BENGALURU CITY UNIVERSITY

CHOICE BASED CREDIT SYSTEM

(As per SEP)

Syllabus for Chemistry

2024-25

PROCEEDINGS OF THE MEETING OF THE BOARD OF STUDIES IN CHEMISTRY (UG) HELD ON 11TH JUNE 2024 IN THE DEPARTMENT OF CHEMISTRY, JNANA JYOTHI - CENTRAL COLLEGE CAMPUS, BENGALURU CITY UNIVERISTY, BANGALORE - 560001.

A meeting of the Board of Studies in Chemistry (UG) was held today Tuesday the 11th June **2024 starting** at 10.30 am in the Department of Chemistry for framing syllabus for the first and second semesters of the three year B.Sc., course under State Education Policy, Government of Karnataka - 2024.

The Chairman welcomed the members and as per the agenda below, discussion was prompted.

1. **Item one: Framing of syllabus for the 1st and 2nd semester B.Sc., course with Chemistry under SEP and**
2. **Providing framework for the entire 3 years course.**

The members carefully discussed the agenda and recommended the syllabi and framework.

The Chairman finally thanked all the members for their presence and their valuable inputs for the deliberations of the day.

The following BOS members were present.

Name	Signature
1. Dr. Kantharaju S	
2. Mr. Shiva Prakash M	
3. Dr. Prasanna Kumar S G	
4. Dr. Ramakrishna Reddy. K	
5. Dr. Ronald J Mascarenhas	
6. Mr. Srivatsa L K Vijaya College	
7. Dr. Sanjeevarayyappa C GFGC Yelahanka	
8. Dr. Sujatha M MES	
9. Mr. Siddaraju	
10. Dr. Chinnadevi C N MES	
11. Mr. Harish K M SJRC	
12. Ms. Chandrima Dutta MES	
13. Dr. Balasubramani K J (Industry)	
14. Prof. Chethana P R	
15. Prof. Devaraj V R	
16. Prof. Hariprasad. S.	

Professor and Chairman.

Dr. Hari Prasad. S.
Senior Professor and Chairman
DOS in Chemistry, Central College Campus
Bengaluru City University
BENGALURU - 560 001

Proposed Structure for I Semester to VI Semester B.Sc., Chemistry Syllabus from 2024 onwards

I Semester		II Semester		III Semester		IV Semester		V Semester		VI Semester	
Topics	No. of Hours	Topics	No. of Hours	Topics	No. of Hours	Topics	No. of Hours	Topics	No. of Hours	Topics	No. of Hours
Unit 1		**Unit 1**		**Unit 1**		**Unit 1**		**P 5 (Physical chemistry)**		**P 7 (Organic chemistry)**	
Atomic structure	5	Quantum mechanics	8	Chemical kinetics	7	Phase equilibria	7	Molecular spectroscopy	20	Stereochemistry	10
Periodic Table and Periodic properties	8	Photochemistry	5	Nuclear and Radiochemistry	6	Solid state	6	Electrochemistry - II	6	Industrial organic chemistry	5
Unit 2		**Unit 2**		**Unit 2**		**Unit 2**		**Analytical methods in chemistry**	14	Spectroscopy of simple organic compounds	10
Elementary aspects of Analytical chemistry	13	Chemical bonding	13	Thermodynamics - I	7	Electrochemistry - I	8	**P 6 (Inorganic chemistry)**		Chemistry of Natural products	10
Unit 3		**Unit 3**		Thermodynamics - II	6	Ionic equilibria	5	Industrial materials	13	Heterocyclic compounds	5
Gaseous state	7	Polymers	4	**Unit 3**				Chemistry of newer materials	10	**P 8 (Biochemistry)**	
Liquids and Solutions	6	Chromatography	9	Metallurgy	5	**Unit 3**		Bio-inorganic chemistry	3	**Carbohydrates & carbohydrates metabolism**	7
Unit 4		**Unit 4**		Powder metallurgy and Steel	6	Coordination chemistry	13	Industrial gases and Inorganic chemicals	10	Lipids & lipid metabolism	6
Basic concepts in Organic chemistry	4	Aromatic hydrocarbons	9	Non-aqueous solvents	2	**Unit 4**		**synthetic and modification of inorganic solids**	2	Amino acids and proteins and Protein metabolism	7
Aliphatic hydrocarbons	9	Organic halogen compounds	4	**Unit 4**		Aldehydes and Ketones	4	Explosives	2	Enzymes	3
				Alcohols, Phenols, Thiols and ethers	11	Carboxylic acids and their derivatives	5			Nucleic acids	3
				Organometallic compounds	2	Amines	4			Information flow in biological systems	4
										Bioenergetics and Biological oxidation	6
										Vitamins and Harmones	4
No. of credits: 3	52	**No. of credits: 3**	52	**No. of credits: 3**	52	**No. of credits: 3**	52	**No. of credits: 6**	80	**No. of credits: 6**	80

Practicals

I Semester

1. Volumetric analysis (Performance & Procedure writing)

II Semester

Determination of density and viscosity/surface tension of a liquid (Performance)

Determination of CST of phenol - water system (Procedure writing)

Determination of percentage of NaCl by finding the CST of phenol - water system (Performance)

Determination of distribution coefficient of benzoic acid between water and toluene. (Performance)

Determination of molar mass of a non-electrolyate solute by Walker-Lumsden method. (Procedure writing)

III Semester

1. Prepartion of organic compounds - Single step (Performance)
2. Prepartion of organic compounds - Two steps (Procedure writing)

IV Semester

1. Qualitative analysis of a mixture of two simpe inorganic salts
2. Chromatographic experiments/separation techniques (Procedure writing)

V Semester

1. Qualitative analysis of mono functional organic compounds (Performance)
2. Quantitative analysis of amino acids/sugars/oils & fats (Procedure writing)
3. Colorimetric estimation of reducing sugars/phosphate/copper/iron (Procedure writing)

VI Semester

1. Conductometric & Potentiometric titrations (Performance)
2. pH metry (Performance/Procedure writing)

I Semester B.Sc.

Chemistry Paper – I

Instructions per week	Total contact hours	Marks		Duration of Examination	Total marks	Credits
		Internal assessment	End Semester Examination		100	3
4 Hours	52	20	80	3 Hours		

UNIT - I

Atomic Structure 5 hours

Review of Bohr's atomic model. Derivation of expressions for radius, energy and ionization energies of hydrogen and hydrogen like species. Numerical Problems. Hydrogen spectrum - Rydberg equation. Calculation of wavenumber of spectral lines and ionization energy.

Quantum numbers (only qualitative): definition and significance. Calculation of *l*, *m* and *s* values for a given values of *n* (1, 2 and 3). Rules for filling electrons in various orbitals: Aufbau principle and its limitations, Pauli's exclusion principle and Hund's rule of maximum multiplicity. Electronic configuration of elements (up to atomic number 30). Stability of half-filled and completely filled orbitals. Concept of exchange energy. Relative energies of atomic orbitals. Anomalous electronic configurations.

Periodic Table and Periodic properties 8 hours

Review of the modern periodic table (with respect to classification of elements based on outer electronic configuration)

Periodic properties: Atomic and ionic radii, ionization energy, electron affinity and electronegativity-definitions. Trends in the periodic properties- across the period and down the group. Applications in predicting and explaining chemical behavior - reactivity and reducing power. Factorsaffecting the values of ionization energy. Determination of electronegativity by Pauling's method. Diagonal relationship and its influence on the properties on beryllium and aluminium.

Comparative study of elements of alkali and alkaline earth metals; chalcogens and halogens - with respect to electronic configuration, atomic and ionic radii, ionisation energy and electronegativity.

Halides, oxides and carbonates of alkali and alkaline earth metals.

Hydrides of chalcogens and halogens-comparative study of all these with respect to their reactivity.

UNIT - II

Elementary aspects of Analytical chemistry 13 hours

Errors: Classification - determinate and indeterminate types, minimization of determinate errors, accuracy and precision-definitions. Significant figures-definition. Rules for computing significant figures and their computations with an example.

Avogadro number and mole concept. Equivalent weights of acids-definition, examples for a monobasic and a dibasic acid. Equivalent weights of bases-definition, sodium hydroxide and barium hydroxide as examples. Equivalent weights of salts-definition with sodium carbonate as an example. Methods of expressing concentration of solutions in terms of normality and molarity

and their definitions. (The method of preparation of 1 N and 1 M solutions are to be emphasized). Numerical problems on normality and molarity.

Types of acid – base titrations and titration curves.

Oxidation numbers: Definition, rules, calculation of oxidation numbers of elements in molecules and ions. Balancing of red-ox reactions by ion-electron method. Equivalent weights of oxidizing and reducing agents-definitions, examples of potassium dichromate, potassium permanganate, ferrous ammonium sulphate.

UNIT - III

Gaseous state 7 hours

Introduction: Need for Maxwell-Boltzmann distribution law, mathematical expression for Maxwell-Boltzmann distribution law both in terms of mole and molecule – explanation of the terms only. Explanation of velocity distribution curves based on this law (no derivation). Mean free path, collision frequency and collision number. Definition and expressions using SI units (no derivations). Derivation of expression for most probable speed from Maxwell-Boltzmann equation. Definitions and expressions for *rms* velocity and average velocity (no derivations), relationships between them. Problems on *rms* velocity and average velocity. Andrew's isotherm on carbon dioxide and explanation of the curves (no experimental details). Derivation of critical constants T_c, P_c and V_c from van der Waal's equation. Problems on the calculation of T_c, P_c and V_c, van der Waal's constants *a* and *b*.

Law of corresponding states – statement, reduced equation of state and explanation.

Joule - Thomson effect: Statement with explanation. Joule - Thomson co-efficient, inversion temperature-definition (no derivation). The application of Joule-Thomson effect to the liquefaction of air and hydrogen by Linde's process.

Liquids and Solutions 6 hours

Liquid Mixture: Review of Raoult's law of dilute solutions. Ideal and non-ideal solutions. Completely miscible liquids - theory of fractional distillation of binary liquids with diagram. T-C curves for all the three types. Azeotropic mixtures -examples.

Partially miscible liquids: Critical solution temperature-definition with any one example for each type - explanations with curves (three types). Effect of addition of salt on CST of phenol-water system. Immiscible liquids, examples. Theory of Steam distillation with derivation for the expression of ratio proportion of liquid mixtures and its applications.

Distribution law: Statement, partition coefficient and condition for validity of distribution law. Application-solvent extraction (no derivation)

Dilute solutions: Review of colligative properties. Determination of molecular mass of a solute by (i) Berkeley-Hartley's method (ΔT_b) (ii) Beckmann's method (ΔT_f) and (iii) Landsberger's method. Numerical problems on determination of molar mass. Abnormal molar mass, van't Hoff factor *i* and its significance.

UNIT - IV

Basic concepts in organic chemistry 4 hours

Nomenclature of organic compounds.

Bond cleavage - Homolytic and heterolytic cleavages - Explanation with examples for each type – curved arrow notations. Types of reagents: Electrophilic and nucleophilic reagents-meaning, examples for each type.

Reactive intermediates - generation and relative stabilities of carbocation, carbanion, carbon free radicals and carbenes - explanation of relative stability and reactivity based on inductive, resonance and hyperconjugative effects. Types of reactions: addition, substitution and elimination-explanation with examples for each type of reaction.

Aliphatic Hydrocarbons 9 hours

Alkanes: Sources and Nomenclature of alkanes. Preparation of symmetrical and unsymmetrical alkanes: Wurtz reaction. Conformational analysis of ethane and *n*-butane, Sawhorse and Newman projection formulae to be used – Energy profile diagram.

