UNIVERSITY OF CALCUTTA

Notification No. CSR/75/2026

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of his powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 07.07.2026, approved the new revised complete Syllabus of 4-Year Honours & Honours with Research and 3-year MDC Courses of Studies in **Chemistry including Examination Modalities and Programme Outcome (PO) / Course Outcome (CO)** under CCF, 2022.

The above shall take effect from the Odd semester examinations, 2026 and onwards.

08/7/2026

Prof.(Dr.) Debasis Das

Registrar

SENATE HOUSE
Kolkata-700073
08.07.2026

Four-Year B.A./B.Sc.

(Honours and Honours with Research)

Courses of Studies

(Under Curriculum & Credit framework, 2022)

SYLLABUS

FOR

CHEMISTRY

(1st to 8th Semester)

UNIVERSITY OF CALCUTTA

Important recommendations

- **Minor Courses for Chemistry Major are to be taken preferably (Not Compulsory) from Physics and Mathematics disciplines.**

- **All graphs for Physical / Inorganic Courses must be done using standard Spreadsheet Software**

- **Each college should take necessary measures to ensure they should have the following facilities:**

  1. Spectrophotometer with printer, pH-Meter, Conductivity Meter, Potentiometer, Polarimeter.

  2. Internet facility.

  3. Requisite number of computers (One computer for 3-4 students).

For proper maintenance of above-mentioned facilities, clean & dry AC rooms are mandatory.

Chemistry Course Structure
(4-year Honours and Honours with Research)

Semester	Paper Code	Paper Name	Credit	Page No.
1	(DSCC-1)/(MN-1)	Fundamentals of Chemistry-I	(3 Th + 1Pr)	11
	(SEC-1) (4-year Major)	Quantitative Analysis and Basic Laboratory Practices	(3Th + 1 Tu)	15
	IDC (4-year Major)	Chemistry in Daily Life	(2Th + 1 Tu)	18
2	(DSCC-2)/(MN-2)	Fundamentals of Chemistry-II	(3 Th + 1Pr)	21
	(SEC-2) (4-year Major)	AI for Everyone	(2Th + 2 Tu)	24
	IDC (4-year Major)	Chemistry in Daily Life	(2Th + 1 Tu)	18
3	(DSCC-3)	Physical Chemistry – I	(3 Th + 1Pr)	26
	(DSCC-4)	Organic Chemistry – I	(3 Th + 1Pr)	29
	(SEC-3) (4-year Major)	Introduction to Numerical Methods for Chemists	(3Th + 1 Tu)	32
	MN-1	Fundamentals of Chemistry-I	(3 Th + 1Pr)	11
	IDC (4-year Major)	Chemistry in Daily Life	(2Th + 1 Tu)	18
4	(DSCC-5)	Inorganic Chemistry – I	(3 Th + 1Pr)	35
	(DSCC-6)	Organic Chemistry – II	(3 Th + 1Pr)	37
	(DSCC-7)	Physical Chemistry – II	(3 Th + 1Pr)	40
	(DSCC-8)	Inorganic Chemistry – II	(3 Th + 1Pr)	44
	MN-2	Fundamentals of Chemistry-II	(3 Th + 1Pr)	21
5	(DSCC-9)	Organic Chemistry – III	(3 Th + 1Pr)	47
	(DSCC-10)	Inorganic Chemistry – III	(3 Th + 1Pr)	51

	(DSCC-11)	Physical Chemistry – III	(3 Th + 1Pr)	54
	(DSCC-12)	Organic Chemistry – IV	(3 Th + 1Pr)	57
	MN-3	Organic Chemistry – I	(3 Th + 1Pr)	29
	MN-4	Inorganic Chemistry – I	(3 Th + 1Pr)	35
6	(DSCC-13)	Physical Chemistry – IV	(3 Th + 1Pr)	60
	(DSCC-14)	Fundamentals of Chemistry-III	(3 Th + 1Pr)	64
	(DSCC-15)	Inorganic Chemistry – IV	(3 Th + 1Pr)	69
	MN-3	Organic Chemistry – I	(3 Th + 1Pr)	29
	MN-4	Inorganic Chemistry – I	(3 Th + 1Pr)	35
7	(DSCC-16) (4-YEAR B.A./ B.Sc. HONOURS AND HONOURS WITH RESEARCH COURSES OF STUDIES)	Inorganic Chemistry – V	(3 Th + 1Tu)	72
	(DSCC-17) (4-YEAR B.A./ B.Sc. HONOURS AND HONOURS WITH RESEARCH COURSES OF STUDIES)	Organic Chemistry – V	(3 Th + 1Tu)	75
	(DSCC-18) (4-YEAR B.A./ B.Sc. HONOURS AND HONOURS WITH RESEARCH COURSES OF STUDIES)	Physical Chemistry – V	(3 Th + 1Tu)	78
	(DSCC-19) (4-YEAR B.A./ B.Sc. HONOURS AND HONOURS WITH RESEARCH	Inorganic Chemistry – Practical	4 Pr	80

	COURSES OF STUDIES)			
	(DSCC-20) (4-YEAR B.A./ B.Sc. HONOURS AND HONOURS WITH RESEARCH COURSES OF STUDIES)	Physical Chemistry – Practical	4 Pr	81
8	(DSCC-21) (4-YEAR B.A./ B.Sc. HONOURS COURSES OF STUDIES)	Inorganic Chemistry – VI	(3 Th + 1Tu)	82
	(DSCC-22) (4-YEAR B.A./ B.Sc. HONOURS COURSES OF STUDIES)	Organic Chemistry – VI	(3 Th + 1Tu)	84
	(DSCC-23) (4-YEAR B.A./ B.Sc. HONOURS COURSES OF STUDIES)	Physical Chemistry – VI	(3 Th + 1Tu)	87
	(DSCC-24) (4-YEAR B.A./ B.Sc. HONOURS COURSES OF STUDIES)	Organic Chemistry - Practical	4Pr	90
	(DSCC-25a) (4-YEAR B.A./ B.Sc. HONOURS COURSES OF STUDIES)	Physical Chemistry – Practical	2Pr	91
	(DSCC-25b) (4-YEAR B.A./ B.Sc. HONOURS COURSES OF STUDIES)	Inorganic Chemistry – Practical	2Pr	93
	RM-1 (4-YEAR B.A./ B.Sc. HONOURS with RESEARCH COURSES OF STUDIES)	Research Methodology for Chemistry-1	(3 Th+ 1 Viva)	97
	RM-2 (4-YEAR B.A./ B.Sc. HONOURS with RESEARCH	Research Methodology for Chemistry-2	(3 Th+ 1 Viva)	99

	COURSES OF STUDIES			
	Research Internship **(4-YEAR B.A./ B.Sc. HONOURS with RESEARCH COURSES OF STUDIES)**	**Research Internship**	**(3 Th+ 1 Viva)**	**10**
	Dissertation/ Project **(4-YEAR B.A./ B.Sc. HONOURS with RESEARCH COURSES OF STUDIES)**	**Dissertation/ Project**	**(6 Th +2 Viva)**	**10**

Programme Outcomes (POs)

B.Sc. Chemistry (Honours/Major)

1. *Develop Scientific Inquiry*: Demonstrate a spirit of scientific inquiry and critical thinking by understanding the fundamental principles and concepts of the core areas of Chemistry.
2. *Analyze Chemical Phenomena*: Apply theoretical knowledge to analyze, interpret, and explain chemical observations, reactions, and phenomena encountered in various branches of Chemistry.
3. *Problem-Solving Ability*: Develop the ability to identify, formulate, and solve qualitative and quantitative problems using appropriate chemical principles and analytical methods.
4. *Practical Competence*: Acquire hands-on laboratory skills through experiments and practical exercises, enabling the application of theoretical concepts in real-life chemical investigations.
5. *Laboratory Safety and Technical Skills*: Demonstrate proficiency in the safe handling of chemicals, reagents, laboratory apparatus, and scientific instruments while adhering to standard laboratory practices and safety protocols.
6. *Data Analysis and Interpretation*: Develop the ability to record observations accurately, analyse experimental data, interpret results scientifically, and draw valid conclusions based on experimental evidence.

Summer Internship:

All the students are required to do one 3 credits Summer Internship at the end of the 2^{nd} or 4^{th} or 6^{th} semester. Students completing Internship at the end of the 2^{nd} semester will be allowed to take exit from the course and will be awarded Certificate of 45 credits. Students completing Internship at the end of the 4^{th} semester will be allowed to take exit from the course and will be awarded Diploma of 88 credits. Students completing Internship at the end of the 6^{th} semester will be allowed to take exit from the course and will be awarded three-year Single major Degree of 132 credits [Following the Notification No. CSR/05/2023, dated 23^{rd} June, 2023 of University of Calcutta].

Modalities of Summer Internship for Chemistry Major Students:
(i) Summer Internship can be conducted in any other College, University, Research Institute or any Industry. Topics should be related to Theoretical or Experimental Chemistry.
(ii) Summer Internship can also be conducted in interdisciplinary domain of relevance (Physics, Biological Sciences, Mathematics) of parent institute or any other institute.
(iii) Under no circumstance, summer internship can be conducted by any faculty member of the same department of parent institute.

Note: A student will have to take 8 Minor courses from 2 subjects (m1 and m2) from the same broad discipline as the Major excluding the Major subject. Students have to study 4 minor courses in the first two years (1 in each semester) and 4 Minor courses in the 3^{rd} year (2 in each semester).

Choice of MN-1 and MN-2:

Option-1: A student will opt for MN-1 in semester-1 and MN-2 in semester –2

Or,

Option 2: A student will opt for MN-1 in semester-3 and MN-2-Th in semester –4

No other combinations of MN-1 and MN-2 will be allowed.

Choice of MN-3 and MN-4:

A student will opt for both MN-3 and MN-4 either in semester –5 or in semester –6.

4-YEAR B.A./ B.Sc. HONOURS WITH RESEARCH

Research Internship (4 credits) & Dissertation / Project (8 credit)

The students pursuing B.Sc. Chemistry Honours with research has to complete one Research Internship (3 TH+1 viva) and one Dissertation / Project (6 TH+2 viva) in the 8^{th} semester. The student has to pursue this under the guidance of a faculty member in any recognized University/ other colleges or research institute. Topics should be related to Theoretical or Experimental Chemistry. Under no circumstance, it could be executed under the guidance of a faculty from parent college/institution. The PowerPoint presentation and viva-voce to be conducted in presence of an external expert appointed by the University on the recommendation of the parent college/institute.

Semester-I

PAPER: (DSCC-1)/(MN-1)/(CC-1)/(MN-1, 3-year)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Provide students with a comprehensive understanding of the extranuclear structure of atoms and their influence on chemical properties and explore the periodic table, periodic trends, and their correlation with atomic structure.
CO-II	Learn fundamental concepts of organic chemistry, focusing on the nature of chemical bonding and the relationship between molecular structure and physical properties.
CO-III	Provide a basic understanding of thermodynamics and chemical kinetics.

Fundamentals of Chemistry - I

Theory: (45 Lectures)

Module: I

Extra nuclear structure of atoms and Periodicity: (15 Lectures)

Wave-Particle duality; de Broglie hypothesis. Heisenberg's uncertainty principle. Introducing Schrödinger equation. Hydrogen and hydrogen like systems (detailed solution not required). Concept of Atomic Orbital; shapes of s, p and d orbitals. Radial and angular distribution curves. Extension to multielectronic systems. Aufbau principle and its limitations; Pauli's exclusion principle; Hund's rules and multiplicity. Effective nuclear charge. Shielding and penetration; Slater's rules.

The general idea about modern periodic table, atomic and ionic radii, ionization energy, electron affinity and electro negativity –definition, trends of variation in periodic table and their application in explaining and predicting the chemical behavior of elements and compounds. Electronegativity scales (Pauling's, Mulliken's and Allred-Rochow's scales). Inert pair effect.

Module: II

Basics of Organic Chemistry Bonding and Physical Properties

(10 Lectures)

Valence Bond Theory

Nomenclature of Organic Compounds, Concept of hybridisation, shapes and structures of molecules, double bond equivalent (DBE), Resonance (including hyperconjugation) and Resonance energy.

Electronic displacement

Inductive effect, bond polarization and bond polarizability; steric effect, steric inhibition of resonance.

MO Theory

Qualitative idea about molecular orbitals, bonding and antibonding interactions, idea about σ, σ*, π, π *, n – MOs; concept of HOMO, LUMO and SOMO; sketch and energy levels of π MOs of i) acyclic p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems) ii) cyclic p orbital system (neutral systems: [4], [6] annulenes; charged systems: 3-,4-,5-7 membered ring systems); Hückel's rules for aromaticity up to [8] annulene; concept of antiaromaticity; non-aromatic molecules.

Physical properties

Melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular forces; polarity of molecules and dipole moments.

Stereochemistry – I (5 Lectures)

Bonding geometries of carbon compounds and representation of molecules: tetrahedral nature of carbon and concept of asymmetry; Fischer, sawhorse, flying wedge and Newman projection formulae and their inter translations. Concept of chirality and symmetry: symmetry elements, molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of stereogenicity, chiral centres and number of stereoisomers: systems involving 1/2/3-chiral centre(s).

Module: III

Thermodynamics -I (9 Lectures)

Concept of systems (open, closed and isolated) and surroundings. State of a system; Intensive and extensive variables. Partial derivatives. Exact and inexact differentials. Path function and State function. Concept of heat and work. Zeroth law of thermodynamics. Concept of thermodynamic reversibility. Concept of internal energy and 1st law of thermodynamics. Enthalpy and heat capacity, Relations between C_p and C_v. Isothermal and Adiabatic processes. Calculations of ΔU, ΔH, q and w involving ideal gases in different processes.

Enthalpy of reaction. Hess's law. Enthalpy of formation and combustion. Kirchhoff's equation.

Chemical Kinetics-I (6 Lectures)

Concept of order and molecularity. Rate laws for zero, 1st and 2nd order reactions and in general for any n-th order reaction. Determination of order of a reaction by half-life and differential methods. Rate determining step and steady state approximation. Opposing, Consecutive and parallel reactions (first order steps only). Temperature dependence of rate constant and Arrhenius equation.

Recommended Text Books

1. Lee, J. D. Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008.
2. Atkins, Overton, Rourke, Weller, Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press, (2010).
3. Finar, I. L. Organic Chemistry (Volume 1), 6th Edition, Pearson Education, 2002
4. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
5. Nasipuri, D. Stereochemistry of Organic Compounds, 4th Edition, New Age International Pvt Ltd, 2020
6. Levine, I. N. Physical Chemistry, 6th Edition McGraw-Hill India, 2011
7. Castellan, G. W. Physical Chemistry, Narosa, 2004
8. Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11th Edition, Oxford University Press, 2018
9. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008

Practical :(30 Lectures)

PAPER: (DSCC-1)/(MN-1)/(CC-1)/(MN-1, 3-year)

Course Outcome (CO)	
CO	Demonstrate proficiency in volumetric analysis by preparing and standardizing solutions, performing acid–base and redox titrations, and accurately estimating acids, carbonates, bicarbonates, and iron species in unknown samples.

(1) Calibration and use of apparatus.

(2) Preparation of primary standard solutions (Oxalic Acid and $K_2Cr_2O_7$)

Acid-Base Titrations

(3) Standardization of NaOH standard oxalic acid solution.

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

(5) Estimation of acetic acid in commercial Vinegar.

Oxidation-Reduction Titrimetry

(6) Standardization of $KMnO_4$ standard oxalic acid solution.

(7) Estimation of Fe (II) using standardized $KMnO_4$ solution.

(8) Estimation of Fe (III) using standard $K_2Cr_2O_7$ solution.

(9) Estimation of Fe (II) and Fe (III) in a given mixture using standard $K_2Cr_2O_7$ solution.

Reference Books

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

2. Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015

Paper: SEC-1

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Introduce students to the fundamental principles and techniques of quantitative analysis and its extensive applications across various scientific field.
CO-II	Introduce the principles and methods of titrimetric analysis, focusing on different types of titrations and their applications; learn about key concepts such as normality, molarity, molality, mole fraction, ppm, and ppb, along with the preparation and dilution of standard solutions.
CO-III	Learn about impurities in water and the standards for water quality for potable, domestic, industrial, and agricultural purposes; provide students with a solid foundation in water quality analysis and treatment, essential for ensuring safe and sustainable water use.

Quantitative Analysis and Basic Laboratory Practices

Theory: (45 Lectures)

Module: I

Introduction to Quantitative analysis and its interdisciplinary nature:(15 Lectures)

Definitions of analysis, determination, measurement, techniques and methods. Classification of analytical techniques. Choice of an analytical method, Figures of merit of analytical methods - accuracy, precision, sensitivity, selectivity, method validation, limit of detection (LOD), limit of quantitation (LOQ), linear dynamic range (LDR).
Limitations of analytical methods. Errors: Determinate and indeterminate errors, absolute error, relative error, minimization of errors. Statistical treatment of finite samples -mean, median, range, standard deviation and variance. External standard calibration -regression equation (least squares method), correlation coefficient (R) and coefficient of determination (R^2). Presentation of experimental data and results from the point of view of significant figures. Propagation of error.
Numerical problems are to be solved wherever applicable.

Module: II

Titrimetric analysis: (15 Lectures)

Principle, classification, normality, molarity, molality, mole fraction, ppm, ppb etc. Standard solutions, preparation and dilution of reagents/ solutions using $N_1 V_1 = N_2 V_2$, preparation of ppm level solutions from source materials (salts).
Numerical problems are to be solved wherever applicable.

Acid-base titrimetry:

Titration curves for strong acid vs strong base, weak acid vs strong base and weak base vs strong acid titrations. Quantitative applications – selecting and standardizing a titrant, inorganic analysis - alkalinity, acidity.
Numerical problems are to be solved wherever applicable.

Redox titrimetry:

Theory, balancing redox equations, titration curves, theory of redox indicators and applications.
Numerical problems are to be solved wherever applicable.

Precipitation titrimetry:

Theory, titration curves, indicators for precipitation titrations involving silver nitrate- Volhard's and Mohr's methods and their differences.
Numerical problems are to be solved wherever applicable.

Complexometric titrimetry:

Theory, titration methods employing EDTA (direct, back, displacement and indirect determinations). Indicators for EDTA titrations - theory of metal ion indicators. Determination of hardness of water.
Numerical problems are to be solved wherever applicable.

