

Choice Based Credit System (CBCS)

**NOWGONG COLLEGE
(AUTONOMOUS)**



SYLLABUS

DEPARTMENT OF CHEMISTRY

**Learning Outcomes-based Curriculum Framework (LOCF)
of
Undergraduate Programme**

BACHELOR OF SCIENCE

(Effective from Academic Year 2020-21)

**Syllabus Approved in Academic Council
Nowgong College (Autonomous)**

Department of Chemistry

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1. Introduction to Programme

B.Sc. (Honours) Chemistry is a three-year undergraduate program with specialization in Chemistry. The programme fosters interdisciplinary approach to the study of Chemistry, Mathematics, Physics and Biology aiming to promote holistic education. The curriculum is dispensed using a combination of classroom teaching, project-based learning, practical, group discussions, presentations, home assignments, industry interactions and exposure visit, internships and fieldwork.

2. Programme Structure

The B.Sc. (Honours) Chemistry is a three year programme divided into six semesters. A student is required to complete 148 credits for the completion of programme as honours student and 132 credits for the completion of programme as Regular student.

The B.Sc. (Honours) Chemistry programme is aligned with CBCS structure as given in the following Table

Honours Course		Credits		
		Theory with Practical		
		Theory	Practical	Total
Honours Core Course HCC (14 Papers)		14x4=56	14x2=28	84
Honours Discipline Specific Elective Course (HDS) (4 Papers)		4x4=16	4x2=8	24
Honours Generic Elective Course HGE (4 Papers)		4x4=16	4x2=8	24
Ability Enhancement Course AEC	Communication Language (1 Paper)	1x4=4	0	4
	Environmental Studies (1 Paper)	1x4=4	0	4
Skill Enhancement Course SEC (2 Papers)		2x2=4	2x2=4	8
Total		100	48	148

The B.Sc. (Regular Course) in Chemistry programme is aligned with CBCS structure as given in the following Table

Regular Course		Credits		
		Theory with Practical		
		Theory	Practical	Total
Regular Core Course RCC (12 Papers)		12x4=48	12x2=28	76
Regular Discipline Specific Elective Course (RDS) (6 Papers)		6x4=24	6x2=8	32
Ability Enhancement Course AEC	Communication Language (1 Paper)	1x4=4	0	4
	Environmental Studies (1 Paper)	1x4=4	0	4
Skill Enhancement Course SEC (4 Papers)		4x2=8	4x2=8	16
Total		88	44	132

1. Details of Courses in the Programme

Ability Enhancement Compulsory Course (AECC) papers

ENGL/ASSA/HIND/BENG -AEC-1014 (Theory)

ENST-AEC-2014..... (Theory)

3(A) Honours Core Course (HCC) (Credits: 6 each) (14 papers)

CHEM-HCC-1016 INORGANIC CHEMISTRY-I (Theory+ Practical)

CHEM-HCC-1026 PHYSICAL CHEMISTRY- I (Theory+ Practical)

CHEM -HCC-2016 ORGANIC CHEMISTRY-I (Theory+ Practical)

CHEM -HCC-2026 PHYSICAL CHEMISTRY-II (Theory+ Practical)

CHEM -HCC-3016 INORGANIC CHEMISTRY-II (Theory+ Practical)

CHEM -HCC-3026 ORGANIC CHEMISTRY-II (Theory+ Practical)

CHEM -HCC-3036 PHYSICAL CHEMISTRY-III (Theory+ Practical)

CHEM -HCC-4016 INORGANIC CHEMISTRY-III (Theory+ Practical)

CHEM -HCC-4026 ORGANIC CHEMISTRY-III (Theory+ Practical)

CHEM -HCC-4036 PHYSICAL CHEMISTRY-IV (Theory+ Practical)

CHEM -HCC-5016 ORGANIC CHEMISTRY-IV (Theory+ Practical)

CHEM -HCC-5026 PHYSICAL CHEMISTRY-V (Theory+ Practical)

CHEM -HCC-6016 INORGANIC CHEMISTRY-IV (Theory+ Practical)

CHEM -HCC-6026 ORGANIC CHEMISTRY-V (Theory+ Practical)

Honours Discipline Specific Papers (Credits: 6 each)(Any two papers each from of 5th and 6th Semester).

CHEM -HDS-5016 Analytical Methods in Chemistry (Theory+ Practical)

CHEM -HDS-5026 Polymer Chemistry (Theory+ Practical)

CHEM-HDS-6016 Industrial Chemicals and Environment (Theory+ Practical)

CHEM -HDS-6026 Dissertation

Skill Enhancement Courses (Credits: 4 each)

CHEM -SEC-3014 Basic Analytical Chemistry

CHEM-SEC-4014 Pesticide Chemistry

Honours Generic Elective Papers (HGE) (to be offered to other Departments/Disciplines)

CHEM -HGE-1016 CHEMISTRY1

CHEM -HGE-2016 CHEMISTRY2

CHEM -HGE-3016 CHEMISTRY 3

CHEM -HGE-4016 CHEMISTRY4

3 (B). Regular Core Course (RCC)

Ability Enhancement Compulsory Course (AECC) papers

ENGL/ASSA/HIND/BENG-AEC-1014 (Theory)

ENST-AEC-2014..... (Theory)

Regular Core Papers

CHEM -HGE-1016 CHEMISTRY1

CHEM -HGE-2016 CHEMISTRY2

CHEM -HGE-3016 CHEMISTRY 3

CHEM -HGE-4016 CHEMISTRY4

Regular Discipline Specific (RDS) Papers (Any one each from semester 5th and 6th)

CHEM-RDS-5016: ANALYTICAL METHODS IN CHEMISTRY (Theory + Practical)

CHEM-RDS-5026 : POLYMER CHEMISTRY (Theory + Practical)

CHEM-RDS-6016: INDUSTRIAL CHEMICALS AND ENVIRONMENT (Theory + Practical)

CHEM-RDS-6026: GREEN CHEMISTRY (Theory + Practical)

Skill Enhancement Courses

CHEM-SEC-3014: BASIC ANALYTICAL CHEMISTRY (Theory+ Practical/Presentation)

CHEM-SEC-4014: PESTICIDE CHEMISTRY (Theory + Practical/Presentation)

CHEM-SEC-5014: CHEMICAL TECHNOLOGY & SOCIETY (Theory+ Practical/ Presentation)

3. Semester-wise distribution of Courses

4.(A) Semester-wise distribution of Honours Course

SEM	Credit					Total
	Honours Core Course (HCC) 14X6=84 (L+P)/(L+Tu) 4+2	Ability Enhancement Course (AEC) 2X4=8 (L) 4	Skill Enhancement Course (SEC) 2x4=8 (L+P) 4+2	Honours Discipline Specific Elective (HDS) 4x6=24 ((L+P)/(L+Tu) 4+2 / (W+P) 4+2	Honours Generic Elective (HGE) 4x6=24 (L+P)/(L+Tu) 4+2	
I	CHEM-HCC-1016 CHEM -HCC-1026	ENGL/ASSA/ HIND/BENG- AEC-1014			CHEM -HGE- 1016	22
II	CHEM -HCC-2016 CHEM -HCC-2026	ENST-AEC- 2014			CHEM -HGE- 2016	22
III	CHEM -HCC-3016 CHEM -HCC-3026 CHEM -HCC-3036		CHEM - SEC-3014		CHEM -HGE- 3016	28
IV	CHEM -HCC-4016 CHEM -HCC-4026 CHEM -HCC-4036		CHEM - SEC-4014		CHEM -HGE- 4016	28
V	CHEM -HCC-5016 CHEM -HCC-5026			CHEM -HDS 5016 CHEM -HDS- 5026		24
VI	CHEM -HCC-6016 CHEM -HCC-6026			CHEM -HDS- 6016 CHEM -HDS- 6026		24
Total						148

4.(B) Semester-wise distribution of Regular Course

SEM	Credit				
	Regular Core Course (RCC) 12X6=72 (L+P)/(L+Tu) 4+2	Ability Enhancement Course (AEC) 2X4=8 (L) 4	Skill Enhancement Course (SEC) 4x4=16 (L+P) 4+2	Regular Discipline Specific Elective (RDS) 6x6=36 (L+P)/(L+Tu) 4+2	
I	CHEM-RCC-1016 XXXX-RCC-1016 ZZZZ-RCC-1016	ENGL/ASSA/HIND/BENG-AEC-1014			
II	CHEM-RCC-2016 XXXX-RCC-2016 ZZZZ-RCC-2016	ENST-AEC-2014			
III	CHEM-RCC-3016 XXXX-RCC-3016 ZZZZ-RCC-3016		CHEM-SEC-3014		
IV	CHEM-RCC-4016 XXXX-RCC-4016 ZZZZ-RCC-4016		CHEM-SEC-4014		
V			CHEM-SEC-5014	CHEM-RDS-5016 XXXX-RDS-5016 ZZZZ-RDS-5016	
VI			XXXX-SEC-6014	CHEM-RDS-6016 XXXX-RDS-6016 ZZZZ-RDS-6016	
Total Credit					132

4. Graduate Attributes

On completion of the programme, students are expected to have acquired the skills of effective communication, critical thinking, scientific temperament and social outreach. The attributes expected from the graduates of B.Sc. (Honours) Chemistry are:

- i. A holistic knowledge and understanding of basic concepts and skills in chemistry and allied subjects.
- ii. The capacity to identify, understand and solve the problems of the society.
- iii. Team building and leadership skills, communication, creative and critical thinking, logical reasoning and innovative problem solving ability.
- iv. To enable the students to understand basic concepts and aspects related to research and innovation.

6. Programme Objectives

- i. To imbibe strong foundation of chemistry and allied subjects in students.
- ii. To skill and acquaint the learners with the sophisticated instruments necessary for chemical research.
- iii. To motivate the learners to pursue higher education and research in chemistry.
- iv. To skill the students with necessary practical knowledge to meet the market demand.
- v. To promote application-oriented pedagogy by exposing students to real world data.

7. Programme Learning Outcomes

This program exposes students to the beautiful world of chemistry and how it affects all aspects of our daily lives. This course aims to provide students with all important chemistry concepts and the tools necessary to implement them. The course aims to provide appropriate practical knowledge to the learners and motivate them to pursue higher education and research in chemistry. The skill enhancement courses foster practical skill to the students to meet the market demand. Students after completion of the course will have the options either to pursue higher education in chemistry or to join any public/private/ government sector as a skilled resource.

Teaching Learning Process

The Department of Chemistry at Nowgong College (Autonomous) is primarily responsible for organizing the Bachelor of Science course (Honours) Chemistry. Tutorial and practice related instructions are provided by the respective registering units under the general guidance of Department of Chemistry of Nowgong College (Autonomous).

There shall be 90 instructional days excluding examination in a semester.