Cycloalkanes: Methods of preparation of cyclopropane to cyclohexane from respective terminal dihalides. Explanation for stability based on heat of hydrogenation data. Baeyer's strain theory and its limitations, Sachse - Mohr theory of strainless rings.

Alkenes: Preparation of alkenes by (i) dehydrohalogenation and (ii) dehalogenation. Reactions of alkenes - addition of (i) X_2 and (ii) HX. Markownikov's rule and anti Markownikov's addition with mechanisms. Epoxidation - with an example of ethene and propene.

Oxidation with $KMnO_4$ and OsO_4. Ozonolysis and its importance.

Dienes: Classification - isolated, conjugated and cumulated-one example for each type. Structure of allene and butadiene. Reactions: 1,2-addition and 1,4 addition reactions. Diels-Alder reaction:1,3-butadiene with maleic anhydride as an example.

Cycloalkenes (C_nH_{2n}): Introduction with examples.

Alkynes: Methods of preparation: dehydrohalogenation of vicinal and geminal dihalides. Reactions of alkynes – (i) Catalytic hydrogenation, (ii) Oxidation with $KMnO_4$, (iii) acidic nature of terminal alkynes with example of reaction with ammoniacal solutions of silver nitrate and cuprous chloride.

Cyclolkynes (C_nH_{2n-2}): Introduction with examples. Relative stability of cycloalkynes (in brief).

I Semester B.Sc. (DSC 1) - Question Paper Blue Print

Paper - I

Sl. No.	Topic	No. of Teaching Hours	Marks per Teaching hour, 116/52 = 2.24	Part A		Part B		Part C		Total Marks
				No. of questions	Marks	No. of questions	Marks	No. of questions	Marks	
UNIT I										
1	Atomic structure	5	11	1	2		0	1	**10**	12
2	Periodic table and periodic properties of elements	8	18	1	2	1	5	1	**10**	17
UNIT II										
3	Elementary aspects of analytical chemistry	13	29	4	8	2	10	1	**10**	28
UNIT III										
4	Gaseous state	7	16	2	4		0	1	**10**	14
5	Liquids and solutions	6	13	2	4		0	1	**10**	14
UNIT IV										
6	Basic concepts in Organic chemistry	4	9	1	2	1	5	0.5	**5**	12
7	Alphatic hydrocarbons	9	20	2	4	2	10	0.5	**5**	19
		52	**116**	**13**	**26**	**6**	**30**	**6**	**60**	**116**

Part A			Part B			Part C		
2 Marks Questions			5 Mark questions			10 Mark questions = (5 + 5) or (6 + 4) Pattern		
No. of questions		Total Marks	No. of questions		Total Marks	No. of questions		Total Marks
To set	To answer		To set	To answer		To set	To answer	
13	**10**	**10 × 2 = 20**	**6**	**4**	**4 × 5 = 20**	**6**	**4**	**40**

Chemistry Practical - I Semester B.Sc.

Instructions per week	Marks		Total marks	Duration of Examination	Credits
	Internal assessment marks	End Semester Examination	50		2
3 Hours	10	40		3 Hours	

Safety Data Sheet

1. Calibration of glass wares: (i) Pipettte, (ii) Burette, (iii) Volumetric flask.
2. Estimation of potassium permanganate using standard sodium oxalate solution.
3. Estimation of ferrous ammonium sulphate using standard potassium dichromate solution with diphenyl amine as an internal indicator.
4. Estimation of sodium thiosulphate using standard potassium dichromate solution.
5. Estimation of zinc in the solution using standard EDTA solution.
6. Standardisation of EDTA solution and the estimation of total hardness of a sample of water.
7. Determination of percentage of iron in haematite using standard potassium dichromate solution with diphenyl amine as an internal indicator.
8. Estimation of carbonate and bicarbonate in a given mixture.
9. Determination of chloride by Mohr's method using potassium chromate as an adsorption indicator.
10. Determination of percentage of available chlorine in a sample of bleaching powder.

Note: *Standard solutions to be prepared for experiments 2 to 4.*

Different volumes of the solutions to be given in volumetric flask for estimation for experiments 5 and 6.

II Semester B.Sc.

Chemistry Paper – II

Instructions per week	Total contact hours	Marks		Duration of Examination	Total marks	Credits
		Internal assessment	End Semester Examination		100	3
4 Hours	52	20	80	3 Hours		

UNIT - I

Quantum Mechanics 8 hours

Limitations of classical mechanics. Wave particle duality, de Broglie equation. Heisenberg's uncertainty principle. Sinusoidal wave equation (explain sinusoidal wave and classical wave mechanics); Schrodinger wave equation. Derivation of time independent Schrodinger wave equation. Postulates of quantum mechanics.

Concept of operators. Significance of: (i) Laplacian operator, (ii) Hamiltonian operator (iii) Eigen values and Eigen functions. Significance of ψ and ψ^2. Application of Schrodinger equation to a particle in one dimensional box (derivation).

Radial probability distribution and angular probability distribution curves. Orbitals-definition and difference between an orbit and orbital. Nodes or nodal planes for *s* and *p* orbitals. Shapes of *s*, *p*, *d* and *f* orbitals.

Photochemistry 5 hours

Laws of photochemistry. Grotthus-Draper law, Stark-Einstein law – Statements, differences between photophysical and photochemical processes with examples.

Comparison of photochemical and thermal reactions with an example each. Quantum yield-definition. Magnitude of Quantum yield of photochemical combination of (i) H_2 and Cl_2 (ii) H_2 and Br_2 (iii) dissociation of HI (iv) dimerisation of anthracene: reason for low, high and medium quantum yields.

Singlet and triplet states – definitions. Fluorescence, phosphorescence – basic Jablonski diagram. Luminescence, bioluminescence and chemical sensors – definitions of all these with suitable examples.

Photosensitization-definition with example. Photo stationary equilibrium – definition and example.

Beer-Lambert's law-statement and its application in colorimetric estimations. Numerical problems on absorption coefficient and molar extinction coefficient.

UNIT - II

Chemical bonding 13 hours

Ionic bond: Lattice energy: definition and significance. Born-Haber cycle for NaCl and MgO. Calculation of lattice energy. Born - Lande equation (derivation not required). Problems on Born-Lande equation. Effect of lattice energy on solubility of ionic compounds.

Covalent bond: Valence bond approach - postulates of valence bond theory. Hybridization-definition and directional characteristics of *sp*, sp^2, sp^3, sp^3d, sp^3d^2 hybridisations. Formation and shapes of $BeCl_2$, BF_3, $SiCl_4$, PCl_5 and SF_6 molecules.

VSEPR theory: Illustration with reference to shapes of CH_4, NH_3, NH_4^+, H_2O, BrF_3 and ICl^-.

Molecular orbital theory: Bond order, stability and magnetic properties to be discussed for: $H_2, He_2^+, Be_2, N_2, O_2, O_2^-, O_2^{2-}, O_2^+$, CO, NO and NO^+. Polarization concept: Fajan's rules, explanation with examples, bond length, bond angle and bond energy-definitions. Polar and non-polar molecules- examples. Dipole moment-definition and unit.

Hydrogen bond: Intra-molecular and Inter-molecular types with examples - HF, H_2O, NH_3, alcohols, carboxylic acids, nitro phenols and biomolecules. Anomalous properties of water. van-der Waal's forces: Noble gases, molecular crystals (dry ice, iodine and solid SO_2) and clathrates.

Metallic bond: Band theory and electrical properties of metals. Semiconductors and insulators.

UNIT - III

Polymers 4 hours

Introduction and classification. Polymerization - definition. Types of polymerisation: (i) Addition polymerization: (ii) Condensation polymerization.

Resins: Synthesis and uses of: (1) Thermoplastic resins – (i) Polyethenic or Vinyl resins *Ex*: (a) Polymethyl methacrylate or Lucite or Plexiglass, (b) TEFLON. (2) Thermosetting resins – (i) Phenolic resins or phenoplasts *Ex*: (a) Novalac, (b) Bakelite (ii) Polyurethanes,(iii) epoxy resins.

Chromatography 9 hours

General description, definition, terms and parameters used in chromatography. Classification of chromatographic methods, criteria for selection of stationary and mobile phases. Nature of adsorbents and R_f value.

Paper chromatography: Principle and applications.

Thin layer chromatography: Principle, mechanism, efficiency of TLC plates, methodology – selection of stationary and mobile phases, plate development, spray reagents, identification of analytes and qualitative applications.

Column chromatography: Principle - Column efficiency, factors affecting the column efficiency, van Deemter's equation and its modern version.

Ion exchange chromatography: Principle. Resins - types with examples- cation exchange and anion exchange resins. Mechanism of cation and anion exchange process and applications of ion-exchange chromatography (softening of hard water, separation of lanthanides, industrial applications).

UNIT - IV

Aromatic hydrocarbons 9 hours

Nomenclature, structure of benzene - using molecular orbital theory. Huckel's rule. Stability based on Huckel's rule of aromaticity. (*Ex*: naphthalene, anthracene, phenanthrene, cyclopentadienyl anion and cycloheptatrienyl cation). Anti-aromaticity: definition and examples.

Aromatic electrophilic substitution: General mechanism of aromatic electrophilic substitution. Mechanism of: (i) nitration of benzene - evidence for the formation of nitronium ion, energy profile diagram and isotopic effect, (ii) sulphonation of benzene.

Orienting influence of substituents in toluene, chlorobenzene, nitrobenzene and phenol towards electrophilic substitutions reactions.

Benzyne – Introduction and stability based on Huckel's rule of aromaticity. Generation of benzyne with mechanism.

Aromatic nucleophilic substitution: *Ipso* substitution - *Ex*: conversion of 2,4-dinitrochlorobenzene to 2,4-dinitrophenylhydrazine.

Oxidation of naphthalene to (i) phthalic anhydride and (ii) 1,4-napthaquinone. Anthracene to anthraquinone and phenanthrene to phenanthraquinone.

Diels-Alder reaction between anthracene with 1,2-dichloroethene.

Alkenyl benzenes: Styrene, *cis*- and *trans*-stilbenes - structures and their preparations. Biphenyl: Preparation by Ullmann reaction.

Organic halogen compounds 4 hours

Alkyl halides: Nomenclature.

Nucleophilic substitution reactions – Substitution nucleophilic unimolecular (S_N1) and Substitution nucleophilic bimolecular (S_N2) mechanisms with energy profile diagrams. Effect of (i) nature of alkyl groups (ii) nature of leaving groups (iii) nucleophiles and (iv) solvents.

Elimination reactions – Elimination unimolecular (E1) and Elimination bimolecular (E2) mechanisms; Hofmann and Saytzeff eliminations-explanation with mechanism.

Alkenyl halides: Types with examples.

Aryl and aralkyl halides: Preparation by halogenation.

Relative reactivity of alkyl, allyl, vinyl, aryl and aralkyl halides towards nucleophilic substitution.

