statistical thermodynamics.

Unit 1. Chemical Kinetics **12 Lectures**

Steady-state approximation and its applications, Oscillating reactions, chemical Chaos, Belousov-Zhabotinski reaction, straight-chain reaction-hydrogen halogen reactions, alkane pyrolysis, Branching-chain reactions- the hydrogen-oxygen reaction, explosion limits, Enzyme catalyzed reactions, Michaelis-Menten mechanism- Lineweaver-Burk and Eadie plots, enzyme inhibition.

Unit 2. Molecular Reaction Dynamics **12 Lectures**

Collisions of real molecules- trajectory calculations, Laser techniques, reactions in molecular beam, -reaction dynamics, Estimation of activation energy and calculation of potential energy surface- the transition state theory (TST) of bimolecular gaseous reactions, statistical and thermodynamic formulations. Comparison between TST and hard-sphere collision theory, Theory of unimolecular reactions- Lindemann theory and its limitations, the kinetics of reactions in solution- diffusion-controlled and chemically controlled reactions, TST of reactions in solution- Bronsted and Bjerrum equation, effect of ionic strength, kinetic salt effect.

Unit 3. Study of Fast Reactions **10 Lectures**

Stopped flow technique, temperature and pressure jump methods, NMR studies in fast reactions, shock tube kinetics, relaxation kinetics, Linearized rate equation, relaxation time in single step fast reactions, determination of relaxation time.

Unit 4. Theories of Unimolecular Reactions **06 Lectures**

Drawbacks of Lindemann theory- Hinshelwood modification, RRK theory, slaters treatment, RRKM theory.

Unit 5. Statistical Thermodynamics – I **10 Lectures**

Basic Terminology: probability, phase space, micro and macro states, thermodynamic probability, statistical weight, assembly, ensemble, The most probable distribution: Maxwell-Boltzmann distribution, quantum statistics: The Bose-Einstein statistics and Fermi- Dirac Statistics. Thermodynamic probability (W) for the three types of statistics. Lagrange's undetermined multipliers. Stirling's approximation, Molecular partition function and its importance.

Applications to ideal gases: The molecular partition function and its factorization. Evaluation of translational, rotational and vibrational partition functions, the electronic and nuclear partition functions. For monatomic, diatomic and polyatomic gases.

Unit 6. Statistical Thermodynamics–II **10 Lectures**

Thermodynamic properties of molecules from partition function: Total energy, entropy, Helmholtz free energy, pressure, heat content, heat capacity and Gibb's free energy, equilibrium constant and partition function, Heat capacity of crystals and statistical thermodynamics, Third law of thermodynamics and entropy. Ortho- and para-hydrogen, statistical weights of ortho and para states, symmetry number. Calculation of equilibrium constants of gaseous solutions in terms of partition function, Einstein theory and Debye theory of heat capacities of monatomic solids.

SEMESTER X

Course Code: CHMSPL 25074

Course Title: Organic Synthesis and Heterocyclic Chemistry

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Outcomes**:** After learning the course, students will be able to understand various photochemical organic synthesis, c-c single and double bond formation, application of organometallic compounds in organic synthesis, heterocyclic chemistry and designing organic synthesis.

Unit 1. Photochemistry in organic synthesis **10 Lectures**

Photochemistry of carbonyl compounds–representation of the excited states of ketones, photolysis of saturated and *β,γ*- unsaturated ketones. Photo reduction of saturated, arylalkyl and *α,β*-unsaturated ketones and *p*-benzoquinone; Paterno-Buchi reaction, [2+2]- cycloaddition, reactions of singlet oxygen- photooxidation, ene reaction, synthetic applications of singlet oxygen. Olefinic photochemistry–photostereomutation of cis-trans isomers, optical pumping, [2+2] cycloaddition. Photochemistry of conjugated polyenes – cycloaddition and dimerization of 1,3-butadiene, photochemistry of vision. Photorearrangements–di-π-methane rearrangement, Photo-Fries rearrangement and photorearrangement of cyclohexadienones, Barton rearrangement, Singlet oxygen photochemistry.

Unit 2. Designing Organic Synthesis **10 Lectures**

Concepts in organic synthesis: Overview of Retrosynthetic analysis: connection, disconnection, synthons, protection and deprotection of functional groups.

Retrosynthesis and Synthesis of (Ethoheptazine (analgesic), Piperocaine (local anaesthetic), Choloroquine (antimalarial), diclofenac (non-steroidal anti inflammatory drug),

Unit 3. Formation of C-C single and double bonds **15 Lectures**

Alkylation–importance of enolate anions, alkylation of activated methylene groups, dianion in synthesis, alkylation of ketones, enamine and related reactions; alkylation of thio-and seleno-carbanions; allylic alkylation of alkenes, Michael addition (conjugate addition). Aldol reaction–use of boron and silyl enolates; directed aldol reaction. Synthetic applications of carbene and carbenoids; formation of carbon-carbon bond by addition of free radicals-to alkenes; photocyclization reactions.

Elimination reactions–acid catalysed dehydration of alcohols, solvolytic and base-induced elimination from alkyl halides & sulphones, Hofmann elimination from quaternary ammonium salts. Pyrolytic syn elimination–pyrolyses of carboxylic esters and xanthates (Chugaev reaction) and amine oxides (Cope reaction). Wittig and related reactions–use of stabilized and unstabilized phosphorus ylides, Peterson reaction. Alkenes from sulphones, decarboxylation of lactones, stereoselective synthesis of tri and tetrasubstituted alkenes.