8. Teaching Pedagogy

Teaching Pedagogy involves classroom interaction, discussion, lectures, course-based practical work, viva-voce, mock test, demonstration, presentation, classroom tests, and assignments. Section 13 "Promoting the achievement of course learning outcomes" describes each course in the course in detail.

9. Assessment Methods/Evaluation Scheme

The students registered for academic programmes will study semester I to VI at the Nowgong College (Autonomous) and during these semesters Core, AECC, HDS, RDS and SEC courses are offered.

- (i) English shall be the medium of instruction and examination for Honours course and English/Assamese for Generic Elective course and Regular course.
- (ii) Examinations shall be conducted at the end of each Semester as per the Academic calendar notified by the Nowgong College (Autonomous).
- (iii) The assessment broadly comprises of Internal Assessment (Sessional Examination, Attendance, Assignments) and End Semester Examination.
- (iv) Theory papers without practical/presentation i.e only Ability Enhancement Compulsory Course (AEC) Papers consist of total 100 marks divided into 80 marks for theory, 20 marks for internal assessment.
- (v) Theory papers with practical/presentation i.e Core Courses (CCC- EN; CCC-ASSA, HIND, BENG and ALEN; HCC; RCC). Discipline Specific Electives (HDS & RDS), Generic Electives (HGE & RGE), Skill Enhancement Courses (SEC) consist of total 100 marks divided into 60 marks for theory, 20 marks for internal assessment and 20 marks for Practical/Presentation.
- (vi) Internal assessment of 20 marks is comprises with 06 marks from assignment, 10 marks from sessional examination and 4 marks from attendance.
- (vii) Each practical paper will carry 20 marks including 15 marks for continuous evaluation and 2 marks for practical note book and 3 marks for the oral test or *viva voce*.
Hardcopy of practical file has to be maintained by the students for each practical paper and has to be submitted in the concerned department at the time of examination.
- (viii) Each presentation will carry 20 marks including 15 marks for continuous evaluation and 2 marks for presented report and 3 marks for the oral test or *viva voce*. The departments will decide the process of continuous evaluation for the task carried-out against the presentation.
Hardcopy of the report has to be maintained by the students for each presented paper and has to be submitted in the concerned department at the time of examination.

The dissertation paper in 6th semester (Paper Code: CHEM-HDS-6026) consists of 100 marks where 80 marks for the work and 20 marks for presentation.

B. SC. (HONOURS) IN CHEMISTRY SEMESTER-I

PAPER CODE: CHEM-HCC-1016: Inorganic Chemistry-I

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: The course will give the students a theoretical understanding of molecules, atoms and ions with special emphasis on their structure, stability and reactivity. Quantum mechanical treatment of chemical bonding will be introduced. Detail periodic classification of elements will be thought. Accompanying laboratory course will give students a hands-on experience of basic techniques of volumetric titrations.

Learning Outcome: At the end of the course students would expect to have proper understanding of the underlying concepts of atomic and molecular structure, chemical bonding and periodic properties of the elements. Students will also develop the skill of preparing standard solutions in different concentration units and

CONTENTS

THEORY

UNIT 1: ATOMIC STRUCTURE

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

(14 Lectures)

UNIT 2: PERIODICITY OF ELEMENTS

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

- Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
- Atomic radii (van der Waals)
- Ionic and crystal radii.
- Covalent radii (octahedral and tetrahedral)
- Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
- Electron gain enthalpy, trends of electron gain enthalpy.
- Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

(16 Lectures)

UNIT 3: CHEMICAL BONDING

(i) *Ionic bond*: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) *Covalent bond*: Lewis structure, Valence Bond theory (Heitler-London approach). Energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N₂, O₂, C₂, B₂, F₂, CO, NO, and their ions; HCl, BeF₂, CO₂, (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths.

Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization.

Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

(iii) *Metallic Bond*: Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

(iv) *Weak Chemical Forces*: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment) Effects of chemical force, melting and boiling points, solubility energetics of dissolution process.

(26 Lectures)

UNIT 4: OXIDATION-REDUCTION

Redox equations, Standard Electrode Potential and its application to inorganic reactions.

Principles involved in volumetric analysis to be carried out in class.

(4 Lectures)

Recommended Books:

1. Lee, J. D. Concise Inorganic Chemistry, 5th Ed., Oxford University Press, 2008.
2. Douglas, B.E. and Mc Daniel, D.H., Concepts and Models of Inorganic Chemistry, 3rd Ed. Wiley India, 2006.
3. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
5. Atkins, P.W. & Paula, J. Physical Chemistry, 11th Ed., Oxford University Press, 2018.
6. Housecroft, C. E. and Sharpe, A. G. Inorganic Chemistry, 5th Ed., Pearson, 2018.
7. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, Literary Licensing, LLC, 2012.

PRACTICAL

(A) Titrimetric Analysis

- (i) Calibration and use of common laboratory apparatus
- (ii) Preparation of solutions of different Molarity/Normality of titrants

(B) Acid-Base Titrations

- (i) Estimation of carbonate and hydroxide present together in mixture.
- (ii) Estimation of carbonate and bicarbonate present together in a mixture.
- (iii) Estimation of free alkali present in different soaps/detergents

(C) Oxidation-Reduction Titrimetry

- (i) Estimation of Fe(II) and oxalic acid using standardized KMnO_4 solution.
- (ii) Estimation of oxalic acid and sodium oxalate in a given mixture.
- (ii) Estimation of Fe(II) with $\text{K}_2\text{Cr}_2\text{O}_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis; 6th Ed. Pearson Education, 2009.

PAPER CODE: CHEM-HCC-1026: Physical Chemistry-I

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course objective: This course contains states of matter- gaseous, liquid and solid states along with ionic equilibria. A small unit of molecular and crystal symmetry is also there in the course.

Learning outcome: In gaseous state unit the students will learn the kinetic theory of gases, ideal gas and real gases. In liquid state unit, the students are expected to learn the qualitative treatment of the structure of liquid along with the physical properties of liquid, viz, vapour pressure, surface tension and viscosity. In the molecular and crystal symmetry unit they will be introduced to the elementary idea of symmetry which will be useful to understand solid state chemistry and group theory in some higher courses. In solid state unit the students will learn the basic solid state chemistry application of x-ray crystallography for the determination of some very simple crystal structures. The students will also learn another important topic "ionic equilibria" in this course.

UNIT 1: GASEOUS STATE

Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation;

collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η ; variation of viscosity with temperature and pressure.

Maxwell distribution and its use in evaluating molecular velocities (average, root meansquare and most probable) and average kinetic energy.

Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, Z , and its variation with pressure for different gases. Causes of deviation from ideal behaviour. Van der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dieterici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states.

(18 Lectures)

UNIT 2: LIQUID STATE

Qualitative treatment of the structure of the liquid state; Radial distribution function; physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases.

Qualitative discussion of structure of water.

(6 Lectures)

UNIT 3: MOLECULAR AND CRYSTAL SYMMETRY

Elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices.

(6 Lectures)

UNIT 4: SOLID STATE

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Defects in crystals. Liquid crystals (Introductory idea)

(10 Lectures)

UNIT 4: IONIC EQUILIBRIUM

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

Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body.

Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations.

Multistage equilibria in polyelectrolyte systems; hydrolysis and hydrolysis constants.

(20 Lectures)

Recommended Books:

1. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry Ed., Oxford University Press (2006).
2. Ball, D. W. Physical Chemistry Thomson Press, India (2007).
3. Castellan, G. W. Physical Chemistry 4th Ed. Narosa (2004).
4. Mortimer, R. G. Physical Chemistry 3rd Ed. Elsevier: NOIDA, UP (2009).
5. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co. (2017)
6. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 1) McGraw Hill Education; Sixth edition (2019)

PRACTICAL

1. Surface tension measurements.

- a. Determine the surface tension by (i) drop number (ii) drop weight method.
- b. Study the variation of surface tension of detergent solutions with concentration.

2. Viscosity measurement using Ostwald's viscometer.

- a. Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
- b. Study the variation of viscosity of sucrose solution with the concentration of solute.

3. Indexing of a given powder diffraction pattern of a cubic crystalline system.

4. pH metry

- a. Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
- b. Preparation of buffer solutions of different pH
 - i. Sodium acetate-acetic acid
 - ii. Ammonium chloride-ammonium hydroxide
- c. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.
- d. Determination of dissociation constant of a weak acid.

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).

SEMESTER-II

PAPER CODE: CHEM-HCC-2016: Organic Chemistry-1

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: This course is inducted to apprise students with introduction to organic compounds, electron displacement, type of reagents and reaction intermediates. The chemistry of aliphatic and aromatic hydrocarbon, conformational analysis of cycloalkanes and basic stereochemical phenomena are included.

Students are expected to learn different classes learn, explain, describe and analyze different classes of organic compounds, their reactivities and mechanisms along with stereo chemical considerations.

Learning Outcome: Students will be able to identify different classes of organic compounds, describe their reactivity and explain/analyze their chemical and stereo chemical aspects.

CONTENTS

THEORY

UNIT 1: BASICS OF ORGANIC CHEMISTRY

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties.

Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength.

Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophilicity and basicity; Types, shape and their relative stability of Carbocations, Carbanions, Free radicals and Carbenes.

Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

(8 Lectures)

UNIT 2: STEREOCHEMISTRY

Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: cis-trans and, syn-anti isomerism E/Z notations with C.I.P rules.

Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations.

(16 Lectures)

UNIT 3: CHEMISTRY OF ALIPHATIC HYDROCARBONS

A. Carbon-Carbon sigma bonds

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation -relative reactivity and selectivity.

B. Carbon-Carbon pi bonds:

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations.

Reactions of alkenes: Electrophilic additions and their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroborationoxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation). 1,2-and 1,4-addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene.

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

C. Cycloalkanes and Conformational Analysis

Types of cycloalkanes and their relative stability, Baeyer strain theory, Conformation analysis of alkanes: Relative stability: Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms; Relative stability with energy diagrams.

(24 Lectures)

UNIT 4: AROMATIC HYDROCARBONS

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

(12 Lectures)

Recommended Books:

1. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry* (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Eliel, E. L. & Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
4. Nasipuri, D. *Stereochemistry of Organic Compounds*, Wiley Eastern Limited.
5. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
6. Subrata Sen Gupta, *Basic Stereochemistry of Organic Molecules*, Oxford Higher Education.
7. Dhillon, R. S.; Singh, I. P. & Baskar, C. *Stereochemistry*, Narosa.

8. Loudon, G. M. *Organic Chemistry*, Oxford.
9. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003.
10. Clayden, J., Greeves, N. & Warren, S. *Organic Chemistry*, Second edition, Oxford University Press, 2012.