II Semester B.Sc. (DSC 2) - Question Paper Blue Print

Paper - 2

Sl. No.	Topic	No. of Teaching Hours	Marks per Teaching hour, 116/52 = 2.23	Part A		Part B		Part C		Total Marks
				No. of questions	Marks	No. of questions	Marks	No. of questions	Marks	
UNIT I										
1	Quantum Mechanics	8	18	1	2	1	5	1	**10**	17
2	Photochemistry	5	11	1	2		0	1	**10**	12
UNIT II										
3	Chemical bonding	13	29	5	10	2	10	1	**10**	30
UNIT III										
4	Polymers	4	9		0		0	1	**10**	10
5	Chromatography	9	20	2	4	1	5	1	**10**	19
UNIT IV										
6	Aromatic hydrocarbons	9	20	4	8	1	5	0.5	**5**	18
7	Organic halogen compounds	4	9		0	1	5	0.5	**5**	10
		52	**116**	**13**	**26**	**6**	**30**	**6**	**60**	**116**

Part A			Part B			Part C		
2 Marks Questions			5 Mark questions			10 Mark questions = (5 + 5) or (6 + 4) Pattern		
No. of questions		Total Marks	No. of questions		Total Marks	No. of questions		Total Marks
To set	To answer		To set	To answer		To set	To answer	
13	**10**	**10 × 2 = 20**	**6**	**4**	**4 × 5 = 20**	**6**	**4**	**40**

Chemistry Practical - II Semester B.Sc.

Instructions per week	Marks		Total marks	Duration of Examination	Credits
	Internal assessment marks	End Semester Examination	50		2
3 Hours	10	40		3 Hours	

1. Determination of density using specific gravity bottle and viscosity of a liquid using Ostwald's viscometer.
2. Determination of density using specific gravity bottle and surface tension of a liquid using Stalagmometer.
3. To study the variation of viscosity of sucrose solution with concentration of the solute.
4. Determination of percentage composition of a binary liquid mixture by viscosity method.
5. Determination of critical solution temperature of phenol-water system.
6. Determination of percentage of sodium chloride solution by finding out the CST of phenol-water system.
7. Determination of molar mass of a non-electrolyte by Walker-Lumsden method.
8. Determination of distribution coefficient of benzoic acid between water and toluene.
9. Determination of distribution coefficient of acetic acid between water and butanol.
10. To study the effect of surfactants on the surface tension of water (Stock solution to be given).

BENGALURU CITY UNIVERSITY

CHOICE BASED CREDIT SYSTEM

(Semester Scheme with Multiple Entry and Exit Options for Under Graduate Course- as per NEP 2020)

Syllabus for B.Sc. Chemistry
(III & IV Semester)

2022-23 onwards

Proceedings of the Meeting of Board of Studies in Chemistry (UG) Bengaluru City University held on 30th Sep 2022 at 10.30 am in the Department of Chemistry, Central College Campus, Bengaluru-560 001

The Chairperson welcomed the members of the Board to the meeting and placed the agenda before the Committee for discussion.

Agenda 1: As per the directive from the Bengaluru City University, the Chemistry syllabus for the B. Sc., degree programme as per NEP model II A model programme structure for the **Third and Fourth semester** B.Sc. (Honors) Chemistry course undergraduate programs in universities and colleges [subjects with practicals] was prepared. The proposed syllabus is to be introduced from 2022-23 onwards after the approval from different bodies.

Agenda 2: Chairperson informed that syllabus has to be made in such a way that,

- The rules governing the NEP II A model (semester scheme) for UG program to be followed are as per the university guidelines.
- To equip and strengthen students with analytical skills needed for their careers in teaching, industry, and research.
- With the changing trends and latest developments in research updating of the curriculum is a necessary exercise.

Agenda 3: Scrutiny and approval of the Syllabus (theory and practical) and Scheme of Examination under NEP model (Semester Scheme) for the Chemistry Course in B.Sc., Degree Programme was finalized and approved in the BOS Meeting.

The Board of Studies (UG) approved the Syllabus after appropriate modifications for the Chemistry Course **Third and Fourth semester** in B. Sc., Degree Programme starting from the academic year 2022-23.

Agenda 4: Approval of Board of Examiners list (Chemistry UG) for the academic year 2022-23.

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The Chairperson recorded her thanks to the teachers involved in the preparation of this syllabus.

The following BOS members were present.

Name of members of BOS	**Signature**
1. **Dr. Mahesh Aravind**	
2. **Dr. Rita Battacharjee**	
3. **Dr. Vasundara D E**	ABSENT
4. **Dr. S Kantharaju**	ABSENT
5. **Prof. Shiva Prakash M**	
6. **Dr. Nanjundappa V S**	ABSENT
7. **Dr. Prasanna Kumar**	
8. **Dr. Ramakrishna Reddy K**	30/09/22
9. **Dr. Ronald J Mascarenhas**	ABSENT
10. **Prof. V R Devraj**	
11. **Prof. Hariprasad. S.**	30.9.22
12. **Dr. V Gayathri.** **Professor and Chairperson**	

Dr. V. GAYATHRI
Professor & Chairperson
Department of Studies in Chemistry
Bengaluru City University
Central College Campus
BENGALURU - 560001.

CHEMISTRY DSC-3: Analytical and Organic Chemistry-II

Contact Hours: 56 **Work load: 4 Hours/Week.**

Credit Points :4

Evaluation: Continuous Internal Assesment-40 Marks

Semester End Examination -60 Marks

Course Objectives:

1) Interrelationship among frequency, wavelength and wave number and importance of validation parameters of an instrumental method will be taught
2) Principle, instrumentation and applications of spectrophotometry, nephelometry and turbidometry will be taught
3) Fundamentals of separation methods and principles of paper, thin layer and column chromatography will be taught
4) Principle, types and applications of solvent extraction will be taught
5) Principle and mechanism of ion-exchange, types of resins and domestic and industrial applications of ion-exchange chromatography will be taught
6) The concept of mechanism and its importance will be taught to the student
7) Concept and importance of intermediates in organic chemistry will be taught taking proper examples
8) The various techniques for identification of reaction mechanism will be taught to the student taking proper examples
9) Concept of stereochemistry and its importance will be taught.
10) The various projection formulae and the techniques of designating the molecules into R, S, D, L will be taught taking proper examples
11) The theory and concept of Cis-, Trans- isomerism and its importance and the techniques to differentiate between them will be taught taking examples

Course Specific Outcomes

After the completion of this course, the student would be able to

1) Understand the importance of fundamental law and validation parameters in chemical analysis
2) Know how different analytes in different matrices (water and real samples) can be determined by spectrophotometric, nephelometric and turbidometric methods.
3) Understand the requirement for chemical analysis by paper, thin layer and column chromatography.
4) Apply solvent extraction method for quantitative determination of metal ions in different samples
5) Utilize the ion-exchange chromatography for domestic and industrial applications
6) Explain mechanism for a given reaction.
7) Predict the probable mechanism for a reaction. Explain the importance of reactive intermediates role and techniques of generating such intermediates
8) Explain the importance of Stereochemistry in predicting the structure and property of organic molecules.
9) Predict the configuration of an organic molecule and able to designate it. 10)Identify the chiral molecules and predict its actual configuration

Unit-I

Quantitative Analysis-Instrumental methods

Electromagnetic spectrum, absorption of electromagnetic radiation, Definition and units of frequency, wavelength, wave number,

Beer-Lambert law and its derivation, deviations, limitations, construction of calibration graph (Plot of absorbance vs concentration). Evaluation Procedures- standard addition, Internal standard addition, validation parameters-detection limits, sensitivity, linearity, Instrumentation, single beam and double beam spectrophotometers, quantitative applications of colorimetry (determination of Fe, Cu, Ti and PO_4^{3-}). Numerical problems

10 hrs.

Nephelometry and Turbidometry: Introduction, principle, instrumentation of nephelometry and turbidometry; effects of concentration, particle size and wavelength on scattering, choice between nephelometry and turbidometry, Applications of nephelometry and turbidometry (determination of SO_4^{2-} and PO_4^{3-})

4 hrs.

Unit-II

Separation methods

Fundamentals of chromatography: General description, definition, terms and parameters used in chromatography, classification of chromatographic methods, criteria for selection of stationary and mobile phases and nature of adsorbents.

Column chromatography. Principle- Column efficiency, factors affecting the column efficiency, van Deemter's equation and its modern version.

3hrs

Paper chromatography: Principle and applications

Thin layer chromatography (TLC): Principle, Mechanism, Rf value, efficiency of TLC plates, methodology–selection of stationary and mobile phases, plate development, spray reagents, identification of analytes, qualitative applications. **4 hrs.**

Ion exchange chromatography: Principle resins, types with examples- cation exchange and anion exchange resins, mechanism of cation and anion exchange process and applications of ion-exchange chromatography (softening of hard water, separation of lanthanides, industrial applications).

3hrs

Solvent Extraction: Principle,Types- batch, continuous, efficiency, selectivity, distribution coefficient, Nernst distribution law, derivation, factors affecting the partition, relationship between % extraction and volume fraction, Numerical problems.

Solvent extraction of lanthanides, iron and copper.

4hrs

Unit-III

Reactive Intermediates: Generation, Stability and Reactions of, i) arbocations ii) Carbanions iii) Free Radicals iv) Carbenes and Nitrenesv) Arynes.

Applications:

i) Carbocations: Dienone-phenol; and Pinacol-Pinacolone Rearrangement.

ii) Carbanions: Perkin Reaction, Aldol condensation, Claisen-Schmidt condensation.

iii) Free Radicals: Sand meyer Reaction

iv) Carbenes and Nitrenes: Singlet and triplet states, relative stability and reactions: addition to Carbon-Carbon double bond

v)Arynes: Formation, Diels-Alder reaction to dienes

8hrs.

Methods for Identifying Reaction Mechanisms:

Product analysis- Isolation and identification of intermediates, Stereo chemical evidences effect of catalyst, crossover experiments, Isotopic studies, Kinetic Studies

6 hrs.

Unit-IV

Stereochemistry of Organic Compounds:

Fischer - , Newman and Sawhorse projection formulae and their interconversions.

Geometrical isomerism: Cis-trans and syn-anti isomerism, E/Z notations. Optical Isomerism: Optical activity, Specific rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral centers, Diastereoisomers, meso structures, Racemic mixtures and Resolution, Relative and absolute configuration, D/L and R/S designations (for single carbon stereo centers) with CIP rules

14 hrs.

References:

1. Fundamental of Analytical Chemistry, D.A. Skoog, D.M. West, Holler and Crouch Ninth edition. Saunders College Publishing, New York (2014).
2. Analytical Chemistry, G.D. Christian, 6th edition, John Wiley & Sons, (2007)
3. Analytical Chemistry, 7th Edition: Seventh Edition Gary D. Christian, Purnendu (Sandy) Dasgupta, Kevin Schug Wiley Global Education, (2013)
4. Quantitative Analysis, R.A. Day and A.L. Underwood, 6th edition, PHI Learning Pvt Ltd. New Delhi (2015).
5. Vogel's Textbook of Quantitative Chemical Analysis, J. Mendham, R.C. Denney, J.D. Barnes and M.J.K. Thomas, 6th edition, Third Indian Reprint, Pearson Education Pvt. Ltd. (2007).
6. Organic Reaction Mechanism by V.K. Ahluwalia and R.K. Parashar (Narosa Publishers) [2002],
7. Organic Chemistry by S.M. Mukherji, S.P. Singh and R.K. Kapoor New age publishers (2017)
8. Organic Chemistry by Robert T. Morrison, Robert N. Boyd Dorling Kindersley (India) Pvt Ltd. Pearson Education India; 7th edition (2010)
9. F. A. Carey, Organic Chemistry, Seventh Edition, Tata McGraw Hill (2008)
10. Organic Chemistry by FINAR (Vol I and II) Pearson Education India; 6th edition (2002)
11. Introduction to Organic Chemistry by John E. McMurry CENGAGE LEARNING (RS); 9th edition (2008)
12. Stereochemistry of Organic Compounds Ernest L. Eliel, Samuel H. Wilen. Wiley publishers; 1st edition (2008)
13. P Sykes, A Guide Book to Mechanism in Organic Chemistry, 6th Edition (1997), Orient
14. Solomons, T.W G., Fryhle, B. Craig. Organic Chemistry, John Wiley & Sons, Inc (2009).