Unit 4. Synthetic application of organometallic and activation of C-H bonds
10 Lectures

Preparation, stability, reactivity and synthetic applications of organo-lithium, tin, copper, zinc, palladium, Mo, Ru, Rh reagents. (emphasis on important name reactions viz. Hofmann-Loeffler-Freytag reactions, Heck Reaction, Suzuki Reaction, Sonogashira Reaction, Negishi Reaction, Stille Reaction, Hiyama Reaction, Kumada Reaction, Buchwald-Hartwig, Mc Murry reaction, Ito oxidation, etc.)

Unit 5. Heterocyclic Chemistry **15 Lectures**

Nomenclature, π-excessive and π-deficient heterocycles, Principles of heterocyclic synthesis involving cyclization and cycloaddition reaction. Synthesis and properties of three, four, five, six and seven membered heterocycles containing one, two and three heteroatoms *viz*., N, O and S (aziridine, oxirane, thiirane, azetidine, oxetane, thietane, pyrazole, isoxazole, isothiazole, imidazole, oxazole and thiazole, pyran, azepine, oxepine, thiepine).

SEMESTER X

Course Code: CHMSPL 25084
Course Title: Inorganic Photochemistry
Credits: 3+1+0
(Theory: 45 Hours, Tutorials: 15 Hours)
Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Outcomes: Students will be able to explore the synthesis, properties, and applications of diverse inorganic materials, alongside investigating the magnetic behavior of transition metal ions in different coordination environments. Additionally, they will be able to analyze the electronic spectra of transition metal complexes, correlating electronic transitions with molecular structure and ligand-field effects. Furthermore, students will delve into the principles of Photoinorganic chemistry, studying photochemical processes and their applications in light-driven reactions, photocatalysis, and photovoltaic devices, contributing to advancements in sustainable energy and environmental remediation.

Unit 1. Inorganic Materials **16 Lectures**

Magnetic exchange and exchange coupling phenomena, magnetic materials, molecular magnets, ferrofluids. Crystalline, liquid crystalline and amorphous materials, non-stoichiometric oxides, crystal defects, nano materials. Classification, manufacture and applications of Inorganic fibers, and Inorganic fillers, condensed phosphates, and coordination polymers. Band theory of metals, semiconductors, *p*- and *n*- type semi-conductor. Defect perovskites, high Tc superconductivity in cuprates, preparation and characterization of 1-2-3 materials, application of high Tc materials. Thermoelectric properties – dielectric, ferroelectric, piezo electric materials, solid electrolytes and Fuel Cells.

Unit 2. Magnetic properties of transition metal ion **16 Lectures**

Magnetic properties of free ions, spin-only magnetic moments of d^n ions in weak and strong crystal fields of O_h and T_d symmetries, orbital contribution and the effect of spin-orbit coupling, quenching of orbital angular momenta by crystal fields, temperature independent paramagnetism, high-spin low-spin equilibria, Ferromagnetism and antiferromagnetism with examples from metal complexes, Magnetic properties of second and third transition series and the lanthanide elements. Measurement of magnetic susceptibility.

Unit 3. Electronic spectra **10 Lectures**

La Porte Selection Rules, Effect of vibronic coupling and spin-orbit coupling, band intensities and band widths, Jahn Teller effect. Spectra of aqueous solutions of $M(H_2O)_6^+$, Spectra of high spin and low-spin ML_6^{n+} complexes, Calculation of 10 Dq and values from spectra, distorted octahedral and tetrahedral complexes, M to L and L to M charge transfer spectra.

Unit 4. Photoinorganic chemistry **18 Lectures**

Ligand field and charge transfer states (Thexi and DOSENCO states), Energy dissipation by radiative and non-radiative processes, Jablonski diagram. Photosubstitution on Cr(III) and

Co(II) compounds, cis-trans isomerisation, metal carbonyls. Photoredox reactions of Co(III) complexes, Photo catalysis and solar energy conservation by $Ru(bpy)_3^{2+}$. Photochemical pathways (unimolecular or intramolecular process and bimolecular or intermolecular process), quantum yield, Kasha's rule and Stoke shifts, identification of excited states, examples of main photochemical processes: non-redox processes (photoisomerization, photodissociation, photosubstitution), Photosynthesis reactions (mechanism and salient features of photosynthesis reaction I and II), light harvesting, solar energy conversion, metal ion sensors, chemosensors, artificial photosynthesis.

SEMESTER X

Course Code: CHMSPL 25094

Course Title: Polymer Science

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Outcome: The students will acquire detailed knowledge about polymers, their synthesis, processing abilities, properties, and structure-property relationship to their applications.

Course Objectives: The main objective of this course is to understand the fundamental concepts of polymerization. To know about various types of polymerization reaction and their mechanisms. To learn the various techniques of polymer synthesis and polymer characterization. To know various applications of biodegradable polymers.

Unit 1. Introduction to Polymers 10 Lectures

Importance, historical background, raw materials and basic nature of polymers. Concept of monomer, repeating unit, degree of polymerization. Classification of polymers Average molecular weight concept. Polydispersity and molecular weight distribution. Measurement of molecular weights: end-group analysis, viscosity, light scattering, osmotic and ultracentrifugation methods.