PRACTICAL

1. Checking the calibration of the thermometer
2. Purification of organic compounds by crystallization using the following solvents:
 - a. Water
 - b. Alcohol Alcohol-Water
3. Determination of the melting points of above compounds and unknown organic compounds.
4. Effect of impurities on the melting point – mixed melting point of two unknown organic Compounds.
5. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and use of thiele tube method)
6. Chromatography
 - a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography
 - b. Separation of a mixture of two sugars by ascending paper chromatography
 - c. Separation of a mixture of o-and p-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC)

Recommended Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009).
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)
3. Vogel, A. I. *Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis*, CBS Publishers and Distributors.
4. Bhattacharyya, R. C, *A Manual of Practical Chemistry*.
5. Dutta, S, B. *Sc. Honours Practical Chemistry*, Bharati Book Stall.

PAPER CODE: CHEM-HCC-2026: Physical Chemistry-II

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: In this course the chemical thermodynamics, chemical equilibrium, solutions and colligative properties will be taught to the students. Another unit of this course is systems of variable compositions.

Learning Outcome: In this course the students are expected to learn laws of thermodynamics, thermochemistry, thermodynamic functions, relations between thermodynamic properties, Gibbs Helmholtz equation, Maxwell relations etc. Moreover the students are expected to learn partial molar quantities, chemical equilibrium, solutions and colligative properties. After completion of this course, the students will be able to understand the chemical systems from thermodynamic point of view.

CONTENTS THEORY

UNIT 1: CHEMICAL THERMODYNAMICS

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics.

First law: Concept of heat, q , work, w , internal energy, U , and statement of first law; enthalpy, H , relation between heat capacities, calculations of q , w , U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

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

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

Third Law: Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules.

Free Energy Functions: Gibbs and Helmholtz energy; variation of S , G , A with T , V , P ; spontaneous process-enthalpy change, entropy change and free energy change considerations. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

(36 Lectures)

UNIT 2: SYSTEMS OF VARIABLE COMPOSITION

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

(8 Lectures)

UNIT 3: CHEMICAL EQUILIBRIUM

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

(8 Lectures)

UNIT 4: SOLUTIONS AND COLLIGATIVE PROPERTIES

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions.

Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

(8 Lectures)

Recommended Books

1. Peter, A. & Paula, J. de. *Physical Chemistry 9th Ed.*, Oxford University Press (2011).
2. Castellan, G. W. *Physical Chemistry 4th Ed.*, Narosa (2004).
3. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
4. McQuarrie, D. A. & Simon, J. D. *Molecular Thermodynamics* Viva Books Pvt. Ltd.:New Delhi (2004).
5. Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. *Commonly Asked Questions in Thermodynamics*. CRC Press: NY (2011).
6. Levine, I.N. *Physical Chemistry 6th Ed.*, Tata Mc Graw Hill (2010).
7. Metz, C.R. *2000 solved problems in chemistry*, Schaum Series (2006)
8. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, VishalPublishing Co.; 47th Ed. (2017)
9. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 2) McGraw HillEducation; Sixth edition (2019)

PRACTICAL

Thermochemistry

- (a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).
- (b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
- (c) Calculation of the enthalpy of ionization of ethanoic acid.
- (d) Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.
- (e) Determination of basicity/proticity of a polyprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculate the enthalpy of neutralization of the first step.
- (f) Determination of enthalpy of hydration of copper sulphate.
- (g) Study of the solubility of benzoic acid in water and determination of ΔH .

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R.Chand & Co.: New Delhi (2011).
2. Athawale, V. D. & Mathur, P. *Experimental Physical Chemistry* New AgeInternational: New Delhi (2001).

SEMESTER-III

PAPER CODE: CHEM-HCC-3016: Inorganic Chemistry-II

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This course starts with the basic principles of metallurgy so as to acquaint the students with the application of the redox chemistry they have learnt in the earlier course on inorganic chemistry. Concepts of protonic and non-protonic acids and bases are introduced for students to appreciate different types of chemical reactions. Periodic behavior of s and p block elements related to their electronic structure and their reactivity is included to acquaint students with the principles governing their reactivity. This course further intend to apprise students about the variety of compounds of the main group elements including oxides, hydrides, nitrides, interhalogens, noble gases and inorganic polymers. As part of the accompanying lab course, experiments involving iodo- and iodimetric titrations are included for the students to explore other varieties of redox titration. Preparation of simple inorganic compounds is introduced to give hands-on experience of inorganic synthesis.

Learning Outcome: On successful completion of this course students would be able to apply theoretical principles of redox chemistry in the understanding of metallurgical processes.

Students will be able to identify the variety of s and p block compounds and comprehend their preparation, structure, bonding, properties and uses. Experiments in this course will boost their quantitative estimation skills and introduce the students to preparative methods in inorganic chemistry.

UNIT 1: GENERAL PRINCIPLES OF METALLURGY

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining.

(6 Lectures)

UNIT 2: ACIDS AND BASES

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

principle.

(8 Lectures)

UNIT 3: CHEMISTRY OF *S* AND *P* BLOCK ELEMENTS

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Complex formation tendency of *s* and *p* block elements.

Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrogen compounds, boranes, carboranes and graphitic compounds, silanes, oxides and oxoacids of nitrogen, phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogenes and basic properties of halogens.

(30 Lectures)

UNIT 4: NOBLE GASES

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF₂, XeF₄ and XeF₆; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF₂). Molecular shapes of noble gas compounds (VSEPR theory).

(8 Lectures)

UNIT 5: INORGANIC POLYMERS

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Silicates – clays and zeolites, polyphosphazenes, metal-organic framework compounds (MOFs).

(8 Lectures)

Recommended Books:

1. Lee, J. D., Concise Inorganic Chemistry, 5th Ed., Oxford University Press, 2008.
2. Douglas, B.E. and Mc Daniel, D.H., Concepts and Models of Inorganic Chemistry, 3rd Ed. Wiley India, 2006.
3. Greenwood, N.N. & Earnshaw, A., Chemistry of the Elements, 2nd Ed., Elsevier India, 2010.
4. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
5. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
6. Miessler, G. L. & Tarr, D. A., Inorganic Chemistry 4th Ed., Pearson, 2010.
7. Weller, M., Armstrong, F., Rourke, J. & Overton, T., Inorganic Chemistry 6th Ed. 2015.

PRACTICAL

(A) Iodo / Iodimetric Titrations

- (i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).
- (ii) Estimation of (i) arsenite and (ii) antimony in tartar-emetica iodimetrically
- (iii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic preparations

- (i) Cuprous Chloride, $CuCl$
- (ii) Preparation of manganese(III) phosphate, $MnPO_4 \cdot H_2O$
- (iii) Preparation of aluminium potassium sulphate $KAl(SO_4)_2 \cdot 12H_2O$ (Potash alum) or Chrome alum.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.

PAPER CODE: CHEM-HCC-3026: Organic Chemistry-II

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: This course is intended to apprise students about different classes of organic compounds, including halogenated hydrocarbons, alcohols, phenols, epoxides, carbonyl compounds and carboxylic and sulfonic acids.

Students are expected to learn and differentiate between various organic functional groups; explain, analyze and design transformations between different functional groups.

Learning Outcome: Students will be able to describe and classify organic compounds in terms of their functional groups and reactivity.

CONTENTS

THEORY

UNIT 1: CHEMISTRY OF HALOGENATED HYDROCARBONS

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – SN_1 , SN_2 and SN_i mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

Aryl halides: Preparation, including preparation from diazonium salts. nucleophilic aromatic

substitution; S_NAr, Benzyne mechanism. Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

(16 Lectures)

UNIT 2: ALCOHOLS, PHENOLS, ETHERS AND EPOXIDES

Alcohols: preparation, properties and relative reactivity of 1°,2°,3° alcohols, Bouveault-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement;

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe’s–Schmidt Reactions, Fries and Claisen rearrangements with mechanism;

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and LiAlH₄

(16 Lectures)

UNIT 3: CARBONYL COMPOUNDS

Preparation, properties, structure and reactivity;

Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and

Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α -substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, LiAlH₄, NaBH₄, MPV, PDC and PGC);

Addition reactions of unsaturated carbonyl compounds: Michael addition.

Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

(14 Lectures)

UNIT 4: CARBOXYLIC ACIDS AND THEIR DERIVATIVES

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids;

Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

UNIT 5: SULPHUR CONTAINING COMPOUNDS

Preparation and reactions of thiols, thioethers and sulphonic acids.

(10 Lectures)

Recommended Books:

1. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
2. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
4. Clayden, J., Greeves, N. & Warren, S. *Organic Chemistry*, Second edition, Oxford University Press, 2012.
5. Keeler, J., Wothers, P. *Chemical Structure and Reactivity – An Integrated approach*, Oxford University Press.
6. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
7. Carey, F. A.; Sundberg, R. J. *Advanced Organic Chemistry: Reactions and Synthesis (Part B)*, Springer.

PRACTICAL

1. Test of functional groups like alcohols, phenols, carbonyl and carboxylic acid group.
2. Organic preparations:
 - i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines *o*-, *m*-, *p*-anisidine) and phenols (β -naphthol, vanillin, salicylic acid) by any one method:
 - a. Using conventional method.
 - b. Using green approach
 - ii. Benzoylation of one of the following amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine) and one of the following phenols (β -naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.
 - iii. Oxidation of ethanol/ isopropanol (Iodoform reaction).
 - iv. Bromination of any one of the following:
 - a. Acetanilide by conventional methods
 - b. Acetanilide using green approach (Bromate-bromide method)
 - v. Nitration of any one of the following:
 - a. Acetanilide/nitrobenzene by conventional method
 - b. Salicylic acid by green approach (using ceric ammonium nitrate).
 - vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.
 - vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.
 - viii. Hydrolysis of amides and esters.

- ix. Semicarbazone of any one of the following compounds: acetone, ethylmethyl ketone, cyclohexanone, benzaldehyde.
- x. *S*-Benzylisothiuronium salt of one each of water soluble and water insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).
- xi. Aldol condensation using either conventional or green method.
- xii. Benzil-Benzilic acid rearrangement.

The above preparations should be done using 0.5-1g of the organic compound. The solid samples must be collected and may be used for recrystallization, melting point and TLC.

Recommended Books

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

PAPER CODE: CHEM-HCC-3036: Physical Chemistry-III

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: The aim of this course is to teach students four important topics of physical chemistry- phase equilibria, chemical kinetics, surface chemistry and catalysis. Phase equilibria and chemical kinetics will be discussed in detail but surface chemistry and catalysis will be introduced to the students.

Learning Outcome: The students are expected to learn phase rule and its application in some specific systems. They will also learn rate laws of chemical transformation, experimental methods of rate law determination, steady state approximation etc. in chemical

kinetics unit. After attending this course the students will be able to understand different types of surface adsorption processes and basics of catalysis including enzyme catalysis, acid base catalysis and particle size effect on catalysis.

CONTENTS

THEORY

UNIT 1: PHASE EQUILIBRIA

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solidliquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications.

Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions.

Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and nonideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation.

Nernst distribution law: its derivation and applications.

(28 Lectures)

UNIT 2: CHEMICAL KINETICS

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (iv) chain reactions.

Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates.

Reaction mechanism- steady-state approximation and rate determining step approximation methods.

(18 Lectures)

UNIT 3: CATALYSIS

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

(8 Lectures)

UNIT 4: SURFACE CHEMISTRY

Physical adsorption, chemisorption, adsorption isotherms, nature of adsorbed state.

Recommended Books:

1. Peter Atkins & Julio De Paula, *Physical Chemistry 9th Ed.*, Oxford University Press (2010).
2. Castellan, G. W. *Physical Chemistry*, 4th Ed., Narosa (2004).
3. McQuarrie, D. A. & Simon, J. D., *Molecular Thermodynamics*, Viva Books Pvt.Ltd.:New Delhi (2004).
4. Zundhal, S.S. *Chemistry concepts and applications* Cengage India (2011).
5. Ball, D. W. *Physical Chemistry* Cengage India (2012).
6. Mortimer, R. G. *Physical Chemistry 3rd Ed.*, Elsevier: NOIDA, UP (2009).
7. Levine, I. N. *Physical Chemistry 6th Ed.*, Tata McGraw-Hill (2011).
8. Metz, C. R. *Physical Chemistry 2nd Ed.*, Tata McGraw-Hill (2009).
9. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co.; 47th Ed. (2017)
10. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 5) McGraw Hill Education; 5th edition (2017)

PRACTICAL

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

II. Phase equilibria: Construction of the phase diagram using cooling curves or ignition tube method:

- a. simple eutectic and
- b. congruently melting systems.

III. Distribution of acetic/ benzoic acid between water and cyclohexane.

IV. Study the equilibrium of at least one of the following reactions by the distribution method:

- (i) $I_2(aq) + I^- \rightarrow I_3^-(aq)$
- (ii) $Cu^{2+}(aq) + nNH_3 \rightarrow Cu(NH_3)_n$

V. Study the kinetics of the following reactions.

1. Initial rate method: Iodide-persulphate reaction
2. Integrated rate method:
 - a. Acid hydrolysis of methyl acetate with hydrochloric acid.
 - b. Saponification of ethyl acetate.
3. Compare the strengths of HCl and H₂SO₄ by studying kinetics of hydrolysis of methyl acetate.

VI. Adsorption

I. Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R.Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H.Freeman & Co.: New York (2003).

SEMESTER-IV

PAPER CODE: CHEM-HCC-4016: Inorganic Chemistry-III**PAPER CREDIT: 06 (4T+2P)****Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)****L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical**

Course Objective: This course introduces students to coordination chemistry. Various aspects like nomenclature, structure, bonding, variety and reactivity of the coordination compounds are included for the students to appreciate.

Bioinorganic chemistry is included in this course to acquaint students on the useful and harmful aspects of metals in biological systems.

Through the accompanying lab course, experiments related to gravimetric analysis, synthesis of coordination compounds and separation of metal ions using chromatography is included. This will broaden the experimental skills of the students where students will learn about various aspects of experiment design depending upon the requirements like synthesis, estimation or separation.

Learning Outcome: On successful completion, students will be able name coordination compounds according to IUPAC, explain bonding in this class of compounds, understand their various properties in terms of CFSE and predict reactivity. Students will be able to appreciate the general trends in the properties of transition elements in the periodic table and identify differences among the rows.

Through the experiments students not only will be able to prepare, estimate or separate metal complexes/compounds but also will be able to design experiments independently which they should be able to apply if and when required.

CONTENTS**THEORY****UNIT 1: COORDINATION CHEMISTRY**

Coordination compounds, types of ligands, Werner's theory, IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6

coordination numbers.

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

(26 Lectures)

UNIT 2: TRANSITION ELEMENTS

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Frost diagrams). Difference between the first, second and third transition series.

Chemistry of Ti, V, Cr Mn, Fe and Co (Chemistry of first -row transition elements) in various oxidation states as halides, oxides, hydroxides.

(18 Lectures)

UNIT 3: LANTHANOIDS AND ACTINOIDS

Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction, separation of lanthanides (ion-exchange method only).

(6 Lectures)

UNIT 4: BIOINORGANIC CHEMISTRY

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on the distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd and As), reasons for toxicity, Use of chelating agents in medicine.

Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

(10 Lectures)

Recommended Books:

1. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
2. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed., Pearson Education India, 2006.

- Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry, Panima Publishing Company, 1994.
- Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
- Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967

PRACTICAL

Gravimetric Analysis:

- Estimation of nickel(II) using dimethyl glyoxime (DMG).
- Estimation of copper as CuSCN
- Estimation of iron as Fe₂O₃ by precipitating iron as Fe(OH)₃.
- Estimation of Al (III) by precipitating with oxine and weighing as Al(oxine)₃ (aluminiumoxinate).

Inorganic Preparations:

- Tetraamminecopper(II) sulphate, [Cu(NH₃)₄]SO₄.H₂O
- Cis* and *trans* K[Cr(C₂O₄)₂.(H₂O)₂] Potassium dioxalato diaquachromate (III)
- Tetraamminecarbonatocobalt (III) ion
- Potassium tris(oxalato)ferrate(III)

Chromatography of metal ions

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

- Ni(II) and Co(II)
- Fe(III) and Al(III)

Recommended Book:

- Mendham, J. et al.: Vogel's Textbook of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
- Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.
- Inorganic Syntheses*, Vol. 1-10.

PAPER CODE: CHEM-HCC-4026: Organic Chemistry-III

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: The course intrudes students to different classes of N-based compounds, including alkaloids and terpenoids and their potential application.

Students are expected to learn about different classes of N-based compounds; their structures, synthesis and reactivity.

Learning Outcome: Students shall demonstrate the ability to identify and classify different types of N-based derivatives, alkaloids and heterocyclic compounds/explain their structure mechanism and reactivity/critically examine their synthesis and reactions mechanism.

CONTENTS

THEORY

UNIT 1: NITROGEN CONTAINING FUNCTIONAL GROUPS

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

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

Diazonium Salts: Preparation and their synthetic applications.

(18 Lectures)

UNIT 2: POLYNUCLEAR HYDROCARBONS

Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

(8 Lectures)

UNIT 2: HETEROCYCLIC COMPOUNDS

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom;

Synthesis, reactions and mechanism of substitution reactions of:

Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine.

Indole: Fischer indole synthesis and Madelung synthesis).

Quinoline and isoquinoline: Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner- Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction

(22 Lectures)

UNIT 3: ALKALOIDS

Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine,

Cocaine, and Reserpine.

(6 Lectures)

UNIT 4: TERPENES

Occurrence, classification, isoprene rule; Elucidation of structure and synthesis of Citral, Neral and α -terpineol.

(6 Lectures)

Recommended Books:

1. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Kalsi, P. S. *Textbook of Organic Chemistry 1st Ed.*, New Age International (P) Ltd. Pub.
5. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
6. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Parakashan (2010). (2010).

PRACTICAL

1. Detection N, S, halogens in organic compounds.
2. Functional group test for nitro, amine and amide groups.
3. Qualitative analysis of unknown organic compounds containing simple functional groups (alcohols, carboxylic acids, phenols and carbonyl compounds)

Recommended Books

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

PAPER CODE: CHEM-HCC-4036: Physical Chemistry-IV

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: The aim of this course is to introduce students with primarily two areas of physical chemistry- electrochemistry and electrical and magnetic properties of atoms and molecules. It contains three units- conductance, electrochemistry and electrical & magnetic properties of atoms and molecules.

Learning Outcome: In this course the students will learn theories of conductance and electrochemistry. Students will also understand some very important topics such as solubility and solubility products, ionic products of water, conductometric titrations etc. The students are also expected to understand the various parts of electrochemical cells along with Faraday's Laws of electrolysis. The students will also gain basic theoretical idea of electrical & magnetic properties of atoms and molecules.

CONTENTS

THEORY

UNIT 1: CONDUCTANCE

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules.

Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

(20 Lectures)

UNIT 2: ELECTROCHEMISTRY

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials.

Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining

free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and $\text{SbO/Sb}_2\text{O}_3$ electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations

(acid-base, redox, precipitation). Applications of electrolysis in metallurgy and industry.
(28 Lectures)

UNIT 3: ELECTRICAL & MAGNETIC PROPERTIES OF ATOMS AND MOLECULES

Basic ideas of electrostatics, Electrostatics of dielectric media, Clausius-Mosotti equation, Lorenz-Laurentz equation, Dipole moment and molecular polarizabilities and their measurements. Diamagnetism, paramagnetism, magnetic susceptibility and its measurement, molecular interpretation.

(12 Lectures)

Recommended Books:

1. Atkins, P.W & Paula, J.D. *Physical Chemistry*, 9th Ed., Oxford University Press(2011).
2. Castellan, G. W. *Physical Chemistry 4th Ed.*, Narosa (2004).
3. Mortimer, R. G. *Physical Chemistry 3rd Ed.*, Elsevier: NOIDA, UP (2009).
4. Barrow, G. M., *Physical Chemistry 5th Ed.*, Tata McGraw Hill: New Delhi (2006).
5. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
6. Rogers, D. W. *Concise Physical Chemistry* Wiley (2010).
7. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co.; 47th Ed. (2017)

PRACTICAL

Conductometry

- I. Determination of cell constant
- II. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
- III. Perform the following conductometric titrations:
 - i. Strong acid vs. strong base
 - ii. Weak acid vs. strong base
 - iii. Mixture of strong acid and weak acid vs. strong base
 - iv. Strong acid vs. weak base

Potentiometry

- I Perform the following potentiometric titrations:
 - i. Strong acid vs. strong base
 - ii. Weak acid vs. strong base
 - iii. Dibasic acid vs. strong base
 - iv. Potassium dichromate vs. Mohr's salt

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical*

- Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H.Freeman & Co.: New York (2003).

SEMESTER-V

PAPER CODE: CHEM-HCC-5016: Organic Chemistry-IV

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: This course introduces students to nucleic acids, amino acids and pharmaceutical compounds.

Students will be familiarized with the importance of nucleic acids, amino acids and develop basic understanding of enzymes, bioenergetics and pharmaceutical compounds.

Learning Outcome: Students will be able to explain/describe the important features of nucleic acids, amino acids and enzymes and develop their ability to examine their properties and applications.

CONTENTS

THEORY

UNIT 1: NUCLEIC ACIDS

Components of nucleic acids; Nucleosides and nucleotides;

Synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine;
Polynucleotides: DNA and RNA

(9 Lectures)

UNIT 2: AMINO ACIDS, PEPTIDES AND PROTEINS

Amino acids, Peptides and their classification.