PRACTICALS (III SEMESTER)

Credit Points: 2 **Teaching Hours:4 hrs.**

Evaluation: Continuous Internal Assessment- :25 marks

Semester End Examination :25 marks

Course Objectives

1) To impart skills related to preparation of stock and working solutions and handling of instrumental methods
2) To know the principle of colorimetric analysis and construction of calibration plot
3) To understand the chemistry involved in colorimetric determination of metal ions and anions
4) To determine Rf values of different metal ions present in a mixture
5) To impart knowledge on the importance of functional groups in organic compounds.
6) Techniques to identify the functional groups in an compound by performing physical and chemical tests
7) To record its melting point/boiling point.
8) To prepare suitable derivative for that compound and to characterize it.

Course Specific outcomes

After the completion of this course, the student would be able to

1) Understand the importance of instrumental methods for quantitative applications
2) Apply colorimetric methods for accurate determination of metal ions and anions in water or real samples
3) Understand how functional groups in an compound is responsible for its characteristic property
4) Learn the importance of qualitative tests in identifying functional groups.
5) Learn how to prepare a derivative for particular functional groups and how to purify it’

PART-A (Analytical Chemistry)

1) Colorimetric determination of copper using ammonium hydroxide.
2) Colorimetric determination of iron using thiocyanate
3) Colorimetric determination of nickel using DMG
4) Colorimetric determination of titanium using hydrogen peroxide
5) Colorimetric determination of nitrite in water sample (diazo coupling Reaction using Griess reagent
6) Colorimetric determination of phosphate as ammonium phosphomolybdate
7) Measurement of Rf values of two component systems by TLC (ortho and para nitro anilines)
8) Separation of different metal ions by paper chromatography (Co, Ni, and Cu) or
   Solvent extraction of iron using oxine (demonstration)

PART-B (Organic Chemistry)

Qualitative analysis of Organic compounds.

1) Salicylic acid,2) Glucose 3) Methyl salicylate

4)p-Amino benzoic acid, 5) p-Chloro benzoic acid 6) Salicylaldehyde,

7)Acetophenone, 8) Benzoic acid 9) Salicylamide 10) Benzamide etc.

(Atleast 6-8 compounds to be analyzed in a semester)

References

1) Vogel's Textbook of Quantitative Chemical Analysis, J. Mendham, R.C. Denney, J.D.Barnes and M.J.K. Thomas, 6^{th} edition, Third Indian Reprint, Pearson Education Pvt.Ltd.(2007)
2) Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
3) Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012)
4) Ahluwalia, V.K. &Dhingra, S. Comprehensive Practical Organic Chemistry: Qualitative Analysis, University Press (2000)

CHEMISTRY DSC-4: Inorganic and Physical Chemistry-II

Contact Hours: 56 **Work load: 4 Hours/Week.**

Credit Points :4

Evaluation: Continuous Internal Assessment -40 Marks

Semester End Examination -60 Marks

Course Objectives:

Students learn about

1. Different types of bonding in molecules/compounds/ions
2. The structures of molecules/compounds/ions based on different models/theories
3. Properties of compounds based on bonding and structure
4. The fundamentals of thermodynamics including the laws, the concept of entropy and free energy functions and their applications.
5. The concepts of surface chemistry, catalysis and their applications.
6. The theoretical and experimental aspects of chemical kinetics including basic theories of reaction rates and methods of determining order.
7. Electrochemistry dealing with electrolytes in solution. Conductance measurements and applications. Concept of ionic mobility and their determination.

Course outcomes:

After the completion of this course, the student would be able to

1. Predict the nature of the bond formed between different elements
2. Identify the possible type of arrangements of ions in ionic compounds
3. Write Born - Haber cycle for different ionic compounds
4. Relate different energy parameters like, lattice energy, entropy, enthalpy and solvation energy in the dissolution of ionic solids
5. Explain covalent nature in ionic compounds
6. Write the M.O. energy diagrams for simple molecules
7. Differentiate bonding in metals from their compounds
8. Learn important laws of thermodynamics and their applications to various thermodynamic systems
9. Understand adsorption processes and their mechanisms and the function and purpose of a catalyst

10. Apply adsorption as a versatile method for waste water purification.
11. Understand the concept of rate of a chemical reaction, integrated rate equations, energy of activation and determination of order of a reaction based on experimental data
12. Know different types of electrolytes, usefulness of conductance and ionic mobility measurements
13. Determine the transport numbers

Unit - I

Structure and Bonding -I

The ionic bond:

Structures of ionic solids, Radius ratio rules and its limitations: Calculation of some limiting radius ratio, Coordination number 3 (planar triangle), 4 (tetrahedral and square planar) and 6 (octahedral), Close packing. **3hrs**

Classification of ionic structures:

Ionic compounds of the types AX (ZnS, NaCl, CsCl), AX_2 (Calcium fluoride: fluorite) and Rutile structure.

Layer structures :CdI_2, **2hrs**

Lattice energy and Born-Haber cycle, Derivation of Born-Lande equation and its drawbacks, Kapustinskii equation, solvation energy and solubility of ionic solids, polarizing power and polarizability, Fajan's rules with applications.

Numerical problems **4 hrs.**

Covalent bond: Valence bond theory, The Lewis theory, The octet rule, Exceptions to the octet rule, Sidgwick- Powell theory. Valence shell electron pair repulsion (VSEPR) theory, effect of lone pairs, electronegativity, isoelectronic principle, examples using VSEPR theory: $BF_3$and BF_4^-, $NH_3$and NH_4^+, H_2O, PCl_5, ClF_3, SF_4, SF_6, and $\underline{IF_7}$.
Limitations of VSEPR theory. **5 hrs.**

Unit - II

Structure and Bonding -II

Concept of resonance, resonance energy, hybridization, types of hybridization, sp, sp^2, sp^3 dsp^2 dsp^3, d^2sp^3, sp^3d^2 with one example each, and energetics of hybridization.

Bent's rule, Limitations of Valence Bond Theory.

3 hrs.

Molecular Orbital theory:

LCAO concept: s-s, s-p, p-p, p-d and d-d combinations of orbitals, bonding, nonbonding and antibonding molecular orbitals, non-bonding combinations of orbitals, Rules for linear combination of atomic orbitals

Examples of molecular orbital treatment for Homonuclear diatomic molecules and ions. H_2 and H_2^+, He_2 and He_2^+, Li_2, Be_2, B_2, C_2, N_2, and N_2^+, O_2, O_2^- and O_2^{2-}

M.O. energy diagrams of heteronuclear diatomic molecules with examples (NO, NO^+, CO and HCl). Calculation of bond order, relationship between bond order, bond energy and bond length, magnetic properties based on MOT.

7 hrs.

Metallic Bonding:

General properties of metals: conductivity, lustre, malleability and cohesive force

Crystal structures of metals and bond lengths.

Theories of bonding in metals:

Free electron theory, Valence bond theory, Molecular orbital or band theory of solids

Prediction of conducting properties of conductors, insulators and semiconductors, extrinsic and intrinsic semiconductors using M.O. theory.

4 hrs.

UNIT III

First Law of Thermodynamics

Thermodynamic processes, Reversible and Irreversible Processes, nature of Heat and work, internal energy, First Law of thermodynamics, Enthalpy of a System, Work done in isothermal and adiabatic expansion of an ideal gas, Numerical problems, Joule - Thomson expansion, Relation between Joule-Thomson coefficient and other thermodynamic parameters.

Second law of Thermodynamics

Concept of entropy, thermodynamic scale of temperature, Statements of the Second law of Thermodynamics, molecular and statistical interpretation of entropy,

Calculation of entropy change for reversible and irreversible processes, Free Energy Functions: Gibbs and Helmholtz energy, Variation of S, G, A with T, V and P, Numerical problems, Free energy change and spontaneity, Gibbs-Helmholtz equation.

Third Law of Thermodynamics

Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules. **09 hrs.**

Surface Chemistry

Adsorption

Types of adsorption isotherms. Freundlich adsorption isotherm (only equation), its limitations. Langmuir adsorption isotherm (derivation to be done) and BET equation (derivation not included).

Catalysis

Types of catalysis and theories with examples (intermediate compound theory and adsorption theory), Theory of acid base catalysis, Michaelis-Menten mechanism. Heterogeneous catalysis: surface reactions, unimolecular, bimolecular surface reactions. Autocatalysis with examples. Applications: Design process to removal of toxic compounds from industrial wastewater and treatment of portable water requirements. **5hrs**

UNIT IV

Chemical Kinetics

Differential and integrated form of rate expressions up to second order reactions, Derivationof expression of rate constant of second order reaction (a=b and a ≠ b), Problems on rate constant (a=b), Methods of determination of order of a reaction, temperature dependence of reaction rates; Arrhenius equation, activation energy, Numerical problems on Arrhenius equation in calculating energy of activation and rate constants. Collision theory of reaction rates, Lindemann's mechanism, qualitative treatment of the theory of absolute reaction rates. Experimental determination of

kinetics of (i) inversion of cane sugar by polarimetric method (ii) spectrophotometric method for the reaction between potassium persulphate and potassium iodide.

7 hrs.

Electrochemistry – I

Arrhenius theory of electrolytic dissociation. Merits and Demerits, Conductance, Specific conductance, equivalent and molar conductivity and their variation with dilution. Molar conductivity at infinite dilution. Numerical problems.

Kohlrausch's law of independent migration of ions and its applications, Debye-Huckel- Onsager equation. Ionic mobilities and their determinations, transference numbers and their relation to ionic mobility's, determination of transference numbers using Hittorf and Moving boundary methods.

Applications of conductance measurement: (i) degree of dissociation of weak electrolytes (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts (iv) conductometric titrations (acid base titrations only) and (v) Hydrolysis constants of salts. Numerical problems.

7 hrs.

Reference Books.

1. Peter Atkins & Julio De Paula, Physical Chemistry, 9th Ed., Oxford university Press (2010)
2. G W Castellan, Physical Chemistry, 4th Ed., Narosa (2004)
3. R G Mortimer, Physical Chemistry 3rd Ed., Elsevier: Noida, UP (2009)
4. B R Puri, L R Sharma and M S Pathania, Principal of Physical Chemistry, Vishal Publishing Co.48 edition (2021)
5. B S Bahl, G D Tuli and ArunBahl, Essentials of Physical chemistry, S Chand Publishing; Twenty-eight edition (2020)
6. A S Negi and S C Anand, A textbook of Physical Chemistry, New Age InternationalPublishers. 3rd Edition (2021)
7. B N Bajpai, Advanced Physical chemistry, S Chand and Company ltd. (2001)
8. R L Madan, Chemistry for Degree Students, Semester I, II, III and IV, S Chand and company Ltd. (2020)
9. P L Soni, O P Dharmarha and U N Dash, Textbook of Physical Chemistry, Sultan Chand and Sons. (2007)
10. Ball, D. W. Physical Chemistry Thomson Press, India (2007).