Unit 2. Polymerization and Kinetics 10 Lectures

Step polymerization, chain polymerization including carbonyl polymerization, Ziegler–Natta coordination polymerization, group transfer polymerization, ring opening polymerization, metathesis polymerization, controlled radical polymerization, supramolecular polymerization, Step copolymerization, chain copolymerization, Types of copolymers, Copolymer equation, Monomer reactivity ratios. Structure and reactivity of monomers and radicals, Alfrey price Q-e scheme, Block and graft copolymers.

Unit 3. Polymer characterization **10 Lectures**

Chromatographic method, Spectroscopic methods, X-ray diffraction study, microscopy, thermal analysis, thermal transition in polymer (Tg, Tm). Physical testing: tensile strength, tear strength, fatigue failure, resilience, hardness, impact and abrasion resistance.

Unit 4. Structure and Properties **10 Lectures**

Morphology and order in crystalline polymers-configurations of polymer chains. Crystal structures of polymers. Morphology of crystalline polymers, strain-induced morphology, crystallization and melting.

Polymer structure and physical properties-crystalline melting point Tm – melting points of homogeneous series, effect of chain flexibility and other steric factors, entropy and heat of fusion.

The glass transition temperature Tg: Relationship between Tm and Tg, effects of molecular weight, diluents, chemical structure, chain topology, branching and cross linking.

Unit 5. Polymer Processing **10 Lectures**

Plastics, elastomers and fibres. Compounding reinforcing. Processing techniques: two roll mill mixing, internal mixer, calendaring, die casting, rotational casting, film casting, moulding, extrusion, thermoforming, foaming and fibre spinning.

Unit 6. Polymer in Special uses **10 Lectures**

High temperature and fire-resistant polymers, Liquid crystal polymers, Conducting polymers, Polyelectrolytes, Biodegradable polymers, Superabsorbent, Self-healing polymer. Use of polymers as lubricating oil additives.

SEMESTER X

Course Code: CHMSPL 25104

Course Title: Natural Products Chemistry

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

***Course Outcomes*:** After learning the course, students will be able to understand different types of natural products, their sources and applications. Students will also be able to describe important methods of extraction, their synthesis, and biosynthesis processes.

Unit 1. Chemistry of carbohydrates **13 Lectures**

Open chain and ring structure of monosaccharides, Reactions of the anomeric centre, Reactions of hydroxyl groups, Cyclic acetals, Glycosyl activation

Chemical disaccharide formation, Enzymatic disaccharide formation, Introductory chemical glycobiology.

Unit 2. Chemistry of terpenoids **13 Lectures**

Introduction to terpenoids, isoprene and biogenetic isoprene rule, Biosynthesis of mono and sesquiterpenoids, discussion on caryophylene, longifolene, santonin, abietic acid, and taxol.

Unit 3. Chemistry of alkaloids **12 Lectures**

Introduction to alkaloids, Physiological activity of alkaloids, Discussion on morphine, and reserpine.

Unit 4. Chemistry of porphyrins **12 Lectures**

Porphyrin ring and chemistry of heme, oxygen transport by haemoglobin, chemistry of chlorophyll and its role in photosynthesis.

Unit 5. Carotenoids and Vitamins **10 Lectures**

General Introduction, Discussion on alpha-, beta- and gamma-carotenes, vitamin-A.

SEMESTER X

Course Code: CHMSPL 25114

Course Title: Bioinorganic Chemistry

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Outcomes: Students will be able to identify/elucidate the basis of supramolecular chemistry and ion transport, carrier transport storage and activation of dioxygen, metalloenzymes, electron transfer proteins, metals in medicine and demonstrate their various applications in analyzing and interpreting various questions.

Unit 1. Supramolecular Chemistry and Ion Transport **16 Lectures**

Definition and examples of Supramolecules, Self-assembly and membranes, Molecular receptors- Cryptands, Valinomycine, Spherands, Molecular recognition. Interaction of metal ions and metal complexes with DNA.

Supramolecular Transport: Active transport of ions across cell membranes, Selectivity of Na and K with crown ethers, cryptands and ionophores, Na/K pump; Transport of Ca^{2+}, Bio-minerals containing Ca and Fe; Transport and Storage of Iron; Transferrins, Sideraphores, and Ferritin.

Unit 2. Carrier, Transport, Storage and Activation of Dioxygen 14 Lectures

Active site structure and function of oxygen carrying proteins: Metalothionins and Ceruloplasmin. Haemoglobin, Myoglobin, Haemerythrin and Haemocyanine; O_2 binding equilibria and mechanism of cooperativity in Hemoglobin, Design of Model O_2 carriers, Reaction leading to toxicity due to dioxygen. Oxidases and Oxygenase: Catalase, Peroxidase, Superoxide Dismutase, Cytochrome *c* Oxidase, Cytochrome P-450, and Pyrocatechol Dioxygenase - their biological functions, role of metal and dioxygen reactivity.

Unit 3. Metalloenzymes 10 Lectures

Structure and function of carboxypeptidase A and carbonic anhydrase. Importance of Co(II) substitution in Zn proteins; Structure and function of co-enzyme B_{12}. Role of Ni, Cr and V in enzymes; Molybdenum enzymes, structure and function of Nitrogenase, chemistry of dinitrogen fixation, Xanthine oxidases, Metalloenzymes- Classifications, metallohydrolases, Metallo oxidoreductases, Metallo isomerases, Metallo synthases, Metallolyases, Ligases, the role of metal ions in structural context - selected examples-Heme vs non-heme centers

Unit 4. Electron transfer proteins 10 Lectures

Metalloproteins in the electron transfer chains in membrane, The Cytochromes (*a, b, c* types), Mechanism of electron transfer reactions in proteins; Iron Sulfur proteins–Rubredoxin, Ferredoxin, and HiPIP.