Gravimetric Analysis:

Stages in gravimetric analysis, requisites of precipitation, theories of precipitation, factors influencing precipitation, co-precipitation and post precipitation. Structure, specificity, conditions and applications of organic reagents such as salcylaldoxime, oxine, dimethyl glyoxime, cupron and cupferron in inorganic analysis. Advantages of organic reagents over inorganic reagents.

Module: III

(15 Lectures)

Water analysis:

Water availability, requirement of water. Quality of surface water and ground water. Impurities in water. Standards of water quality for potable, domestic, industrial and agricultural purpose (color, pH, alkalinity, hardness, TDS, sulphate, fluoride, chloride etc.)

Water treatment technologies:

House hold water treatment, municipal water treatment and industrial treatment (primary and secondary treatment of industrial effluent). Softening of water. Disinfection of water. Definition and determinations of DO, BOD and COD, and their significance.
Numerical problems are to be solved wherever required

Basic laboratory practices:

Basic laboratory practices, calibration of glassware (pipette, burette and volumetric flask), Sampling (solids and liquids), weighing, drying, dissolving, Acid treatment, Rules of work in analytical laboratory, General rule for performing quantitative determinations (volumetric and gravimetric), Safety in Chemical laboratory, Rules of fire prevention and accidents, First aid. Precautions to be taken while
handling toxic chemicals, concentrated/fuming acids and organic solvents.

Recommended Text

1. Douglas A. Skoog, D.M. West, F. james Holler, Stanely R. Crouch, Fundamentals of Analytical Chemistry, Cengage learning India Pvt Ltd. 10th Edition, 2022
2. Daniel C. Harris, Quantitative Chemical Analysis, 10th Edition, W.H. Freeman, 2020

Tutorial: (15 hours)

PAPER: SEC-1(Tu)

1. Safety Practices in the Chemistry Laboratory, knowledge about common toxic chemicals and safety measures in their handling, cleaning and drying of glass wares.
2. Calibration of glassware, pipette, burette and volumetric flask.
3. Preparation of TLC plates and separation of amino acids
4. Calibration of instruments like colorimeter, pH-meter, conductivity meter, spectrophotometer using reference standards or reference materials.
5. Conductometric titration between HCl and NaOH.
6. Determination of alkali present in soaps/detergents.

PAPER: (IDC-1)/(IDC-2)/(IDC-3)
(SEC-1)/(SEC-2)/(SEC-3) (3 year)

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Learn about the composition and analysis of dairy products and beverages, including tests for quality and adulteration. Identifying food additives, preservatives, contaminants, artificial colorants, and pesticide residues, and evaluate their impact on food safety.
CO-II	To understand the chemistry and significance of vitamins, oils, fats, soaps, and detergents. Applying analytical methods to evaluate consumer products.
CO-III	Explain the principles and applications of batteries, fuel cells, and renewable energy sources. To evaluate sustainable approaches to polymer use and plastic waste management.

Theory: (45 Lectures)

CHEMISTRY IN DAILY LIFE

Module: I

(15 Lectures)

Dairy Products

Composition of milk and milk products. Analysis of fat content, minerals in milk and butter. Estimation of added water in milk.

Beverages: Analysis of caffeine in coffee and tea, detection of chicory in coffee, chloral hydrate in toddy, determination of methyl alcohol in alcoholic beverages.

Food additives, adulterants, and contaminants

Food preservatives like benzoates, propionates, sorbates, disulphites. Artificial sweeteners: Aspartame, saccharin, dulcin, sucralose, and sodium cyclamate. Flavors: Vanillin, alkyl esters (fruit flavors), and monosodium glutamate.

Artificial food colorants

Coal tar dyes and non-permitted colors and metallic salts. Analysis of pesticide residues in food.

Module: II

(15 Lectures)

Vitamins

Classification and Nomenclature. Sources, deficiency diseases, and structures of Vitamin A1, Vitamin B1, Vitamin C, Vitamin D, Vitamin E & Vitamin K1.

Oils and fats

Composition of edible oils, detection of purity, rancidity of fats and oil. Tests for adulterants like argemone oil and mineral oils. Halphen test.

Soaps & Detergents

Definition, classification, manufacturing of soaps and detergents, composition and uses

Module: III

(15 Lectures)

Chemical and Renewable Energy Sources

Principles and applications of primary & secondary batteries and fuel cells. Basics of solar energy.

Polymers

Basic concept of polymers, classification and characteristics of polymers. Applications of polymers as plastics in electronics, automobile components, medical fields and aerospace materials. Problems of plastic waste management. Strategies for the development of environment-friendly polymers.

Recommended Text Books

1. B. K. Sharma: Introduction to Industrial Chemistry, Goel Publishing, Meerut (1998)
2. Ashtoush Kar. Medicinal Chemistry (Two Colour Edition), New Age International Pvt Ltd, 2022
3. Edward Cox Henry, The Chemical analysis of Foods , Hardcover , Hassell Street Press , 2021
4. Fred Billmeyer: Textbook of polymer science; Wiley 3rd addition.

Tutorial: (15 hours)

PAPER: SEC-1/SEC-2/SEC-3/IDC-1/IDC-2/IDC-3

1. Estimation of Vitamin C
2. Determination of Iodine number of oil.
3. Determination of saponification number of oil.
4. Determination of methyl alcohol in alcoholic beverages.

Semester-II

PAPER: (DSCC-2)/(MN-2)/(CC-2)/(MN-2, 3-year)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Understand the fundamental principles of the kinetic theory of gases, including molecular motion, gas laws, and the behavior of ideal and real gases.
CO-II	Learn about different types of chemical bonds, including ionic, covalent, and metallic bonds; understanding bond formation, bond energy, hybridization, molecular geometry, and the impact of bonding on molecular properties.
CO-III	Develop a deeper understanding of stereochemistry; gain foundational knowledge of reaction mechanisms, including types of reactions (substitution), reaction intermediates, and the role of energy profiles in determining reaction pathways.

Fundamentals of Chemistry - II

Theory: (45 Lectures)

Module: I

Kinetic Theory and Gaseous state (8 Lectures)

Concept of pressure and temperature from kinetic theory of gas. Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Wall collision and rate of effusion Calculation of number of molecules having energy $\geq \varepsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

Real gas and Virial equation (7 Lectures)

Deviation of gases from ideal behavior; Compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behavior ; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; Virial equation of state; van der Waals equation expressed in the Virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential - elementary idea.

Module: II

Chemical Bonding – I (10 Lectures)

i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals. Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Defects in solids (elementary idea). Solubility energetics of dissolution process.

ii) Covalent bond: Polarizing power and polarizabilty, ionic potential, Fajan's rules, Lewis structures, formal charge, Valence Bond Theory, the hydrogen molecule (Heitler – London approach), directional character of covalent bonds, hybridizations, equivalent and non-equivalent hybrid orbitals, Bent's rules, dipole moments, VSEPR theory, shapes of molecules and ions containing lone pairs (examples from main group chemistry) and multiple bonding (σ and π bond approach).

Theoretical principles of inorganic qualitative analysis (5 Lectures)

Basic principles involved in analysis of cations and anions and solubility products, common ion effect. Principle involved in separation of cations into groups and choice of group reagents. Interfering anions (fluoride, borate, oxalate and phosphate) and need to remove them after Group-II.

Module: III

Stereochemistry – II (8 Lectures)

Chirotopicity and its relationship with stereogenicity; concept of pseudoasymmetry for ABA type systems. Relative and absolute configuration: *R/S* descriptors; *erythro/threo* and *meso* nomenclature of compounds; *E/Z* descriptors for C=C, combination of *R/S*- and *E/Z* isomerisms. Optical activity of chiral compounds: optical rotation, and specific rotation; racemic compounds, racemisation (through cationic, anionic intermediates); resolution of acids and bases *via* diastereomeric salt formation; optical purity and enantiomeric excess.

General Treatment of Reaction Mechanism–I (7 Lectures)

Reactive intermediates

Carbocations (carbenium and carbonium ions), non-classical carbocations, carbanions, carbon radicals: generation and stability, structure and electrophilic / nucleophilic behaviour of reactive intermediates (elementary idea).

Reaction thermodynamics

Free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change *via* BDE, intermolecular & intramolecular reactions.

Reaction kinetics

Rate constant and free energy of activation; free energy profiles for one-step, and two-step reactions; catalyzed reactions, principle of microscopic reversibility; Hammond's postulate.

Substitution Reaction

Free-radical substitution reaction: halogenation of alkanes, mechanism (with evidence) and stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate.

Recommended Text Books

1. Lee, J. D. Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008.
2. Atkins, Overton, Rourke, Weller, Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Finar, I. L. Organic Chemistry (Volume 1), 6th Edition, Pearson Education, 2002
4. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
5. Nasipuri, D. Stereochemistry of Organic Compounds, 4th Edition, New Age International Pvt Ltd, 2020
6. Levine, I. N. Physical Chemistry, 6th Edition McGraw-Hill India, 2011
7. Castellan, G. W. Physical Chemistry, Narosa , 2004
8. Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11th Edition, Oxford University Press, 2018
9. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008

Practical :(30 Lectures)

PAPER: (DSCC-2)/(MN-2)/(CC-2)/(MN-2, 3-year)

Course Outcome (CO)	
CO	Systematically identify and confirm cationic and anionic radicals in inorganic mixtures using semimicro qualitative analysis, and interpret the underlying chemical reactions involved in their separation and identification.

Qualitative semimicro analysis of mixtures containing three radicals. Emphasis should be given to the understanding of the chemistry of different reactions (only water /acid soluble salts):

Cation Radicals

Na^{+}, K^{+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Al^{3+}, Cr^{3+}, Fe^{3+}, Mn^{2+}/Mn^{4+}, Co^{2+}/Co^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, NH_4^{+}, Sn^{2+}/Sn^{4+}

Anion Radicals

F^{-}, Cl^{-}, Br^{-}, I^{-}, $S_2O_3^{2-}$, S^{2-}, SO_4^{2-}, NO_3^{-}, NO_2^{-}, PO_4^{3-}, BO_3^{3-}, CrO_4^{2-} / $Cr_2O_7^{2-}$, SCN^{-}, $[Fe(CN)_6]^{3-}$, $[Fe(CN)_6]^{4-}$, AsO_4^{3-}, BrO_3^{-}, IO_3^{-}.

Reference Books

1. Svehla & Sivasankar, Vogel's Qualitative Inorganic Analysis, 7th Ed., Pearson, 2012.
2. Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University Calcutta, 2015

Paper: (SEC-2)

(Credit: Theory -02, Tutorial-02)

Course Outcome (CO)	
CO-I	Understand Artificial Intelligence (AI) and its difference from human intelligence; explore core AI subfields e.g. machine learning, deep learning and neural networks.
CO-II	Introductory understanding of AI's role in healthcare, finance, transportation, customer service, and education; Gain knowledge on critical ethical concerns including bias and fairness in AI systems, privacy and data protection, the impact of AI on employment, and its role in amplifying social inequality.
CO-III	Gain knowledge on ethical guidelines and responsible AI practices; explore how AI drives innovation across industries and examine emerging trends and future directions in AI technology.

AI for Everyone

Theory: (45 Lectures)

Module I

Introduction to Artificial Intelligence, Subfields and Technologies:

(15 Lectures)

- Definition and scope of AI
- Historical overview and key milestones

- Differentiating AI from human intelligence
- Machine learning: Supervised, unsupervised, and reinforcement learning
- Deep learning and neural networks
- Natural language processing (NLP) and computer vision

Module II

Applications of AI and Ethical and Social Implications of AI:

(15 Lectures)

- AI in healthcare: Diagnosis, treatment, and medical imaging
- AI in finance: Fraud detection, algorithmic trading, and risk assessment
- AI in transportation: Autonomous vehicles and traffic optimization
- AI in customer service and chatbots
- AI in education: Personalized learning and intelligent tutoring systems
- Bias and fairness in AI systems
- Privacy and data protection concerns
- Impact of AI on employment and the workforce
- AI and social inequality

Module III

Other Important Issues:

(15 Lectures)

- Ethical guidelines and responsible AI practices
- AI and Innovation
- Emerging trends and future directions in AI
- AI and creativity: Generative models and artistic applications

Reference Book

1.Russell / Norvig , ARTIFICIAL INTELLIGENCE: A MODERN APPROACH, 4th Edition, Pearson Education, 2022

Semester-III

PAPER: (DSCC-3)/(CC-5)/ (MN-5, 3-year)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Develop thorough understanding of the second law of thermodynamics, its principles, and applications; learn about thermodynamics of pure and mixed systems
CO-II	Gain insight on thermodynamic conditions for equilibrium and explore the relationship between standard Gibbs free energy change and reaction conditions.
CO-III	Gain a detailed understanding of electrochemical principles, focusing on conductance and ionic equilibrium; Develop a solid foundation in electrochemical processes and their applications in various fields.

Physical Chemistry - I

Theory: (45 Lectures)

Module: I

Thermodynamics - II **(20 Lectures)**

Second Law

Need for a Second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Carnot engine and refrigerator; Kelvin – Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; Values of §dQ/T and Clausius inequality; Physical concept of Entropy; Entropy is a measure of the microscopic disorder of the system. Entropy changes of systems and surroundings for various processes and transformations; Entropy and unavailable work; Temperature – Entropy diagram.
Useful work and The Gibbs and Helmholtz function. Changes at constant T, P. Application to electric work. Criteria for spontaneity and equilibrium. Gibbs- Helmholtz equation, The Gibbs Function and useful work in biological systems. Gibbs free energy and spontaneous phase transition.

Maxwell's relations; Joule-Thomson experiment and its consequences; inversion temperature; Joule-Thomson coefficient for a van der Waals gas; General heat capacity relations

Systems of Variable Compositions

State functions for system of variable compositions. Criteria of equilibrium and spontaneity in systems of variable composition. Partial molar quantities, dependence of thermodynamic parameters on composition; Chemical potential as an escaping tendency. Gibbs-Duhem equation, Entropy and Gibbs function for mixing of ideal gases, the chemical potential of ideal mixtures. The Fugacity function of a pure real gas. Calculation of the fugacity of a van der Waals gas using compressibility factor. Activities and activity coefficients. Choice of standard states. Dependence of Activity on pressure and temperature.

Module: II

Applications of Thermodynamics – I (8 Lectures)

Chemical Equilibrium

Thermodynamic conditions for equilibrium, degree of advancement; van't Hoff's reaction isotherm (deduction from chemical potential); Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Van't Hoff's reaction isobar and isochore from different standard states; Le Chatelier's principle
and its derivation, variation of equilibrium constant under different conditions Nernst's distribution law; Application- (e.g. dimerization of benzene in benzoic acid). Solvent Extraction.

Module: III

ELECTROCHEMISTRY-I

(i) Conductance (9 Lectures)

Ion conductance; Conductance and measurement of conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye –Huckel theory of Ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Debye-Huckel limiting law-brief qualitative description. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law. Ostwald's dilution law; Ionic mobility; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations. Transport number, Principles of Hittorf's and Moving-boundary method.

(ii) Ionic Equilibrium (8 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. Salt hydrolysis- calculation of hydrolysis constant, degree of hydrolysis and pH for different salts (exact Treatment). Determination of hydrolysis constant conductometrically. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action. Theory of acid–base indicators; selection of indicators and their limitations.

Recommended Text Books

1. Levine, I. N. Physical Chemistry, 6^{th} Edition McGraw-Hill India, 2011
2. Castellan, G. W. Physical Chemistry, Narosa, 2004
3. Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11^{th} Edition, Oxford University Press, 2018

Reference Books

1. Denbigh, K. The Principles of Chemical Equilibrium, Cambridge University Press
2. Zemansky, M. W. & Dittman, R.H, Heat and Thermodynamics, Special Indian Edition, 8^{th} Edition, Tata-McGraw-Hil ,2017
3. Klotz, Irving M, Rosenberg, Robert M, Chemical Thermodynamics, Wiley India, 2013

Practical :(30 Lectures)

PAPER: (DSCC-3)/(CC-5)/(MN-5, 3-year)

Course Outcome (CO)	
CO	Perform kinetic experiments to determine reaction rate constants, investigate reaction mechanisms and catalytic effects, and analyze first-order reaction kinetics using experimental data obtained from chemical and polarimetric methods.

1. Determination of rate constant of the reaction between H_2O_2 and acidified KI solution using Clock reaction.

2. Determination of the rate constant for the decomposition of H_2O_2 using $FeCl_3$ as catalyst.

3. Determination of the rate constant for the first order acid catalyzed hydrolysis of an ester.

4. To study the kinetics of the inversion of cane sugar using a polarimeter.

Reference Books

1.Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015

PAPER: (DSCC-4)/(MN-3)/(CC-3)/(MN-3, 3-year)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Learn about aromatic substitution reactions, focusing on both electrophilic and nucleophilic mechanisms; Introduce essential concepts of organic acids, bases, and tautomerism, with a focus on pKa, the effects of substituents and solvents on acidity.
CO-II	Build solid foundation in the principles of stereochemistry, conformational analysis, and reaction mechanisms, enabling them to apply this knowledge to understand and predict the outcomes of organic reactions.
CO-III	Develop a strong grasp of the chemistry of alkenes and alkynes, including their structural features, reactivity patterns, and various addition reactions; build understanding and predicting the behaviour of these compounds in organic synthesis and other applications.

Organic Chemistry – I

Theory: (45 Lectures)

Module: I

Aromatic Substitution: (12 Lectures)

Electrophilic aromatic substitution

Mechanisms and evidences in favour of it including PKIE; orientation and reactivity; reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction; one-carbon electrophiles (reactions: chloromethylation, Houben-Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt); *Ipso* substitution.

Nucleophilic aromatic substitution

Addition-elimination mechanism and evidences in favour of it; S_N1 mechanism; *cine* substitution (benzyne mechanism), structure of benzyne.

Birch Reduction of benzenoid aromatics

Benzene, Alkylbenzene, Anisole, Benzoic acid (with mechanism).

General Treatment of Reaction Mechanism –II (8 Lectures)

Concept of organic acids and bases

Concept of pK_a and pK_{aH}, effect of structure, substituent and solvent on acidity and basicity; proton sponge.

Tautomerism

Basic difference between tautomerism and resonance, prototropy (keto-enol, phenol-keto); composition of the equilibrium in different systems (simple carbonyl; 1,2- and 1,3-dicarbonyl systems, phenols and related systems), factors affecting keto-enol tautomerism, basic ideas about valence tautomerism and ring-chain tautomerism.