11. Physical chemistry by Samuel Glasstone East-West Press (Pvt.) Ltd. (2006)
12. J.D. Lee Concise Inorganic Chemistry Wiley India Pvt Ltd. (2022)
13. Huheey James E. Inorganic Chemistry: Principles of Structure and Reactivity-Pearson Education India; 4th edition (2006)
14. Cotton and Wilkinson. Advanced Inorganic Chemistry,Wiley; 6th edition (1999)

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PRACTICALS (IV SEMESTER)

Credit Points: 2 **Teaching Hours: 4Hrs**

Evaluation:

Continuous Internal Assessment- **:**25 marks **Semester**

End Examination **:** 25 marks

Course objective: **To attain practical knowledge about:**

1. Analytical skills in detecting the constituents present in unknown samples by systematically carrying out the qualitative analysis.
2. The methods of determining rates of chemical reactions.
3. Designing electrochemical cells and making measurements related to it.
4. Determination of physical characteristics of electrolytes using conductivity measurements in solution.
5. Adsorption phenomenon, mechanism and basic models to explain adsorption.
6. Simple techniques like conductometry to obtain physicochemical parameters of electrolytes.

Course outcomes: **At the end of the course student would be able to**

1. Understand the chemical reactions involved in the detection of cations and anions.
2. Explain basic principles involved in classification of ions into groups in semi-micro qualitative analysis of salt mixture
3. Carryout the separation of cations into groups and understand the concept of common ion effect.
4. Understand the choice of group reagents used in the analysis.
5. Analyse a simple inorganic salt mixture containing two anions and cations
6. Use instruments like conductivity meter to obtain various physicochemical parameters.

7. Apply the theory about chemical kinetics and determine the velocity constants of various reactions.
8. Learn about the reaction mechanisms.
9. Interpret the behaviour of interfaces, the phenomena of physisorption and chemisorptions and their applications in chemical and industrial processes.
10. Learn to fit experimental data with theoretical models and interpret the data

Part A- Inorganic Chemistry Practicals

Qualitative semi-micro analysis of mixtures containing 2 anions and 2 cations. Emphasis should be given to the understanding of different reactions.

The following cations and anions are suggested.

Cations: NH_4^+, Pb^{2+}, Bi^{3+}, Cu^{2+}, Al^{3+}, Fe^{3+}, Co^{2+}, Cr^{3+}, Ni^{2+}, Zn^{2+}, Mn^{2+}, Ba^{2+}, Ca^{2+}, Sr^{2+} Mg^{2+}, Na^+, K^+ and Li^+.

Anions: CO_3^{2-}, CH_3COO^-, Cl^-, Br^-, I^-, NO_3^-, BO_3^{3-}, SO_4^{2-}, $C_2O_4^{2-}$ and PO_4^{3-}

Spot tests and flame tests to be carried out wherever possible.

Part B- Physical Chemistry Practicals

1. Determination of the enthalpy of neutralization of a strong acid with strong base.
2. Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.
3. The study of kinetics of potassium persulphate and potassium iodide volumetrically.
4. Determination of velocity constant for acid catalyzed hydrolysis of methyl acetate.
5. Determination of velocity constant for the saponification of ethyl acetate ($a = b$) volumetrically.
6. Determination of equivalent conductivity of strong electrolyte and verification of DHO equation.
7. Determination of dissociation constant of weak acid by conductivity method.
8. Conductometric titration of strong acid and strong base.
9. Conductometric titration of weak acid and strong base.
10. Determination of the hydrolysis constant of aniline hydrochloride conductometrically.
11. Determination of solubility product of sparingly soluble salt conductometrically.

References

1. Vogel's Qualitative analysis, Revised by G. Svehla, Pearson education, (2002)
2. J B Yadav, Advanced Physical Chemistry, Krishna Prakashan Media (P) Ltd, Meerut. (2015)
3. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
4. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
5. Halpern, A. M. &McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003)
6. Athawale V. D. and Mathur P. Experimental Physical Chemistry, New Age International (2001)

BSc Semester III –Chemistry (Hons)
with Analytical/ Organic/ Inorganic/ Physical specialization

Title of the Course: Open Elective-3:
ATOMIC STRUCTURE, BONDING AND CONCEPTS IN ORGANIC CHEMISTRY

Contact Hours: 42 **Workload: 3 hours per week**

Credit Points: 3

Evaluation: Continuous Internal Assessment - 40 marks
Semester End Examination - 60 marks

Course Objectives:

- To develop an understanding of principles of Atomic structure
- To know the importance of quantum numbers, writing of electronic configurations and representation of orbitals
- To develop an understanding of the periodic trends
- To understand the nature of bonding and to predict the shapes of molecules
- To construct MO energy level diagrams and predict the properties of molecules
- To understand the formation of sigma and pi bonds and the bond strength.
- To study the classification of organic reactions
- To learn nomenclature preparation and reactions of alkanes, alkenes, alkynes and stability of alicyclic compounds

COURSE OUTCOME:

On completion of the course the student will learn and be able to understand/explain

- the concept of atomic sstructure, significance of quantum numbers, filling of electrons of atoms/ions in various orbitals as per rules
- the trends in periodic properties
- the structures of ionic solids, applications of B-H cycle, solubility of compounds and consequences of polarization of ions

- the shapes of molecules/ions based on VSEPR theory
- the construction of MO energy level diagrams and prediction of properties of molecules/ions like bond order, bond energies, bond lengths and magnetic properties.
- the formation of sigma and pi bonds and the bond strength
- the classification of organic reactions
- nomenclature preparation, and reactions of alkanes, alkenes, alkynes and stability of alicyclic compounds.

Unit I

Atomic Structure

History of an atom. Idea of de Broglie matter waves. Heisenberg uncertainty principle. Schrödinger wave equation, significance of wave functions, Bohr's model of hydrogen atom and its limitations. Quantum numbers and their importance, atomic orbitals and shapes of s, p, d orbitals, Multi-electron atoms, Aufbau's and Pauli exclusion principle and Hund's multiplicity rule- Electronic configurations of the elements (atomic no. up to 30), effective nuclear charge and shielding.

8 hrs

Periodic Properties

Atomic radius, covalent, ionic and van der Waal radii-explanation with examples. Definition and periodicity of the following properties - ionic radii, ionization potential, electron affinity and electronegativity, methods of determination of electronegativity. Factors affecting the values of ionization energy.

6 hrs

Unit II

Chemical Bonding

Ionic Solids– Ionic structures (NaCl, CsCl, TiO_2, ZnS), radius ratio rule and coordination number, limitation of radius ratio rule, lattice energy and Born-Haber cycle, solvation energy and solubility of ionic solids, polarizing power and polarizability of ions, Fajan's rule and their consequences.

4 hrs

Covalent Bond – Valence bond theory and its limitations, directional characteristics of covalent bond, various types of hybridization with examples and shapes of simple inorganic molecules and ions. Shapes of NH_3, I_3^+, I_3^-, SF_4, ClF_3, IF_5, ICl_2^- and H_2O using valence shell electron pair repulsion (VSEPR) theory, linear combination of atomic orbitals (LCAO), bonding, nonbonding and antibonding molecular orbitals, physical picture of bonding and antibonding wave functions. Applications of MO theory to explain the stability of homo dinuclear (He_2, N_2, O_2, F_2, C_2) and hetero dinuclear (NO and CO) molecules. Comparison of M.O. and V.B. Models.

7 hrs

Metallic bond-free electron, Band theory – electrical properties of metals, semiconductors and insulators.

Weak interactions – Hydrogen bonding and its consequences, van der Waals forces.

3 hrs

Unit III

Bonding and molecular structure and hydrocarbons

Bonding and molecular structure: Introduction to organic chemistry, atomic orbitals, sigma and pi bond formation-molecular orbital [MO] method, sp, $sp^2$and sp^3 hybridization, bond length, bond dissociation energies and bond angles (open chain

and cyclic compounds). Electronegativity and polarity of the bonds. Classification and reactions of organic compounds (with examples).

7 hrs.

Aliphatic Hydrocarbons: Alkanes, Alkenes and Alkynes

Definition, Nomenclature, preparations (any two methods)

Reactions: Electrophilic, nucleophilic and free radical addition reactions

Alicyclic compounds:

Nomenclature, preparation and stability of cyclopropane, cyclobutane, Cyclopentane and cyclohexane.

7 hrs.

Reference Books:

1. J. D. Lee, Concise Inorganic Chemistry, ELBS (1996)
2. A. K. Das, Fundamental Concepts of Inorganic Chemistry, CBS; 2nd edition (2019)
3. James E. Huheey, Ellen A. Keiter, Richard L. Keiter Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education India; 4th edition (2006)
4. Shriver, D.F. & Atkins, P.W Inorganic Chemistry, Oxford University Press (2009)
5. Herbert Meislich Howard Nechamkin and Jacob Sharefkin Schaum's Outline of Organic Chemistry Theory and Problems of Organic Chemistry. McGrawHill Book Co; (1980)
6. Morrison and Boyd, Organic Chemistry, Sixth Edition ,Pearson Education India; 7th edition (2010)
7. I.L. Finar Organic Chemistry Vol. 1 Pearson Education India; 6th edition (2002)

BSc Semester IV –B Sc / B Sc(Honors) with Analytical/ Organic/ Inorganic/ Physical specialization

Title of the Course: Open Elective-4:

Electrochemistry, Corrosion and Metallurgy

Contact Hours: 42 **Workload: 3 hours per week**

Credit Points: 3

Evaluation: Continuous Internal Assessment - 40 marks

Semester End Examination - 60 marks

This course provides a broad introduction to the fundamental principles of electrochemistry, corrosion and metallurgy. The student will gain an understanding of basic and practical applications in various fields of electrochemistry, corrosion and metals and alloy behaviour and manufacturing processes. This course is a valuable prerequisite for taking more technically challenging courses that will be required for career development.

Course Objectives This course will deal with

1. Types of conductance, concept of electrolytes, electrolysis, redox reactions and EMF
2. Concept of different types of electrochemical cells, Types of electrodes and electrode potential. Application of electrochemical series.
3. Basic principles and applications of conductometric, potentiometric and pH titrations.
4. Different types of Batteries their principle construction and working - lead-acid storage and lithium ion battery. Study of Fuels cells.
5. Concept of corrosion, types of corrosion and its prevention by different methods. Introduction to electroplating.

6. Introduction to ores and minerals, extraction of metals from their ores, and purification. Eg., Manganese, Titanium and Uranium.
7. Study of alloys, classification, production and uses of alloys.

Course Outcomes Upon completion of the course students will be able to

1. Understand the concept of conductance in electrolytic solutions, electrolysis and redox reactions involved in electrode reactions.
2. Learn the different types of electrochemical cells, their symbolical representation and application of electrochemical series.
3. Apply conductometric, potentiometric and pH titrations
4. Know the principle, construction and working of batteries
5. Understand different types of corrosion and its prevention by different methods 6.Learn the methods of extraction of metals from their ores and purification

UNIT I

Electrochemistry

Conductance, specific and molar conductance, Types of electrolytes, conductivity in electrolytic solution, electrolysis, Kohlrausch's law and its application, equivalent conductance of weak electrolyte at Infinite dilution.

Oxidation -reduction reactions, electrode potential, EMF of an electrochemical cell, cell reaction, Daniel cell, dry Cells - electrolytic and Galvanic cell, Representation of a cell. Standard electrode potential, Nernst equation (No derivation) and its application to chemical cell, Electrochemical series and its importance. Types of Electrodes.

Basic Principles of (i) Conductometric titrations- HCl Vs NaOH, CH_3COOH Vs NaOH

(ii) Potentiometric titrations: Acid-base titration HCl Vs NaOH, Redox titration (FAS Vs $K_2Cr_2O_7$)

Determination of p^H using glass electrode.

12 hrs.

Batteries- Primary and secondary batteries, Battery components and their role. Working of the Lead acid and Lithium storage batteries, Fuel cells. **2hrs**.