α -Amino Acids - Synthesis, ionic properties and reactions. Zwitterions, pK_a values, isoelectric point and electrophoresis;

Study of peptides: determination of their primary structures-end group analysis, methods of peptide synthesis. Synthesis of peptides using N-protecting, C-protecting and C-activating groups -Solid-phase synthesis

(16 Lectures)

UNIT 3: ENZYMES

Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes.

Mechanism of enzyme action (taking trypsin as example), factors affecting enzyme action, coenzymes and cofactors and their role in biological reactions, specificity of enzyme action (including stereospecificity), enzyme inhibitors and their importance, phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition). **(8 Lectures)**

UNIT 4: LIPIDS

Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenntion of fats and oils, saponification value, acid value, iodine number, rancidity.

(6 Lectures)

UNIT 5: CONCEPT OF ENERGY IN BIOSYSTEMS

Cells obtain energy by the oxidation of foodstuff (organic molecules).

Introduction to metabolism (catabolism, anabolism).

ATP: The universal currency of cellular energy, ATP hydrolysis and free energy change.

Agents for transfer of electrons in biological redox systems: NAD⁺, FAD.

Conversion of food to energy: Outline of catabolic pathways of carbohydrate- glycolysis, fermentation, Krebs cycle.

Overview of catabolic pathways of fat and protein.

Interrelationship in the metabolic pathways of protein, fat and carbohydrate.

Calorific value of food, standard calorie content of food types.

(9 Lectures)

UNIT 6: PHARMACEUTICAL COMPOUNDS: STRUCTURE AND IMPORTANCE

Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis), Antimalarials: Chloroquine (with synthesis). An elementary treatment of Antibiotics and detailed study of chloramphenicol, Medicinal values of curcumin (turmeric), azadirachtin (neem), vitamin C and antacid (ranitidine).

(12 Lectures)

Recommended Books:

1. Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. VIth Edition. W.H. Freeman and Co.
2. Nelson, D.L., Cox, M.M. and Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.
3. Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.

PRACTICAL

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.

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

Recommended Books:

1. Arthur, I. V. *Quantitative Organic Analysis*, Pearson.
2. Plummer, D. T. *An Introduction to Practical Biochemistry*, 3rd Edition, McGraw Hill.

PAPER CODE: CHEM-HCC-5026: Physical Chemistry-V

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: The aim of this course is to introduce the students with three important areas- quantum chemistry, molecular spectroscopy and photochemistry. In quantum chemistry unit the students will be taught the postulates of quantum mechanics and the application of quantum mechanical ideas in some simple systems such as particle in a box, rigid rotor, simple harmonic oscillator etc. In spectroscopy unit, rotational, vibrational, Raman, electronic, spin resonance, and electronic spectroscopy will be introduced.

Learning Outcome: After completion of this course the students are expected to understand the application of quantum mechanics in some simple chemical systems such as hydrogen atom or hydrogen like ions. The students will also learn chemical bonding in some simple molecular systems. They will be able to understand the basics of various kinds of spectroscopic techniques and photochemistry.

UNIT 1: QUANTUM CHEMISTRY

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment), quantization of energy levels, zero-point energy Extension to two and three dimensional boxes, separation of variables, degeneracy.

Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wavefunctions. Vibrational energy of diatomic molecules and zero-point energy.

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component.

Rigid rotator model of rotation of diatomic molecule. Schrödinger equation, transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution.

Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus. Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom).

Chemical bonding: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+ . Bonding and antibonding orbitals. Qualitative extension to H_2 . Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, detailed solution not required) and their limitations. Refinements of the two approaches (Configuration Interaction for MO, ionic terms in VB). Qualitative description of LCAO-MO treatment of homonuclear and heteronuclear diatomic molecules (HF, LiH). Localised and non-localised molecular orbitals treatment of triatomic (BeH_2 , H_2O) molecules. Qualitative MO theory and its application to AH_2 type molecules.

(24 Lectures)

UNIT 2: MOLECULAR SPECTROSCOPY

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation.

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

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.

(24 Lectures)

UNIT 3: PHOTOCHEMISTRY

Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws, of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, photochemical equilibrium and the differential

rate of photochemical reactions, photosensitised reactions, quenching. Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence.

(12 Lectures)

Recommended Books:

1. Banwell, C. N. & McCash, E. M. Fundamentals of Molecular Spectroscopy 4th Ed. Tata McGraw-Hill: New Delhi (2006).
2. Chandra, A. K. Introductory Quantum Chemistry Tata McGraw-Hill (2001).
3. House, J. E. Fundamentals of Quantum Chemistry 2nd Ed. Elsevier: USA (2004).
4. Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).
5. Kakkar, R. Atomic & Molecular Spectroscopy, Cambridge University Press (2015).
6. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 4) McGraw Hill Education; 5th edition (2017)
7. Sen, B. K. Quantum Chemistry- Including Spectroscopy, Kalyani Publishers; 4th edition (2011)

PRACTICAL

UV/Visible spectroscopy

- I. Study the 200-500 nm absorbance spectra of KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1} , kJ mol^{-1} , cm^{-1} , eV).
- II. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $\text{K}_2\text{Cr}_2\text{O}_7$.
- III. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds

Colourimetry

- I. Verify Lambert-Beer's law and determine the concentration of $\text{CuSO}_4/\text{KMnO}_4/\text{K}_2\text{Cr}_2\text{O}_7$ in a solution of unknown concentration
- II. Determine the concentrations of KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ in a mixture.
- III. Study the kinetics of iodination of propanone in acidic medium.
- IV. Determine the amount of iron present in a sample using 1,10-phenanthroline.
- V. Determine the dissociation constant of an indicator (phenolphthalein).
- VI. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.
- VII. Analysis of the given vibration-rotation spectrum of $\text{HCl}(\text{g})$

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R.Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).

3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H.Freeman & Co.: New York (2003).

SEMESTER VI

PAPER CODE: CHEM-HCC-6016: Inorganic Chemistry-IV

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: The unit on reaction mechanism is included for the students to get acquainted with the kinetic and thermodynamic factors governing the reaction path and stability of inorganic compounds.

Organometallic compounds are introduced so as to apprise students about the importance of metal carbon bond to form complexes and their application as catalysts. Students are expected to learn factors leading to stability of organometallic compounds, their synthesis, reactivity and uses.

Qualitative inorganic analysis is included to give students an idea and hands on experience of application of inorganic chemistry. Students should learn how differential reactivity under different conditions of pH can be used to identify variety of ions in a complex mixture.

Experiments related to synthesis and characterization of coordination compounds are included to supplement their theoretical knowledge.

Learning Outcome: By studying this course the students will be expected to learn about how ligand substitution and redox reactions take place in coordination complexes. Students will also learn about organometallic compounds, comprehend their bonding, stability, reactivity and uses. They will be familiar with the variety of catalysts based on transition metals and their application in industry.

On successful completion, students in general will be able to appreciate the use of concepts like solubility product, common ion effect, pH etc. in analysis of ions and how a clever design of reactions, it is possible to identify the components in a mixture.

With the experiments related to coordination compound synthesis, calculation of $10Dq$, controlling factors etc. will make the students appreciate the concepts of theory in experiments.

UNIT 1: MECHANISM OF INORGANIC REACTIONS

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans-effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes. Electron transfer reactions.

(18 Lectures)

UNIT 2: ORGANOMETALLIC COMPOUNDS

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands.

Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π -acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls.

Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.

Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

(22 Lectures)

UNIT 3: TRANSITION METALS IN CATALYSIS

Study of the following industrial processes and their mechanism:

1. Alkene hydrogenation (Wilkinson's Catalyst)
2. Hydroformylation (Co catalysts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes

(10 Lectures)

UNIT 4: THEORETICAL PRINCIPLES IN QUALITATIVE INORGANIC ANALYSIS (H2S SCHEME)

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

(10 Lectures)

Recommended Books:

1. Vogel, A.I. *Qualitative Inorganic Analysis*, Longman, 1972.
2. Svehla, G. & Sivasankar, B., *Vogel's Qualitative Inorganic Analysis*, 7th Ed., PrenticeHall, 2012.
3. Cotton, F.A., Wilkinson, G. and Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley, 2007.
4. Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry*. 6th Ed., Wiley-VCH, 2007.
5. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., *Inorganic Chemistry: Principles of Structure and Reactivity*, 4th Ed., Pearson Education India, 2006.
6. Sharpe, A.G. *Inorganic Chemistry*, 4th Indian Reprint (Pearson Education) 2005
7. Douglas, B.E. and Mc Daniel, D.H., *Concepts and Models of Inorganic Chemistry*, 3rd Ed. Wiley India, 2006.
8. Greenwood, N.N. & Earnshaw, A., *Chemistry of the Elements*, 2nd Ed., Elsevier India, 2010.
9. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Oxford University Press, 2008.
10. Powell, P. *Principles of Organometallic Chemistry*, Chapman and Hall, 1988.
11. Shriver, D.D. & Atkins, P., *Inorganic Chemistry 2nd Ed.*, Oxford University Press, 1994.

PRACTICAL

- Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested: CO_3^{2-} , NO_2^- , S^{2-} , SO_3^{2-} , $\text{S}_2\text{O}_3^{2-}$, CH_3COO^- , F^- , Cl^- , Br^- , I^- , NO_3^- , BO_3^{3-} , $\text{C}_2\text{O}_4^{2-}$, PO_4^{3-} , NH_4^+ , K^+ , Pb^{2+} , Cu^{2+} , Cd^{2+} , Bi^{3+} , Sn^{2+} , Sb^{3+} , Fe^{3+} , Al^{3+} , Cr^{3+} , Zn^{2+} , Mn^{2+} , Co^{2+} , Ni^{2+} , Ba^{2+} , Sr^{2+} , Ca^{2+} , Mg^{2+}
 - Mixtures should preferably contain one interfering anion, **or** insoluble component (BaSO_4 , SrSO_4 , PbSO_4 , CaF_2 or Al_2O_3) **or** combination of anions e.g. CO_3^{2-} and SO_3^{2-} , NO_2 and NO_3^- , Cl^- and Br^- , Cl^- and I^- , Br^- and I^- , NO_3^- and Br^- , NO_3^- and I^- .
 - Spot tests should be done whenever possible.
 - Synthesis of ammine complexes of Ni(II) and their ligand exchange reactions involving bidentate ligands like acetylacetonate, dimethylglyoxime, glycine, etc.
 - Preparation of acetylacetonate complexes of $\text{Cu}^{2+}/\text{Fe}^{3+}$.
- Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs. thermodynamic factors.
- Determination of ϵ_{max} value from UV-visible spectra of complexes.
 - Measurement of 10 Dq by spectrophotometric method, verification of spectrochemical series.

Recommended Books

1. Vogel's *Qualitative Inorganic Analysis*, Revised by G. Svehla.

2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold.1972.