Module: II

Stereochemistry –III (3 Lectures)

Conformation-I

Basic idea of conformation. Conformational Nomenclature (Newman & Sawhorse): eclipsed, staggered, gauche, syn and anti; Special reference to preferred geometry for β-elimination. Relative stability of conformers on the basis of steric effect: butane-gauche interaction.

Substitution and Elimination Reactions: (10 Lectures)

Nucleophilic substitution reactions

Substitution at sp^3 centre [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides, α-halocarbonyls]: mechanisms (with evidence), relative rates & stereochemical features: S_N1, S_N2, S_N2', S_N1' (allylic rearrangement) and S_Ni; effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite); substitutions involving NGP (with heteroatoms and phenyl groups).

Elimination reactions

E1, E2, E1cB and Ei (pyrolytic *syn* eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff / Hofmann) and stereoselectivity; comparison between substitution and elimination reactions, comparison between nucleophilicity and basicity.

Module: III

Chemistry of alkenes and alkynes (12 Lectures)

Addition to C=C

Mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, *syn* and *anti*-hydroxylation, ozonolysis, addition of singlet and triplet carbenes; Simmons-Smith cyclopropanation reaction; electrophilic addition to 1,3-butadiene; concept of kinetic and thermodynamic control of products; radical addition: HBr addition; mechanism of allylic and benzylic bromination in competition with brominations across C=C; use of NBS; interconversion of *E* and *Z* alkenes.

Addition to C≡C (in comparison to C=C)

Mechanism, reactivity, regioselectivity (Markownikoff and anti-Markownikoff addition) and stereoselectivity; reactions: hydrogenation, Hg (II) ion catalysed hydration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity.

Recommended Text Books

1. Finar, I. L. Organic Chemistry (Volume 1), 6th Edition, Pearson Education, 2002
2. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
3. Morrison, R. N. & Boyd, R. N. and Bhattacharjee, Organic Chemistry,7th Edition, Pearson Education, 2010

Practical :(30 Lectures)

PAPER: (DSCC-4)/(MN-3)/(CC-3)/(MN-3, 3-year)

Course Outcome (CO)	
CO	Identify and characterize pure organic compounds by performing systematic qualitative analysis, including preliminary examination, solubility tests, functional group identification, and confirmation through characteristic chemical reactions.

Identification of Pure Single organic Compound.

Solid compounds

Oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, cane sugar, benzoic acid and salicylic acid

Liquid Compounds:

Formic acid, acetic acid, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde and nitrobenzene

ALTEAST 4 UNKNOWN FOR EACH SOLID AND LIQUID COMPOUNDS TO BE REPORTED IN PRACTICAL SESSION.

Reference Books

1. Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015
2. Furniss, Hannaford, Smith, Tatcholl, Vogel's Textbook of Practical Organic Chemistry, 5th Edition, Pearson India, 2003

Paper: (SEC-3)

(Credit: Theory -03, Tutorial – 01)
Theory: (45 Lectures)

Course Outcome (CO)	
CO-I	Equip students with a deep understanding of the fundamental principles and techniques used in numerical analysis. Students will learn about various numerical methods, their applications, and their limitations
CO-II	Gain ability to use these methods to solve equations, approximate functions, and analyze data efficiently and accurately that focuses on practical application of numerical methods in different fields
CO-III	Enhance students' ability to identify and solve problems using numerical techniques and learn to analyze problems, choose appropriate methods, and interpret the results

Introduction to Numerical Methods for Chemists

Theory: (45 Lectures)

Numbers and Precision

Fixed -point representation, Floating - point representation, Floating-point arithmetic, Errors in numbers, Binary representation of numbers.

Finding Roots

Iterative methods, Newton - Raphson, Bisection and Secant Method.

Linear Regression

Least square fit to a straight line, Polynomial regression. Coefficient of Determination, Correlation, Linear Correlation coefficient (r).

Interpolation

Lagrange Interpolation

Numerical Differentiation

Method of finite differences (Forward difference, Backward difference, Central difference). The second derivative.

Numerical Integration

Trapezoidal approximation (Taylor series interpretation, Geometric interpretation, Composite Trapezoidal Rule), Midpoint Rule, Simpson's 1/3rd Rule.

Numerical solution of Differential Equation (ODE Only)

First Order Method (Euler) and extension to fourth order (Runge-Kutta)

The Fourier Transform

Fourier series and Fourier Transform

Reference Book

1. Erwin Kreyszig, Advanced Engineering Mathematics, 10Th Edition, Wiley India.

Tutorial: (15 hours)

PAPER: SEC-3

1. Make a table of the form below to present the results in each case. Draw graphs as required. In the problems, take a=π and b=e , and x_j =0.1, 0.3, 0.5, 0.8,1,2,3,5,7,10,20,25 to get y_j . Use these values in the table for calculations. Report M and C with graph(s). Find out a,b from M and C. Match with the input values.

No. of Obs.	x_j	y_j	$x_j\, y_j$	x_j^2	<x>	<y>	<xy>	<x^2>	M	C
1	...	..	..	..						
2	..	..	..	..						
.	..	..	..	..						
.					..	..	..	..	..	..
.										
.										
N	..	..	..	..						
Sum =										

a) y=ax + b, b) y = ax / (1+bx)

2. Find the molar volume of Argon (a= 1.50 L^2 atm mol^{-2}, b= 0.032 L mol^{-1}) at 144 K and 30 atm pressure, and hence densities of liquid and vapor formed using the van der Waals equation of state.

3. The ionization potential and electron affinity values of a few elements of a periodic table are given below, along with Pauling electronegativities. Show that the Mulliken electronegativities values, defined by (IP + EA) /2, bears a good correlation with the Pauling values. [EN(P) ≈ EN(M) / 270].

System	**IP (kJ/mol)**	**EA (kJ/mol)**	**EN**	**System**	**IP (kJ/mol)**	**EA (kJ/mol)**	**EN**
H	1311	-72	2.1	F	1681	-333	4.0
Li	520	-57	1.0	Na	496	-21	0.9
Be	899	66	1.5	Mg	737	67	1.2
B	801	-15	2.0	Al	577	-26	1.5
C	1086	-121	2.5	P	1012	-60	2.1
N	1403	-31	3.0	S	999	-200	2.5
O	1410	-142	3.5	Cl	1255	-348	3.0

Semester-IV

PAPER: (DSCC-5)/(MN-4)/(CC-4)/(MN-4, 3-year)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Understanding of the principles of molecular orbital theory and its application to different types of chemical bonding; Gain ability to analyze the structure and properties of molecules based on their electronic structure and intermolecular interactions.
CO-II	Build solid understanding of acid-base chemistry, including the different definitions, concepts, and their applications in aqueous solutions; develop ability to analyze acid-base equilibria, calculate pH, and select appropriate indicators for acid-base titrations.
CO-III	Acquire basic knowledge of radioactivity, nuclear stability, and various nuclear reactions; build understanding on the principles and applications of radiocarbon dating

Inorganic Chemistry – I

Theory: (45 Lectures)

Module: I

Chemical bonding -II (28 Lectures)

Molecular orbital concept of bonding

The approximations of the theory, Linear combination of atomic orbitals (LCAO) (elementary pictorial approach): sigma and pi bonds and delta interaction, multiple bonding. Orbital designations: gerade, ungerade, HOMO, LUMO. Orbital mixing, MO diagrams of H_2, Li_2, Be_2, B_2, C_2, N_2, O_2, F_2, and their ions wherever possible; Heteronuclear molecular orbitals: CO, NO, NO^+, CN^-, HF, BeH_2, CO_2 and H_2O. Bond properties: bond orders, bond lengths.

Metallic Bond

Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

Weak Chemical Forces

Hydrogen bonding (theories of hydrogen bonding, valence bond treatment), receptor-guest interactions, Halogen bonds. Effects of chemical force, melting and boiling points.

Module: II

Acids and bases (12 Lectures)

Acid-Base concept

Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 and HF), Bronsted-Lowry's concept, Lux Flood concept, Lewis's concept, group characteristics of Lewis acids, solvent levelling and differentiating effects. Relative strength of acids, Pauling's rules. HSAB principle.

Acid-base equilibria in aqueous solution

Proton transfer equilibria in water, pH, buffer. Acid-base neutralization curves; indicator, choice of indicators.

Module: III

Radioactivity (05 Lectures)

Nuclear stability

Nuclear stability and nuclear binding energy.

Nuclear Reactions

Artificial radioactivity, fission, fusion and spallation.

Radiocarbon dating

Recommended Text Books

1. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008
2. A. G. Sharpe, C. E. Housecroft, Inorganic Chemistry 3rd Edition, Pearson India ,2002
3. Svehla & Sivasankar, Vogel's Qualitative Inorganic Analysis, 7th Ed., Pearson, 2012.

Practical :(30 Lectures)

PAPER: (DSCC-5)/(MN-4)/(CC-4)/(MN-4, 3-year)

Course Outcome (CO)	
CO	Perform complexometric titrations using EDTA to accurately determine the concentration of metal ions in mixtures and evaluate water hardness through appropriate analytical methods.

Complexometric Titration

1. Ca (II) and Mg (II) in a mixture
2. Hardness of water
3. Fe (III) and Al (III) in a mixture
4. Cu (II) and Zn (II) in a mixture
5. Cu (II) and Ni (II) in a mixture

Reference Books

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015

PAPER: (DSCC-6)/(CC-6)/(MN-6, 3-year)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Comprehensive understanding of conformational analysis and chiral molecules, including pro-stereoisomerism and chirality arising from stereoaxes; gain ability to analyze the stereochemistry of various molecules and predict the potential for stereoisomerism.
CO-II	Develop comprehensive understanding of the chemistry of carbonyl compounds, including their structure, reactivity, and various transformations. They will be able to apply this knowledge to design and analyze organic synthesis routes involving carbonyl compounds.
CO-III	Build solid understanding of organometallic compounds, their preparation, reactions, and applications acquire ability to utilize these reagents effectively in organic synthesis to form new carbon-carbon bonds and introduce functional groups.

Organic Chemistry – II

Theory: (45 Lectures)

Module: I

Stereochemistry – IV **(12 Lectures)**

Conformation-II

Concept of dihedral angle, torsion angle; energy barrier of rotation, concept of torsional and steric strains; relative stability of conformers on the basis of steric effect, dipole-dipole interaction and

H-bonding; butane gauche interaction; conformational analysis of ethane, propane, *n*-butane, and 2-methylbutane; 1,2-dihaloalkanes and ethylene glycol.

Concept of prostereoisomerism

Prostereogenic centre; concept of (pro)^n chirality: topicity of ligands and faces (elementary idea); pro-R/pro-S, pro-E/pro-Z and Re/Si descriptors; pro-*r* and pro-*s* descriptors of ligands on propseudoasymmetric centre.

Chirality arising out of stereoaxis

Stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in allenes, and biphenyls; related configurational descriptors (R_a/S_a); atropisomerism; racemisation of chiral biphenyls

Module: II

Chemistry of carbonyl Compounds: (28 Lectures)

Nucleophilic Addition to C=O

Structure and reactivity of carbonyl compounds; mechanism (with evidence), reactivity, equilibrium and kinetic control; formation of hydrates, cyanohydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen-based nucleophiles; reactions: benzoin condensation, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement, oxidations and reductions: Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPVO redox equilibrium, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

Exploitation of acidity of α-H of C=O

Formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence):halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H. V. Z.) reaction, nitrosation, SeO_2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Tollens', Knoevenagel, Claisen-Schmidt, Claisen ester including Dieckmann; Mannich reaction, Perkin reaction; alkylation of active methylene compounds; synthetic applications of diethyl malonate and ethyl acetoacetate; specific enol equivalents (lithium enolates, enamines and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction.

Nucleophilic addition to α, β-unsaturated carbonyl system

General principle and mechanism (with evidence); direct and conjugate addition, addition of enolates (Michael reaction), Robinson annulations reaction.

Substitution at sp^2 carbon (C=O system)

Mechanism (with evidence): $B_{AC}2$, $A_{AC}2$, $A_{AC}1$, $A_{AL}1$ (inconnection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

Module: III

Organometallics (5 Lectures)

Grignard reagents, Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organolithium to carbonyl compounds; substitution on -COX; directed *ortho* metalation of arenes using organolithiums, conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behaviour of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; concept of umpolung.

Recommended Text Books

1. Finar, I. L. Organic Chemistry (Volume 1), 6th Edition, Pearson Education, 2002
2. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
3. Morrison, R. N. & Boyd, R. N. and Bhattacharjee, Organic Chemistry, 7th Edition, (Pearson Education), 2010
4. Nasipuri, D. Stereochemistry of Organic Compounds, 4th Edition, New Age International Pvt Ltd, 2020

Practical :(30 Lectures)

PAPER: (DSCC-6)/(CC-6)/(MN-6, 3-year)

Course Outcome (CO)	
CO	Systematically identify single solid organic compounds by detecting special elements, determining solubility-based classification, and confirming functional groups through standard qualitative chemical tests.

Qualitative analysis of single solid organic compound

1. Detection of special elements (N, S, Cl) by Lassaigne's test

2. Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)

3. Detection of the following functional groups by systematic chemical tests: aromatic amino (Ar-NH_2), aromatic nitro (-NO_2), amido (-$CONH_2$, including imide), phenolic –OH, carboxylic acid (-COOH), carbonyl (distinction between -CHO and >C=O); only one test for each functional group is to be reported.

Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups in known and unknown (**at least four)** organic compounds.

Reference Books

1. Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015
2. Furniss, Hannaford, Smith, Tatcholl, Vogel's Textbook of Practical Organic Chemistry, 5th Edition, Pearson India, 2003

PAPER: (DSCC-7)/(CC-7)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Build strong foundation in transport processes and the properties of liquids; gain understanding on diffusion, viscosity, and surface tension, as well as their underlying principles and applications.
CO-II	Develop solid understanding of the structure and properties of solids; acquire the ability to analyze crystal structures, determine unit cell dimensions, and apply Bragg's law to diffraction experiments.
CO-III	Build a strong understanding of colligative properties, phase equilibria, and electrochemistry; Gain ability to apply these concepts to various systems, calculate molar masses, analyze phase diagrams, and understand the principles of electrochemical cells and their applications.

Physical Chemistry - II

Theory: (45 Lectures)

Module: I

Transport processes and Liquid State

Diffusion and Viscosity (5 Lectures)

Diffusion

Fick's law, Flux, force, phenomenological coefficients & their inter-relationship (general form), different examples of transport properties

Viscosity

General features of fluid flow (streamline flow and turbulent flow); Newton's equation, viscosity coefficient; Poiseuille's equation (with derivation); principle of determination of viscosity coefficient of liquids by falling sphere method and using Ostwald's viscometer. Temperature variation of viscosity of liquids and comparison with that of gases. Relation between viscosity coefficient of a gas and mean free path.

Surface tension and energy (4 Lectures)

Surface tension, surface energy, excess pressure, capillary rise and surface tension; Work of cohesion and adhesion, spreading of liquid over other surface; Vapour pressure over curved surface; Temperature dependence of surface tension

Module: II

Solid State (12 Lectures)

Bravais Lattice and Laws of Crystallography

Types of solid, Bragg's law of diffraction; Laws of crystallography (Haϋy's law and Steno's law); Permissible symmetry axes in crystals; Lattice, space lattice, unit cell, crystal planes, Bravais lattice. Packing of uniform hard sphere, close packed arrangements (fcc and hcp); Tetrahedral and octahedral voids. Void space in cubic systems

Crystal plane

Distance between consecutive planes [cubic and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of d_{hkl}; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation). Determination of crystal structure: Powder method; Structure of NaCl and KCl crystals.

Module: III

Application of Thermodynamics – II (16 Lectures)

Colligative properties

Vapour pressure of solution; Ideal solution, ideally dilute solution and colligative properties; Raoult's law. Thermodynamic derivations (using chemical potential) relating (i) Elevation of boiling point of an ideally dilute solution containing a non- volatile nonelectrolyte solute, (ii) Depression of freezing point of an ideally dilute solution containing a non -volatile nonelectrolyte solute (iii) Osmotic pressure of an ideally dilute solution containing a nonvolatile nonelectrolyte solute with the molality / molar concentration of solute in solution. Applications in calculating molar masses of normal, dissociated and associated solutes in solution; Abnormal colligative properties.

Phase Equilibrium

Phase Rule

Definitions of phase, component and degrees of freedom; Phase rule and its derivations; Definition of phase diagram; Phase diagram for water, CO_2, Sulphur. First order phase transition and Clapeyron equation; Clausius- Clapeyron equation - derivation and use; Ehrenfest Classification of phase transition.

Binary solutions

Liquid vapour equilibrium for two component systems. Ideal solution at fixed temperature and pressure; Lever Rule. Principle of fractional distillation; Duhem-Margules equation; Henry's law; Konowaloff's rule; Positive and negative deviations from ideal behaviors; Azeotropic solution; Liquid-liquid phase diagram using phenol- water system; Solid-liquid phase diagram; Eutectic mixture. Three component systems, water-chloroform-acetic acid system, triangular plots.

ELECTROCHEMISTRY-II: (8 Lectures)

Electromotive Force:

Rules of oxidation/reduction of ions based on half-cell potentials, Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Thermodynamic derivation of 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 and glass electrodes. Concentration cells with and without transference, liquid junction potential; Potentiometric Titration.

Recommended Text Books

1. Levine, I. N. Physical Chemistry, 6^{th} Edition McGraw-Hill India, 2011
2. Castellan, G. W. Physical Chemistry, Narosa , 2004
3. Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11^{th} Edition, Oxford University Press, 2018

Practical :(30 Lectures)

PAPER: (DSCC-7)/(CC-7)

Course Outcome (CO)	
CO	Perform physicochemical experiments to measure surface tension, viscosity, and electrical conductivity, analyze concentration-dependent properties, and apply conductometric methods to titration and reaction kinetics.

1. Surface tension measurements using Stalagmometer

a) Determine the surface tension of a given solution by drop weight method using a stalagmometer.
b) Study the variation of surface tension of acetic acid solutions with concentration and hence determine graphically the concentration of an unknown solution of acetic acid.

2. Viscosity measurement using Ostwald's viscometer

a) Determination of viscosity of aqueous solutions of (i) ethanol and (ii) sugar at room temperature.
b) Study the variation of viscosity of sucrose solution with the concentration of solute and hence determine graphically the concentration of an unknown solution.

