UNIVERSITY OF CALCUTTA

Notification No. CSR/17/2024

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 her powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 04.04.2024 , approved Chemistry Syllabus including Examination Modalities/ Question pattern for semester wise 4-year Chemistry (Honours & Honours with Research) and 3-year Chemistry (MDC) Courses of Studies under CCF,2022, as follows:

1. Examination Modalities/ Question pattern for Semester 2 to 4 of 4-year Chemistry (Honours & Honours with Research) and for semester 2 to 6 of 3-year Chemistry (MDC) Courses of Studies.
2. Syllabus for semester 1 to 4 of 4-year Chemistry (Honours & Honours with Research). syllabus of semester-1, published in CSR/13/23.dt. 12.07.2023 remains same.
3. Syllabus for semester 1 to 6 of 3-year Chemistry (MDC). syllabus of semester-1, published in CSR/13/23, dt. 12.07.2023 remains same.

The above shall take effect from the academic session 2023-2024.

08/4/2024

SENATE HOUSE

Kolkata-700073

Prof.(Dr.) Debasis Das

Registrar

08.04.2024

Examination Regulations and Modalities of Semester-wise UG Examinations

CHEMISTRY

Four-Year B.A./B.Sc (Honours and Honours with Research) Courses of Studies (Under Curriculum & Credit framework, 2022)

(2nd to 4th Semester)

Theoretical examinations

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

Semester	Course Type (Major/ Minor, SEC,IDC)	Paper	Full Marks	Duration	Question Pattern and Marks Distribution
2	Major	CHEM-H-CC2-2-Th	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)
	**SEC	CHEM-H-SEC2-2-Th			
	Minor	CHEM-H-CC2-2-Th			
	IDC	CHEM-H-IDC2-2-Th	50	2 hours	10 short questions of 2 mark each, 3 questions of 10 marks each (4+3+3)
3	Major	CHEM-H-CC3-3-Th	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)
	Major	CHEM-H-CC4-3-Th			
	SEC	CHEM-H-SEC3-3-Th			
	Minor	CHEM-H-CC1-3-Th			
	IDC	CHEM-H-IDC3-3-Th	50	2 hours	10 short questions of 2 mark each, 3 questions of 10 marks each (4+3+3)
4	Major	CHEM-H-CC5-4-Th	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)
	Major	CHEM-H-CC6-4-Th			
	Major	CHEM-H-CC7-4-Th			
	Major	CHEM-H-CC8-4-Th			
	Minor	CHEM-H-CC2-4-Th			

**** Full marks, Duration and Question Pattern will be decided by the University**

Practical Examinations

Semester	Course Type (Major/ Minor)	Paper	Full Marks	Duration	Question Pattern and Marks Distribution
2	**Major**	**CHEM-H-CC2-2-P**	**25**	**3 hours**	**20 marks Examination + 5 marks Laboratory notebook. Experiments by lottery.**
	Minor	**CHEM-H-CC2-2-P**	**25**	**3 hours**	
3	**Major**	**CHEM-H-CC3-3-P**	**25**	**3 hours**	**20 marks Examination + 5 marks Laboratory notebook. Experiments by lottery.**
	Major	**CHEM-H-CC4-3-P**	**25**	**3 hours**	
	Minor	**CHEM-H-CC1-3-P**	**25**	**3 hours**	
4	**Major**	**CHEM-H-CC5-4-P**	**25**	**3 hours**	**20 marks Examination + 5 marks Laboratory notebook. Experiments by lottery.**
	Major	**CHEM-H-CC6-4-P**	**25**	**3 hours**	
	Major	**CHEM-H-CC7-4-P**	**25**	**3 hours**	
	Major	**CHEM-H-CC8-4-P**	**25**	**3 hours**	
	Minor	**CHEM-H-CC2-4-P**	**25**	**3 hours**	

Examination to be conducted by,

1) **For Chemistry Major Papers: Both Internal and External Examiners, following the instructions of UGBOS. (Away Centre)**
2) **For Chemistry Minor Papers: Internal examiners (2) following the instructions of UGBOS. (Home Centre)**

Tutorial Examinations

Semester	Course Type (SEC, IDC)	Paper	Full Marks	Duration	Question Pattern and Marks Distribution	Examination to be conducted/ Evaluation by
2	IDC	CHEM-H-IDC2-2-Tu	25	1 hour examination	20 Marks (10 short questions of 2 marks each) + 5 marks for Tutorial Handbook	To be conducted by Internal examiners(2) following the instructions of UGBOS (Home Centre)
3	SEC	CHEM-H-SEC3-3-Tu				
	IDC	CHEM-H-IDC3-3-Tu				