PAPER CODE: CHEM-HCC-6026: Organic Chemistry-V

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: This is a basic course in organic spectroscopy and provides introduction to carbohydrate chemistry, dyes and polymers.

Students are expected to learn about the different spectroscopic techniques and their applications in organic chemistry. Students shall be apprised with carbohydrate chemistry, dyes and polymers and their structure, reactivity and chemical properties.

Learning Outcome: Students will be able to explain/describe basic principles of different spectroscopic techniques and their importance in chemical/organic analysis. Students shall be able to classify/identify/critically examine carbohydrates, polymers and dye materials.

CONTENTS

THEORY

UNIT 1: SPECTROSCOPY

Introduction to absorption and emission spectroscopy.

UV Spectroscopy: Types of electronic transitions, λ_{\max} , Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Application of Woodward Rules for calculation of λ_{\max} for the following systems: α,β unsaturated aldehydes, ketones, carboxylic acids and esters; Conjugated dienes: alicyclic, homoannular and heteroannular; Extended conjugated systems (aldehydes, ketones and dienes); distinction between cis and trans isomers.

IR Spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O, N and S containing functional groups; Effect of H-bonding, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis.

NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin – Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds.

Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals.

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

(24

Lectures)

UNIT 2: CARBOHYDRATES

Occurrence, classification and their biological importance.

Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, determination of ring size of glucose and fructose, Haworth projections and conformational structures; Interconversions of aldoses and ketoses; Killiani-Fischer synthesis and Ruff degradation;

Disaccharides – Structure elucidation of maltose, lactose and sucrose. Polysaccharides – Elementary treatment of starch, cellulose and glycogen.

(16 Lectures)

UNIT 3: DYES

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

(8 Lectures)

UNIT 4: POLYMERS

Introduction and classification.

Number average molecular weight, Weight average molecular weight, Degree of polymerization, Polydispersity Index.

Polymerisation reactions -Addition and condensation -Mechanism of cationic, anionic and free radical addition polymerization; Preparation and applications of plastics – thermosetting (phenol-formaldehyde, Polyurethanes) and thermosoftening (PVC, polythene);

Fabrics – natural and synthetic (acrylic, polyamido, polyester); Rubbers – natural and synthetic: Buna-S, Chloroprene and Neoprene; Vulcanization; Polymer additives; Introduction to liquid crystal polymers; Biodegradable and conducting polymers with examples.

(12

Lectures)

Recommended Books:

1. Banwell, C. N. & Mc.Cash, E. M. *Fundamentals of Molecular Spectroscopy*, 4th Edition, McGraw Hill.

2. Pavia, Lampman, Kriz & Vyvyan, *Introduction to Spectroscopy*, 5th Edition, CENGAGE Learning.
3. Silverstein, R. M.; Webster, F. X.; Kiemle, D. J. & Bryce, D. L. *Spectrometric Identification of Organic Compounds*, 8th Edition, Wiley.
4. Kemp, W. *Organic Spectroscopy*, Palgrave.
5. Billmeyer, F. W. *Textbook of Polymer Science*, John Wiley & Sons, Inc.
6. Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. *Polymer Science*, New Age International (P) Ltd. Pub.
7. Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
9. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
12. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Prakashan (2010).

PRACTICAL

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

Recommended Books:

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

SKILL ENHANCEMENT COURSE

PAPER CODE: CHEM-SEC-3014: Basic Analytical Chemistry

PAPER CREDIT: 04 (2T+2P)

Total no. of Lectures: 30 + 30 (L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: To familiarize students with different micro and semimicro analytical techniques and help develop the ability to use modern instrumental methods for chemical analysis of food, soil, air and water.

Learning Outcome: Upon completion of this course, students shall be able to explain the basic principles of chemical analysis, design/implement microscale and semimicro experiments, record, interpret and analyze data following scientific methodology.

UNIT 1: INTRODUCTION: Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results, from the point of view of significant figures.

UNIT 2: ANALYSIS OF SOIL: Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators

- a. Determination of pH of soil samples.
- b. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

UNIT 3: ANALYSIS OF WATER: Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

- a. Determination of pH, acidity and alkalinity of a water sample.
- b. Determination of dissolved oxygen (DO) of a water sample.

UNIT 4: Analysis of food products: Nutritional value of foods, idea about food processing and food preservations and adulteration.

- a. Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.
- b. Analysis of preservatives and colouring matter.

UNIT 5: Chromatography: Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

- a. Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).
- b. To compare paint samples by TLC method.

UNIT 6: Ion-exchange: Column, ion-exchange chromatography etc.

Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

UNIT 7: Analysis of cosmetics: Major and minor constituents and their function

- a. Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.
- b. Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration.

PRACTICAL

Suggested Applications (Any one):

- a. To study the use of phenolphthalein in trap cases.
- b. To analyze arson accelerants.
- c. To carry out analysis of gasoline.

Suggested Instrumental demonstrations:

- a. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.
- b. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.
- c. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drink.

Recommended Books:

1. Willard, H. H. *Instrumental Methods of Analysis*, CBS Publishers.
2. Skoog & Lerry. *Instrumental Methods of Analysis*, Saunders College Publications, New York.
3. Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6th Ed.*, Saunders College Publishing, Fort Worth (1992).
4. Harris, D. C. *Quantitative Chemical Analysis*, W. H. Freeman.
5. Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
6. Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India.
7. Freifelder, D. *Physical Biochemistry 2nd Ed.*, W.H. Freeman and Co., N.Y. USA (1982).
8. Cooper, T.G. *The Tools of Biochemistry*, John Wiley and Sons, N.Y. USA. 16(1977).
9. Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7th Ed.*, Prentice Hall.
10. Vogel, A. I. *Vogel's Quantitative Chemical Analysis 6th Ed.*, Prentice Hall.
11. Robinson, J.W. *Undergraduate Instrumental Analysis 5th Ed.*, Marcel Dekker, Inc., New York (1995).

PAPER CODE: CHEM-SEC-4014: Pesticide Chemistry

PAPER CREDIT: 04 (2T+2P)

Total no. of Lectures: 30 + 30 (L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This is a brief and introductory course on pesticides, through which the students will be introduced to various classes of pesticides, their synthesis, applications and possible hazards of their uses.

Learning Outcome: Students will be able to explain or describe and critically examine different types of pesticides, their activity/toxicity and their applications and the need for the search of an alternative based on natural products.

CONTENTS

THEORY

Definition of pesticides, general introduction to pesticides (natural and synthetic), benefits and adverse effects of pesticides. Classification, mode of action, toxicity and methods of pesticides residue analysis. Synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene); organophosphate (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor)

Practicals

1. To calculate acidity/alkalinity in given sample of pesticides formulations as per BIS specifications.
2. Preparation of simple organophosphates, phosphonates and thiophosphates.

Recommended Book:

1. R. Cremllyn: Pesticides, Preparation and Mode of Action, John Wiley & Sons, New York, 1978
2. RPBateman, Pesticide Applications, AAB Press, 2004
3. Principles of Pesticide chemistry: S K Handa, Ed. by Agrobios (India), 2008
4. Pesticide Science & Biotechnology: R Greenhalgh and T R Robers, IUPAC, Blackwell Scientific Publications, 1987
5. The Chemical Process Industries: D N Shreve
6. Pesticide Chemistry : G Matolesy, M. Nadasy, V. Andriska, Elsevier Sc. Publisher, USA, 1988

DISCIPLINE SPECIFIC ELECTIVES (HDS)

PAPER CODE: CHEM-HDS-5016: Analytical Methods in Chemistry

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60 + 30 (L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This is an elective course designed to complement the needs of students who wish to learn more about the qualitative/quantitative characterization and separation techniques. The content of this course aims to cover some of the widely used instrumental techniques for characterization of samples. Experiments included aim at giving students hands on experience using different instrumental techniques and chemical analysis.

Learning outcome: On successful completion students will be have theoretical understanding about choice of various analytical techniques used for qualitative and quantitative characterization of samples. At the same time through the experiments students will gain hands on experience of the discussed techniques. This will enable students to take judicious decisions while analyzing different samples.

UNIT 1: QUALITATIVE AND QUANTITATIVE ASPECTS OF ANALYSIS:

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

(5 Lectures)

UNIT 2: OPTICAL METHODS OF ANALYSIS:

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of metal complex composition using Job's method of continuous variation and mole ratio method.

Infrared Spectroscopy: Basic principles of instrumentation (choice of source, monochromator & detector) for continuous wave and Fourier transform spectrometers; sampling techniques.

Structure elucidation through interpretation of data. Effect and importance of isotope substitution

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and 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. Techniques for the quantitative estimation of trace level of metal ions from water samples.

(25 Lectures)

UNIT 3: THERMAL METHODS OF ANALYSIS:

Theory of thermogravimetry (TG), basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

(5 Lectures)

Electroanalytical methods:

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

(10 Lectures)

UNIT 4: SEPARATION TECHNIQUES:

Solvent extraction: Classification, principle and efficiency of the technique.

Mechanism of extraction: extraction by solvation and chelation.

Technique of extraction: batch, continuous and counter current extractions.

Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

Chromatography: Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange.

Development of chromatograms: frontal, elution and displacement methods.

Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of

enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral chromatographic techniques using chiral columns (GC and HPLC).
Role of computers in instrumental methods of analysis.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. CBS Publishers & Distributors, 2004.
3. Christian, Gary D: Analytical Chemistry, 6th Ed. Wiley India (P) Ltd., 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, 4th Ed. W. H. Freeman, 2008.
5. Khopkar, S.M.: Basic Concepts of Analytical Chemistry, 3rd Ed. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, 6th Ed. Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London. 1979
8. Ditts, R.V. *Analytical Chemistry: Methods of separation*. Van Nostrand, New York, 1974.

PRACTICAL

1. Separation Techniques

I. Chromatography:

(a) Separation of mixtures

(i) Paper chromatographic separation of Fe^{3+} , Al^{3+} , and Cr^{3+} .

(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.

(b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their R_f values.

(c) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:

- (i) To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+} - DMG complex in chloroform, and determine its concentration by spectrophotometry.
- (ii) Solvent extraction of zirconium with amberliti LA-1, separation from a mixture of iron and gallium.

3. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

4. Determination of Na, Ca, Li in cola drinks and fruit juices using flame photometric techniques.

5. Analysis of soil:

- (i) Determination of pH of soil.
- (ii) Total soluble salt
- (iii) Estimation of calcium, magnesium, phosphate, nitrate

6. Ion exchange:

- (i) Determination of exchange capacity of cation exchange resins and anion exchange resins.
- (ii) Separation of metal ions from their binary mixture.
- (iii) Separation of amino acids from organic acids by ion exchange chromatography.

7. Spectrophotometry

- (i) Determination of pKa values of indicator using spectrophotometry.
- (ii) Structural characterization of compounds by infrared spectroscopy.
- (iii) Determination of dissolved oxygen in water.
- (iv) Determination of chemical oxygen demand (COD).
- (v) Determination of Biological oxygen demand (BOD).
- (vi) Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job's method.