3. Conductometric Experiments

a) Conductometric titration of an acid (Mixture Strong and Weak monobasic acid, and Dibasic acid) against strong base.
b) Study of kinetics saponification reaction conductometrically

Reference Books

1.Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015

PAPER: (DSCC-8)/(CC-8)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Acquire solid understanding of coordination chemistry, including fundamental concepts, theories, and applications; Gain ability to analyze the structure, bonding, spectra, and magnetic properties of coordination compounds.
CO-II	Develop a strong understanding of the principles and applications of supramolecular chemistry; Gain ability to analyze the role of non-covalent interactions in the formation and stability of supramolecular interactions.
CO-III	Build a solid understanding of redox reactions, including their principles, balancing, and applications; gain ability to analyze redox processes, predict the feasibility of redox reactions, and perform redox titrations.

Inorganic Chemistry – II

Theory: (45 Lectures)

Module: I

Coordination Chemistry - I (26 Lectures)

Basics of coordination chemistry

Werner's theory, ligands, IUPAC nomenclature, Isomerism (constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes)

Valence bond theory and crystal field theory

VB description and its limitations. Elementary Crystal Field Theory: splitting of d^n configurations in octahedral, square planar, tetrahedral fields; crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion. Octahedral site stabilization energy (OSSE). Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples).

Electronic spectra of complexes and magnetic properties

d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions. Racah parameter. Selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea). Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only);

Module: II

Supramolecular chemistry (08 Lectures)

Hydrogen bonding. Non-covalent interactions – examples of Ion-Dipole Interactions, Dipole-Dipole interactions, Dipole-Induced Dipole and Ion-Induced Dipole interactions, van der Waals or Dispersion Interactions, Halogen bonding, Cation- interactions, Anion-pi interactions, pi - pi interactions, Aromatic-Aromatic Interactions: Edge-to-face *vs* pi-pi Stacking Interactions, N-H- pi interactions, Sulfur-aromatic interactions.

Module: III

Redox reactions: (11 Lectures)

Basic principle of redox reactions

Elementary idea on standard redox potentials with sign conventions. Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential.

Redox titrations

Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions.

Recommended Text Books

1. J. E. Huheey, E. A. Keiter, R. L. Keiter, Okhil K. Medhi, Principles of Structure and Reactivity, 5th Edition, Pearson India, 2022
2. H. J. Arnikar, Essentials of Nuclear Chemistry, 5th Edition, New Age International Pvt, Ltd., 2022
3.G. Friedlander, J.W. Kennedy, E. S. Macias, J.M. Miller, Nuclear and radiochemistry, 3rd Edition, John Wiley, 1981
4. J. W. Steed and J. L. Atwood, Supramolecular Chemistry,2nd Edition, Wiley India, 2017
5. J-M Lehn, Supramolecular Chemistry

Practical :(30 Lectures)

PAPER: (DSCC-8)/(CC-8)

Course Outcome (CO)	
CO	Quantitatively estimate metal ions in binary mixtures using suitable analytical techniques, interpret experimental data, and accurately determine the composition of unknown samples.

Estimation of mixtures of metal ions

1. Estimation of Fe^{3+} and Cu^{2+} in a mixture.
2. Estimation of Fe^{3+} and Cr^{3+} in a mixture.
3. Estimation of Fe^{3+} and $Cr_2O_7^{2-}$ in a mixture.
4. Estimation of Fe^{3+} and Mn^{2+} in a mixture.
5. Estimation of Cr^{3+} and Mn^{2+} in a mixture.

Reference Books

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015

Semester-V

PAPER: (DSCC-9)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Explain the fundamental principles of UV, IR, and NMR spectroscopy and interpret spectral data to identify structural features and functional groups in simple organic molecules.
CO-II	Analyze the mechanisms, stereochemical aspects, and migratory tendencies of important organic rearrangement reactions involving electron-deficient carbon, nitrogen, oxygen, and aromatic systems.
CO-III	Describe the preparation, reactions, and synthetic applications of amines, nitro compounds, nitriles, isonitriles, and diazonium salts, and apply mechanistic concepts to predict reaction outcomes in organic synthesis.

Organic Chemistry – III

Theory: (45 Lectures)

Module: I

Organic Spectroscopy -I (20 Lectures)

UV Spectroscopy

Introduction; types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic and Hypsochromic shifts; intensity of absorptions (Hyper-/Hypochromic effects); relative positions of λ_{max} considering conjugative effect, steric effect, solvent effect, effect of pH.

IR Spectroscopy

Introduction; modes of molecular vibrations(fundamental and non-fundamental); IR active molecules; application of Hooke's law, force constant; fingerprint region and its significance; effect of deuteration; overtone bands; vibrational coupling in IR; characteristic and diagnostic stretching frequencies of C-H, N-H, O-H, C-O, C-N, C-X, C=C (including skeletal vibrations of aromatic compounds), C=O, C=N, N=O, C≡C, C≡N; characteristic bending vibrations are included; factors affecting stretching frequencies: effect of conjugation, electronic effects, mass effect, bond multiplicity, ring-size, solvent effect, H-bonding on IR absorptions; application in functional group analysis.

NMR Spectroscopy

Introduction; nuclear spin; NMR active molecules; basic principles of Proton Magnetic Resonance; choice of solvent and internal standard; equivalent and non-equivalent protons; chemical shift and factors influencing it; ring current effect; significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant (1st order spectra); relative intensities of *first-order* multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR ; anisotropic effects in alkene, alkyne, aldehydes and aromatics; Idea about NMR peak area, integration; relative peak positions; rapid proton exchange; interpretation of NMR spectra of simple compounds: Ethanol, diethyl maleate, diethyl fumarate, *trans*-cinnamic acid, benzene, toluene, benzaldenyde, *p*-nitrobenzaldehyde, dinitrobenzenes, nitroanilines.

Applications of UV, IR and NMR spectroscopy for identification of simple organic molecules

Module: II

Rearrangements (15 Lectures)

Mechanism with evidence (including crossover experiments) and stereochemical features for the following:

Rearrangement to electron-deficient carbon

Wagner-Meerwein rearrangement, pinacol rearrangement, dienone-phenol; Wolff rearrangement in Arndt-Eistert synthesis, benzil-benzilic acid rearrangement, Demjanov rearrangement, Tiffeneau–Demjanov rearrangement.

Rearrangement to electron-deficient nitrogen

Rearrangements: Hofmann, Curtius, Lossen, Schmidt and Beckmann.

Rearrangement to electron-deficient oxygen

Baeyer-Villiger oxidation, cumene hydroperoxide-phenol rearrangement and Dakin reaction.

Aromatic rearrangements: Migration from oxygen to ring carbon

Fries rearrangement and Claisen rearrangement.

Migration from nitrogen to ring carbon

N-azo to *C*-azo rearrangement, Bamberger rearrangement, Orton rearrangement and benzidine rearrangement.

Module: III

Nitrogen compounds **(10 Lectures)**

Amines: Aliphatic & Aromatic

Preparation, separation (Hinsberg's method) and identification of primary, secondary and tertiary amines; reaction (with mechanism): Eschweiler–Clarke methylation, diazo coupling reaction, formation and reactions of phenylenediamines, diazomethane and diazoacetic ester.

Nitro compounds (aliphatic and aromatic)

Preparation and reaction (with mechanism): reduction under different conditions; Nef carbonyl synthesis, Henry reaction and conjugate addition of nitroalkane anion.

Alkylnitrile and isonitrile

Preparation and reaction (with mechanism): Thorpe nitrile condensation, von Richter reaction.

Diazonium salts and their related compounds

Reactions (with mechanism) involving replacement of diazo group; reactions: Gomberg, Meerwein, Japp-Klingermann.

Recommended Text Books

1. Kemp. W, Organic Spectroscopy, Macmillan, 3rd Edition, 2022
2. Dyer, Applications of Absorption Spectroscopy of Organic Compounds, Prentice Hall India Learning Private Limited, 1978
3. Pavia. Donald L, Introduction to Spectroscopy, 5th Edition, Cengage India Private Limited, 2015
4. Finar, I. L. Organic Chemistry (Volume 1), Vol 1, 6th Edition (Pearson Education India), 2002.
5. Morrison, R. N. & Boyd, R. N. and Bhattacharjee, Organic Chemistry,7th Edition, Pearson Education, 2010

Practical: (30 Lecture hours)

PAPER: (DSCC-9)

Course Outcome (CO)	
CO	Carry out fundamental organic synthesis reactions, isolate and purify the products, determine reaction yields, and relate experimental observations to the underlying reaction mechanisms.

Organic Preparations

A. The following reactions (at least 5) are to be performed, noting the yield of the crude product:

1. Nitration of aromatic compounds

2. Condensation reactions

3. Hydrolysis of amides/imides/esters

4. Acetylation of phenols/aromatic amines

5. Side chain oxidation of aromatic compounds

6. Diazo coupling reactions of aromatic amines

7. Bromination of anilides (Bromate-Bromide method)

Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

B. Purification of the crude product is to be made by crystallization from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.

C. Melting point of the purified product is to be noted.

PAPER: (DSCC-10)

(Credit: Theory – 03, Practical – 01)

Course Outcome (CO)	
CO-I	Explain the electronic structure, bonding, preparation, properties, and applications of important compounds of s-, p-, d-, and f-block elements, including inorganic polymers, interhalogen compounds, noble gas compounds, and lanthanoid/actinoid systems.
CO-II	Analyze periodic trends, oxidation states, structural features, magnetic properties, and reactivity patterns of main-group, transition, and inner-transition elements, and correlate these with their practical applications.
CO-III	Describe the fundamental concepts of nuclear chemistry, including nuclear models, radioisotope production, radiotracer techniques, and their applications in chemical research, analysis, and nuclear medicine.

Inorganic Chemistry – III

Theory: (45 Lectures)

Module: I

s- and p- block elements (30 Lectures)

General properties of s- and p-block elements. Behavior of alkali metals in liquid ammonia. Preparation and structure of basic beryllium acetate and nitrate, beryllium halides. Relative stability of different oxidation states of Groups 13, 14 and 15. Allotropy and catenation. Hydrolytic behavior of the halides of Group 15. Structure and magnetism of gallium dichloride. Preparation, structure, bonding, properties and uses of boric acid, borates, diborane, graphitic compounds, fullerenes, oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine. Preparation, structure and properties of peroxo acids of sulphur, sulphur-nitrogen compounds, interhalogen compounds, polyhalides, pseudo halogens, fluorocarbons. Basic properties of halogens, super halogen. Special properties of helium. Preparation of fluorides, oxides of xenon and perxenates. Clathrates of noble gas elements. Uses of noble gases.

Inorganic polymers: General characteristics, comparison with organic polymers. Preparation, structure and uses of silicones and siloxanes, borazines, polymeric boron nitride $(BN)_x$, phosphazenes and polythiazyl $(SN)_x$

Module: II

d- and f- block elements (9 Lectures)

General comparison of 3d, 4d and 5d elements in terms of oxidation states, metal-metal bond, redox properties of Gr. 6-11

General comparison of lanthanoids and actinoids in terms of electronic configuration, oxidation states, spectral and magnetic properties. Lanthanoid and actinoid contraction. Separation of lanthanides (ion-exchange method only). Uses of lanthanoids and actinoids in spectral, magnetic and theranostic applications.

Module: III

Nuclear Model and Radiotracer methods (6 Lectures)

Liquid drop model, Shell model, magic numbers. Concept of nuclear quantum number. Spin Isomerism

Overview of radioisotope production, radiometric titrations. Radiotracer methods: study of mechanism of chemical reactions, nuclear medicine, isotope dilution analysis.

Recommended Text- Books and Reference Books

1. Concise Inorganic Chemistry, J. D. Lee, 5thEd., Wiley India Pvt. Ltd., 2008.

2. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6thEd., Oxford University Press, 2010.

3. N. N. Greenwood, & A. Earnshaw, Chemistry of the Elements, Butterworth-Heinemann, 1997.

4. H. J. Arnikar, Essentials of Nuclear Chemistry, 5thEdition, New Age International Pvt, Ltd., 2022

5. G. Friedlander, J.W. Kennedy, E. S. Macias, J. M. Miller, Nuclear and Radiochemistry, 3rdEd., John Wiley, 1981

6. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e

Practical: (30 Lecture hours)

PAPER: (DSCC-10)

Course Outcome (CO)	
CO	Analyze industrially important materials using appropriate quantitative analytical techniques to determine the composition and quality of metals, minerals, pharmaceuticals, cement, and water samples.

Analysis of materials of industrial importance

1. Cu and Zn in brass (Complexometry)

2. $CaCO_3$ and $MgCO_3$ in Dolomite

3. Cr and Mn in steel

4. Vitamin C

5. DO in water sample

6. Fe_2O_3 in Portland cement

7. Mg in talcum powder

Reference Books

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

2. Practical Workbook Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015

3. University Handbook of Undergraduate Chemistry Experiments, University of Calcutta, 2003

PAPER: (DSCC-11)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Explain the fundamental principles of quantum mechanics, including wave–particle duality, Schrödinger wave equations, operators, eigenvalue problems, and the postulates governing quantum systems.
CO-II	Apply quantum mechanical concepts to exactly solvable systems such as the particle in a box, potential step, potential barrier, and finite potential well, and interpret the physical significance of wave functions, energy quantization, tunneling, and expectation values.
CO-III	Analyze surface phenomena and molecular electrical properties by applying theories of adsorption, colloidal stability, micellization, dielectric polarization, polarizability, and dipole moments to chemical systems and materials.

Physical Chemistry – III

Theory: (45 Lectures)

Module: I

Foundation of Quantum Mechanics **(18 Lectures)**

Particle Aspect of Radiation

Blackbody Radiation, Photoelectric Effect, Compton Effect.

Wave Aspect of particles

de Broglie's Hypothesis: Matter Wave, Heisenberg's Uncertainty Principle. Wave packet, time evolution of wave function. Group and Phase Velocities.

Schrodinger Equation and Wavefunction

The time dependent Schrodinger equation. The time-independent Schrodinger equation; nature of the equation, acceptability conditions for the wave functions and probability interpretations of wave function. Vector representation of wave function. Dirac's bra-ket notation. Orthonormality of wave function.

Concept of Operators

Elementary concepts of operators, eigenfunctions and eigenvalues; Linear operators; Commutation of operators, commutator and uncertainty relation; Expectation value;

The Postulates and General Principles of Quantum Mechanics

Postulates of Quantum Mechanics. Hermitian operators, definition and examples. Theorems about Hermitian operators. Expansion of a function in terms of eigenfunctions. Eigenfunctions of commuting operators.

Module: II

Exactly Solvable Systems -1 (12 Lectures)

Particle in a box

Setting up of Schrodinger equation for one-dimensional box and its solution; Comparison with free particle eigenfunctions and eigenvalues. Properties of PB wave functions (normalization, orthogonality, probability distribution); Expectation values of x, x^2, p_x and p_x^2 and their significance in relation to the uncertainty principle; Extension of the problem to two and three dimensions and the concept of degenerate energy levels.

Stationary states under special potentials

The Potential Step – (I) When $E>V_o$, (II) when $E<V_o$, Reflection coefficient and transmission coefficient. Particle in a 1-D potential barrier of finite height and finite thickness ($E>V_o$ and $E<V_o$). Quantum Mechanical Tunneling. Particle in a finite potential well ($0<E<V_o$). Bound states in slowly varying potential.

Module: III

Surface Chemistry

Adsorption (05 Lectures)

Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm; Gibbs adsorption isotherm and surface excess; Heterogeneous catalysis (single reactant);

Colloids (05 Lectures)

Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, Coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Stability of colloids and zeta potential; Micelles, reverse micelles; micellization equilibrium; thermodynamics of micellization.

Electrical Properties of molecules

Dipole moment and polarizability (05 Lectures)

Polarizability of atoms and molecules, dielectric constant and polarization, molar polarization for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation (both without derivation) and their application; Determination of dipole moments

Recommended Text Books

1. Levine, I. N. Physical Chemistry, 6th Edition, McGraw-Hill India ,2011.
2. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press,1997.
3. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, 11th Edition, Oxford University Press, 2018.
4. Levine, I.N, Quantum Chemistry, 7th Edition, Pearson, , 2016.
5. McQuarrie, D.A, Quantum Chemistry, 2nd Edition, University Science Books, 2008.

Practical: (30 Lecture hours)

Paper: (DSCC-11)

Course Outcome (CO)	
CO	Perform conductometric, potentiometric, and solubility product experiments to determine ionization constants, electrode potentials, solubility products, and related physicochemical parameters, and interpret the results using principles of electrochemistry and solution equilibria.

1. Conductometric Experiments

To determine the ionization constant of a weak acid by conductometric method.

2. Potentiometric Experiments

a) Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ and $KMnO_4$ solution and hence determine the standard reduction potential (E^0) of Fe^{+3} / Fe^{+2} couple in the hydrogen scale.
b) Determination of concentration of (i) $AgNO_3$ solution and (ii) solubility product of AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution.

3. Solubility Product:

a) Determination of solubility and solubility product of a sparingly soluble salt in water, and in various electrolytic media by titrimetric method.
b) Determination of the activity solubility product of KHTa from the variation of concentrated solubility product with the ionic strength of the solution.

Reference Books

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

PAPER: (DSCC-12)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Apply retrosynthetic analysis to the design of organic syntheses by identifying strategic disconnections, synthons, synthetic equivalents, functional group interconversions, protection–deprotection strategies, and ring-forming methodologies.
CO-II	Analyze the structure, reactivity, orientation, and synthetic approaches of polynuclear aromatic and heterocyclic compounds, and elucidate the mechanisms of their important reactions and named syntheses.
CO-III	Interpret the stereochemical and conformational features of alicyclic compounds and predict the influence of ring strain, conformation, stereoelectronic effects, and reaction mechanisms on their chemical reactivity and selectivity.

Organic Chemistry – IV

Theory: (45 Lectures)

Module: I

Organic Synthesis-I (15 Lectures)

Retrosynthetic analysis

Disconnections; synthons, donor and acceptor synthons; natural reactivity and *umpolung*; latent polarity in bifunctional compounds: illogical electrophiles and nucleophiles; synthetic equivalents; functional group interconversion and addition (FGI and FGA); C-C disconnections and synthesis:

one-group and two-group (1,2- to 1,5-dioxygenated compounds), reconnection (1,6-dicarbonyl); protection-deprotection strategy (alcohol, amine, carbonyl, acid).

Strategy of ring synthesis: Thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique, Favorskii Rearrangement in relation to ring contraction.