THREE-YEAR B.A./B.Sc

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

(2nd to 6th Semester)

Type of examinations	Paper	Full Marks	Duration	Question Pattern and Marks Distribution	Examination to be conducted/ Evaluation by
Theoretical	All MDC Theoretical Papers (Core Course 1 &2, Minor),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)	---------
	IDC	50	2 hours	10 short questions of 2 mark each, 3 questions of 10 marks each (4+3+3)	---------
Practical	All MDC Practical Papers(Core Course 1 &2, Minor)	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	To be conducted by Internal examiners(2) following the instructions of UGBOS (Home Centre)

Four-YearB.A./B.Sc (Honours and Honours with Research) Courses of Studies (Under Curriculum & Credit framework, 2022)

SYLLABUS

FOR

CHEMISTRY

UNIVERSITY OF CALCUTTA

Course Structure (Chemistry-Major With Honours and Honours With Research)

Course Credits

Theory+ Practical

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Discipline Specific Core (DSC)

Theory (Honours)
(25 papers of 3 credits each) **25 X 3 = 75**

Practical / Tutorial
(25 papers of 1 credit each) **25 X 1 = 25**

Minor (For Chemistry Major)

Theory
(Including Practical/ Tutorial)
(8 papers of 4 credits each) **8 X 4 = 32**

Ability Enhancement Course (AEC)

(4 papers of 2 credits each) **4 X 2 = 8**

Skill Enhancement Courses (SEC)

(3 papers of 4 credits each) **3 X 4 = 12**

Interdisciplinary Courses (IDC)

(3 papers of 3 credits each) **3 X 3 = 9**

Common Value-Added Courses (CVAC)

(4 papers of 2 credits each) **4 X 2 = 8**

Summer Internship **3**
(6th Semester)

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Total Credits **172**

*** Honours students undertaking Research will take 3 Research papers of 12 Credits in place of 3 DSC Papers of 12 credits.**

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

Four-year Chemistry Major Course Structure
(Theory)

Semester	Paper Code	Paper Name	Brief Descriptions
1	CHEM-H-CC1-1-Th	Fundamentals Of Chemistry-I	Extra nuclear structure of atoms and Periodicity, Basics of Organic Chemistry Bonding and Physical Properties, Stereochemistry – I, Thermodynamics –I, Chemical Kinetics-I.
	CHEM-H-SEC1-1-Th	Quantitative Analysis and Basic Laboratory Practices	Introduction to Quantitative analysis and its interdisciplinary nature, Titrimetric analysis etc. , Water analysis, Basic laboratory practices.
2	CHEM-H-CC2-2-Th	Fundamentals Of Chemistry-II	Kinetic Theory and Gaseous state, Chemical Bonding – I , Theoretical principles of inorganic qualitative analysis , Stereochemistry – II, General Treatment of Reaction Mechanism-I
	CHEM-H-SEC2-2-Th	AI for Everyone	Introduction to Artificial Intelligence, Subfields and technologies, Applications of AI.
3	CHEM-H-CC3-3-Th	Physical Chemistry - I	Thermodynamics -II , Applications of Thermodynamics – I , Electrochemistry-I.
	CHEM-H-CC4-3-Th	Organic Chemistry – I	Aromatic Substitution Reaction. General Treatment of Reaction Mechanism-II, Stereochemistry –III, Conformation, Substitution, elimination, Addition to alkenes, dienes, alkynes.
	CHEM-H-SEC3-3-Th	Introduction to Numerical Methods for Chemists	Linear Regression, Root Finding , Numerical Differential and Integration, Fourier Transform
4	CHEM-H-CC5-4-Th	Inorganic Chemistry – I	Chemical bonding- II, Acids and bases, Radioactivity
	CHEM-H-CC6-4-Th	Organic Chemistry – II	Stereochemistry – IV, Chemistry of Carbonyl Compounds, Organometallics.
	CHEM-H-CC7-4-Th	Physical Chemistry - II	Transport processes and Liquid State, Solid State, Application of Thermodynamics– II, Electrochemistry-II.
	CHEM-H-CC8-4-Th	Inorganic Chemistry – II	Coordination chemistry, Supramolecular Chemistry Redox reactions.