Recommended Books:

1. Vogel, Arthur I: A Text book of Quantitative Inorganic Analysis (Rev. by G.H.Jeffery and others) 5th Ed. The English Language Book Society of Longman .
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, Gary D; Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.

7. Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.

PAPER CODE: CHEM-HDS-5026: Polymer Chemistry

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60 + 30 (L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course objective: This is an introductory level course in polymer chemistry. The aim of the course is to introduce the theory and applications of polymer chemistry to the students. Some industrially important polymers and conducting polymers, a promising class of polymeric materials for next generation devices will also be introduced in this course.

Learning outcome: After completion of this course the students will learn the definition and classifications of polymers, kinetics of polymerization, molecular weight of polymers, glass transition temperature, and polymer solutions etc. They also learn the brief introduction of preparation, structure and properties of some industrially important and technologically promising polymers.

UNIT 1: INTRODUCTION AND HISTORY OF POLYMERIC MATERIALS:

Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.

(4 Lectures)

UNIT 2: FUNCTIONALITY AND ITS IMPORTANCE:

Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems.

(8 Lectures)

UNIT 3: KINETICS OF POLYMERIZATION:

Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques.

(8

lectures)

UNIT 4: CRYSTALLIZATION AND CRYSTALLINITY:

Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.

(4 Lectures)

Nature and structure of polymers-Structure Property relationships.

(2 Lectures)

UNIT 5: DETERMINATION OF MOLECULAR WEIGHT OF POLYMERS (M_n , M_w , etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

Glass transition temperature (T_g) and determination of T_g , Free volume theory,

WLF equation, Factors affecting glass transition temperature (T_g).

(8 Lectures)

UNIT 6: POLYMER SOLUTION – Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymer solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

(8

Lectures)

Properties of Polymers (Physical, thermal, Flow & Mechanical Properties).

Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylenesulphide polypyrrole, polythiophene)].

(10 Lectures)

Recommended Books:

1. *Seymour's Polymer Chemistry*, Marcel Dekker, Inc.
2. G. Odian: *Principles of Polymerization*, John Wiley.
3. F.W. Billmeyer: *Text Book of Polymer Science*, John Wiley.
4. P. Ghosh: *Polymer Science & Technology*, Tata McGraw-Hill.
5. R.W. Lenz: *Organic Chemistry of Synthetic High Polymers*.

PRACTICAL

1. Polymer synthesis

1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).
 - a. Purification of monomer
 - b. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bis-isobutyronitrile(AIBN)
2. Preparation of nylon 66/6
 1. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
 - a. Preparation of IPC
 - b. Purification of IPC
 - c. Interfacial polymerization
 3. Redox polymerization of acrylamide
 4. Precipitation polymerization of acrylonitrile
 5. Preparation of urea-formaldehyde resin
 6. Preparations of novalac resin/resold resin.
 7. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry:
 - (a) Polyacrylamide-aq. NaNO₂ solution
 - (b) (Poly vinyl propylidene (PVP) in water
2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol)(PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG)(OH group).
4. Testing of mechanical properties of polymers.
5. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer analysis

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method
2. Instrumental Techniques
3. IR studies of polymers
4. DSC analysis of polymers
5. Preparation of polyacrylamide and its electrophoresis.

*At least 7 experiments to be carried out.

Recommended Books:

1. Malcom P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed.
2. Harry R. Allcock, Frederick W. Lampe and James E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003)

3. Fred W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984)
4. Joel R. Fried, Polymer Science and Technology, 2nd ed. Prentice-Hall (2003)
5. Petr Munk and Tejraj M. Aminabhavi, Introduction to Macromolecular Science, 2nd ed. John Wiley & Sons (2002)
6. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005)
7. Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd ed. Oxford University Press (2005)

(8 Lectures)

PAPER CODE: CHEM-HDS-6016: Industrial Chemicals and Environment

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60 + 30 (L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: This course provides an introduction to the various industrial gases and inorganic chemicals, their manufacturing processes, applications, storage and the hazards of handling them. Contribution of these industrial chemicals towards air and water pollution and their effects on living organisms and the environment has also been covered. Students are also expected to learn about metallurgy, energy generation industry and the pollution threat they pose. This course also discusses about management of the different

kinds of wastes, their safe disposal and the importance of practicing green chemistry in chemical industry.

Learning Outcomes: After successful completion of the course, students would have learnt about the manufacture, applications and safe ways of storage and handling gaseous and inorganic industrial chemicals. Students will get to know about industrial metallurgy and the energy generation industry. Students will also learn about environmental pollution by various gaseous, liquid wastes and nuclear wastes and their effects on living beings. Finally, the students will learn about industrial waste management, their safe disposal and the importance of environment friendly “green chemistry” in chemical industry.

CONTENTS

THEORY

UNIT 1: INDUSTRIAL GASES AND INORGANIC CHEMICALS

Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.

Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

(10 Lectures)

UNIT 2: INDUSTRIAL METALLURGY

Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

(4 Lectures)

UNIT 3: ENVIRONMENT AND ITS SEGMENTS

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur.

Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution.

Pollution by SO₂, CO₂, CO, NO_x, H₂S and other foul smelling gases. Methods of estimation of CO, NO_x, SO_x and control procedures.

Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.

Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems.

Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal.

Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

(30 Lectures)

UNIT 4: ENERGY & ENVIRONMENT

Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.

Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

(10 Lectures)

UNIT 5: BIOCATALYSIS

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

(6 Lectures)

Recommended Books:

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

PRACTICAL

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Determination of Biological Oxygen Demand (BOD)
4. Percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by simple

titration method (AgNO₃ and potassium chromate).

6. Estimation of total alkalinity of water samples (CO₃²⁻, HCO₃⁻) using double titration method.

7. Measurement of dissolved CO₂.

8. Study of some of the common bio-indicators of pollution.

9. Estimation of SPM in air samples.

10. Preparation of borax/ boric acid.

Recommended Books:

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

PAPER CODE: CHEM-HDS-6026: Dissertation

PAPER CREDIT: 06

W: Work (Field/Laboratory/Library etc.) P: Presentation

Total no. of period: 90P Total Marks: 100 (W80+ P20)

P: Period W: Work (Field/Laboratory/Library etc.), P: Presentation

Student will complete a project work and then prepare a report on that.

The dissertation contains

Broad Area of Dissertation

TITLE

INTRODUCTION

REVIEW OF LITERATURE

METHODOLOGY

RESULTS/FINDINGS

DISCUSSION

SUMMARY

ACKNOWLEDGEMENT

REFERENCES/BIBLIOGRAPHY

**Syllabus of B.Sc. with Chemistry
&
Chemistry as Generic Elective**

SEMESTER-I

PAPER CODE: CHEM-RCC/HGE-1016: Chemistry-1 ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This course may be divided into two broad parts-inorganic and organic chemistry. In inorganic chemistry part the students will be taught atomic structure, chemical bonding and molecular structure. The organic chemistry part contains fundamentals of organic chemistry, stereochemistry and aliphatic hydrocarbons.

Learning Outcome: After completion of this course the students will learn the atomic structure through the basic concepts of quantum mechanics. They will understand the chemical bonding through VB and MO approaches. In organic part, the students are

expected to learn basic ideas used in organic chemistry, stereochemistry, functional groups, alkanes, alkenes, alkynes etc.

UNIT 1: INORGANIC CHEMISTRY (30 PERIODS)

Atomic Structure: *Review of: Bohr's theory and its limitations, dual behaviour of matter and radiation, de-Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a new approach to Atomic structure.*

What is Quantum mechanics? Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ^2 , Schrödinger equation for hydrogen atom. Radial and angular parts of the hydrogenic wavefunctions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers m_l and m_s . Shapes of *s*, *p* and *d* atomic orbitals, nodal planes. Discovery of spin, spin quantum number (*s*) and magnetic spin quantum number (m_s).

Rules for filling electrons in various orbitals, Electronic configurations of the atoms.

Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

(14 Lectures)

Chemical Bonding and Molecular Structure

Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.

Concept of resonance and resonating structures in various inorganic and organic compounds. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for *s-s*, *s-p* and *p-p* combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods

(including idea of *s-p* mixing) and heteronuclear diatomic molecules such as CO, NO and NO⁺. Comparison of VB and MO approaches.

(16 Lectures)

UNIT 2: ORGANIC CHEMISTRY

(30 PERIODS)

Fundamentals of Organic Chemistry

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis.

Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles.

Reactive Intermediates: Carbocations, Carbanions and free radicals.

Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Hückel's rule.

(8 Lectures)

Stereochemistry

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

(10 Lectures)

Aliphatic Hydrocarbons

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Alkanes: (Upto 5 Carbons). *Preparation:* Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. *Reactions:* Free radical Substitution: Halogenation.

Alkenes: (Upto 5 Carbons) *Preparation:* Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). *Reactions:* cis-addition (alk. KMnO_4) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation.

Alkynes: (Upto 5 Carbons) *Preparation:* Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides.

Reactions: formation of metal acetylides, addition of bromine and alkaline KMnO_4 , ozonolysis and oxidation with hot alk. KMnO_4 .

(12 Lectures)

Recommended Books:

1. J. D. Lee: *A new Concise Inorganic Chemistry*, E L. B. S.
2. F. A. Cotton & G. Wilkinson: *Basic Inorganic Chemistry*, John Wiley.
3. Douglas, McDaniel and Alexander: *Concepts and Models in Inorganic Chemistry*, John Wiley.
4. James E. Huheey, Ellen Keiter and Richard Keiter: *Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Publication.
5. T. W. Graham Solomon: *Organic Chemistry*, John Wiley and Sons.
6. Peter Sykes: *A Guide Book to Mechanism in Organic Chemistry*, Orient Longman.
7. E. L. Eliel: *Stereochemistry of Carbon Compounds*, Tata McGraw Hill.
8. I. L. Finar: *Organic Chemistry* (Vol. I & II), E. L. B. S.
9. R. T. Morrison & R. N. Boyd: *Organic Chemistry*, Prentice Hall.
10. Arun Bahl and B. S. Bahl: *Advanced Organic Chemistry*, S. Chand

PRACTICAL: CHEMISTRY1

ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS

Section A: Inorganic Chemistry - Volumetric Analysis

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with KMnO_4 .

3. Estimation of water of crystallization in Mohr's salt by titrating with KMnO_4 .
4. Estimation of Fe (II) ions by titrating it with $\text{K}_2\text{Cr}_2\text{O}_7$ using internal indicator.
5. Estimation of Cu (II) ions iodometrically using $\text{Na}_2\text{S}_2\text{O}_3$.