UNIT II

Corrosion:

Introduction, definition, Types of corrosion, corrosion rate, factors affecting corrosion rate, Metallic factor-purity, electrode potential of metal, hydrogen over voltage, nature of corrosion product. Environmental factors-Temperature, pH of the medium, humidity, presence of impurities, electrical conductivity, velocity and concentration of the medium.

Prevention of Corrosion: Material selection - Metals and alloys, metal purification, non-metallic, Alteration of environment - Changing media, inhibitors, Design-wall thickness, design rules, Coating-Metallic and other inorganic coatings, organic coating.

Electroplating: Introduction, Electroplating of chromium (hard and decorative). Electroless plating: Introduction, distinction between electroplating and electrode plating processes. Electroless plating of copper.

14 hrs.

UNIT III

Metallurgy

Introduction: Ore, minerals, important ores of some common elements in India, General principles of pyrometallurgy, roasting, calcination, gangue, smelting, flux, gravity separation, froth flotation process, leaching. Techniques employed for purification of metal :Distillation process, Bessemerization, Electro-refining ,Van Arkel and De Boer's process.

6 hrs.

Extraction of metals: Extraction of Manganese (Pyrolusite), Titanium (Ilmanite) and Uranium.

4 hrs.

Alloys: Introduction, Classification of alloys, commercially important alloys, gold karats, Production of Ferro alloys- Ferrochrome, Ferromanganese, Uses of alloys.

-4 hrs.

Reference Books

1. Barrow. G.M, Physical chemistry, Tata McGraw-Hill, (2007)
2. An introduction to electrochemistry, Samuel Glasstone, East-West edition New Delhi, (1942)
3. Text book of physical chemistry, Samuel Glasstone, 2nd Edition, Mac Millan India Ltd, (1991)
4. Principles and applications of electrochemistry, D. R. Crow, 3rd edition, Chapmanhall London, (1988)
5. Fundamentals of electrochemical deposition, Milan Paunovic and Mordechay Schlesinger, Wiley Interscience Publications, New York, (1998)
6. Engineering Chemistry, V R Kulkarni and K Ramakrishna Reddy, New Age International, (2015)
7. Electrochemistry and corrosion Science, Nestor Perez, Springer (India) Pvt. Ltd., (2004)
8. Principles and prevention of corrosion, D. A. Jones, Macmillan Publ. Co., (1996)
9. Essential of materials science and engineering, Donald R. Askeland, Thomson Learning, 5th Edition, (2006)
10. Introduction to engineering materials, B. K. Agarwal, Tata McGraw Hill, 1st Edition (2013)
11. Material science and engineering, V. Raghavan, PHI Learning, 5th Edition (2004)
12. Engineering materials and metallurgy, R. K. Rajput, S. Chand - 1st Edition, (2011)

B.Sc III & IV SEMESTER MODEL QUESTION PAPER

CHEMISTRY

Time:2.5 h Max. marks :60

Note : all sections are compulsory

SECTION-A

1. Answer any FIVE of the following 5x2=10
   a.
   b.
   c.
   d.
   e.
   f.
   g.

SECTION-B

Answer any FOUR of the following4x5=20

2.
3.
4.
5.
6.
7.

SECTION-C

Answer any THREE of the following 3x10=30

8.
9.
10.
11.
12.

Note: Section C may include sub questions, a, and b

B.Sc III & IV SEMESTER MODEL QUESTION PAPER

CHEMISTRY OPEN ELECTIVE

Time:2.5 h Max. marks :60

Note : all sections are compulsory

SECTION-A

1. Answer any FIVE of the following 5x2=10
   a.
   b.
   c.
   d.
   e.
   f.
   g.

SECTION-B

Answer any FOUR of the following 4x5=20

2.
3.
4.
5.
6.
7.

SECTION-C

Answer any THREE of the following3x10=30

8.
9.
10.
11.
12.

Note: Section C may include sub questions, a, and b

INTERNAL ASSESMENT (as on 4th October meeting proceedings)

DISCIPLINE CORE	DISCIPLINE/OPEN ELECTIVE	PRACTICALS
60+40 (IA)	60+40 (IA)	25+25 (IA)
Class Test-20	Class Test-20	Continuous evaluation & class test-15
Seminars/Assignment-10	Seminars/Assignment-10	Record/Attendance- 5+5
Activity/Opendiscussion-10	Activity/Opendiscussion-10	

Discipline Core Course

V - Semester

Paper V (Inorganic chemistry - III & Organic chemistry - III)

INORGANIC CHEMISTRY – III (28 Hours)

Coordination compounds 10 hours

Coordination compounds- difference between double salts and complex salts with examples. Ligands

-definition and their classification (mono, bi, tri, tetra, penta and hexadentate ligands and ambidentate ligands), examples for each class.

Coordination number- definition with examples. Nomenclature of coordination compounds in detail.

Theories of structure and bonding: explanation for the formation of complexes by Werner's Theoryin detail and its limitations. EAN rule- statement with illustrations.

Valence bond theory: postulates, low spin and high spin complexes with examples, limitations ofVBT.

Crystal field theory: (octahedral, tetrahedral and square planar complexes). Crystal field splitting and crystal field stabilization energies- definition and illustrations with examples. Limitations of CFT. Magnetic properties of $[CoF_6]^{3-}$, $[Co(NH_3)_6]^{3+}$, $Fe(CN)_6]^{4-}$,$[Fe(CN)_6]^{3-}$. Spectral properties of $[Ti(H_2O)_6]^{3+}$, $[Co(H_2O)_6]^{3+}$, $[CoCl_4]^{2-}$. Isomerism in complexes: Structural isomerism - ionization, linkage, hydrate and coordination isomerism with examples. Stereoisomerism- geometrical and optical isomerism of coordination compounds with coordination number 4 and 6 with examples.

Organometallic compounds 4 hours

Organometallic compounds - ligands, classification (hapticity). Synthesis and structure of $K[PtCl_3(\eta^2\text{-}C_2H_4)]$ and $[Fe(\eta^5 - C_5H_5)_2]$.

Metal carbonyls: Structures of $Cr(CO)_6$, $Co_2(CO)_8$, $Mn_2(CO)_{10}$; eighteen electron rule and its deviations with examples. Applications of coordination/organometallic compounds: cis-platin in cancer therapy, Na_2Ca EDTA in the treatment of heavy metal (Pb, Hg) poisoning, Wilkinson's Catalyst in alkene hydrogenation, Monsanto acetic acid process.

Nuclear and Radiochemistry 8 hours

Review of the property of radioactivity, types of radiations and their properties, atomic number and mass number, isotopes and isobars.

Nucleus – nucleons, nuclear force, nuclear density, stability - explanation using meson theory, n/p

ratio, n versus p graph. Mass defect; Binding energy - definition, graph, calculation of binding energy to show that 1 *amu* = 931MeV. Explanation of the instability of the nuclei. Problems.

Radioactive decay law, derivation of $N = N_0 e^{-\lambda t}$, half life period of a radioisotope, relationship between half life and decay constant, numerical problems. Radioactive equilibrium - explanation, introduction of the terms parent and daughter elements. Group displacement law - statement and explanation taking examples; radioactive series - U, Th, Ac and Np series (mention of the first and last stable elements, number of α and β particles. Type of series namely 4n, (4n+1), (4n+2) and (4n+3).

Artificial radioactivity: Rutherford's first artificial transmutation, induced radioactivity; nuclear reactions – differences between chemical and nuclear reactions; reason for the large amount of Q value; symbolic representation of a nuclear reaction, introduction of the term projectile, comparison of neutron, proton, α, γ and deuteron as projectiles. Examples of nuclear reaction induced by γ-radiation, α, n, p and deuteron. Nuclear fission - explanation with an example, chain reaction, principle of atomic bomb, calculation of energy liberated, fissionable isotopes. Nuclear fusion - explanation with an example, thermonuclear reaction, advantages and disadvantages of fusion over fission, principle of hydrogen bomb. Nuclear reactors - principle, working of a thermal reactor, diagram, and explanation of the terms like nuclear fuel, control rods, moderators and coolant. Breeder reactors- brief explanation of the functioning. Atomic energy programme in India. Use of radio isotopes in tracer technique - agriculture (phosphorous in agriculture research), medicine (phosphorous to check crack in bones, sodium/iodine to detect clots in blood vessels), food preservation.

Carbon dating - formation of radioactive carbon in the atmosphere. Explanation of the determination of age of wood or peat or fossil. Numerical problems on carbon dating.

Steel and Alloys — 6 Hours

Manufacture of steel by Bessermer process. (Removal of silicon, decarbonisation, demanganisation, desulphurisation, dephosphorisation) and surface treatment (argon treatment, heat treatment, nitriding, carburizing). Composition and properties of different types of steels (role of Ni, Cr, Mo, Si, Mn, V, W, Al).

Classification of alloys - ferrous alloys (iron base alloys -cast iron and steel, tool steel, stellite hard alloy) and non-ferrous alloys (copper, lead and tin alloys – composition of brass, bronze, cupro nickel, manganin, constantan, antifriction bearing, cable alloys, solders, Pb-Sn, Pb-Sb) Specific properties of elements in alloys (role of Ti in Al and Mg alloys, Ni in copper and iron alloys, Sn and Cu in lead base alloys).

ORGANIC CHEMISTRY – III (28 Hours)

Aldehydes and Ketones 5 hours

Nomenclature: Relative reactivity of aldehydes and ketones towards Nucleophilic addition reactions. General mechanism of condensation with ammonia and its derivatives (NH_2−R; R = −NH_2, −OH, −NH−CO−NH_2).

Mechanisms of: acetal formation, Claisen condensation, Knoevenagel condensation and benzoin condensation. Reduction: Reduction by $LiAlH_4$ and $NaBH_4$. Mechanism of Clemmensen and Wolff-Kishner reductions.

Carboxylic acids and their derivatives 7 hours

Nomenclature of Di and tri carboxylic acids: Action of heat on dicarboxylic acids (oxalic acid, malonic acid, succinic acid, glutaric acid and adipic acid).

Hydroxy acids: Reactions of tartaric acid and citric acid – (i) action of heat and (ii) reduction with HI.

Reactions of acid chlorides (example: acetyl chloride) - hydrolysis, reaction with alcohol, ammonia and lithium dialkylcuprates.

Reactions of acid anhydrides - hydrolysis, reaction with alcohol, ammonia. Reactions of amides - hydrolysis, reduction.

Reactions of esters - alkaline hydrolysis, ammonolysis and alcoholysis. Mechanism of ester hydrolysis - acid and base catalysed (acyl O-cleavage: $B_{AC}2$, $A_{AC}2$; alkyl O-cleavage: $A_{AL}1$ mechanisms).

Amines 7 hours

Classification, nomenclature, preparation of alkyl and aryl amines - reductive amination of carbonyl compounds (Ethanamine and 2-propanamine), Gabriel phthalimide synthesis (Ethanamine), reduction of nitrobenzene, Hoffmann's bromamide reaction. Relative basicity of amines in aqueous solution, explanation using inductive, resonance, steric and solvation effects [(a) ammonia, methyl amine, dimethyl amine and trimethyl amine (b) methyl amine and aniline].

Reactions - amines as nucleophiles (methylation and acylation), formation of quaternary ammonium salts (reaction of tertiary amine and alkyl halide), distinguishing reactions of 1^o, 2^o and 3^o amines (Reactions with equations for Hinsbergs test).

Diazotization: formation of benzene diazonium chloride.

Synthetic applications of benzenediazonium chloride in the preparation of (i) chlorobenzene, bromobenzene and benzonitrile by Sandmeyer's reaction (ii) phenol (iii) phenyl hydrazine and aniline by reduction reaction and (iv) p-hydroxyazobenzene and 1- phenylazo-2-naphthol by coupling reaction.