*** Students who secure 75% marks and above in the first six semesters and wish to undertake research at the UG level can choose a research supervisor in the fourth year.**

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 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 credits. Students completing Internship at the end of the 6th 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 23rd June, 2023 of University of Calcutta].

Four-year Chemistry Major Course Structure
(Practical / Tutorial)

Semester	Paper Code	Paper Name	Brief Descriptions
1	CHEM-H-CC1-1-P	Fundamentals Of Chemistry-I	Acid-Base Titration, Oxidation-Reduction Titrimetry.
	CHEM-H-SEC1-1-Tu	Quantitative Analysis and Basic Laboratory Practices	Tutorial
2	CHEM-H-CC2-2-P	Fundamentals Of Chemistry-II	Qualitative semimicro analysis of mixtures containing three radicals
3	CHEM-H-CC3-3-P	Physical Chemistry - I	Chemical Kinetics (Analytical).
	CHEM-H-CC4-3-P	Organic Chemistry – I	Identification of Single Organic Compounds.
	CHEM-H-SEC3-3-Tu	Introduction to Numerical Methods for Chemists	Tutorial
4	CHEM-H-CC5-4-P	Inorganic Chemistry – I	Complexometric Titration
	CHEM-H-CC6-4-P	Organic Chemistry – II	Qualitative analysis of single solid Organic compounds.
	CHEM-H-CC7-4-P	Physical Chemistry - II	Surface Tension, Viscosity, Conductometry.
	CHEM-H-CC8-4-P	Inorganic Chemistry – II	Estimation of mixtures of metal ions.

*** Students who secure 75% marks and above in the first six semesters and wish to undertake research at the UG level can choose a research stream in the fourth year**.

CHEMISTRY MINOR COURSE STRUCTURE
(Theory)

Semester	Paper Code	Paper Name	Brief Descriptions
1 or 3	CHEM-H-CC1-1-Th Or CHEM-H-CC1-3-Th	Chemistry MINOR-I	Extra nuclear structure of atoms and Periodicity, Basics of Organic Chemistry Bonding and Physical Properties, Stereochemistry – I, Thermodynamics –I, Chemical Kinetics-I.
2 or 4	CHEM-H-CC2-2-Th Or CHEM-H-CC2-4-Th	Chemistry MINOR-II	Kinetic Theory and Gaseous state, Chemical Bonding – I , Theoretical principles of inorganic qualitative analysis , Stereochemistry – II, General Treatment of Reaction Mechanism-I
5	CHEM-H-CC4-5-Th	Chemistry MINOR-III	Aromatic Substitution Reaction , General Treatment of Reaction Mechanism-II, Conformation , Substitution, elimination, Addition to alkenes, dienes, alkynes.
6	CHEM-H-CC5-6-Th	Chemistry MINOR-IV	Chemical bonding II, Acids and bases, Radioactivity

Note 1: The above course structure for Minor is applicable to students admitted in 4-year Honours / Honours with Research course with Major different from Chemistry.

Note 2: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 3rd year (2 in each semester).

For example: A student with Chemistry Minor have two options for choosing Chemistry from Semesters 1 to 4.

Option-1: A student can take CHEM-H-CC1-1-Th in semester-I and CHEM-H-CC2-2-Th in semester –II

Or,

Option 2: A student can take CHEM-H-CC1-3-Th in semester-III and CHEM-H-CC2-4-Th in semester –IV

No other combinations of CHEM-H-CC1-1-Th and CHEM-H-CC2-2-Th will be allowed. In the semesters 1 & 2 minor papers from the same subject has to be chosen, e.g. either M1 or M2. In semesters 3 & 4 the other subject, not chosen previously has to be chosen.

Note 3:

In the 3rd year (in semesters 5 & 6) two minor subjects in each semester will have to be taken from two different subjects.