Unit 5. Metals in medicine 10 Lectures

Metal deficiency and disease, toxic effect of metals - Fe and Cu overload, Thalassemia, toxicity due to Hg, As, Cd, and Pd; Chelation therapy (EDTA, BAL, Penicillamine); Gold compounds in Rh. arthritis, Cisplatin with case studies and related Anticancer drugs.

SEMESTER X

Course Code: CHMSPL 25124

Course Title: Catalysis

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: The aim of this course is to introduce fundamentals of catalysis and characterization techniques employed in catalysis. A detail idea on the homogeneous, heterogeneous and photocatalysis is also introduced in this course.

Course Outcomes: The students are expected to learn about types of catalysis - comparison of homogeneous & heterogeneous catalysis, photocatalysis and different characterization techniques of solid catalysts.

Unit 1. Homogeneous Catalysis **15 Lectures**

Atom transfer and electron transfer processes. Role of transition metal ions with special reference to Cu, Pd, Pt, Co, Ru and Rh, catalysis in non-aqueous media. Rates of homogeneously catalysed reactions, turnover number and frequency. Catalysis of isomerisation, hydrogenation, oxidation and polymerization reactions. Asymmetric catalysis, biocatalysis and metal clusters in catalysis. Phase-transfer catalysis.

Unit 2. Heterogeneous catalysis **15 Lectures**

Adsorption isotherms - surface area - pore size and acid strength measurements -porous solids -catalysis by metals - semiconductors and solid acids -supported metal catalysts -catalyst preparation - deactivation and regeneration -model catalysts -ammonia synthesis - hydrogenation of carbon monoxide -hydrocarbon conversion - selective catalytic reduction - polymerization.

Unit 3. Photocatalysis **10 Lectures**

Photocatalytic reactions, general mechanism of photocatalysis, semiconductor as photo catalysts in photolysis reactions - generation of hydrogen by photo catalysts - photocatalytic break down of water and harnessing solar energy - photocatalytic degradation of dyes - environmental applications.

Unit 4. Characterization of solid catalysts **20 Lectures**

Surface area & surface morphology, BET surface area analysis, porosity - pore volume - diameter - particle size, principles and applications of PXRD, SEM, TEM, EDX, XPS, AFM to surface studies - TPD, TPR for acidity and basicity of the catalysts, boundary layer theory - Wolkenstein theory -Balanding’s approach.

SEMESTER X

Course Code: CHMSPL 25134

Course Title: Medicinal and Bioorganic Chemistry

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: The students will be taught to about the chemistry behind the development and activity of pharmaceutical materials, to understand the basic idea of lipid chemistry, and to understand the concept of vitamins and their role.

Course Outcomes: Students will be able to predict a drugs properties based on its structure, will gain the knowledge of mechanism of action and adverse effects of drugs. Students are expected to learn the relationship between drug’s chemical structure and its therapeutic properties. They will learn about lipids and their importance in biological system. They will also understand about their synthesis. They will also learn about different types of vitamins and their synthesis and role in biological system.

Section A: Medicinal Chemistry

Unit 1. Basic concept of medicinal chemistry 5 Lectures

Introduction, targets, Agonist, antagonist, partial agonist. Receptors, Receptor types, Theories of Drug – receptor interaction, Drug synergism, Drug resistance, physicochemical factors influencing drug action. Isosterism and bioisosterism

Unit 2. Antibiotics 6 Lectures

Introduction, Targets of antibiotics action, classification of antibiotics, enzyme-based mechanism of action, SAR of penicllins and tetracyclins, clinical application of penicillins, cephalosporin, Beta lactamase inhibitors, tetracyclines, Current trends in antibiotic therapy.

Unit 3. Antihypertensive agents and diuretics 5 Lectures

Classification of cardiovascular agents, introduction to hypertension, etiology, types, classification of antihypertensive agents, classification and mechanism of action of diuretics, Furosemide, Hydrochlorothiazide, Amiloride.

Unit 4. Analgesics, Antipyretics and Anti-inflammatory Drugs 5 Lectures

Introduction, Mechanism of inflammation, classification and mechanism of action of NSAIDs and SAR of paracetamol, Ibuprofen, Diclofenac, naproxen, indomethacin, phenylbutazone and meperidine

Unit 5. Antidiabetic Agents and antimalarials 8 Lectures

Introduction, Types of diabetics, Drugs used for the treatment, chemical classification, SAR, Mechanism of action, Study the treatment strategy of diabetic mellitus. Chemistry of insulin, sulfonyl ureas

Classification, mechanism of action of drugs employed for the treatment of malaria. Current treatment strategy for malaria.

Unit 6. Drugs for CNS 7 Lectures

CNS Active Drugs, CNS depressants, Hypnotics and Sedatives: Barbiturates, non-barbiturates, amides and imides, glutethimide, benzodiazepines, aldehydes and derivatives, methaqualone and other miscellaneous agents. (Mode of action only)

Anticonvulsants: Barbiturates, hydanatoins, oxazolidinediones, succinimides, bezodiazepines, thenacemide, glutethimide. (Mode of action only)

CNS-Stimulants & Psychoactive Drugs: Analeptics, purines, psychomotor stimulants, sympathomimetics, monamine oxidase inhibitors, tricyclic antidepressants, miscellaneous psychomotor stimulants. Hallucinogens (psychedelics, psychometrics): Indolethylamines, R-phenylethylamines, butyrophenones and other miscellaneous drugs. (Mode of action only)

Unit 7. Computational approach in medicinal chemistry 4 Lectures

Structure activity relationship, concept of QSAR, physicochemical parameters- lipophilcity, partition coefficient, electronic-ionization constants, H-bonding, steric parameters, Isosterism, bioisosterism.