Tautomerism and Enolates 4 hours

Tautomerism in carbonyl compounds – keto-enol tautomerism; oxime-nitroso tautomerism. Acidity of α-hydrogen atoms in aldehydes, ketones and active methylene compounds (example: diethyl malonate, ethyl acetoacetate and acetyl acetone).

Preparation of diethyl malonate from acetic acid and synthetic applications of diethyl malonate (preparation of monocarboxylic acids - butanoic acid, dicarboxylic acid - adipic acid, unsaturated acids -cinnamic acid, ketones - butanone, cyclic compounds - barbituric acid).

Preparation of ethyl acetoacetate (from ethyl acetate). Synthetic applications of ethyl acetoacetate (preparation of monocarboxylic acids - butanoic acid, dicarboxylic acid - succinic acid, unsaturated acids- crotonic acid and cinnamic acid, ketones - butanone).

Rearrangements 4 hours

Wagner - Meerwein, Fries, Beckmann, Hoffmann rearrangements. Benzil - benzilic acid rearrangement, Favorskii rearrangements and Baeyer - Villiger oxidation.

Paper VI (Physical chemistry - III & Spectroscopy - I)

PHYSICAL CHEMISTRY - III (42 Hours)

Chemical Dynamics 8 hours

Macroscopic and microscopic kinetics, Review of theories of reaction rate-Collision theory and Transition state theory, Comparison of collision theory with transition state theory, Arrhenious equation- characteristics, Significance of energy of activation, Temperature coefficient and its evaluation. Thermodynamical formulation of reaction rates (Wyne-Jones and Eyring treatment), Reaction between ions in solutions - Influence of ionic strength on reaction rates (primary and secondary salt effects). Numerical problems.

Concept of Steady state kinetics, Chain reactions - chain length and chain inhibition, comparison of photochemical and thermal reactions, Mechanisms of thermal and photochemical reactions between hydrogen-bromine and hydrogen-chlorine. Comparative study of thermal and photochemical hydrogen-halogen reactions.

Photochemistry 5 hours

Laws of photochemistry (Grotthus - Draper and Stark-Einstein laws). Quantum yield (definition, Einstein and its significance). Actinometry (explain uranyl oxalate actinometer for measurement of energy of radiation absorbed). Examples of low and high quantum yields (examples for $\phi = 1$, $\phi < 1$ and ϕ very high): Photochemical combination of (i) H_2 and Cl_2 (ii) H_2 and Br_2 (iii) dissociation of HI. Photochemical equilibrium (Statement) and the differential rate of photochemical reactions (derivation of an expression for rate). Photosensitized reactions (explanation taking example), quenching (explanation taking example). Singlet and triplet states, Fluorescence and phosphorescence (explanation using Jablonski diagram). Role of photochemical reactions in biochemical processes (bioluminescence), photo stationary states, chemiluminescence (definition and example).

Phase Equilibria 7 hours

Phases, components and degrees of freedom of a system (explanation of the terms taking suitable examples), criteria of phase equilibrium (thermal, mechanical and chemical). Gibb's Phase Rule and its thermodynamic derivation.

Phase diagrams of one-component systems (water and sulphur - phase diagram, explanation of the various equilibria, triple point, effect of external pressure on transition temperatures, calculation of degree of freedom). Two component systems (condensed phase rule) involving eutectics, congruent and incongruent melting points (lead-silver system- phase diagram, effect of impurity elements on the melting point, calculation of degree of freedom, eutectic mixture - definition, composition and applications, cooling of molten mixtures and Pattinson's process. $FeCl_3$ - H_2O system phase diagram, freezing mixture-definition and applications. Na - K system phase diagram).

Ionic equilibria 6 Hours

Common ion effect: statement and example (ammonium hydroxide - ammonium chloride and acetic acid - sodium acetate). Buffers: Types and examples. Buffer action and buffer capacity. pH of buffers- Henderson's equation and its derivation for acidic and basic buffers. Problems in calculating the pH of buffers. Solubility product and ionic product definitions and their applications in the precipitation of II and IV group basic radicals in the qualitative analysis of simple salt mixtures. Analytical and biological applications of buffers. Numerical problems.

Theories of indicators (Mentioning the different theories). Acid-base theory by taking phenolphthalein and methyl orange as examples.

Electrochemistry 8 Hours

Reversible and irreversible cells (Definition and examples, Introduction of an electrochemical cell and explanation taking suitable examples). Concept of EMF of a cell (origin of EMF in an electrochemical cell, oxidation and reduction reactions, single electrode potential, reduction and oxidation potentials and formula for EMF). Measurement of EMF of a cell (compensation method, mention of standard cell-Weston cadmium cell) Nernst equation (derivation from free energy concepts for a cell and then to a single electrode) and its importance. Numerical problems. Types of electrodes [examples and their applications (i) metal/metal ion electrode - Zn/Zn^{2+} and Cu/Cu^{2+} (ii) metal/insoluble salt/anion electrode-calomel and Ag/AgCl electrodes.

(iii) metal/gas-ion electrode- hydrogen electrode (iv) inert metal/ organic compound electrode-quinhydrone electrode (v) Glass electrode (vi) Red-ox electrode]. Standard electrode potential (definition, explanation of the importance of reference electrodes, mention of primary-SHE and secondary reference electrodes-calomel electrode, convention of representing a cell, differences between standard reduction potential and standard oxidation potential,) Electrochemical series (definition, SRP values of common reference electrodes, uses). Thermodynamics of a reversible cell (equations depicting relationship between free energy change, enthalpy change, entropy change, equilibrium constant and EMF), calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data. Calculation of equilibrium constant from EMF data (Numerical problems). Concentration cells with transference and without transference (definition and examples) Liquid junction potential (definition) and salt bridge (significance). pH determination using hydrogen electrode, Glass and quinhydrone electrodes (setting up of a suitable electrochemical cell, measurement of EMF and calculation of pH).

Quantum Mechanics - II **6 hours**

Concepts of Operators: Laplacian, Hamiltonian, Linear and Hermitian operators. Angular Momentum operators and their properties. Commutation of operators. Solutions of Schrödinger wave equation for a particle in a three-dimensional box. Quantum mechanical degeneracy, tunneling (no derivation). Application of Schrödinger equation to harmonic oscillator and rigid rotator (*Equations to be assumed*). Eigen functions and eigen values of angular momentum. Ladder operator method for angular momentum.

Schrödinger equation to hydrogen atom in spherical polar co-ordinates (No derivation). Solution

of Θ, Φ, R equation and statements of solution of R equation. Total wave functions of hydrogen atom. Quantum numbers and their characteristics.

SPECTROSCOPY - I (14 Hours)

Molecular Spectroscopy:

Interaction of electromagnetic radiation with molecules (emission and absorption spectra, electromagnetic spectrum in terms of wave length/wave number, difference between atomic and molecular spectra and molecular energy levels) and various types of spectra (UV, IR, MW, Raman, and NMR and mention of the region), Born - Oppenheimer approximation (statement and explanation).

Rotation spectroscopy

(Expressions for energy of diatomic rigid rotor in terms of *joule* and m^{-1}, rotational constant, reduced mass, moment of inertia and spacing between rotational levels) Selection rules [statement, expression for frequency for transition between J to (J+1), condition for absorption and spacing between spectral lines], intensities of spectral lines (explanation based on populations of energy levels), determination of bond lengths of diatomic molecules. Numerical problems.

Vibrational spectroscopy

Classical equation of vibration (mention of expression for frequency/wave number for diatomic S H O), computation of force constant (definition of force constant, significance and statement of Hooke's law) amplitude of diatomic molecular vibrations (potential energy curve for diatomic SHO, expression for vibrational energy (from solutions to Schrödinger wave equation), zero point energy, selection rule, condition for absorption and fundamental vibrational frequency). Anharmonicity (difference in potential energy curves for SHO and others), Morse potential (energy expression for anharmonic oscillator, selection rules), dissociation energies, fundamental frequencies, overtones (compare the intensities), hot bands, degrees of freedom for polyatomic molecules (linear and non-linear – explanation taking suitable examples), modes of vibration

(stretching and bending vibrations – types, comparison of frequencies, sketching of vibrational modes for CO_2 and H_2O), concept of group frequencies. Vibration-rotation spectroscopy – (pure vibrational spectra in liquids and mixing of vibration and rotational levels) diatomic vibrating rotator (expression for energy, selection rule and expression for energy change), P, Q, R branches explanation using diagram).

Raman spectroscopy

(Raman scattering, Rayleigh scattering, polarisability and Raman shift) Qualitative treatment of Rotational Raman effect (selection rule, expression for energy difference of a rigid diatomic rotor); Vibrational Raman spectra (selection rule) Stokes and anti-Stokes lines (explanation using diagram); their intensity difference, rule of mutual exclusion (explanation using molecules such as CO_2, O_2, N_2 etc.).

Electronic spectroscopy

(Complexity of electronic spectra), Franck-Condon principle (statement and demonstration using potential energy vs. internuclear distance plot), electronic transitions (HOMO, LUMO, bonding, antibonding and non-bonding orbitals, energy level diagram, examples for $\sigma \rightarrow \sigma^*$, $\pi \rightarrow \pi^*$, $n \rightarrow \sigma^*$ and $n \rightarrow \pi^*$ transitions). Dissociation and pre-dissociation (chemical reactions and non-radiative transitions), calculation of electronic transitions of polyenes using free electron model (qualitative explanation of electronic spectra of conjugated systems using free electron molecular orbital theory and formula for calculation of frequency of electronic transition taking butadiene as an example).

Nuclear Magnetic Resonance (NMR) spectroscopy

Principles of NMR spectroscopy (nuclear spin, examples for half integral, zero and integral values, magnetic moment, orientations in an external magnetic field and absorption of radiofrequency and magnetic resonance), Larmor precession (definition, Larmor frequency and an expression),

Paper VII (Inorganic chemistry - IV & Physical chemistry - IV)

INORGANIC CHEMISTRY – IV (28 Hours)

UNIT - I

Industrial Materials- I **6 Hours**

Refractories: Definition**.** Properties of a good refractory, classification, determination of PCE values.

Abrasives: Definition and classification with examples, applications, hardness-definition and magnitude of hardness, manufacture and importance of carborandum and tungsten carbide.

Glass: Properties, types, manufacture of soda glass. Composition and applications of borosilicate, metallic glass, optical glasses and polycarbonate glass, safety glass, fire and bullet proof glasses.

Ceramics: Raw materials and their roles, varieties of clay, production of ceramic ware, glazing,ceramic insulators.

Cement: Raw materials, manufacture of Portland cement (by wet process), setting of cement, role of water and gypsum.

Industrial Materials - II **7 Hours**

Paints and Varnishes: Constituents of oil and emulsion paints and their role. Constituents of varnishes.

Fuels: Characteristics, calorific value - definition and its determination using bomb calorimeter.

Coal – varieties. Gaseous fuels- advantages, constituents and their significance. Production of Coalgas, composition of LPG. Octane number-definition and significance.

Explosives: Classification, preparation of dynamite and TNT. Propellants: Characteristics, classification and their applications.

Fertilisers **4 Hours**

Different types of fertilizers (definition and examples) Classification based on agrochemical nature (Direct and Indirect) Based on number of basic nutrients (Simple, double/triple, micro and complex) Based on application (Single and mixed fertilizers)

Manufacture of the following fertilizers (Method, drying and finishing)

Urea (Sindri method), Ammonium nitrate (Production-Prilling process, drying- Stengel process; Finishing- Nitrochalk / parting agents), Calcium ammonium nitrate (From ammonia. nitric acid and limestone), Ammonium phosphates and polyphosphate (from ammonia and phosphoric acid), Superphosphate (from rock phosphate and sulphuric acid), Potassium chloride (Manufacture from Carnallite, Sylvinite), Potassium sulphate (Manufacture from Kainite).