CHEMISTRY MINOR COURSE STRUCTURE
(Practical)

Semester	Paper Code	Paper Name	Brief Descriptions
1 or 3	CHEM-H-CC1-1-P Or CHEM-H-CC1-3-P	Chemistry MINOR-I	Acid-Base Titration, Oxidation-Reduction Titrimetry.
2 or 4	CHEM-H-CC2-2-P Or CHEM-H-CC2-4-P	Chemistry MINOR-II	Qualitative semimicro analysis of mixtures containing three radicals
5	CHEM-H-CC4-5-P	Chemistry MINOR-III	Identification of Single organic Compound.
6	CHEM-H-CC5-6-P	Chemistry MINOR-IV	Complexometric Titrations

Interdisciplinary Course Structure in Chemistry

Semester	Paper Code	Paper Name	Brief Descriptions
1	CHEM-H-IDC1-1-Th	Quantitative Analysis and Basic Laboratory Practices	Introduction to Quantitative analysis and its interdisciplinary nature, Titrimetric analysis etc. , Water analysis, Basic laboratory practices.
2	CHEM-H-IDC2-2-Th	Quantitative Analysis and Basic Laboratory Practices	Introduction to Quantitative analysis and its interdisciplinary nature, Titrimetric analysis etc. , Water analysis, Basic laboratory practices.
3	CHEM-H-IDC3-3-Th	Chemistry in Daily Life	Dairy Products, Food additives, adulterants, and contaminants, Artificial food colorants , Vitamins, Oils and fats, Soaps & Detergents , Chemical and Renewable Energy Sources, Polymers.

A student can take either **CHEM-H-IDC1-1-Th** **in the first semester** or **CHEM-H-IDC2-2-Th** **in the second semester** or **CHEM-H-IDC3-3-Th** **in the third semester**.

CHEMISTRY MAJOR

PAPER : CHEM-H-CC1-1-Th

(Credit : Theory -03, Practical – 01)

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 rule.

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-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 1^{st} 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, 1^{st} and 2^{nd} 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 : CHEM-H-CC1-1-P

(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**

CHEMISTRY MAJOR

PAPER : CHEM-H-CC2-2-Th

(Credit : Theory -03, Practical – 01)

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: CHEM-H-CC2-2-P

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 of Calcutta, 2015**

CHEMISTRY MAJOR

PAPER : CHEM-H-CC3-3-Th

(Credit : Theory -03, Practical – 01)

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 change 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, 6th Edition McGraw-Hill India, 2011**
2. **Castellan, G. W. Physical Chemistry, Narosa , 2004**
3. **Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11th 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 , 8th Edition, Tata-McGraw-Hil ,2017**
3. **Klotz, Irving M , Rosenberg, Robert M,Chemical Thermodynamics ,Wiley India , 2013**

Practical :(30 Lectures)

PAPER: CHEM-H-CC3-3-P

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

CHEMISTRY MAJOR

PAPER : CHEM-H-CC4-3-Th

(Credit : Theory -03, Practical – 01)

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-carbonelectrophiles (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 acidityand 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 ofkinetic 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: CHEM-H-CC4-3-P

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

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**

CHEMISTRY MAJOR

PAPER : CHEM-H-CC5-4-Th

(Credit : Theory -03, Practical – 01)

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 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: CHEM-H-CC5-4-P

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**

CHEMISTRY MAJOR

PAPER : CHEM-H-CC6-4-Th

(Credit : Theory -03, Practical – 01)

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, thiolsand 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: CHEM-H-CC6-4-P

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% NaHCO3)

3. Detection of the following functional groups by systematic chemical tests: aromatic amino (Ar-NH2), aromatic nitro (-NO2), amido (-CONH2, 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 six)** 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**

CHEMISTRY MAJOR

PAPER : CHEM-H-CC7-4-Th

(Credit : Theory -03, Practical – 01)

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 (Haüy'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:

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 behaviour; 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, 6th Edition McGraw-Hill India, 2011**
2. **Castellan, G. W. Physical Chemistry, Narosa , 2004**
3. **Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11th Edition, Oxford University Press, 2018**

Practical :(30 Lectures)

PAPER : CHEM-H-CC7-4-P

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) polymer (ii) ethanol and (iii) 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. ConductometricExperiments :
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

CHEMISTRY MAJOR

PAPER : CHEM-H-CC8-4-Th

(Credit : Theory -03, Practical – 01)

Inorganic Chemistry – II

Theory: (45 Lectures)

Module : I

Coordination chemistry: **(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 and 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

Ion-electron method of balancing equation of redox reaction. 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 (typical examples).

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: CHEM-H-CC8-4-P

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**

CHEMISTRY MINOR

PAPER : CHEM-H-CC1-1-Th Or CHEM-H-CC1-3-Th

(Credit : Theory -03, Practical – 01)

Chemistry Minor - 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 rule.