Section B: Bioorganic Chemistry

Unit 1. Biochemistry of Lipids 10 Lectures

Biological importance of fatty acids and lipids, even chain and odd chain fatty acids, saturated and unsaturated fats, ketone bodies. Biosynthesis of fatty acids, triacylglycerols, phospholipids, cholesterol and related steroids; prostaglandins.

Unit 2. Chemistry of Vitamins 10 Lectures

Carotenoids - classification, chemistry of β-carotene, lycopene and canthaxanthin. Synthesis of β-carotene, provitamin A, singlet oxygen quenching and food coloring properties of carotenes. Classification and functional role in biological systems; chemistry of thiamine, riboflavin, retinol, tocopherols, vitamin C and pyridoxine.

SEMESTER X

Course Code: CHMSPL 25144

Course Title: Organometallic Chemistry

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course outcomes: Students will be able to explain and compare relationships between nature of metal-carbon bonds in transition metal compounds, organometallic complexes and its synthesis and structural properties, organometallics in catalysis and fundamental reactions of organotransition metal complexes.

Unit 1. Nature of metal-carbon bonds in transition metal compounds

20 Lectures

Classification of organometallic compounds, M–C σ bond in metal alkyls, β-hydrogen elimination. Complexes with metal carbon π-bonds - with olefins, mechanism of olefin methathesis (Ring opening metathesis, cross metathesis, ring closing metathesis). Bonding in metal carbocyclic systems cyclopentadienyl and other carbocyclic ligands, MO treatment of bonding in ferrocene based on symmetry properties of the ligand and metal orbitals. Bonding in carbene and carbine complexes.

Unit 2. Synthesis, structure and properties of organometallic complexes
18 Lectures

Olefin complexes, acetylene complexes, complexes formed by polyenes and allylic compounds -synthesis and relevance. Cyclopentadiene and arene metal complexes– general reactions. Bent sandwich compounds, Chemistry of arene sandwich compounds, Transition metal alkyls and ylides complexes, metal carbene and metal carbyne complexes -synthesis and reactivity. Synthesis of metal carbonyls and metal carbonyl hydrides reactions and synthetic utilities. High nuclearity carbonyl cluster, structures, electron counting schemes and bonding - Wade's rules (isolobal analogy).

Unit 3. Fundamental reactions of organotransition metal complexes 10 Lectures

Ligand co-ordination and dissociation - displacement reaction in square planar complexes, steric and electronic influences of ligands. Oxidative addition and reductive elimination. Insertion reactions- insertion of CO, alkenes. Reaction of co-ordinated ligands- reactions of co-ordinated olefins, acetylenes and arenes.

Unit 4. Organometallics in catalysis 12 Lectures

Homogeneous and heterogeneous catalysis. Polymerization and oligomerization of olefins and dienes. Hydrogenation, hydroformylation, isomerization, metathesis and carboxylation of olefins. Synthesis of acetic acid from methanol, reactions of synthesis gas. Oxidation of olefins by Wacker process, synthesis of acrylates, olefin epoxidation. C-H bond activationhydroxylation and autoxidation - basic idea. Allylic oxidations, deactivation and regeneration of catalysts, (catalytic poisons and promoter), Synthetic gasoline preparation (Fischer Tropsch reaction), Monsanto Acetic Acid process

SEMESTER X

Course Code: CHMSPL 25154
Course Title: Computational Chemistry
Credits: 3+1+0
(Theory: 45 Hours, Tutorials: 15 Hours)
Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: To provide a good understanding and practice of the various programming languages like BASIC and FORTRAN and impart a thorough knowledge of the empirical and semi-empirical electronic structure calculations, computational background and simulations.
Course Outcomes: The students are expected to learn various programming languages that are required for different types of molecular simulations and electronic structure calculations. They will be able to write independent programs, correctly compile them and use computer to study molecular electronic structures and molecular modelling.

Unit 1. Chemistry and BASIC Programming 15 Lectures

Principles of BASIC Programming- BASIC expressions, statements, Library functions, Arrays, Functions and subroutines, Algorithm and flow-chart. Programming examples from Chemistry illustrating the principles of BASIC language- calculation of molecular weights, mean activity coefficient, ionic mobilities, ionic strength, reduced mass, molecular velocities, calculation of thermodynamic parameters, average value of rate constants

Unit 2. Chemistry and FORTRAN Programming 15 Lectures

Principles of FORTRAN Programming-Characters, constants and variables, FORTRAN expressions and statements, library functions, Algorithm and flow-chart. Programming examples from Chemistry illustrating the principles of FORTRAN language- calculation of molecular velocities, determination of moment of inertia and internuclear distance from Raman spectra data, critical constants of van der Waals gases, dissociation constant of weak acid.

Unit 3. Numerical methods used in chemistry 15 Lectures

Some illustrative numerical methods in chemistry: Least squares fit, root finding, numerical differentiation, integration and solution of ODE, matrix inversion and diagonalization, interpolation. Pattern recognition techniques and molecular graphics. Basics of electronic structure calculations, Molecular Mechanics, Monte Carlo and Molecular Dynamics simulations.