Module: II

Carbocycles (5 Lectures)

Polynuclear hydrocarbons and their derivatives

*S*ynthetic methods include Haworth, Bardhan-Sengupta, Bogert-Cook (with mechanistic details); fixation of double bonds and Fries rule; reactions (with mechanism) of naphthalene, anthracene and phenanthrene and their derivatives.

Heterocycle-I (13 Lectures)

Heterocyclic compounds

Reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine; synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis, Paal-Knorr synthesis, Hantzsch; furan: Paal-Knorr synthesis, Feist-Benary synthesis and its variation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis; benzo-fused 5-and 6-membered rings with one heteroatom: reactivity, orientation and important reactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, quinoline: Skraup, isoquinoline: Bischler-Napieralski synthesis

Module: III

Stereochemistry and Reactions of Alicyclic Compound (12 Lectures)

Concept of I-strain (Baeyer's strain theory); conformational analysis: cyclohexane, mono and disubstituted cyclohexane; symmetry properties and optical activity; topomerisation; ring size and ease of cyclisation; conformation & reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic *syn* elimination and fragmentation reactions.

Recommended Text Books

1. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), 2002.

2. Eliel, E. L. &Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.

3. Organic Synthesis: The Disconnection Approach, Stuart Warren (Author), Paul Wyatt (Author), 2008.

4. John Joule , Keith Mills , George Smith , Heterocyclic Chemistry,3rd Edition,1995, CRC Press.

5. J. Joule, Heterocyclic Chemistry,5th Edition, Wiley, 2010.

Practical: (30 Lecture hours)

Paper: (DSCC-12)

Course Outcome (CO)	
CO	Perform chromatographic separations using thin-layer chromatography (TLC), paper chromatography, and column chromatography, and analyze the separation and identification of amino acids and dyes based on their chromatographic behavior.

TLC & PAPER CHROMATOGRAPHY – AMINO ACIDS, DYES COLUMN CHROMATOGRAPHY (DEMO)

Chromatographic Separations

1. TLC separation of a mixture containing 2/3 amino acids

2. TLC separation of a mixture of dyes (fluorescein and methylene blue)

3. Paper chromatographic separation of a mixture containing 2/3 amino acids

4. Column chromatographic separation of mixture of dyes (DEMO)

Reference Books

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

Semester-VI

PAPER: (DSCC-13)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Apply the principles of quantum mechanics to solve model systems such as the quantum harmonic oscillator, rigid rotator, and hydrogen atom, and interpret the physical significance of wave functions, angular momentum, and quantized energy levels.
CO-II	Analyze molecular spectra arising from rotational, vibrational, electronic, and Raman transitions, and use spectroscopic principles to determine molecular properties such as bond lengths, force constants, vibrational frequencies, and dissociation energies.
CO-III	Explain the fundamental laws and kinetics of photochemical processes, evaluate quantum yields and photostationary states, and interpret the role of photochemical reactions in chemical and biological systems.

Physical Chemistry - IV

Theory: (45 Lectures)

Module: I

(20 Lectures)

Exactly Solvable Systems -2

1. **Quantum Harmonic Oscillator**

Setting up of One-dimensional Schrödinger equation. Expressions of wave function. Zero-point energy and uncertainty principle. Classical turning points, Expectation values of x, x^2, p_x and p_x^2.

2. **Rigid Rotator**

Commutation rules of angular momentum, Angular Momentum operators in spherical polar coordinates. Quantization of square of total angular momentum and z-component (Expressions only); Rigid rotator model of rotation of diatomic molecule; Schrödinger equation, transformation to spherical polar coordinates; Separation of variables. Spherical harmonics; Discussion of solution

3. Hydrogen atom and hydrogen-like ions

Setting up of Schrödinger equation in spherical polar coordinates, Separation of variables, Solution of angular Part (φ part only), quantization of energy (only final energy expression); Real wave functions. Average and most probable distances of electron from nucleus; Setting up of Schrödinger equation for many-electron atoms (He, Li)

Approximation Methods in Quantum Mechanics

Variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom). Linear Variation principle. Secular determinant.

Electronic structure of diatomic molecules

The Born-Oppenheimer approximation. Nuclear motion in diatomic molecules. LCAO-MO and Valence bond approach. **The hydrogen molecule ion:** LCAO-MO treatment of H_2^+ ground electronic state; Bonding and antibonding orbitals. **The hydrogen molecule:** LCAO-MO treatment of H_2 ground electronic state. Valence bond treatment of H_2. Comparison of LCAO-MO and VB treatments of H_2 and their limitations. Electronic terms of diatomic molecules.

Module: II

Molecular Spectroscopy (15 Lectures)

Interaction of electromagnetic radiation with molecules and various types of spectra;

Rotation spectroscopy

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

Vibrational spectroscopy

Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, Diatomic vibrating rotator, P, Q, R branches

Electronic Spectroscopy

Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Frank Condon factor. Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non- radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonskii diagram;

Raman spectroscopy

Classical Treatment. Rotational Raman effect; Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion

Module: III

Photochemistry (10 Lectures)

Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields

Rate of Photochemical processes

Photochemical equilibrium and the differential rate of photochemical reactions, Photo stationary state; HI decomposition, H_2-Br_2 reaction, dimerization of anthracene; photosensitized reactions, quenching, Stern-Volmer equation. Role of photochemical reactions in biochemical processes.

Chemical Kinetics - II

Catalysis

Homogeneous catalysis with reference to acid-base catalysis; Enzyme catalysis; Michaelis-Menten equation, Lineweaver-Burk plot, turn-over number.

Reaction Dynamics

Collision theory of reaction rate (detailed treatment). Lindemann theory of unimolecular reaction; The RRK model. Potential energy surface., minimum energy path, saddle point, concept of transition state. Transition State theory. The Eyring Equation. Thermodynamic aspects. Primary Kinetic Salt Effect.

Recommended Text Books

1. Levine, I. N. Physical Chemistry, 6th Edition, McGraw-Hill India ,2011.

2. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press,1997.

3. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, 11th Edition, Oxford University Press, 2018.

4. Levine, I.N, Quantum Chemistry, 7th Edition, Pearson, 2016.

5. McQuarrie, D.A, Quantum Chemistry, 2nd Edition, University Science Books, 2008.

6. Colin Banwell and Elaine McCASH, Fundamentals of Molecular Spectroscopy, 6th Edition Affiliated East-West Press ,2024.

7. Barrow, G. M. Molecular Spectroscopy, McGraw-Hill, 1962.

Practical: (30 Lecture hours)

Paper: (DSCC-13)

Course Outcome (CO)	
CO	Apply spreadsheet software to perform scientific computations, numerical methods, regression analysis, and graphical data analysis for solving problems in thermodynamics, quantum mechanics, chemical equilibria, enzyme kinetics, titration, and reaction modeling.

Using Spreadsheet Software

1. Determination of Molar Enthalpy of Vaporization using Linear and Non-Linear Least squares fit.

2. Calculation and Plotting of a Precipitation Titration Curve with MS Excel.

3. Acid-Base Titration Curve using Excel Goal Seek Function.

4. Plotting of First and Second Derivative Curve for pH metric and Potentiometric titration.

5. Use of spreadsheet to solve the 1D Schrodinger Equation (Numerov Method), Particle in a box.

6. Michaelis-Menten Kinetics for Enzyme Catalysis using Linear and Non - Linear Regression.

7. Roots of equation –Newton-Raphson method. (e.g volume of van der Waals gas and comparison with ideal gas, pH of a weak acid)

8. Numerical Integration using Simpson's 1/3rd rule and Trapezoidal rule. (e.g. entropy/enthalpy change from heat capacity data), (probability distributions (gas, kinetic theory) and mean values)

Recommended Books

1. Levine, I. N. Physical Chemistry, 6th Edition, McGraw-Hill India ,2011.

2. Levine, I.N, Quantum Chemistry, 7th Edition, Pearson, 2016.

3. Stanley Crouch , Douglas Skoog , F. Holler , Donald West, Applications of Microsoft Excel in Analytical Chemistry, Cengage Learning,2021.

PAPER: (DSCC-14)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Explain the structure, stereochemistry, synthesis, reactions, and biological significance of carbohydrates, amino acids, peptides, and nucleic acids, and apply mechanistic principles to analyze their chemical transformations and molecular functions.
CO-II	Explain the principles of statistical thermodynamics and apply partition functions to derive thermodynamic properties, analyze molecular energy distributions, chemical equilibria, low-temperature phenomena, and the heat capacities of solids.
CO-III	Explain the composition, manufacture, properties, and industrial applications of glass, ceramics, and cements, and describe the chemistry, preparation, and applications of important chemical explosives and rocket propellants.

FUNDAMENTALS OF CHEMISTRY – III

Theory: (45 Lectures)

INSTRUCTIONS

1. A single question paper of 75 Marks to be set with equal weightage to all modules.

2. Separate answer booklet to be used for each module.

3. For each module, separate coordinator to be appointed by CU.

Module-I

Chemistry of Biomolecules:

Carbohydrate Chemistry (7 Lectures)

Monosaccharides:

Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases with D-glucose only): Fischer glycosidation, osazone formation (comparison with mannose & fructose), bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $–CH_2OH$ of aldoses, reduction to alditols, Lobry de Bruyn-van Ekenstein rearrangement; stepping–up (Kiliani-Fischer method) and stepping–down (Ruff's method) of aldoses; end-group-interchange of aldoses; acetonide (isopropylidene and benzylidene protections).

Amino acids, peptides and nucleic acids (8 Lectures)

Amino acids

Synthesis with mechanistic details: Strecker, Gabriel; acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperizine, isoelectric point, zwitter ions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction.

Peptides:

Peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using *N*-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: *C*-terminal and *N*-terminal unit determination (Edman, Sanger and 'dansyl' methods); partial hydrolysis.

Nucleic acids:

pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA.

Recommended Text Books

1. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), 2002.

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

3. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Pearson Education India. 7th Edition, (Pearson Education), 2010.

Module-II

Statistical Thermodynamics (15 Lectures)

The Boltzmann Distribution

Microstates and Configurations. Counting Microstates and weights. The dominant configuration. Derivation of the Boltzmann Distribution law. Molecular partition function and its significance. Degeneracy. Physical meaning of the Boltzmann Distribution law. Thermodynamic probability and Entropy. Barometric formula from Boltzmann Distribution.

Ensemble and Molecular Partition function

The concept of ensemble. The Canonical, Micro canonical and Grand Canonical ensemble. Relations between Molecular partition function and Canonical partition function for (i) distinguishable independent molecules and, (ii) indistinguishable independent molecules. Molecular energy levels. Translational partition function, Rotational partition function for diatomic molecules and Vibrational partition function.

Thermodynamic variables and partition function

Internal energy and partition function. Entropy and partition function. Relations between derived thermodynamic variables and partition function. Residual entropy.

Applications

Application to chemical/ionization equilibrium, Equipartition principle. Gibbs paradox.
Blackbody radiation.

3rd law of thermodynamics

Absolute entropy, Plank's law, Calculation of entropy, Nernst heat theorem

Adiabatic demagnetization

Approach to zero Kelvin, adiabatic cooling, demagnetization, adiabatic demagnetization – involved curves.

Specific heat of Solids

Coefficient of thermal expansion, thermal compressibility of solids; Dulong –Petit's law; Perfect Crystal model, Einstein's theory – derivation from partition function, limitations; Debye's T^3 law – analysis at the two extremes

Recommended Text Books

1. Levine, I. N. Physical Chemistry, 6th Edition ,2011, McGraw-Hill India.

2. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.

Module-III

Silicate Materials of Industrial Importance (12 Lectures)

Glass

Glassy state and its properties, Manufacture and processing of glass, composition and properties of the following types of glasses: sodalime glass, potash glass, lead glass, borosilicate glass, fluorosilicate glass, tempered glass, armoured glass, coloured glass, photochromatic glass.

Ceramics

Important clays and feldspar, types and manufacture of ceramics, high technology ceramics and their applications, super conducting and semi conducting oxides.

Cements

Classification of cements, ingredients and their roles, manufacture of cements and the setting process, quick setting cement.

Chemical Explosives (3 Lectures)

Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX), introduction to rocket propellants.

Reference Books:

1. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.

2. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas Publications, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.

Practical: (30 Lecture hours)

Paper: (DSCC-14)

Course Outcome (CO)	
CO	Interpret ^{1}H NMR and IR spectra to identify functional groups, assign spectral peaks, and elucidate the structures of organic compounds based on their characteristic spectroscopic features.

Spectroscopy (^{1}H-NMR and IR)

Spectroscopic Analysis of Organic Compounds

1. Assignment of labelled peaks in the ^{1}H NMR spectra of the known organic compounds explaining the relative δ-values and splitting pattern.

2. Assignment of labelled peaks in the IR spectrum of the same compound with the nature of the

bands (C-H, O-H, N-H, C-O, C-N, C-X, C=C, C=O, N=O, C≡C, C≡N stretching frequencies)

3. The students must record full spectral analysis of compounds from the following list:

(i) 4′-Bromoacetanilide (ii) 2-Bromo-4'-methylacetophenone (iii) Vanillin (iv) 2′-Methoxyacetophenone (v) Salicylamide (vi) 2′- Hydroxyacetophenone (vii) *trans*-Cinnamic acid (viii) 4′-Methylacetanilide (ix) 3-nitroanisole (x) 2,3-Dimethylbenzonitrile (xi) Pent-1-yn-3-ol (xii) 3-Nitrobenzaldehyde (xiii) 3-Aminobenzoic acid (xiv) Ethyl 3- aminobenzoate (xv) Ethyl 4-aminobenzoate.

Reference Books

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

PAPER: (DSCC-15)

(Credit: Theory -03, Practical – 01)

Course Outcome (CO)	
CO-I	Explain the bonding, structure, electron-counting rules, synthesis, and reactivity of organometallic compounds, and evaluate their applications in homogeneous and heterogeneous catalysis and industrial chemical processes.
CO-II	Analyze the role of biologically important metal ions and metalloproteins in living systems, including oxygen transport, electron transfer, and essential biochemical processes.
CO-III	Interpret the kinetics and mechanisms of coordination compound reactions by applying concepts of thermodynamic and kinetic stability, substitution pathways, trans effect/trans influence, and electron-transfer mechanisms.

Inorganic Chemistry – IV

Theory: (45 Lectures)

Module: I

Organometallic Chemistry–I (25 Lectures)

Definition and classification of organometallic compounds based on bond type. Concept of hapticity.18-electron and 16-electron rules and its stability (pictorial MO approach). Applications of 18-electron rule to transition metal organometallic complexes. General methods of preparation of mono and binuclear carbonyls of 3d series. Structures of mono-, bi-, tri- and tetranuclear carbonyls. Different binding modes of CO and NO with examples. Comparison of σ- donor and π-acceptor behavior of CO, NO and CN^-. Synergistic effect and its interpretation through IR spectra. Bonding of iron nitrosyl (brown ring) complex as a special case. Zeise's salt: preparation, structure, bonding. Ferrocene: Structure, preparation, properties and reactions (acetylation, alkylation, oxidation, nitration, halogenation, metalation, Mannich condensation). Reactions of organometallic complexes: ligand dissociation, substitution, oxidative addition, reductive elimination, migration and insertion reactions. Organometallic catalysis –Homogeneous and Heterogeneous- Industrial importance- hydroformylation, hydrogenation of alkenes by Wilkinson's catalyst (Tolman catalytic loop), Ziegler – Natta polymerization.

Module: II

Bioinorganic Chemistry – I (10 Lectures)

Elements of life: essential and beneficial elements, major, trace and ultra-trace elements. Basic chemical reactions in biological systems and the role of metal ions (specially Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, $Fe^{3+/2+}$, $Cu^{2+/1+}$, Zn^{2+} and $Mo^{3+/4+/6+}$) in biology. Dioxygen management proteins: Hemoglobin, Myoglobin, Hemocyanin and Hemerythrin. Electron Transport Proteins: Ferredoxins (2Fe-2S, 4Fe-4S, Reiske protein), Cytochrome C and Cytochrome C oxidase.

Module: III

Reaction kinetics and mechanism (10 Lectures)

Thermodynamic and kinetic stability. Significance of LFAE, Inert and Labile complexes. Substitution reaction pathways. Mechanism of nucleophilic substitution in square planar and octahedral complexes. Trans- effect and trans influence and its application in complex synthesis. Explanation of trans-effect through MO approach. Electron transfer reactions (basic ideas of Inner sphere and Outer sphere mechanisms).

Recommended Text-Books

1. James E. Huheey / Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5thEd., Pearson,2022.

2. G.L. Meissler, P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson

3. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999

Reference Books

1. P. Powell, Principles of Organometallic Chemistry, Chapman and Hall, 1988.

2. J. P. Collman et al. Principles and Applications of Organo transition Metal Chemistry, Mill Valley, CA: University Science Books, 1987.

3. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork, NY: John Wiley, 2000.

4. Robert R. Crichton, Biological Inorganic Chemistry: A New Introduction to Molecular Structure and Function,3rd Ed., Academic Press, 2018.

5. L. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine, Bioinorganic Chemistry, Viva, 2007.

6. F. Basolo and R.C. Pearson, Mechanisms of Inorganic Chemistry, John Wiley& Sons, NY, 1967.

17. K.F. Purcell and J.C. Kotz An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.

18. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e

9. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed., Oxford University Press, 2010.

Practical: (30 Lecture hours)

PAPER: (DSCC-15)

Course Outcome (CO)	
CO	Synthesize and characterize coordination compounds of transition metals, relate their composition and properties to coordination chemistry principles, and evaluate the efficiency of synthesis through product isolation and yield determination.