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 displacements
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-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 1^{st} 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, 1^{st} and 2^{nd} 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: CHEM-H-CC1-1-P Or CHEM-H-CC1-3-P

(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

CHEMISTRY MINOR

PAPER : CHEM-H-CC2-3-Th Or CHEM-H-CC2-4-Th

(Credit : Theory -03, Practical – 01)

Chemistry Minor - 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, other equations of state ; 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 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 energetic 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)**

Chirotopicityand 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: CHEM-H-CC2-3-P Or CHEM-H-CC2-4-P

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 of Calcutta, 2015**

CHEMISTRY MINOR

PAPER : CHEM-H-CC4-5-Th

(Credit : Theory -03, Practical – 01)

Chemistry Minor– III

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 (13 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:

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: CHEM-H-CC4-3-P

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, chloroform and nitrobenzene

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**

CHEMISTRY MINOR

PAPER : CHEM-H-CC5-6-Th

(Credit : Theory -03, Practical – 01)

Chemistry Minor – IV

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 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 neutralisation 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. J. E. Huheey, E. A. Keiter, R. L. Keiter, Okhil K. Medhi , Principles of Structure and Reactivity, 5th Edition ,Pearson India, 2022

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Practical :(30 Lectures)

PAPER: CHEM-H-CC5-6-P

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**

SKILL ENHANCEMENT COURSE

CHEMISTRY

Paper : CHEM-H-SEC1-1-Th
(Credit : Theory -03, Tutorial – 01)

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 -accuracy, precision, sensitivity, selectivity, method validation. Figures of merit of analytical methods and limit of detection (LOD). 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^2). Presentation of experimental data and results from the point of view of significant figures.
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:(15hours)

PAPER: CHEM-H-SEC1-1-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.

SKILL ENHANCEMENT COURSE
CHEMISTRY

Paper : CHEM-H-SEC2-2-Th
(Credit : Theory -04)

Theory: (45 Lectures)

AI for Everyone

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**

SKILL ENHANCEMENT COURSE

CHEMISTRY

Paper :CHEM-H-SEC3-3-Th
(Credit : Theory -03, Tutorial – 01)
Theory: (45 Lectures)

Introduction to Numerical Methods for Chemists

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 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 $1/3^{rd}$ 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, 10^{Th} Edition, Wiley India**

Tutorial: (15 hours)

PAPER: CHEM-H-SEC3-3-Tu

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	99	-200	2.5
O	1410	-142	3.5	Cl	1255	-348	3.0

Interdisciplinary Course in Chemistry

Paper: CHEM-H-IDC1-1-Th
or
CHEM-H-IDC2-2-Th

(Credit : Theory -02, Tutorial – 01)

Quantitative Analysis and Basic Laboratory Practices

Theory: (30 Lectures)

Module : I

(**10 Lectures)**

Introduction to Quantitative analysis and its interdisciplinary nature:
Definitions of analysis, determination, measurement, techniques and methods. Classification of analytical techniques. Choice of an analytical method -accuracy, precision, sensitivity . 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^2). Presentation of experimental data and results from the point of view of significant figures.

Module : II

(**10 Lectures)**

Titrimetric analysis:
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).

Acid-base titrimetry:
Titration curves for strong acid vs strong base, weak acid vs strong base and weak base vs strong acid titrations.

Redox titrimetry:
Theory, balancing redox equations..

Precipitation titrimetry:
Theory,indicators for precipitation titrations.

Complexometric titrimetry:
Theory, titration methods employing EDTA (direct, back, displacement and indirect determinations). Indicators for EDTA titrations .Determination of hardness of water.

Module : III

(**10 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.

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: CHEM-H-IDC1-1-Tu or PAPER: CHEM-H-IDC2-2-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. Determination of alkali present in soaps/detergents.

Interdisciplinary Course in Chemistry

Paper: CHEM-H-IDC3-3-Th

Theory: (30 Lectures)

(Credit : Theory -02, Tutorial – 01)

CHEMISTRY IN DAILY LIFE

Module : I

(10 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

(10 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

(10 Lectures)

Chemical and Renewable Energy Sources:
Principles and applications of primary & secondary batteries and fuel cells. Basics of solar energy, future energy storer.

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 : CHEM-H-IDC3-3-Tu

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.