Chemistry of Newer materials 11 Hours

Nanomaterials: Overview of nanostructures and nanomaterials (Introduction, Nanostructures - types with examples. Nano materials-Size, shape, specific surface area, crystallinity, solubility and surface morphology; Reasons for special properties attributed to materials with nano size) Classification (Classification of nano materials based on dimensions & type of material - organic, inorganic) Preparation of gold and silver metallic nanoparticles (Turkevich method) self-assembled nanostructures (definition, types of synthesis). Carbon nanotubes (definition, SWCNT & MWCNT, brief structure & applications) and inorganic nanowires (examples).

Conducting polymers: Introduction, definition and examples- polyaniline, polyacetylene. Mechanism of conduction. Qualitative treatment of doping. Properties: elasticity with high electricalconductivities, Engineering and biological applications.

Superconductors: Introduction, definition, type-1, type-2 and atypical. Preparation of high temperature superconductor- $Y_1Ba_2Cu_3O_{x\pm\delta}$. BCS theory (qualitative treatment only) and general applications of high temperature super conductors.

Fullerenes: Introduction, definition, preparation and isolation of C_{60}. Structure and chemical reactions (redox reactions, electrophilic aromatic substitution and bromination) of C_{60}.Commercial uses of C60.

PHYSICAL CHEMISTRY – IV (28 Hours)

Electroanalytical methods 12 Hours

Introduction. Classification of electroanalytical methods (explanation of the principle of pH meter, conductometer and potentiometer). Potentiometric (acid base and redox, calibration, choice of electrodes) and conductometric (acid base - 4 types, conductivity cell, cell constant and its determination) titrations. Techniques used for the determination of equivalence points (comparison of use of indicator and graphical method). Techniques used for the determination of pKa values (conductometry and potentiometry). Advantages of conductometric and potentiometric methods.

Voltametry: Polarography – Type of mercury electrodes – types of mass transport – Faradaic and non-Faradaic currents. Polarogram – sign conventions.

Cyclic voltametry: Principle – explanation of electro-oxidation and electro-reduction based on Frontier orbitals. Reversible and irreversible and quausi reversible electrochemical processes. Ilkovic equation and its applications. Current - potential relation for a cathodic process - half wave potential and its significance. Experimental setup for electrochemical reversible system based on potassium ferricyanide.

Thermal methods of analysis: (Introduction to gravimetry) Theory of thermogravimetry (TG),

basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg.

Thermodynamics 8 Hours

Gibb's-Helmholtz equation - derivation from dG = VdP – SdT. Concepts of partial molar properties - partial molar free energy, chemical potential, partial molar volume and its significance. Derivation of Gibbs-Duhem equation.

Concept of fugacity: Determination of fugacity by graphical method. Activity and activity coefficient and its significance.

Derivation of van't Hoff reaction isotherm, van't Hoff reaction isochore and Clausius-Clapeyron equation. The application of Clausius-Clapeyron equation to the determination of ΔT_b and ΔT_f (in detail with derivations). Numerical problems. Nernst heat theorem (qualitative treatment only).

Flame atomic and absorption spectrometry 4 Hours

Basic principles of instrumentation (choice of source, monochromator, detector, choice of flame and burner designs). Techniques of atomization and sample introduction. Method of background correction. Sources of chemical interferences and their method of removal.

Physical properties and Molecular structures 4 Hours

Dipole moment (a brief review). Polarization and orientation of dipoles in an electric field. Clausius-Mossotti equation (derivation). Electrical properties of solids: types of solids-metals, insulators and semiconductors. Pyroelectricity, piezoelectricity, ferroelectricity, inverse piezoelectricity. Definition and examples. Thomson effect, Seebeck effect and Peltier effect - definitions with examples.

Paper VIII (Organic chemistry - IV & Spectroscopy - II)

ORGANIC CHEMISTRY – IV (42 Hours)

Heterocyclic compounds 5 Hours

Introduction: Nomenclature of heterocyclic compounds. Aromaticity of pyrrole, furan, thiophene and pyridine. Comparison of their aromaticity and with benzene Structure, reactivity, synthesis and reactions of: pyrrole, furan, thiophene, pyridine. Structures of indole, pyrimidine and purine.

Chemistry of Natural Products 12 Hours

Carbohydrates: Introduction and classification (based on number of monosaccharide units and sugars and non-sugars) with examples. Monosaccharides: Definition with examples, classification of monosaccharides (based on functional group).

Aldoses: Structures of D-aldohexoses (glucose, galactose and mannose). Open and Haworth structures. Epimers (Example: D-galactose and D-glucose, D-glucose and D-mannose). Elucidation of open chain structure of D-glucose. Limitations of open chain structure of glucose. Mechanism of mutarotation and anomeric effect.

Elucidation of ring structure and size of D-glucose by oxidation with HIO_4 and HNO_3.

Ketoses: Structure of fructose-pyranose and furanose forms. Inter-conversion of glucose and fructose Disaccharides: Definition with examples. Formation of glycosidic bond with examples. Haworth and conformational structures of maltose, lactose and sucrose.

Terpenes and terpenoids: Occurrence, isoprene rule and classification (on the basis of number of isoprene units, acyclic and cyclic). Elucidation of structure and synthesis of citral (from methyl heptenone) and zingiberene (from methylheptenone and *p*-methoxyphenylmagnesium bromide). Structures and uses of limonene, menthol, α-terpineol, and camphor.

Alkaloids: Introduction, classification (based on heterocyclic ring present) and general characteristics. Structural elucidation and synthesis of nicotine (from succinimde). Structures and uses of ephedrine, caffeine, cocaine, atropine, quinine and morphine.

Polymers 4 Hours

Brief introduction (definition of polymers and polymerization); preparation, structure, properties and application of the following polymers: Polyolefins – polystyrene and styrene copolymers (BUNA-S), polyvinyl acetate. Acrylic polymers – polyacrylonitrile. Fluoropolymers - teflon, Polyamides - nylon-6,6. Phenol formaldehyde resins – Bakelite. Polyurethanes. Silicone polymers and Polycarbonates.

Pharmaceutical chemistry 4 Hours

Chemotherapy. Drugs: classification of drugs (i) drugs used for the treatment of diseases due to infection (antimalarial, sulpha drugs, antibiotics and antiseptic drugs with examples) (ii) drugs used for the treatment of diseases not due to infection (antipyretics, analgesics, anesthetics, tranquilizers and hypnotics, narcotics, anticonvulsants, cardiac or cardiovascular and diuretics drugs with examples**).** Synthesis of (i) asprin (from phenol), (ii), paracetamol (from phenol),

(iii) chlorophenaramine, (iv) sulphanilamide (from acetanilide). Structure and uses of (i) Penicillin and (ii) cephalosporin.

Green chemistry 2 Hours

Introduction. Principles of Green chemistry with examples - special emphasis on atom economy, reducing toxicity and green solvents. Green chemistry and catalysis (taking the synthesis of ibuprofen as an example).

Lipids 4 hours

Introduction, Classification -simple, complex and derived with examples.

Fatty acids: definition, classification as saturated and unsaturated with examples and structure (lauric, myristic, palmitic, stearic, oleic, linoleic, linolenic and arachidonic acids). Essential fatty acids - definition with examples.

Triglycerides: Structure of simple and mixed glycerides, properties of triglycerides- acid and alkali hydrolysis, saponification number and its significance, iodine number and its significance, rancidity (oxidative and hydrolytic), causes and prevention. Biological importance of triglycerides.

Phosphoglycerides: General structure of 3-Sn–phosphatidic acid, lipid bilayer (as in cell membrane), micelles, liposomes and its applications, structure and biological importance of lecithin, cephalin, phosphatidylserine, phosphatidylinositol.

Cholesterol: structure, biological & clinical significance.

Amino acids & Protiens 5 Hours

α - *Amino acids*: introduction, structure, classification on the basis of polarity of R - groups, essential and non-essential amino acids. Preparation of glycine by Gabriel method. zwitter ion, reaction of amino acids with Ninhydrin, peptide bond, Sanger's, Edman's reaction and their significance.

Proteins: levels of organisations of proteins: primary, secondary, tertiary and quaternary structures with examples (α - helix, β - pleated sheet, triple helix and heamoglobin). Denaturation and renaturation. Anfinsen's experiment; separation of proteins by PAGE.

Enzymes 4 hours

Introduction, holoenzyme (apo enzyme and co-enzyme). Active site, specificity (Group, absolute and stereo selectivity with examples). Classification of enzymes (EC code number not required) with examples.Enzyme substrate interaction- Fischer and Koshland models.

Enzyme kinetics - factors affecting rate of enzymatic reactions - enzyme concentration, substrate concentration (mention M. M. equation), pH and temperature. Allosteric enzymes - definition and example. Enzyme inhibitions - Competitive, noncompetitive and uncompetitive inhibition with one example foreach.

Vitamins 2 Hours

Classification. Biological importance and deficiency symptoms of Vitamins A, Vitamin B1 (thiamine), Vitamin B6 (pyridoxine), folic acid, pantothenic acid, riboflavin, Vitamin C, Vitamin E (α-tocopherol), Vitamin H (biotin), Vitamins K_1 and K_2.

SPECTROSCOPY – II: Organic Spectroscopy (14 Hours)

UV Spectroscopy 4 Hours

Introduction. Types of electronic transitions, λ_{max}, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts. Beer-Lambert's law. Woodward – Fieser rules for calculation of λ_{max} Conjugated dienes and α, ß unsaturated carbonyl compounds. Influence of conjugation on λ_{max} absorption in UV-Visible region. Comparison of UV spectra of acetone and methyl vinyl ketone. Graphical representation of spectra of 1,3-butadiene, benzene and lycopene. Applications of UV-Visible spectroscopy.

IR Spectroscopy 4 Hours

Introduction. Basic priniciples of IR Spectroscopy. Conditions for IR active organic compounds. Stretching and bending modes of vibrations. Factors affecting the position of IR absorption peak (atomic and force constant-electronic effects and hydrogen bonding). Types of IR region (functional group region and finger print region). Explanation of stretching frequencies of –OH (free and H-bonded), alkyl C–H, alkenyl C–H, alkynl C–H, C–C, C = C, C–O and C = O groups. (IR spectra of benzene, ethanol, phenol, acetaldehyde, acetone and acetic acid – mention the absorption of functional groups and their identification). Applications of IR spectroscopy.

Nuclear Magnetic Resonance spectroscopy 6 hours

Basic principles of proton magnetic resonance: Nuclear magnetic spin quantum number I, influence of the magnetic field on the spin of nuclei, spin population, saturation using radio frequency. Nuclear magnetic resonance. Chemical shift (δ values), uses of TMS as reference. Nuclear shielding and de-shielding effects. Equivalent and non-equivalent protons. Effect of: (i) electronegativity of adjacent atoms (ii) magnetic induction by pi (π) electrons-Magnetic anisotropy on chemical shift values. Spin-spin splitting and spin-spin coupling (qualitative treatment only). H-NMR spectra of: (i) methane (ii) $CH_3{-}Cl$ (iii) CH_2Cl_2 and (iv) $CHCl_3$ using –I effect. First order splitting rules: Spectra of: (i) Cl_2CHCHO (ii) 1,1,2- trichloroethane and (iii) CH_3CH_2Cl.

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