Unit 4. Computer applications in Chemistry 15 Lectures

Use of some packages to study molecular electronic structures and molecular modelling (GAMESS, MOPAC, molecular dynamics packages, etc. Use of electronic spreadsheets in chemistry. Basic ideas on structure-activity relationships, computational background of molecular modelling: potential energy surfaces, molecular mechanics, MO methods, drug and catalysis design, etc. Development of some simulation programs and use of the internet for chemical information retrieval. Chemoinformatics.

SEMESTER X

Course Code: CHMSPL 25164
Course Title: Advanced Topics in Organic Chemistry
Credits: 3+1+0
(Theory: 45 Hours, Tutorials: 15 Hours)
Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Objectives: The students will be introduced to the recent development in chemistry including Click Chemistry, ionic liquids, organic electronics, energy and mechanochemistry.
Course Outcomes: Students will be able to learn the role of click chemistry in organic synthesis, predict the synthetic route of various useful chemicals from simple molecules. They will also learn the basics of ionic liquids and its application in green chemistry approaches in organic chemistry, get the idea of organic chemistry in impending electronic industry, learn about the renewable energy and role of organic chemistry in biofuels and have a concept of mechanochemistry and how it will be applied in organic chemistry.

Unit 1. Click chemistry **10 Lectures**
Basic principle of click chemistry, Cu(I)- catalyzed Azide - Alkyne Click Chemistry reaction (CuAAC), Strain-promoted Azide - Alkyne Click Chemistry reaction (SPAAC), Strain-Promoted Alkyne-Nitrone Cycloaddition (SPANC**),** Tetrazine – Alkene Ligation, Reactions of Strained Alkenes; Other applications of click chemistry.

Unit 2. Platform chemicals **10 Lectures**
Basic concept; different types of platform chemicals, their source and preparation; Chemistry of 5-Hydroxymethylfurfural, 2.5-Furandicarboxylic acid, alkyl glycosides, glucaric acid, N-acetylglucosamine, etc. in the preparation of chemicals.

Unit 3. Ionic liquids in chemistry **10 Lectures**
Definition, composition, application in green chemistry as: solvent, electrolytes, pharmaceuticals, biopolymer processing, reprocessing of nuclear fuel, tribology, waste recycling, solar thermal energy. Challenges of ionic liquids.

Unit 4. Organic electronics **10 Lectures**
Introduction of organic electronics, historical milestones, Chemistry of organic light emitting diodes, organic field-effect transistors, organic semiconductors, challenges of organic electronics, etc. Prospects of organic electronics in industries.

Unit 5. Bioenergy and biofuels **10 Lectures**
Introduction, types, production and application of biofuels- ethanol, cellulosic ethanol, biodiesel, renewable hydrocarbons, biogases, etc. Challenges of biofuels.

Unit 6. Organic Mechanochemistry **10 Lectures**

Basic of mechanochemistry; Application of mechanochemistry in functional group transformation, catalytic process, photochemical reaction, etc.

SEMESTER X

Course Code: CHMSPL 25174

Course Title: Group Theory and Application

Credits: 3+1+0

(Theory: 45 Hours, Tutorials: 15 Hours)

Total Marks: 100 (Theory: 70, Internal Assessment: 30)

Course Outcomes: Students will learn about the fundamental principles of group theory, including symmetry operations and representations, and their applications in molecular symmetry and spectroscopy. Additionally, they will understand the chemical applications of group theory, focusing on its role in predicting molecular properties.

Unit 1. Basics of group theory **12 Lectures**

Representation of symmetry operators by matrices, representation of groups - reducible and irreducible representations, the Great orthogonality theorem and properties of irreducible representations, Character tables Mulliken notations.

Unit 2. Application of group theory **12 Lectures**

Transformation properties of atomic orbitals, the Direct Product Representations, construction of Hybrid orbitals for AB_n molecules, construction of symmetry adapted linear combinations (SALCs) and MOs of simple AB_n molecules. Selection rules for electronic and vibrational spectroscopy.

Unit 3. Chemical applications of Group Theory **18 Lectures**

Molecular vibrations, molecular vibration of symmetrical AB_2 (bent) molecules, symmetry of normal modes of ethylene. Binding in water molecule, symmetries of molecular orbitals and electronic configuration. Vanishing matrix elements.

Unit 4. Ligand Field Theory **18 Lectures**

The d wave functions (orbitals), Crystal field potential, Symmetry aspects of d orbital splitting by ligands. Electron repulsion in many electron atoms, Free ion terms for d^n configurations, Electron repulsion parameters, spin - orbit coupling, Effect of weak crystal field on O_h symmetry on the S, P, D and F terms, Free ions in strong crystal fields. Term energy level diagram for d^n configurations in O_h and T_d symmetries, Tanabe-Sugano diagrams. Influence of the d-configuration on the geometry and stability of complexes. MO theory of complex compounds, LGO and MOs of ML_6 and tetrahedral complexes.

SEMESTER X

Course Code: CHMSPL 25184

Course Title: Physical Chemistry Practical

Credits: 0+0+4

(Practical: 120 Hours)

Total Marks: 100 (Practical: 70, Internal Assessment: 30)

Course Objectives: This is a special laboratory course introducing some experimental and theoretical experiments of physical chemistry. The objective of the course is to introduce two types of experiments. The objective of first type is involved with basic physical chemistry such as chemical kinetics, theoretical chemistry, thermodynamics, photochemistry etc. The objective of second type of experiments is to introduce students to some modern techniques of analysis such as spectrophotometry, electrochemical analysis and surface chemistry.