THREE-YEAR B.A./B.Sc

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

SYLLABUS

FOR

CHEMISTRY

UNIVERSITY OF CALCUTTA

Chemistry Course Structure (CC1 & CC2)
For
Three-year MULTIDISCIPLINARY Studies
(Theory)

Semester	Paper Code	Paper Name	Brief Descriptions
1	CHEM-MD-CC1-1-Th	Chemistry MDC- I	Extra nuclear structure of atoms and Periodicity, Basics of Organic Chemistry Bonding and Physical Properties , Stereochemistry – I, Thermodynamics – I, Chemical Kinetics-I.
2	CHEM-MD-CC2-2-Th	Chemistry MDC- II	Kinetic Theory and Gaseous state, Chemical Bonding – I , Theoretical principles of inorganic qualitative analysis , Stereochemistry – II, General Treatment of Reaction Mechanism-I
3	CHEM-MD-CC3-3-Th	Chemistry MDC- III	Aromatic Substitution Reaction , General Treatment of Reaction Mechanism-II, Stereochemistry – IIIConformation , Substitution, elimination, Addition to alkenes, dienes, alkynes..
4	CHEM-MD-CC4-4-Th	Chemistry MDC- IV	Chemical bonding- II, Acids and bases, Radioactivity.
	CHEM-MD-CC5-4-Th	Chemistry MDC- V	Thermodynamics-II , Applications of Thermodynamics – I ,Electrochemistry-I.
5 & 6	CHEM-MD-CC6-5-Th	Chemistry MDC- VI	Stereochemistry – IV, Chemistry of Carbonyl Compounds, Organometallics.
	CHEM-MD-CC7-5-Th Or CHEM-MD-CC7-6-Th	Chemistry MDC- VII	Transport processes and Liquid State, Solid State, Application of Thermodynamics - II, Electrochemistry-II.
	CHEM-MD-CC8-6-Th	Chemistry MDC- VIII	Coordination chemistry, Redox reactions .

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 CHEM-MD-CC6-5-Thand CHEM MD-CC7-5-Th in Semester 5 and CHEM-MD-CC8-6-Th 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 CHEM-MD-CC6-5-Thin Semester 5 and CHEM-MD-CC7-6-Th &CHEM-MD-CC8-6-Th in Semester 6.

Chemistry Course Structure (CC1 & CC2)

For

Three-year MULTIDISCIPLINARY Studies

(Practical)

Semester	Paper Code	Paper Name	Brief Descriptions
1	CHEM-MD-CC1-1-P	Chemistry MDC- I	Acid-Base Titration, Oxidation-Reduction Titrimetry.
2	CHEM-MD-CC2-2-P	Chemistry MDC- II	Qualitative semimicro analysis of mixtures containing three radicals
3	CHEM-MD-CC3-3-P	Chemistry MDC- III	Identification of Single organic Compound.
4	CHEM-MD-CC4-4-P	Chemistry MDC- IV	Complexometric Titration
	CHEM-MD-CC5-4-P	Chemistry MDC- V	Chemical Kinetics (Analytical).
5 & 6	CHEM-MD-CC6-5-P	Chemistry MDC- VI	Qualitative analysis of single solid Organic compounds.
	CHEM-MD-CC7-5-P Or CHEM-MD-CC7-6-P	Chemistry MDC- VII	Surface Tension, Viscosity, Conductometry.
	CHEM-MD-CC8-6-P	Chemistry MDC- VIII	Estimation of mixtures of metal ions.

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 CHEM-MD-CC6-5-P and CHEM MD-CC7-5-P in Semester 5 and CHEM-MD-CC8-6-P 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 CHEM-MD-CC6-5-P in Semester 5 and CHEM-MD-CC7-6-P &CHEM-MD-CC8-6-P in Semester 6.

Chemistry Course Structure (Minor)

For

Three-year MULTIDISCIPLINARY Studies

(Theory)

Semester	Paper Code	Paper Name	Brief Descriptions
3	CHEM-MD-CC1-3-Th	Chemistry MDC- I	Extra nuclear structure of atoms and Periodicity, Basics of Organic Chemistry Bonding and Physical Properties , Stereochemistry – I, Thermodynamics –I, Chemical Kinetics-I.
4	CHEM-MD-CC2-4-Th	Chemistry MDC- II	Kinetic Theory and Gaseous state, Chemical Bonding – I , Theoretical principles of inorganic qualitative analysis , Stereochemistry – II, General Treatment of Reaction Mechanism-I
5	CHEM-MD-CC3-5-Th	Chemistry MDC- III	Aromatic Substitution Reaction , General Treatment of Reaction Mechanism-II, Stereochemistry –III Conformation , Substitution, elimination, Addition to alkenes, dienes, alkynes..
5	CHEM-MD-CC4-5-Th	Chemistry MDC- IV	Chemical bonding- II, Acids and bases, Radioactivity
6	CHEM-MD-CC5-6-Th	Chemistry MDC- V	Thermodynamics II , Applications of Thermodynamics – I , Electrochemistry-I.
6	CHEM-MD-CC6-6-Th	Chemistry MDC- VI	Stereochemistry – IV, Chemistry of Carbonyl Compounds, Organometallics..