Preparation of Inorganic Complexes

1. *cis*-$K[Cr(C_2O_4)_2(H_2O)_2]$

2. $[Co(NH_3)_4(CO_3)]NO_3.0.5H_2O$

3. $[Ni(\mathit{en})_3]Cl_2.2H_2O$

4. $[Fe(acac)_3]$

5. $[Cu(acac)_2]$

6. $[VO(acac)_2]$

7. $[Ni(salen)_2]$ [salen = The Schiff base synthesised by condensation of salicylaldehyde and ethylenediamaine]

Reference Books

1. Inorganic Syntheses, Wiley Publications

Semester-VII

PAPER: (DSCC-16)

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Explain the principles of advanced coordination chemistry, including crystal field theory, d-orbital splitting in different geometries, crystal field stabilization energy (CFSE), nephelauxetic effect, electronic spectra, Tanabe–Sugano diagrams, and microstate/term symbol analysis for transition metal complexes.
CO-II	Interpret EPR and Mössbauer spectroscopic data to determine the electronic structure, oxidation state, spin state, and coordination environment of transition metal complexes, particularly iron-containing systems.
CO-III	Analyze the structure, function, and mechanisms of biologically important metal-containing systems, including ion transport, metalloenzymes, photosynthetic processes, vitamin B12, metal toxicity, chelation therapy, medicinal metal complexes, and metal-dependent diseases.
CO-IV	Explain the bonding, structure, reactivity, and applications of advanced organometallic compounds, including fluxional molecules, isolobal relationships, metal–allyl/alkyne complexes, ferrocene, C–H bond activation, carbene and carbyne complexes, and organometallic compounds used as drugs and sensors.
CO-V	Apply electrochemical analytical techniques such as cyclic voltammetry, polarography, anodic stripping voltammetry, amperometry, coulometry, and electrogravimetry for qualitative and quantitative chemical analysis, including solving relevant numerical problems.

Inorganic Chemistry – V

Module – I

Coordination Chemistry – II (12 Lectures)

Crystal field theory. Splitting of d-orbitals in linear, triagonal planar, tetrahedral, square planar, trigonal bipyramidal, square pyramidal, octahedral, triagonal prism, pentagonal bipyramidal and cubic fields. Crystal field stabilization energies in weak field and strong field environments. Crystal Field Activation Energy and its Application, Nephelauxetic effect and Nephelauxetic Series, Distorted shapes of complexes (Coordination No. 4, 5) based on Yang and Addison parameters. Microstates, determination of various microstates for different d^n configurations, Ground and excited state terms, deduction up to d^3 configuration, Qualitative idea of Tanabe-

Sugano diagram and evaluation of 10Dq and B values. Interpretation of electronic spectra of d^2, d^3, d^7, d^8 systems from simplified Tanabe Sugano diagram.

Module – II

EPR and Mössbauer Spectroscopy (12 Lectures)

EPR Spectroscopy: Principle, comparison with NMR spectroscopy, line-width, nuclear hyperfine interactions, splitting constant, allowed transitions using energy diagram - $\dot{H}$, $\dot{C}H_3$, $Cu(acac)_2$, VO $(acac)_2$

Mössbauer Spectroscopy: Principle, Mössbauer energy levels with isomer shift, line-width, center shift, quadrupole interaction, quadrupole splitting and hyperfine interaction with reference to ^{57}Fe. Information of spin and oxidation states of Fe nuclei in variety of environments.

Module – III

Bioinorganic Chemistry-II (12 Lectures)

Ionophores, Metal ion Transport (Na^+/K^+ ion). $Na^{+/}K^+$ ion pump. Bioenergetic principle and role of ATP. Active site structure, function, mechanism of action and synthetic model system for various metalloenzymes: carbonic anhydrase, carboxypeptidase, superoxide dismutase, catalase, peroxidase. Photosynthesis, Chlorophyll, PS-I, PS-II, photosynthetic electron transport chain. Vitamin B_{12}. Toxicity of metal ions (As, Pb, Hg) and their effects, LD_{50} (basic idea only), chelation therapy, Pt, Rh, Ru and Au complexes in medicine (examples only). Metal dependent diseases – Wilson's and Alzheimer's diseases.

Module – IV

Organometallic Chemistry –II (12 Lectures)

Stereochemical non-rigidity and fluxional behaviour of $[Ti(\eta^1\text{-}Cp)_2(\eta^5\text{-}Cp)_2]$ (characterization with ^1H NMR). Isolobal and isoelectronic relationships with examples (MO approach). Structure and bonding (evidence from IR/bond length data) in metal-allyl, metal-alkyne complexes with typical examples: $[Ni(\eta^3\text{-}C_3H_5)_2]$, $[Co_2(CO)_6(C_2H_2)]$,$[(PPh_3)_2Pt(C_2Ph_2)]$ and $[PtCl_2(ArNH_2)(C_2Bu^t{}_2)]$. MO diagram of ferrocene. C–H bond activation by organometallic complexes – cyclometallation reactions. Metal-Carbon bonding in Fischer and Schrock type carbene and carbyne complexes.Organometallic compounds as drugs (examples only) and sensors.

Module – V

Electrochemical Analyses (12 Lectures)

Voltammetry: cyclic voltammetry, polarography, anodic stripping voltammetry; amperometry, coulometry, electrogravimetry and numerical problems therein.

Tutorial: (30 Lecture hours)

PAPER: (DSCC-16)

1. Applications of Mossbauer Spectroscopy in Biomimetic Chemistry of Fe metalloproteins
2. Bioremediation of Metals
3. Biological Defense Mechanism
4. Application of Transition Metal Organometallic Compounds in Click Chemistry
5. Application of Cyclic Voltammetry in Transition Metal complexes.
6. Composite Materials.
7. Bioorganometallic Chemistry.
8. Application of Tanabe Sugano diagram in determination of Δo for d^1, d^2, d^3,d^4 (H.S.) d^6(H.S.) d^7 (H.S.) d^8, d^9 metal complexes.
9. Jahn – Teller distortion and its applications in solid state chemistry and materials.
10. Fischer and Shrock carbene complexes.

PAPER: (DSCC-17)

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Explain the concepts of aromaticity and linear free energy relationships by applying Hückel molecular orbital theory, Frost diagrams, Hammett equations, and substituent effects to predict the stability and reactivity of conjugated organic systems.
CO-II	Analyze the mechanisms, stereochemistry, regioselectivity, and orbital symmetry requirements of pericyclic reactions, including cycloaddition, electrocyclic, and sigmatropic rearrangements using Frontier Molecular Orbital (FMO) and correlation diagram approaches.
CO-III	Describe the structure, synthesis, biological activity, medicinal importance, and structure elucidation of representative terpenoids and alkaloids using chemical and spectroscopic methods.
CO-IV	Apply the principles of green chemistry to design environmentally benign chemical syntheses by emphasizing atom economy, waste minimization, green solvents, energy-efficient methodologies, catalysis, and sustainable chemical processes.
CO-V	Evaluate and apply green synthetic methodologies, including microwave- and ultrasound-assisted reactions, green alternatives to conventional organic reactions, and environmentally friendly rearrangement reactions for sustainable organic synthesis.

Organic Chemistry – V

Module – I

Aromaticity & Linear Free Energy Relationships (12 Lectures)

Aromaticity: Hückel MO treatment of acyclic and cyclic conjugated systems (Interaction Matrix, Formulation of Determinants and Solving for E and c values from Secular Equations) for Ethylene, allyl systems, 1,3-butadiene, cyclopropenyl systems, cyclobutadiene systems and benzene; Hückel's rule and concept of aromaticity: annulenes (upto [18]-annulene), fulvenes and fulvalenes, fullerenes (C60), charged systems (upto 7 membered), anti-aromaticity, homoaromaticity; graphical methods-Frost diagram. Definition with examples for Alternate and Non alternate Hydrocarbons.

Linear Free Energy Relationship: Introduction, Hammett Plots, Hammett equations: Substituent Constant (σ), Reaction Constant (ρ), Significance of σ and ρ, Concept of through- conjugation, Yukawa-Tsuno Equation. Use of Hammett Plots: Calculation of k and K values, Deviation from straight line plots- Acetolysis of 3-aryl-2-butyl brosylates, Cyclodehydration of 2-phenyltriarylmethanols.

Module – II

Pericyclic Reactions (12 Lectures)

Introduction to Pericyclic reactions, mechanism, stereochemistry, regioselectivity in case of:

Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions. Correlation diagram for [2+2] and [4+2] cycloaddition reaction.

Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions. Correlation diagram for cyclobutene ring opening.

Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3] and [1,5] H shifts and [3,3] shifts with reference to Claisen and Cope rearrangements.

Module – III

Alkaloids & Terpenoids (12 Lectures)

Terpenoids: Isoprene rule, structure elucidation (by chemical and spectroscopical methods), Synthesis and Medicinal Use of representative examples of acyclic (Citral), monocyclic (Camphor) and bicyclic monoterpenes (Caryophyllene); structural types: general concept and examples of sesqui-, di- and tri-terpenoids.

Alkaloids: Hoffmann's exhaustive methylation, Emde's modification, classifications, familiarity with methods (chemical and spectroscopic) for structure elucidation, synthesis and biological activity of hygrine, nicotine, coniine and papaverine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine and Reserpine.

Module – IV

Green Chemistry – I (12 Lectures)

Introduction to Green Chemistry:

What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry

Principles of Green Chemistry and Designing a Chemical synthesis:

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:

- Designing a Green Synthesis using these principles: Prevention of Waste/Byproducts, Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.

- Prevention/minimization of hazardous/toxic products.

- Green solvents–supercritical fluids, water as a solvent for organic reactions, ionic liquids, PEG, solventless processes.

- Energy requirements for reactions–alternative sources of energy: use of microwaves and ultrasonic energy.

- Use of catalytic reagents in preference to stoichiometric reagents, catalysis and green chemistry.

Future Trends in Green Chemistry:

Qualitative idea (definition, representative example and importance) about Biomimetic, Multifunctional reagents, Combinatorial green chemistry. Green chemistry in sustainable development.

Module –V

Green Chemistry – II (12 Lectures)

1. Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis).
2. Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols, microwave assisted reactions in organic solvents, Diels-Alder reaction and Decarboxylation reaction.
3. Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)
4. Green counterpart of common organic reactions: Friedel-Crafts, Michael and Cannizzaro reactions, Aldol, Knoevenagel, Benzoin and Dieckmann condensations.
5. Rearrangement reactions by green approach: Fries rearrangement, Claisen rearrangement, Beckmann rearrangement, Baeyer-Villiger oxidation.

Tutorial: (30 Lecture hours)

PAPER: (DSCC-17)

A. Multistep organic synthesis and monitoring the reaction progress by TLC.

Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

B. Purification of the crude product is to be made by crystallization from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.

C. Melting point of the purified product is to be noted.

[***Model reactions:*** (i) Preparation of *p*-bromoaniline from aniline (ii) Preparation of benzilic acid from benzoin.]

PAPER: (DSCC-18)

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Apply mathematical concepts such as calculus, Legendre transformations, constrained optimization, power and Taylor series, and matrix methods to solve problems in physical chemistry and thermodynamics.
CO-II	Explain the origin and interpretation of atomic spectra, including Zeeman splitting, fine structure, spin–orbit coupling, Lande *g* factor, and atomic and molecular term symbols.
CO-III	Analyze the kinetics of fast and ultra-fast chemical reactions using modern experimental techniques, and interpret kinetic models involving autocatalysis, oscillating reactions, and electrode processes through the Nernst, Butler–Volmer, and Tafel equations.
CO-IV	Describe the mechanisms, kinetics, thermodynamics, and molecular weight characteristics of polymers, distinguishing between step-growth and chain-growth polymerization processes.
CO-V	Interpret absorption and emission spectroscopic phenomena by applying Beer–Lambert law, Einstein's transition theory, fluorescence principles, laser concepts, charge and energy transfer processes, fluorescence quenching, and time-resolved spectroscopic techniques.

Physical Chemistry - V

Module – 1

Mathematical Concepts (12 Lectures)

Elements of Calculus, Legendre transformation: Application to thermodynamics, Extremum principle, Constrained extremization: Example and application in Physical Chemistry, Power series: Convergence and divergence, Taylor series: Example and application in Physical Chemistry, Matrices: Finding eigenvectors and eigenvalues and applications

Module – II

Atomic Spectra **(12 Lectures)**

Magnetic Effects on Atomic Spectra: Zeeman effect, fine structure, concept of spin; spin-orbit interaction, effect of high magnetic field, Lande g factor, Atomic (and molecular) terms

Module – III

Chemical Kinetics III **(12 Lectures)**

Fast and ultra-fast kinetics: Luminescence and Energy transfer processes, Study of kinetics: Stopped flow, Relaxation, Magnetic resonance method and Flash photolysis, Autocatalysis, Prey-predator model, oscillating reactions (Belousov-Zhabolinskii reaction), Electrode kinetics: Nernst equation, Butler-Volmer equation, Tafel equation, Tafel plot etc.

Module – IV

Polymer Chemistry **(12 Lectures)**

Chain and branched Polymers, Kinetics and mechanisms of polymerization: Step-growth vs. chain-growth, Thermodynamics of polymer solutions. Molecular weight of polymer and its distribution: Number-average and weight average.

Module – V

Absorption and Emission Spectroscopy **(12 Lectures)**

Lambert-Beer's Law, Absorption measurement and its limitations, Einstein's two-level transition model: Maser, Population inversion and Laser, Einstein coefficients, Transition moment integral and their relation to molar extinction coefficient, Photo-induced charge transfer, Proton transfer and electron transfer processes, Delayed emission, Excimer, Exciplex, Polarization characteristics of emission, Fluorescence Quenching (Static and Dynamic), Steady state and time-resolved Fluorescence measurement and limitations

Tutorial: (30 Lecture hours)

PAPER: (DSCC-18)

Python Fundamentals (Basic Programming)-I

- Python environment and execution
- Variables, data types, and operators

- Input/output statements
- Control statements
- (i) The if statement
- (ii) The if….else statement
- (iii) The if….elif….else statement
- Looping
- (i) The while Loop
- (ii) The for Loop
- (iii) Nested Loops
- (iv) The break and continue statements

Simple Programs

1. Write a python program to test whether a given number is even or odd
2. Write a python program to display even numbers between 100 and 200
3. Write a python program to display numbers from 10 to 1 in descending order.
4. Write a python program to write a function that returns the result of sum of two numbers.
5. Write a python program to generate Fibonacci number series.
6. Write a python program to calculate the Sine value of a given angle in degrees by evaluating (a) Sine series, (b) Cosine series
7. Write a python program to evaluate exponential series.

PAPER: (DSCC-19)

(Credit: Practical – 04)

Course Outcome (CO)	
CO	Systematically analyze and identify cationic and anionic radicals, including rare elements and insoluble materials, in complex inorganic mixtures using semimicro qualitative analysis and interpret the chemical principles underlying their separation and confirmation.

Practical (60 Lectures)

Qualitative/semimicro analysis of mixtures containing six radicals with composition.

Cation Radicals: Na^{+},K^{+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Al^{3+}, Cr^{3+}, Mn^{2+}/Mn^{4+}, Fe^{3+}, Co^{2+}/Co^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}, $Sb^{+3/+5}$, NH_4^{+}
Anion Radicals: F^{-}, Cl^{-}, Br^{-}, BrO_3^{-}, I^{-}, IO_3^{-}, SCN^{-}, S^{2-}, SO_4^{2-}, NO_3^{-}, NO_2^{-}, PO_4^{3-}, AsO_4^{3--}, BO_3^{3-}, CrO_4^{2-} / $Cr_2O_7^{2-}$, $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$.
Cation and anion radicals derived from some rare elements: Ti^{4+}, Zr^{4+}, Ce^{4+}, V^{5+}, Mo^{6+}, W^{6+}.

Insoluble Materials: Al_2O_3(ig), Fe_2O_3(ig), Cr_2O_3(ig), $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$, TiO_2, ZrO_2, CeO_2.

The unknown mixture should contain two cations/anions derived from rare elements.

PAPER: (DSCC-20)

(Credit: Practical – 04)

Course Outcome (CO)	
CO	Perform pH-metric and spectrophotometric analyses to determine acid–base properties, validate Lambert–Beer's law, estimate unknown concentrations, evaluate spectroscopic parameters, and investigate reaction kinetics using experimental data.

Practical (60 Lectures)

1. **pH-metric Study**
   a) Titration of a strong/weak acid vs strong base and determination of unknown concentration of the acid
   b) Determination of pK_a value of a weak (mono/di) basic acid

2. **Spectrophotometric Study**
   a) Determination of λ_{max} of $K_2Cr_2O_7$ and $KMnO_4$
   b) Testing of validity of Lambert–Beer's law for $K_2Cr_2O_7$ and $KMnO_4$ and hence determination of concentration of the given solutions
   c) Determination of extinction coefficient of $K_2Cr_2O_7$ and $KMnO_4$ at λ_{max} using Lambert – Beer's law
   d) Determination of pK_{in} value of acid-base indicators (Bromocresol Green, Methyl orange and Phenolphthalein)
   e) Study of kinetics of the reaction between $S_2O_8^{2-}$ and I^- and determination of the rate constant
   f) Study of kinetics of the reaction between Crystal Violet and OH^- and determination of the rate constant

3. **Physicochemical Study**
   a) Study of the phase diagram of phenol-water system in presence of a substance which increases the CST.
   b) Study of the phase diagram of phenol-water system in presence of a substance which decreases the CST.

Semester-VIII

PAPER: (DSCC-21)

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Explain the principles of molecular symmetry and group theory, including symmetry operations, point groups, group multiplication tables, conjugate classes, and the symmetry properties of molecular structures.
CO-II	Apply group theoretical methods such as matrix representations, character tables, irreducible representations, direct products, and correlation diagrams to predict molecular properties, spectroscopic selection rules (IR and Raman), and electronic state splitting.
CO-III	Analyze the structure, bonding, and reactivity of advanced *s*- and *p*-block compounds, including boranes, carboranes, metalloboranes, borohydrides, and alkali metal complexes with macrocyclic ligands using Wade's rules and Lipscomb's concepts.
CO-IV	Explain the principles, instrumentation, and analytical applications of Atomic Absorption Spectroscopy (AAS) and Atomic Emission Spectroscopy (AES) for qualitative and quantitative determination of trace metal ions, including interference correction techniques.
CO-V	Describe the fundamental concepts of nanoscience and nanotechnology, including the synthesis, characterization, and applications of nanomaterials, with emphasis on metal nanoparticle preparation and electron microscopy techniques.

Inorganic Chemistry - VI

Module – I

Symmetry and Group Theory – I (12 Lectures)

Symmetry elements, Symmetry operations, Schöenflies symbols, Point group, Groups and subgroups, Similarity transformation and Conjugate elements, classes, order, Group Multiplication table, Platonic solids.

Module – II

Symmetry and Group Theory – II (12 Lectures)

Matrix representation and Characters of symmetry operations, Different types of bases, Reducible and Irreducible representation, Great Orthogonality theorem (Postulates only), Construction of character tables, Mülliken symbols, Direct product representations, Interaction energy between states, Spectral intensity, Symmetries of the first excited states of normal modes and their application in spectroscopy (IR and Raman), Splitting of free-ion terms, Correlation diagrams (d^1 and d^2 only).