Course outcomes: After completing this course, the students will understand physical chemistry from experimental point of view. Moreover, they will learn some modern methods of analysis required in different area of research.

Unit 1. [Minimum 10 experiments, at least 3 experiments from each section, a, b, c]

(a) Experiments on Chemical Kinetics:

1. Determination of the temperature coefficient and energy of activation of acid hydrolysis of methyl acetate, using least squares calculation.
2. Study of the autocatalytic reaction between oxalic acid and $KMnO_4$ and determination of the order of the reaction.
3. Study of the decomposition kinetics of the formation of complex between sodium sulphide and sodium nitroprusside spectrophotometrically. Determination of the rate constant and order of the reaction.
4. Study of the kinetics of the reaction between peroxydisulphate and potassium iodide and to find the influence of ionic strength on the rate constant.
5. Study of the kinetics of oxidation of ethanol by chromium(VI) and to find the rate constant of the reaction. Also find the order of the reaction by half-life period method.

6. Study of the double exponential time dependence of the reduction of Cr (VI) by glutathione in an aqueous medium and to obtain the rate constants of the process. (EPC, Halpern Ex. No. 23, 381).
7. Determination of the rate constants for the α-chymotrypsin-catalyzed hydrolysis of an ester. (EPC, Halpern Ex. No. 24, 395).
8. Determination of the relative strength of two acids (HCl and H_2SO_4) by studying the hydrolysis of an ester (methyl acetate/ ethyl acetate). [Yadav, 288].
9. Investigation of the inversion of cane sugar in presence of HCl and H_2SO_4 and hence determination of the relative strengths of the two acids.

(b) Experiments on Conductometric Titrations:
1. Determination of the equivalent conductivity of acetic acid at infinite dilution by Kohlrausch‘s method and hence to find the degree of dissociation constant of the acid.
2. Comparison of the relative strength of acetic acid and monochloroacetic acid by conductance measurement.
3. Determination of the degree of hydrolysis and hydrolysis constant of aniline hydrochloride /sodium acetate.
4. Determination of the strength of the components of the following binary mixture by conductometric titration.
   (i) Hydrochloric acid and acetic acid
   (ii) Sulphuric acid and copper sulphate
5. Determination of the amount of each component of the following ternary mixture by conductometric titration. Hydrochloric acid, acetic acid and copper sulphate
6. Determination of the degree of hydrolysis and hydrolysis constant of CH_3COONa of NH_4Cl by conductance measurement.

(c) Experiments of Spectrophotometry:
1. Verify Beers law and determine concentration of
   (i) $K_2Cr_2O_7$ (ii) Organic dyes like methylene blue, Rhodamine B (iii) $CuSO_4$

2. Determination of the concentration of chromium and manganese in a mixture of dichromate and permanganate by spectrophotometric method.
3. Determination of the composition of iron salicylic acid complex spectrophotometrically by Job‘s method of continuous variation.
4. Investigation of the complex ion formation between Ni^{2+} and o-phenanthroline by Job‘s method.
5. Investigation of the reaction between acetone and iodine by colorimetry.
6. Determination of the refractive index of a given liquid by Abbe refractometer and to find the molar and specific refractions.

Unit 2. [Minimum 5 experiments, at least 1 experiment from each section, a, b, c]

(a) Experiments on pH metric Titrations
1. Determination of the dissociation constant of acetic acid/oxalic acid by using Hendersen‘s equation.

2. Finding the amount of the components of the following mixtures using pH metric titration: Hydrochloric acid + Oxalic acid
3. Determination of the pH of a buffer solution by using quinhydrone electrode.
4. Potentiometric estimation of strength of solutions of hydrochloric acid and acetic acid individually and a mixture of the two using standard sodium hydroxide solution.
5. Titration of ferrous ammonium sulphate against potassium dichromate potentiometrically and determination of the standard electrode potential of the ferrous/ferric system.

(b) Electrochemical experiments: Cyclic voltammetry
1. Cyclic voltammetry of a standard solution at different scan rates and calculation of redox potential ofelectro-active species.
2. Determination of diffusion coefficient from cyclic voltammetry
3. Determination of Electrode surface area from Cyclic voltammetry
4. Determination of rate of heterogeneous electron transfer from cyclic voltammetry
5. Chronocoulometry of a redox dye and determination of amount adsorbed on to the electrode surface

(c) Adsorptio-desorption on porous materials, Equilibrium study, kinetic study, thermodynamic studies
1. Adsorption of dye on activated carbon and analysis of result by different adsorption models.
2. Determination of adsorption kinetics of dye on activated carbon.
3. Determination of desorption kinetics of dyes from adsorbents
4. Determination of thermodynamic quantities ΔH, ΔS and ΔG of dye adsorption on activated carbon.

Unit 3. [Minimum 5 experiments, at least 1 experiment from each section, a, b]
(a) Experiments of Theoretical Chemistry
1. Least squares fitting and plotting linear and exponential graphs using computer.
2. Potential energy diagram of hydrogen molecule ion with the help of fortran programming.

(b) Miscellaneous Experiments
1. Determination the molar mass of a polymer by viscometric method.
2. Study of the variation of surface tension of a solution of n-propyl alcohol/ethanol with concentration and determination of the limiting cross-sectional area of the alcohol molecule.
3. Determination of the partial molar volume of methanol/ethanol/formic acid by graphical method by determining the densities of solutions at different concentrations.
4. Determination of the influence of NaCl, naphthalene and succinic acid on the critical solution temperature of phenolwater system using 0.5, 1 and 1.5 % concentrations.
5. Determination of the Van‘t Hoff factor for an electrolyte by cryoscopic method.
6. Determination of the percentage composition of binary mixture of non-electrolyte (urea and glucose) by cryoscopic method.
7. Study of the variation of solubility of $Ca(OH)_2$ in NaOH solution and hence to determine its solubility product.