Chemistry Course Structure (Minor)
For
Three-year MULTIDISCIPLINARY Studies
(Practical)

Semester	Paper Code	Paper Name	Brief Descriptions
3	CHEM-MD-CC1-3-P	Chemistry MDC- I	Acid-Base Titration, Oxidation-Reduction Titrimetry.
4	CHEM-MD-CC2-4-P	Chemistry MDC- II	Qualitative semimicro analysis of mixtures containing three radicals
5	CHEM-MD-CC3-5-P	Chemistry MDC- III	Identification of Single organic Compound.
5	CHEM-MD-CC4-5-P	Chemistry MDC- IV	Complexometric Titration
6	CHEM-MD-CC5-6-P	Chemistry MDC- V	Chemical Kinetics (Analytical).
6	CHEM-MD-CC6-6-P	Chemistry MDC- VI	Qualitative analysis of single solid organic compound.

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].

CHEMISTRY MDC

PAPER :CHEM-MD-CC1-1-Th/CHEM-MD-CC1-3-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC- I

Theory: (45 Lectures)

Module : I

(15 Lectures)

Extra nuclear structure of atoms and Periodicity:

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 tomultielectronicsystems. Aufbau principle and its limitations; Pauli's exclusion principle ; Hund's rules and multiplicity. Effective nuclear charge. Shielding and penetration; Slater's rule.

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 displacements

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 (05 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-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 1stlaw of thermodynamics. Enthalpy and heat capacity, Relations between C_p andC_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), 6thEdition , 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 PvtLtd , 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: CHEM-MD-CC1-1-P /CHEM-MD-CC1-3-P

(1) Calibration and use of apparatus.

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

Acid-Base Titrations:

(3) Standardization ofNaOH 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**

CHEMISTRY MDC

PAPER :CHEM-MD-CC2-2-Th/CHEM-MD-CC2-4-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC- 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)**

Chirotopicityand its relationship with stereogenicity; concept of pseudoasymmetry forABA 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), 6thEdition , 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 PvtLtd , 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: CHEM-MD-CC2-2-P/CHEM-MD-CC2-4-P

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 of Calcutta, 2015

CHEMISTRY MDC

PAPER :CHEM-MD-CC3-3-Th/CHEM-MD-CC3-5-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC- III

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-carbonelectrophiles (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 acidityand 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^3centre[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 ofkinetic 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), 6thEdition , 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: CHEM-MD-CC3-3-P/CHEM-MD-CC3-5-P

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, chloroform and nitrobenzene

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 ,5thEdition , Pearson India, 2003

CHEMISTRY MDC

PAPER :CHEM-MD-CC4-4-Th/CHEM-MD-CC4-5-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC- IV

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 concept, group characteristics of Lewis acids, solvent levelling and differentiating effects. Relative strength of acids, Pauling's rules. HSAB principle.

Thermodynamic acidity parameters
Drago-Wayland equation. Superacids, Gas phase acidity and proton affinity.

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 3rdEdition , Pearson India ,2002
3. Svehla&Sivasankar , Vogel's Qualitative Inorganic Analysis, 7th Ed., Pearson, 2012.

Practical : (30 Lectures)

PAPER: CHEM-MD-CC4-4-P/CHEM-MD-CC4-5-P

Complexometric Titration

1. **Ca(II) and Mg(II) in a mixture**
2. **Hardness of water**
3. **Fe(III) andAl(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

CHEMISTRY MDC

PAPER :CHEM-MD-CC5-4-Th/CHEM-MD-CC5-6-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC- V

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 change 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, thechemical 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.

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; 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 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 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 scaleSalt hydrolysis- calculation of hydrolysis constant, degree of hydrolysis and pH for different salts.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 theirlimitations.