Module – III

Advanced chemistry of chemistry of s and p block elements (12 Lectures)

Classification of boron clusters, skeletal electron counting. Structure and bonding in higher boranes, borohydride and carboranes based on Lipscomb's topological concept (*styx* number) and Wade's rules. Metallo boranes and its important reactions, Alkali metal complexes with macrocyclic ligands (crown ethers, cryptands and spherands).

Module – IV

Atomic Absorption Spectroscopy (AAS) and Atomic Emission Spectroscopy (AES) (12 Lectures)

Basic principles of instrumentation (choice of source, monochromator, detector, choice of flame and Burner designs). Techniques of atomization and sample introduction; Method of background correction, sources of chemical interferences and their methods of removal. Techniques for the quantitative estimation of trace level of metal ionsfrom water samples, (iron, calcium as phosphate, arsenic as AsH_3).

Module – V

Nanoscience and nanotechnology (12 Lectures)

Fundamentals of Nanoscience and Nanotechnology: Definition, Classificationof nanomaterials based on their dimensions. Nanotechnology applications.

Synthesis of Nanomaterials: Top-down and bottom-up approaches, precipitation and co-precipitation, nucleation and growth, Ostwald ripening. Metal nanocrystal synthesis (gold and silver nanoparticles only) by borohydride reduction method.

Basic introduction to characterization of nanomaterials (names of various techniques with basic principles of SEM and TEM).

Tutorial: (30 Lecture hours)

PAPER: (DSCC-21)

1. Application of Cryptands and Spherands in Metal extraction and Separation.

2. Application of AES and AAS in analysis of Trace Metals in Food Products

3. Carbon footprint

4. Application of Nanomaterials in Targeted Drug Delivery

5. Application of Nanomaterials in solar Cells

6. Application of Nanomaterials in water Purification

7. Metallo organic frameworks (MOF).

8. Covalent organic frameworks (COF).

9. Zintl ions / clusters.

10. Application of Group Theory in Transition metal complexes.

PAPER: (DSCC-22)

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Explain the synthesis, structure, reactivity, and mechanistic aspects of advanced heterocyclic compounds, particularly 1,2- and 1,3-azoles, including electrophilic substitution, metallation, electrocyclic, photochemical, and synthetic transformations.
CO-II	Analyze the mechanisms and synthetic applications of organic photochemical reactions and organosulphur compounds, including sulfur ylides, rearrangement reactions, and oxidation methodologies used in modern organic synthesis.
CO-III	Apply the principles of stereoselective and asymmetric synthesis to predict stereochemical outcomes in organic reactions using models such as Felkin–Anh, Cram’s chelate, Prelog’s rule, and Zimmerman–Traxler.
CO-IV	Interpret and assign **^{13}C NMR** spectra, including DEPT-135 data, by correlating chemical shifts, coupling patterns, and carbon multiplicities for the structural elucidation of organic compounds.
CO-V	Interpret mass spectrometric data, including fragmentation patterns and rearrangements, and integrate IR, ^{1}H NMR, ^{13}C NMR, and mass spectrometry data for the structural elucidation of organic molecules.

Organic Chemistry - VI

Module – I

Advanced Heterocyclic Chemistry (12 Lectures)

1,3 - Azoles: Imidazoles and Oxazoles: Introduction, physical properties; Reactions with mechanism in relevant cases - Reactions with Electrophilic Reagents: Addition at Nitrogen (Protonation, Alkylation, Acylation); Substitution at Carbon (Protonation, Nitration, Sulfonation, Halogenation, Acylation); C - Metallation and Reactions of C - Metallated 1,3 – Azoles: Direct Ring C – H Metallation, Metal – Halogen Exchange; Electrocyclic Reactions; Synthesis of 1,3 – Azoles (with mechanism): From an α - Halo - Carbonyl - Component (or an Equivalent) and a Three - Atom Unit Supplying C - 2 and Both of the Heteroatoms, By Cyclising Dehydration of α - Acylamino - Carbonyl – Compounds and From Isocyanides.

1,2 - Azoles: Pyrazoles and Isoxazoles: Introduction, physical properties; Reactions with mechanism in relevant cases - Reactions with Electrophilic Reagents: Addition at Nitrogen (Protonation, Alkylation, Acylation); Substitution at Carbon (Protonation, Nitration, Sulfonation, Halogenation, Acylation); C - Metallation and Reactions of C - Metallated 1,2 – Azoles: Direct Ring C – H Metallation, Metal – Halogen Exchange; Electrocyclic and Photochemical Reactions; Synthesis of 1,2 – Azoles (with mechanism): From 1,3 - Dicarbonyl Compounds and Hydrazines or Hydroxylamine, Dipolar Cycloadditions of Nitrile Oxides and Nitrile Imines and From Oximes and Hydrazones.

Module – II

Organic Photochemistry And Synthetic Methodology – Organo Sulphur Compounds (12 Lectures)

Organic Photochemistry: Basic principles, Jablonski diagram, Reactions (with mechanism): Photochemistry of olefinic compounds, cis-trans isomerization, Paterno-Buchi reaction, Norrish Type-I and Type-II reactions, di-π methane rearrangement.

Synthetic Methodology - Organosulphur Compounds: Chemistry of organosulphur compounds, preparation of sulphur ylides and its reactions with carbonyl compounds and conjugated carbonyl systems, Comparison of reactivity of dimethylsulphonium methylide and dimethylsulphoxonium methylide; Catalytic sulphur ylide epoxidation; Applications (with mechanism): Steven's rearrangement, [2+3]–sigmatropic rearrangement, Sommelet Hauser rearrangement, Pummerer rearrangement, Pfitzner Mofatt oxidation and Swern oxidation.

Module – III

Organic Synthesis-II (12 Lectures)

Stereospecific and stereoselective reactions, enantiomeric excess, determination of optical purity; Principles in asymmetric synthesis (definition & example): substrate control, chiral auxiliary control, reagent control, asymmetric catalysis, kinetic resolution, double asymmetric induction; Enantioselectivity (only definition); Diastereoselectivity: Definition, Addition of nucleophiles to C=O adjacent to a stereogenic centre: Felkin-Anh model, Cram's chelate model, Prelog's rule; Zimmerman-Traxler model for diastereoselective aldol condensation using lithium enolates.

Module – IV

^{13}C Spectroscopy (12 Lectures)

Introduction to C-13 NMR spectra, Explanation of the total range of ^{13}C from δ 0 – 220, Factors affecting the chemical shifts of carbon, spin-spin coupling in ^{13}C-spectra, principles of decoupling, gated and inverse gated decoupling techniques, proton decoupled ^{13}C-spectra, Calculation and assignment of CH_3, CH_2, CH and quaternary carbons in ^{13}C-NMR (both aliphatic and aromatic systems), Preliminary idea about DEPT-135; ^{13}C-NMR spectra of isomeric dichlorobenzenes, toluene, cyclohexanol and cyclohexanone; Simple problems involving ^{13}C-NMR spectra and DEPT-135.

Module – V

Mass Spectroscopy (12 Lectures)

Principles, instrumentation and applications of mass spectrometry. Methods of generation of ions in EI and CI. Detection of ions, ion analysis, ion abundance, molecular ion peak, metastable peak, isotopes, ion-molecule interaction and analysis of fragmentation patterns for: Alkane (linear & branched), ethers (with 1°, 2°, 3° alkyl chain), alcohols (1°, 2°, 3°), benzyl alcohol, carbonyl compounds, toluene, xylenes; Mclafferty rearrangement.

Simple problems on elucidation of structure of organic molecules from given spectral data (UV, IR, ^{1}H & ^{13}C-NMR and MS)

Tutorial: (30 Lecture hours)

PAPER: (DSCC-22)

Systematic analysis of a binary solid mixture and identification of individual components by derivatization and literature survey.

PAPER: (DSCC-23)

(Credit: Theory -03, Tutorial – 01)

Course Outcome (CO)	
CO-I	Apply the principles of group theory to analyze molecular symmetry, construct and use character tables, determine irreducible representations, and predict molecular properties, normal modes, and IR/Raman spectral activity.
CO-II	Explain the fundamental concepts of quantum mechanics, including vector spaces, Hermitian operators, uncertainty principles, and the quantum harmonic oscillator, and apply these concepts to solve quantum mechanical problems.
CO-III	Derive and interpret the wave functions of the hydrogen atom by solving the Schrödinger equation in spherical polar coordinates and explain the significance of radial and angular probability distributions. Apply advanced quantum mechanical methods, including perturbation theory, antisymmetric wave functions, Slater determinants
CO-IV	Analyze the statistical behavior of classical and quantum systems using Maxwell–Boltzmann, Bose–Einstein, and Fermi–Dirac statistics, and explain their applications to phenomena such as Bose–Einstein condensation and superconductivity.
CO-V	Hückel molecular orbital theory, to describe atomic and molecular electronic structures. Self-consistent field concepts, and Basis sets.

Physical Chemistry - VI

Module – I

Group Theory (12 Lectures)

Symmetry elements and operations, Group properties, Multiplication tables, Point groups, Character tables, Great Orthogonality theorem, Chemical applications of group theory: Reducible and irreducible representations, Orbital symmetry (Mulliken Terms), Selection rules in spectral transitions, Study of normal modes, IR and Raman activity

Module – II

Quantum Mechanics-I (12 Lectures)

Sequential Stern-Gerlach experiment, Vector space and operators, Diagonalization and simultaneous diagonalization of Hermitian operators, Cayley-Hamilton theorem, Schwarz inequality, generalized uncertainty principle, Mandelstam-Tamm uncertainty relation and its implication, Quantum harmonic oscillators, Solving Hermite differential equation, Algebraic solution for the ground and excited states of QHO.

Module – III

Quantum Mechanics-II (12 Lectures)

Cartesian and polar coordinates. Center of mass and relative coordinates. Radial and angular parts, Solution of radial equation (Laguerre polynomials) of hydrogen atom. Solution of angular part (spherical harmonics) hydrogen atom.
Time independent Perturbation theory: up to second order in energy and application to the helium atom; Anti-symmetry and exclusion Principle, Slater determinantal wave functions.

Module – IV

Statistical Thermodynamics II (12 Lectures)

Maxwell Boltzmann, Bose-Einstein and Fermi-Dirac statistics: Thermodynamic probability, Population distribution and Comparative study, Bose-Einstein condensate, Superconductivity, BCS theory

Module – V

Introduction to Quantum Mechanics in Computational Chemistry

(12 Lectures)

The simple Huckel Method-Theory., Applications, Strength and weaknesses of the Simple Huckel method. The determinant method of calculations. The Extended Huckel Method-Theory, Strength and weaknesses of the Extended Huckel method.

Ab initio calculations: The basic principles. The Hatree-Fock SCF method.

Basis sets- Gaussian functions. Basis set preliminaries.

Tutorial: (30 Lecture hours)

PAPER: (DSCC-23)

Python Fundamentals (Basic Programming)-II

Arrays in Python

- Array
- Creating an Array
- Importing the Array Module
- Indexing and slicing on Arrays
- Processing the Arrays
- Types of Arrays
- Working with Arrays using numpy
- Creating Arrays using an Array
- Creating Arrays using linspace
- Mathematical operators in Arrays
- Matrices in numpy/

Functions and Data Structures

- User-defined functions
- Object oriented programming
- Lists, tuples, dictionaries
- String handling
- Simple error handling
- Programs related to:
    - Molecular weight calculation
    - Stoichiometric calculations
    - Gas laws (Boyle’s, Charles’, Ideal gas

Data Handling and Plotting

- Introduction to scientific libraries:
  - math
  - numpy
  - matplotlib
- Reading and writing data files
- Plotting:
  - Absorbance vs concentration
  - Time vs concentration
  - Titration curves
- Graph formatting and labelling

Simple Programs

1. Write a python program to create an integer type array.
2. Write a python program to create one array from another array.
3. Write a python program to retrieve the elements of an array using array index.
4. Write a python program to retrieve and display only a range of elements from an array using slicing.
5. Write a python program to create a simple array using numpy.
6. Write a python program to create an array with 5 equal points using linspace.

PAPER: (DSCC-24)

(Credit: Practical – 04)

Course Outcome (CO)	
CO	Systematically identify unknown organic liquid compounds through qualitative analysis, functional group detection, derivatization, and literature comparison, and confirm their identity using characteristic physical constants and derivative melting points.

Practical (60 Lectures)

Systematic qualitative analysis of an organic liquid and its identification by derivatization and literature survey.

[Recording of the boiling point of the sample, Preliminary tests, Lassaigne's Test, Miscibility test and classification, Detection of nitrogenous functional groups (amide, anilide, nitrile, nitro, aromatic amines – 1^o, 2^o and 3^o), Detection of non-nitrogenous functional groups (Phenolic-OH, carboxylic acid, carbonyl, ester, alcohol), Distinction between aldehyde and ketones to be performed, Literature survey, Preparation of suitable solid derivatives (crystallization and determination of melting point of the derivative included)]

At least 4 unknown to be reported in the practical notebook.

Note: SBT derivative will not be accepted as a derivative of carboxylic acids.

Book: A Handbook of Organic Analysis (Qualitative & Quantitative by H.T. Clarke.

PAPER: (DSCC-25a)

(Credit: Practical – 02)

Course Outcome (CO)	
CO	Develop and implement Python programs to solve chemical and mathematical problems involving molecular calculations, gas laws, buffer solutions, kinetics, titrations, statistical analysis, numerical methods, differential equations, and numerical integration using appropriate scientific libraries.

Practical (30 Lectures)

Simple Programs

1. Write a Python program that:
   a) Stores atomic weights of at least H, C, N, O, S, Cl, Na, K in a dictionary
   b) Takes a chemical formula input (simple formula like H_2SO_4, NaCl, $C_6H_{12}O_6$)
   c) Calculates: molecular mass and percentage composition of each element
   d) Displays results neatly

2. Write a Python program that: Takes input values of P, V, T, n and uses ideal gas equation: $PV=nRT$
   a) If one variable is missing (entered as 0), compute it, using R = 0.0821 $L \cdot atm \cdot mol^{-1} \cdot K^{-1}$
   b) Display computed value with correct units

3. Write a Python program to compute buffer pH: using pH = pKa+log ($[A-]/[HA]$)
   Inputs: pK_a, [A-], [HA]
   a) Validate inputs (no zero/negative concentrations)
   b) Print pH to 2 decimal places

4. Write a Python program that: For a strong acid-strong base titration, takes two lists: volume of base added (ml) and measured pH and finds and prints:
   a) The equivalence point region (maximum change in pH between consecutive points)
   b) The corresponding volume
   c) Display result clearly

5. Write a Python program to compute:
   a) mean
   b) standard deviation
   c) % relative error (if true value is given)

Given a set of repeated readings (user input list) and true value

6. Given initial concentration a and concentration a-x at time t, write a program to compute the first-order rate constant:

$$k = \frac{2.303}{t} \log\left(\frac{a}{a-x}\right)$$

   a) Input: a, a-x, t
   b) Output: k with unit (s^{-1} or min^{-1} depending on input time)

7. Write a computer program to calculate roots of equation using Newton-Raphson method. And bisection method (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid)

8. Write a computer program for Numerical Integration using Midpoint rule, Simpson's $1/3^{rd}$ rule and Trapezoidal rule. (e.g. entropy/enthalpy change from heat capacity data), (probability distributions (gas, kinetic theory) and mean values)

9. Use the forward Euler method to solve the initial value problem $y'(x) = x\, y(x)$, $y(0) = 2$ between $0 \le x \le 1$. (Similar type of problems)

10. Use the forward Euler method to solve the initial value problem $y'(x) = x\, y(x)$, $y(0) = 2$ between $0 \le x \le 1$. (Implementing RK4) . (Similar type of problems)

11. Numerical integration using Midpoint rule, Simpson's $1/3^{rd}$ rule and Trapezoidal rule. (e.g. entropy/enthalpy change from heat capacity data, probability distribution of gas and mean values).

Recommended Software/Resources

- Python 3.x
- IDLE
- Libraries: numpy, matplotlib

PAPER: (DSCC-25b)

(Credit: Practical – 02)

Course Outcome (CO)	
CO	Perform spectrophotometric and colorimetric analyses to determine ligand field parameters, absorption maxima, and quantitatively estimate metal ions and phosphorus in samples, with accurate data analysis and graphical presentation using MS Excel.

Practical (30Lectures)

Spectral Analysis: (i). Determination of 10Dq and (ii). Determination of λ_{max}

a) $[Cu(acac)_2]$
b) $[Ni(en)_3]Cl_2 . 2H_2O$
c) *cis*-$K[Cr(C_2O_4)_2(H_2O)_2]$

Colorimetric estimation

1. Iron as Fe^{III}- thiocyanate complex

2. Manganese as permanganate

3. Phosphorous as phosphomolybdate blue complex

4. Fe^{II} and Fe^{III} mixture as Fe^{II} – 1, 10-phenanthroline complex

5. MnO_4^- - $Cr_2O_7^{2-}$ mixture

Note: i) The experiments can be done spectrophotometrically / colorimetrically.

ii) Graphs should be drawn by MS-Excel.

SEMESTER-VII AND SEMESTER-VIII

SUGGESTED BOOKS FOR INORGANIC CHEMISTRY

1. Inorganic Chemistry - F. A. Cotton & G. Wilkinson
2. Inorganic Chemistry - J. E. Huheey, E. A. Keiter & R. L. Keiter
3. Chemistry of the Elements – N. N. Greenwood & A. Earnshaw
4. An Introduction to Inorganic Chemistry – K. L. Purcell & J. C. Kotz
5. Concepts and Models in Inorganic Chemistry – Douglass, McDanniel & Alexander
6. Coordination Chemistry – S. F. A. Kettle
7. Chemical Application of Group Theory – F. A. Cotton
8. Theoretical Approach to Inorganic Chemistry – A. Williams
9. Inorganic Chemistry – D. F. Shriver, P. W. Atkins & C. H.Langford
10. Instrumental Methods of Analysis – Williard, Meritt, Dean & Sett
11. Electroanalytical Chemistry –A. J. Bard
12. Electrochemical Techniques for Inorganic Chemistry – J. B. Headri
13. Comprehensive Coordination Chemistry - G. Wilkinson, R. A. Gillard & J. A. McCleverty (eds)
14. Inorganic Chemistry –A. G. Sharpe
15. Inorganic Chemistry – Modern Introduction – T. Moeller
16. Vogel's Textbook of Quantitative Chemical Analysis - G.H. Jeffery, J. Bassett, J. Mendham and R.C. Denney
17. Analytical Chemistry – G.D. Christian
18. Fundamentals of Analytical Chemistry – D.A. Skoog, D.M. West and F.J. Holler
19. Inorganic Chemistry – Catherine E. Housecroft and A. G. Sharpe
20. Macrocyclic Chemistry, Current Trend and Future Perspectives – KarstenGloe
21. Organometallic Chemistry of transition Metals- R. H. Crabtree
22. Basic Organometallic Chemistry-B. D. Gupta & A. J. Elias, C. P. Horwitz& D. F. Shriver,
23. Advances in Organometallic Chemistry, Vol. 23, 1984
24. Comprehensive Organometallic Chemistry- G. Wilkinson, F. G. A. Stone & E. W. Abel (Eds)
25. Nanomaterials and Nano chemistry by Catherine Brechignac and Philippe Houdy, Springer.
26. Nano chemistry by Kenneth Klabunde Gleb Sergeev, Elsevier.