8. Determination of the equilibrium constant of the reaction: $KI + I_2 \leftrightharpoons KI_3$ by distribution method.
9. Determination of the formula of the complex formed between Cu^{2+} and NH_3 by distribution method.

SEMESTER X

Course Code: CHMSPL 25194
Course Title: Organic Chemistry Practical
Credits: 0+0+4
(Practical: 120 Hours)
Total Marks: 100 (Practical: 70, Internal Assessment: 30)

Course Outcomes**:** The students are expected to learn laboratory skills for preparation of organic compounds via coupling reaction, diazotization reaction, Click chemistry method and synthesis of heterocyclic compounds. After studying the lab course of this paper, students will be able to know the characterization of organic compounds using various spectroscopic techniques.

Unit 1. Coupling reaction, purification and characterization of the product using various spectroscopic techniques. **30 Hours**

a. Heck Reaction
b. Suzuki Reaction
c. Sonogashira Reaction
d. Stille Reaction

Unit 2. Preparation of organic compounds using Click chemistry method and their purification & characterization using spectroscopic techniques. **30 Hours**

Unit 3. Synthesis of heterocyclic compounds, purification and characterization using spectroscopic techniques. **30 Hours**

a. Quinoline
b. 2-Phenyl indole
c. 1,2,3,4-Tetrahydrocarbazole
d. 5-Hydroxy-1,3-benzoxal-2-one

Unit 4. Synthesis using diazotization reaction, purification and characterization using spectroscopic techniques. **30 Hours**

a. p-Chlorotoluene

b. o-Chlorobenzoic acid
c. p-Iodonitrobenzene

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER X

Course Code: CHMSPL 25204

Course Title: Inorganic Chemistry Practical

Credits: 0+0+4

(Practical: 120 Hours)

Total Marks: 100 (Practical: 70, Internal Assessment: 30)

Course Outcomes: By the end of this lab course, students will be able to synthesize and characterize a range of inorganic compounds, including molecular frameworks, metal oxide nanoparticles, chemically synthesized metal oxide nanoparticles, and zeolites, using advanced laboratory techniques. They will gain proficiency in interpreting characterization data to determine the structural and chemical properties of these materials. Additionally, students will develop critical thinking skills, problem-solving abilities, and experimental design expertise, preparing them for further research or professional work in areas such as materials science, catalysis, environmental science, and nanotechnology.

Synthesis and characterization using various analytical techniques

(a) Synthesize of an inorganic Supramolecular complex (molecular frameworks)
(b) Synthesis of transition metal oxide nanoparticles by hydrothermal method
(c) To determine UV-Vis characterization of chemically synthesized metal oxide (ZnO, SnO_2) nanoparticles
(d) Synthesis and characterization of co-crystals of 5, 7, 7, 12, 14, 14-hexmethyl-1, 4, 8, 11- tetraazacyclo tetra deca-4, 1, 1-dinene with perchloric acid
(e) Ligand synthesis for multimetal complex: Preparation of bis- (N,N-disalicylidene ethylenediamine) µ-aquo-dicobalt
(f) Synthesis and characterization of bispyridine iodide nitrate
(g) Synthesis of zeolites and its characterization.

N.B.: New experiments will be introduced from time to time subject to the availability of chemicals and instrument.

SEMESTER X

- Research thesis/ Project with minimum 1 conference paper. Peer reviewed research publication should be encouraged.

Course Code: CHMDIS 250620
Course Title: Research Project/Dissertation
Total Credit: 20
Duration: Six Months (*One Semester*)
Total Marks: 500 (Internal Assessment: 30%)

Course Outcomes: The students would be able to demonstrate and plan scientific research, and implement it within a reasonable time-frame. It is expected that after completing this project/dissertation, students will learn to work independently and how to keep accurate/readable record of their experimental works. In addition, students will be able to handle laboratory equipment and chemicals, and utilize sophisticated instruments for analysis, data collection and interpretation. Moreover, students will learn how to perform literature review and will be able to critically examine research articles, find out research gap and improve their scientific writing/communication and be able to disseminate their work by attending conferences.

Option C **– Only Research i.e. only Research both in the 9th and 10th Semesters (*Total Credits: 40*)**

SEMESTER IX & X

- Research thesis/Project with minimum 2 conferences papers. Peer reviewed research publication should be encouraged.

Course Code: CHMDIS 250140
Course Title: Research Project/Dissertation
Total Credit: 40
Duration: One Year (*Two Semester*)
Total Marks: 1000 (Internal Assessment: 30%)

Course Outcomes: The students would be able to demonstrate and plan scientific research, and implement it within a reasonable time-frame. It is expected that after completing this project/dissertation, students will learn to work independently and how to keep accurate/readable record of their experimental works. In addition, students will be able to handle laboratory equipment and chemicals, and utilize sophisticated instruments for analysis, data collection and interpretation. Moreover, students will learn how to perform literature review and will be able to critically examine research articles, find out research gap and improve their scientific writing/communication and be able to disseminate their work by attending conferences.

RECOMMENDED BOOKS & REFERENCES

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