Recommended Text Books:

1.Levine, I. N. Physical Chemistry, 6thEdition McGraw-Hill India, 2011
2.Castellan, G. W. Physical Chemistry, Narosa , 2004
3.Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11th Edition, OxfordUniversity 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 , 8th Edition, Tata-McGraw-Hil ,2017
3. Klotz, Irving M , Rosenberg, Robert M,Chemical Thermodynamics ,Wiley India , 2013

Practical : (30 Lectures)

PAPER: CHEM-MD-CC5-4-P/CHEM-MD-CC5-6-P

Physical Chemistry Practicals:

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

CHEMISTRY MDC

PAPER :CHEM-MD-CC6-5-Th/CHEM-MD-CC6-6-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC- VI

Theory: (45 Lectures)

Module : I

Stereochemistry – IV: **(08 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.

Module : II

Chemistry of carbonyl Compounds: (32 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, thiolsand 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; Mannichreaction,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 , Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard to carbonyl compounds; substitution on -COX; Conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behaviour of Grignard reagents; comparison of reactivity among Grignard, and organocopper reagents; Reformatsky reaction; concept of umpolung.

Recommended Text Books:

1. **Finar, I. L. Organic Chemistry (Volume 1), 6thEdition , 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 PvtLtd , 2020**

Practical : (30 Lectures)

PAPER: CHEM-MD-CC6-5-P/CHEM-MD-CC6-6-P

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% NaHCO3)
3. Detection of the following functional groups by systematic chemical tests: aromatic amino (Ar-NH2), aromatic nitro (-NO2), amido (-CONH2, 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 six)** 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

CHEMISTRY MDC

PAPER :CHEM-MD-CC7-5-Th/CHEM-MD-CC7-6-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC- VII

Theory: (45 Lectures)

Module : I

Transport processes and Liquid State: (9 Lectures)

Viscosity

General features of fluid flow (streamline flow and turbulent flow); Newton's equation, viscosity coefficient; Poiseuille's equation ; 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

Surface tension, surface energy, excess pressure, capillary rise and surface tension; Work of cohesion and adhesion, spreading of liquid over other 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 (Haüy'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 planes

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 . Determination of crystal structure: 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 non-volatile nonelectrolyte solute with the molality / molar concentrationof solute in solution . Applications in calculating molar masses of normal, dissociated and associated solutes in solution; Abnormal colligative properties.

Phase Equilibrium

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;

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 behaviour; Azeotropic solution; Liquid-liquid phase diagram using phenol- water system; Solid-liquid phase diagram; Eutectic mixture

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, 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 glass electrodes. Concentration cells with and without transference, liquid junction potential; Potentiometric Titration.

Recommended Text Books:

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

Practical : (30 Lectures)

PAPER: CHEM-MD-CC7-5-P/CHEM-MD-CC7-6-P

Physical Chemistry Practicals:

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) polymer (ii) ethanol and(iii) 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. 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), UGBOS, Chemistry, University of Calcutta, 2015**

CHEMISTRY MDC

PAPER :CHEM-MD-CC8-6-Th

(Credit : Theory -03, Practical – 01)

Chemistry MDC-VIII

Theory: (45 Lectures)

Module : I

Coordination chemistry: (20 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 and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemicalseries. 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).

Module : II

Electronic spectra of complexes and magnetic properties (10 Lectures)

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.

Module : III

Redox reactions : (15 Lectures)

Basic principle of redox reactions

Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions. Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH onredox 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 (typical examples).

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

Practical : (30 Lectures)

PAPER: CHEM-MD-CC8-6-P

Inorganic Chemistry Practicals:

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

SKILL ENHANCEMENT COURSE

CHEMISTRY

PAPER :CHEM-MD-SEC-Th

(Credit : Theory -03, Tutorial – 01)

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. **AshtoushKar. Medicinal Chemistry (TwoColour 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: CHEM-MD-SEC-Tu

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.

Interdisciplinary Course in Chemistry

PAPER: CHEM-MD-IDC-Th

(Credit : Theory -02, Tutorial – 01)

Theory: (30 Lectures)

CHEMISTRY IN DAILY LIFE

Module : I

(10 Lectures)

Dairy Products:
Composition of milkand 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

10 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

(10 Lectures)

Chemical and Renewable Energy Sources:
Principles and applications of primary & secondary batteries and fuel cells. Basics of solar energy, future energy storer.

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. **AshtoushKar. Medicinal Chemistry (TwoColour Edition), New Age International Pvt Ltd, 2022**
3. **Edward Cox Henry , The Chemical analysis of Foods , Hardcover , Hassell Street Press , 2021**
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