SUGGESTED BOOKS FOR PHYSICAL CHEMISTRY

1. Levine, I. N. Physical Chemistry, 6th Edition, McGraw-Hill India ,2011.
2. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press,1997.

3. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, 11^{th} Edition, Oxford University Press, 2018.
4. Levine, I.N, Quantum Chemistry, 7^{th} Edition, Pearson, 2016.
5. McQuarrie, D.A, Quantum Chemistry, 2^{nd} Edition, University Science Books, 2008.
6. Hollas J. Michael, Modern Spectroscopy,4^{th} Edition, Wiley, 2004.
7. F. Albert Cotton, Chemical Applications of Group Theory, An Indian Adaptation, Wiley India, 2020
8. David M Bishop, Group Theory and Chemistry (Dover Books on Chemistry), 1993
9. Daniel C Harris, Symmetry and Spectroscopy, (Dover Books on Chemistry), 1989
10. F.W. Billmeyer, Textbook of Polymer Science, 3^{rd} ed. Wiley-Inter science (1984)
11. Physical Chemistry – R. S. Berry, S. A. Rice, J. Ross
12. Introduction to Atomic Spectra – H.E. White
13. Quantum Mechanics- J. L. Powell, B. Crasemann, Penguin Books Ltd., 1998
14. Introduction to Quantum Mechanics- D. J. Griffiths, Darrell F. Schroeter, 3^{rd} Edition, Cambridge University. Press, 2018
15. Introduction to Quantum Mechanics – L. Pauling, E. B. Wilson
16. Chemical Kinetics – K. J. Laidler
17. Foundations of Chemical Kinetics – S.W. Benson
18. Theoretical Chemistry – S. Glasstone
19. Erwin Kreyszig, Advanced Engineering Mathematics, 10^{th} Edition, Wiley India.

SUGGESTED BOOKS FOR ORGANIC CHEMISTRY

1. Aromaticity and Anti-aromaticity: Electronic and Structural Aspects by Vladimir I. Minkin, Mikhail N. Glukhovtsev, and Boris Y. Simkin
2. Aromaticity and Antiaromaticity: Concepts and Applications by Miquel Solà, Alexander I. Boldyrev, et al.
3. Molecular Orbital Theory (for Organic Chemists) – A. Streitwieser Jr
4. Advance Organic Chemistry – Carey & Sundberg
5. Advanced Organic Chemistry – J. March
6. Hammett equation - C. D. Johnson
7. A guidebook to mechanism in Organic Chemistry – Peter Sykes
8. Organic Chemistry – Clayden, Greeves, Warren, Wothers
9. Pericyclic Chemistry - S. M. Mukherjee
10. Pericyclic Reactions – Ian Fleming
11. Organic Chemistry (Volume – II) – I. L. Finar
12. Anastas, P.T & Warner, J.C. Green Chemistry: Theory and Practice, Oxford University Press (1998).
13. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2^{nd} Edition, 2010.

14. Heterocyclic Chemistry - John A. Joule and Keith Mills, Wiley, Fifth Edition.
15. Heterocyclic Chemistry – J. A. Joule, K. Mills and G. F. Smith, Stanley Thornes (Publishers) Ltd., Third Edition.
16. Heterocyclic Chemistry – Thomas L. Gilchrist, Pearson, Third Edition.
17. Organic Photochemistry - J. W. Coxon & B. Halton.
18. Elements of Organic Photochemistry - D. O. Cowan & K. L. Drisco.
19. Organosulfur Chemistry by Gordon H. Whitham.
20. An Introduction to Organosulfur Chemistry by R. J. Cremlyn.
21. Organosulfur Chemistry: Synthetic Aspects by Philip C. B. Page
22. Spectroscopy – Pavia, Lampman, Kriz, Vyvyan
23. NMR in Chemistry - A Multinuclear A approach - W. Kemp.
24. Organic Spectroscopy – W. Kemp.

PAPER: RM-1

(Credit: Theory-03, Viva-01)

Course Outcome (CO)	
CO-I	Understand the concepts, objectives, significance and various types of research, and formulate research problems.
CO-II	Use of internet resources, e-journals, citation databases, and scientific indexing services for efficient literature survey in chemistry research.
CO-III	Prepare scientific reports, literature reviews, research papers by applying principles of academic integrity, proper referencing avoiding plagiarism.

Research Methodology for Chemistry -1

Module: I

Research Methodology (20 Lectures)

An Introduction (Motivation, Types of Research–Fundamental, Applied, Historical, Experimental), Significance of Research. Research Process. Defining the Research Problem (Selecting the problem, Necessity of defining the problem). Research Design (Meaning, Need, features of a good designing). Different research design. Experimental design-Basic principle. Important experimental designs- (i) Informal, (ii) Formal (C.R. designs, R.B. designs, L.S. designs, Factorial designs).

Module: II

Literature Sources in chemistry (20 Lectures)

Print

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

Digital

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

Information Technology and Library Resources

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

Module: III

Methods of Scientific Research and Writing Scientific Papers **(20 Lectures)**

Reporting practical and project work. Writing literature surveys and reviews. Organizing a display. Giving an oral presentation.

Writing scientific papers – justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work. Writing ethics. Avoiding plagiarism.

Reference Text

1. Kothari C.R. Garg Gaurav, Research Methodology –Methods and Techniques, New Age International Publisher, 5^{th} Edition, 2023

2. Kumar Ranjit, Research Methodology- A step-by step guide for beginners, SAGE Publications, 4^{th} Edition, 2023

PAPER: RM-2

(Credit: Theory -03, Viva– 01)

Course Outcome (CO)	
CO-I	Apply descriptive and inferential statistical methods, including estimation, confidence intervals, hypothesis testing, and parametric tests, to analyze and interpret chemical and experimental data.
CO-II	Analyse experimental datasets using chi-square tests, analysis of variance (ANOVA), and linear regression techniques to evaluate relationships, compare groups, and draw statistically valid conclusions.
CO-III	Demonstrate awareness of recent advances in chemistry and intellectual property rights, and utilize modern chemical data presentation and visualization software for effective analysis and scientific communication

Research Methodology for Chemistry -2

Module -I

Data Analysis-I **(20 Lectures)**

Descriptive Statistics
Mean, Median, Mode, Standard Deviation, Measures of Skewness, Covariance.

Estimation
Sampling Distribution, Standard Error, Central Limit Theorem. Confidence Intervals, Confidence Limit and Confidence Level. Point Estimation and Interval Estimation.
Interval Estimation of mean when σ is not known (Large samples). Student's- t distribution. Interval Estimation of mean when σ is not known (Small samples).

Hypothesis Testing
The Null and Alternate hypothesis. The probability of Type-I and Type-II errors. Test statistics and p-value approach.
Testing of Hypothesis: One tailed and two tailed test. Hypothesis testing for mean-(i) Test on a single mean-a normal distribution with variance known, (ii) when variance is not known. Hypothesis testing for difference of two means. The F-distribution.
The two sample t-test and confidence Interval: (i) When standard deviations are significantly different, (ii) When standard deviations are equal (pooled t-test).

Module -II

Data Analysis-II (20 Lectures)

Chi-Square Test

Test of difference of more than two proportions. Test of independence of attributes. Test of goodness of fit.

Analysis of Variance

Basic principle. One way and two-way ANOVA.

Linear Regression Analysis

Simple linear regression model- least squares estimation. Coefficient of determination. Testing the hypothesis about the slope and the correlation coefficient- t test. Regression analysis using spreadsheet.

Multiple linear regression model – assumptions, least squares estimation. R^2. Standard error. T test for the slope.

Module -III

Recent advances in Chemistry (5 Lectures)

Outstanding discoveries and Nobel prizes in Chemistry during last ten years.

Intellectual Property Rights (5 Lectures)

Intellectual property rights: Concept and evolution. Law of designs. Law of copy rights and trademarks. Law of patents

Chemistry data presentation tools (10 Lectures)

Use of drawing tools such as Excel, Sigma Plot, Origin, MATLAB, Chem Draw and open-source software; plotting of various spectra, images and diagrams.

Reference Text

1. Kothari C.R. Garg Gaurav, Research Methodology –Methods and Techniques, New Age International Publisher,5th Edition, 2023

2. Kumar Ranjit, Research Methodology- A step-by step guide for beginners, SAGE Publications, 4th Edition, 2023

Examination Regulations and Modalities of Semester-wise UG Examinations

Theoretical Examinations

(Questions will cover the entire syllabus with weightage according to the number of lecture-hours per module)

<table>
<tr><th>Semester</th><th>Paper Code</th><th>Full Marks</th><th>Duration</th><th>Question Pattern and Marks Distribution</th></tr>
<tr><td rowspan="3">1</td><td>DSCC-1</td><td rowspan="32">75</td><td rowspan="32">3 hours</td><td rowspan="24">10 short questions of 2 mark each, 3 questions of 5 marks each and 4 questions of 10 marks each (4+3+3)</td></tr>
<tr><td>MN-1</td></tr>
<tr><td>SEC-1</td></tr>
<tr><td rowspan="2">2</td><td>DSCC-2</td></tr>
<tr><td>MN-2</td></tr>
<tr><td rowspan="4">3</td><td>DSCC-3</td></tr>
<tr><td>DSCC-4</td></tr>
<tr><td>MN-1</td></tr>
<tr><td>SEC-3</td></tr>
<tr><td rowspan="5">4</td><td>DSCC-5</td></tr>
<tr><td>DSCC-6</td></tr>
<tr><td>DSCC-7</td></tr>
<tr><td>DSCC-8</td></tr>
<tr><td>MN-2</td></tr>
<tr><td rowspan="6">5</td><td>DSCC-9</td></tr>
<tr><td>DSCC-10</td></tr>
<tr><td>DSCC-11</td></tr>
<tr><td>DSCC-12</td></tr>
<tr><td>MN-3</td></tr>
<tr><td>MN-4</td></tr>
<tr><td rowspan="5">6</td><td>DSCC-13</td></tr>
<tr><td>DSCC-15</td></tr>
<tr><td>MN-3</td></tr>
<tr><td>MN-4</td></tr>
<tr><td>DSCC-14</td><td>5 questions of 5 marks each for each Module</td></tr>
<tr><td rowspan="3">7</td><td>DSCC-16</td><td rowspan="3">3 questions of 5 marks each for each Module</td></tr>
<tr><td>DSCC-17</td></tr>
<tr><td>DSCC-18</td></tr>
<tr><td></td><td>DSCC-21</td><td></td></tr>
</table>

8	**DSCC-22**			**3 questions of 5 marks each for each Module**
	DSCC-23			
8	**RM-1**			**5 questions of 5 marks each for each Module**
	RM-2			

Practical Examinations

Semester	Paper Code	Full Marks	Duration	Question Pattern and Marks Distribution
1	DSCC-1	25	3 hours	20 marks Examination + 5 marks Laboratory notebook. Allotment of experiments by Lottery.
	MN-1			
2	DSCC-2			
	MN-2			
3	DSCC-3			
	DSCC-4			
	MN-1			
4	DSCC-5			
	DSCC-6			
	DSCC-7			
	DSCC-8			
	MN-2			
5	DSCC-9			
	DSCC-10			
	DSCC-11			
	DSCC-12			
	MN-3			
	MN-4			
6	DSCC-13			
	DSCC-14			
	DSCC-15			
	MN-3			
	MN-4			
7	DSCC-19	100	6 hours	70 marks Examination + 10 marks Laboratory notebook + 20 marks lab-quiz. Allotment of experiments by lottery.
	DSCC-20			
8	DSCC-24	100	6 hours	
	DSCC-25a	50	4 hours	35 marks Examination + 5 marks Laboratory notebook + 10 marks lab-quiz. Allotment of experiments by lottery.
	DSCC-25b			

Examination to be conducted by:

1) For Chemistry Major Papers (DSCC): Both Internal and External Examiners, following the instructions of UGBOS. (Away Centre)

2) For Chemistry Minor Papers (MN): Internal examiners (2) following the instructions of UGBOS. (Home Centre)

Tutorial Examinations (Home Centre)

Semester	Paper Code	Full Marks	Duration	Question Pattern and Marks Distribution
1	SEC-1	25	1 hour Examination	20 Marks (10 short questions of 2 marks each) + 5 marks for Tutorial Handbook
	IDC-1			
2	IDC-2			
3	SEC-3			
	IDC-3			
7	DSCC-16		Max. 15 mins. for seminar presentation for each student	10 marks for Tutorial Handbook + 15 marks for Seminar Presentation
	DSCC-17			
	DSCC-18			
8	DSCC-21			
	DSCC-22			
	DSCC-23			

Theoretical Examinations (Home Centre)

(Questions will cover the entire syllabus with weightage according to the number of lecture-hours per module)

Semester	Paper Code	Full Marks	Duration	Question Pattern and Marks Distribution
1	IDC-1	50	2 hours	10 short questions of 2 mark each, 3 questions of 10 marks each (4+3+3)
2	IDC-2			
3	IDC-3			

THREE-YEAR B.A./B.Sc.

(Multidisciplinary Courses of Studies, under Curriculum & Credit framework, 2022)

SYLLABUS

FOR

CHEMISTRY

(1st to 6th Semester)

UNIVERSITY OF CALCUTTA

Chemistry Course Structure
For
Three-year MULTIDISCIPLINARY Studies
(Theory)

Semester	Paper Code	Paper Name	Credit	Page No.
1	CC-1	Fundamental of Chemistry-I	(3 Th + 1Pr)	11
	SEC-1	Chemistry in Daily Life	(3 Th + 1Tu)	18
	IDC-1	Chemistry in Daily Life	(2 Th + 1Tu)	18
2	CC-2	Fundamental of Chemistry-II	(3 Th + 1Pr)	21
	SEC-2	Chemistry in Daily Life	(3 Th + 1Tu)	18
	IDC-2	Chemistry in Daily Life	(2 Th + 1Tu)	18
3	CC-3	Organic Chemistry-I	(3 Th + 1Pr)	29
	MN-1 (3-year)	Fundamental of Chemistry-I	(3 Th + 1Pr)	11
	SEC-3	Chemistry in Daily Life	(3 Th + 1Tu)	18
	IDC-3	Chemistry in Daily Life	(2 Th + 1Tu)	18
4	CC-4	Inorganic Chemistry-I	(3 Th + 1Pr)	35
	CC-5	Physical Chemistry-I	(3 Th + 1Pr)	26
	MN-2 (3-year)	Fundamental of Chemistry-II	(3 Th + 1Tu)	21
5 & 6	Semester-5 (CC-6)	Organic Chemistry-II	(3 Th + 1Pr)	37
	Semester-5 MN-3 (3-year)	Organic Chemistry-I	(3 Th + 1Pr)	29
	Semester-5 MN-4 (3-year)	Inorganic Chemistry-I	(3 Th + 1Pr)	35
	Semester-5 or Semester-6 (CC-7)	Physical Chemistry-II	(3 Th + 1Pr)	40
	Semester-6 (CC-8)	Inorganic Chemistry-II	(3 Th + 1Pr)	44
	Semester-6 MN-5 (3-year)	Physical Chemistry-I	(3 Th + 1Pr)	26
	Semester-6 MN-6 (3-year)	Organic Chemistry-II	(3 Th + 1Pr)	37

Important Points

If Chemistry is considered by a student as CC1(Core Course 1 in the CSR/04/2023, dated 23rd June, 2023 of University of Calcutta) then He / She will take CC-6 and CC-7 in Semester 5 and CC-8 in Semester 6. On the other hand, if Chemistry is opted as CC2 (Core Course 2 in the CSR/04/2023, dated 23rd June, 2023 of University of Calcutta) then He / She will take CC-6 in Semester 5 and CC-7 &CC-8 in Semester 6.

Summer Internship:

All the students are required to do one 3 credits Summer Internship at the end of the 2nd or 4th or 6th semester. Students completing Internship at the end of the 2nd semester will be allowed to take exit from the course and will be awarded Certificate of 45 (42+3) credits. Students completing Internship at the end of the 4th semester will be allowed to take exit from the course and will be awarded Diploma of 88 (85+3) credits. Students completing Internship at the end of the 6th semester and after successful completion of all the 6 semesters will be awarded B.A./ B.Sc. Degree of 128 (125+3) credits. [Following the Notification No. CSR/04/2023, dated 23rd June, 2023 of University of Calcutta].

Examination Regulations and Modalities of Semester-wise UG Examinations

Types of Examinations	Paper	Full Marks	Duration	Question Pattern and Marks Distribution	Examination to be conducted/ Evaluation by
Theoretical	CC-1 to CC-8 and MN-1 to MN -6	75	3 hours	10 short questions of 2 mark each, 3 questions of 5 marks each and 4 questions of 10 marks each (4+3+3)	As per University norms
	SEC	75	3 hours	10 short questions of 2 mark each, 3 questions of 5 marks each and 4 questions of 10 marks each (4+3+3)	The College
	IDC	50	2 hours	10 short questions of 2 mark each, 3 questions of 10 marks each (4+3+3)	The College
Practical	CC-1 to CC-8 and MN-1 to MN -6	25	3 hours	20 marks Examination + 5 marks Laboratory notebook. Experiments by lottery.	To be conducted by Internal examiners (2) following the instructions of UGBOS (Home Centre)
Tutorial	SEC and IDC	25	1 hour	20 Marks (10 short questions of 2 marks each) + 5 marks for Tutorial Handbook	The College