Section B: Organic Chemistry

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing upto two extra elements)
2. Separation of mixtures by Chromatography: Measure the R_f value in each case (combination of two compounds to be given)
 - (a) Identify and separate the components of a given mixture of 2 amino acids (glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography
 - (b) Identify and separate the sugars present in the given mixture by paper chromatography.

Recommended Books:

1. Vogel's Qualitative Inorganic Analysis, A.I. Vogel, Prentice Hall, 7th Edition.
2. Vogel's Quantitative Chemical Analysis, A.I. Vogel, Prentice Hall, 6th Edition.
3. Textbook of Practical Organic Chemistry, A.I. Vogel, Prentice Hall, 5th edition.
4. Practical Organic Chemistry, F. G. Mann. & B. C. Saunders, Orient Longman, 1960.

SEMESTER-II

PAPER CODE: CHEM-RCC/HGE-2016: Chemistry-2

s- AND *p*-BLOCK ELEMENTS, TRANSITION ELEMENTS, COORDINATION CHEMISTRY STATES OF MATTER & CHEMICAL KINETICS

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This course may be divided into two broad parts-inorganic and physical chemistry. Three units-main group elements, transition elements and co-ordination chemistry will be taught in the inorganic chemistry part. The physical chemistry part contains states of matter and chemical kinetics.

Learning Outcome: After completion of this course the students will learn periodic properties in main group elements, transition metals (3d series). They will also learn the crystal field theory in coordination chemistry unit. In physical chemistry part, the students are expected to learn kinetic theory of gases, ideal gas and real gases, surface tension, viscosity, basic solid state chemistry and chemical kinetics.

UNIT 1: INORGANIC CHEMISTRY (30 PERIODS)

***s*- and *p*-Block Elements**

Periodicity in *s*- and *p*-block elements with respect to electronic configuration, atomic and ionic size, ionization enthalpy, electronegativity (Pauling, Mulliken, and Alfred-Rochow scales). Allotropy in C, S, and P.

Oxidation states with reference to elements in unusual and rare oxidation states like carbides and nitrides), inert pair effect, diagonal relationship and anomalous behaviour of first member of each group.

(10 Lectures)

Transition Elements (3d series)

General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.

(6 Lectures)

Coordination Chemistry

Coordination compounds, types of ligands, Werner's theory, IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers.

Drawbacks of VBT. Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D . Spectrochemical series. Comparison of CFSE for *Oh* and *Td* complexes, Tetragonal distortion of octahedral geometry. Jahn-Teller distortion, Square planar coordination.

(14 Lectures)

UNIT 2: PHYSICAL CHEMISTRY

(30 LECTURES)

Kinetic Theory of Gases

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation. Deviation of real gases from ideal behaviour, compressibility factor, causes of deviation. Van der Waals equation of state for real gases. Boyle temperature (derivation not required). Critical

phenomena, critical constants and their calculation from van der Waals equation. Andrews isotherms of CO₂.

Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance.

Temperature dependence of these distributions. Most probable, average and root mean square velocities (no derivation). Collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only).

(8 Lectures)

Liquids

Surface tension and its determination using stalagmometer. Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only).

(6 Lectures)

Solids

Forms of solids. Symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices. Miller indices. X-Ray diffraction by crystals, Bragg's law. Structures of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals. Glasses and liquid crystals.

(8 Lectures)

Chemical Kinetics

The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants). Half-life of a reaction. General methods for determination of order of a reaction. Concept of activation energy and its calculation from Arrhenius equation. Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular reactions. Comparison of the two theories (qualitative treatment only).

(8 Lectures)

Reference Books:

1. Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
2. Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
5. Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
6. Cotton, F.A. & Wilkinson, G. *Basic Inorganic Chemistry*, Wiley.
7. Shriver, D.F. & Atkins, P.W. *Inorganic Chemistry*, Oxford University Press.
8. Wulfsberg, G. *Inorganic Chemistry*, Viva Books Pvt. Ltd.
9. Rodgers, G.E. *Inorganic & Solid State Chemistry*, Cengage Learning India Ltd., 2008.

PRACTICAL: CHEMISTRY2

s- AND *p*-BLOCK ELEMENTS, TRANSITION ELEMENTS, COORDINATION CHEMISTRY STATES OF MATTER & CHEMICAL KINETICS

Section A: Inorganic Chemistry

Semi-micro qualitative analysis using H₂S of mixtures - not more than four ionic species (two anions and two cations and excluding insoluble salts) out of the following:

CO₃²⁻, NO₂⁻, S²⁻, SO₃²⁻, S₂O₃²⁻, CH₃COO⁻, F⁻, Cl⁻, Br⁻, I⁻, NO₃⁻, BO₃³⁻, C₂O₄²⁻, PO₄³⁻, NH₄⁺, K⁺, Pb²⁺, Cu²⁺, Cd²⁺, Bi³⁺, Sn²⁺, Sb³⁺, Fe³⁺, Al³⁺, Cr³⁺, Zn²⁺, Mn²⁺, Co²⁺, Ni²⁺, Ba²⁺, Sr²⁺, Ca²⁺, Mg²⁺

(Spot tests should be carried out wherever feasible)

1. Estimate the amount of nickel present in a given solution as bis(dimethylglyoximate) nickel(II) or aluminium as oximate in a given solution gravimetrically.
2. Draw calibration curve (absorbance at λ_{\max} vs. concentration) for various concentrations of a given coloured compound (KMnO₄/ CuSO₄) and estimate the concentration of the same in a given solution.
3. Determine the composition of the Fe³⁺-salicylic acid complex solution by Job's method.
4. Estimation of (i) Mg²⁺ or (ii) Zn²⁺ by complexometric titrations using EDTA.
5. Estimation of total hardness of a given sample of water by complexometric titration.
6. Determination of concentration of Na⁺ and K⁺ using Flame Photometry.

Section B: Physical Chemistry

- (I) Surface tension measurement (use of organic solvents excluded).
 - a) Determination of the surface tension of a liquid or a dilute solution using stalagmometer.
 - b) Study of the variation of surface tension of a detergent solution with concentration.
- (II) Viscosity measurement (use of organic solvents excluded).
 - a) Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer.
 - b) Study of the variation of viscosity of an aqueous solution with concentration of solute.
- (III) Chemical Kinetics
Study the kinetics of the following reactions.
 1. Initial rate method: Iodide-persulphate reaction
 2. Integrated rate method:
 - a. Acid hydrolysis of methyl acetate with hydrochloric acid.
 - b. Saponification of ethyl acetate.
 - c. Compare the strengths of HCl and H₂SO₄ by studying kinetics of hydrolysis of methyl acetate

Reference Books:

1. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
2. Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
3. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R.Chand & Co.: New Delhi (2011).

SEMESTER-III

PAPER CODE: CHEM-RCC/HGE-3016: Chemistry-3 **CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL** **ORGANIC CHEMISTRY-I**

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This course contains two broad parts- physical and organic chemistry. In physical chemistry part the students will be taught chemical energetics, chemical equilibrium and ionic equilibrium. In organic chemistry part, the students will be introduced to different classes of organic compounds.

Learning Outcome: After completion of this course the students will be able to understand the chemical system from thermodynamic points of view. They will also learn two very important topics in chemistry- chemical equilibrium and ionic equilibrium. In organic chemistry part, the students are expected to learn various classes of organic molecules-alkyl halides, aryl halides, alcohols, phenols, ethers, aldehydes and ketones.

UNIT 1: PHYSICAL CHEMISTRY **(30 LECTURES)**

Chemical Energetics

Review of thermodynamics and the Laws of Thermodynamics.

Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchoff's equation. Statement of Third Law of thermodynamics and calculation of absolute entropies of substances.

(10 Lectures)

Chemical Equilibrium:

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ΔG and ΔG° , Le Chatelier's principle. Relationships between K_p , K_c and K_x for reactions involving ideal gases.

(8 Lectures)

Ionic Equilibria:

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect. Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

(12 Lectures)

UNIT 2: ORGANIC CHEMISTRY (30 LECTURES)

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Aromatic hydrocarbons

Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzenesulphonic acid.

Reactions: (Case benzene): Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene).

(8 Lectures)

Alkyl and Aryl Halides

Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (S_N1 , S_N2 and S_Ni) reactions.

Preparation: from alkenes and alcohols.

Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis: Elimination vs substitution.

Aryl Halides Preparation: (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions.

Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/NH_3 (or $\text{NaNH}_2/\text{NH}_3$).
Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and arylhalides.

(8 Lectures)

Alcohols, Phenols and Ethers (Upto 5 Carbons)

Alcohols: *Preparation:* Preparation of 1^o, 2^o and 3^o alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.

Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. KMnO_4 , acidic dichromate, conc. HNO_3). Oppeneauer oxidation *Diols:* (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols: (Phenol case) *Preparation:* Cumene hydroperoxide method, from diazonium salts. *Reactions:* Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-Tiemann Reaction, Gattermann-Koch Reaction, Houben–Hoesch Condensation, Schotten – Baumann Reaction.

Ethers (aliphatic and aromatic): Cleavage of ethers with HI.

Aldehydes and ketones (aliphatic and aromatic): (Formaldehyde, acetaldehyde, acetone and benzaldehyde)

Preparation: from acid chlorides and from nitriles.

Reactions – Reaction with HCN, ROH, NaHSO_3 , $\text{NH}_2\text{-G}$ derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Ponndorf Verley reduction.

(14 Lectures)

Recommended Books:

1. T. W. Graham Solomons: *Organic Chemistry, John Wiley and Sons.*
2. Peter Sykes: *A Guide Book to Mechanism in Organic Chemistry,* Orient Longman.
3. I.L. Finar: *Organic Chemistry* (Vol. I & II), E. L. B. S.
4. R. T. Morrison & R. N. Boyd: *Organic Chemistry,* Prentice Hall.
5. Arun Bahl and B. S. Bahl: *Advanced Organic Chemistry,* S. Chand.
6. G. M. Barrow: *Physical Chemistry* Tata McGraw-Hill (2007).
7. G. W. Castellan: *Physical Chemistry* 4th Edn. Narosa (2004).
8. J. C. Kotz, P. M. Treichel & J. R. Townsend: *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
9. B. H. Mahan: *University Chemistry* 3rd Ed. Narosa (1998).
10. R. H. Petrucci: *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).

PRACTICAL CHEMISTRY3

CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY-I

Section A: Physical Chemistry

Thermochemistry

1. Determination of heat capacity of calorimeter for different volumes.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodiumhydroxide.
3. Determination of enthalpy of ionization of acetic acid.
4. Determination of integral enthalpy of solution of salts (KNO_3 , NH_4Cl).
5. Determination of enthalpy of hydration of copper sulphate.
6. Study of the solubility of benzoic acid in water and determination of ΔH .

Ionic equilibria

pH measurements

a) Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter.

b) Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Section B: Organic Chemistry

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

2. Criteria of Purity: Determination of melting and boiling points.

3. Preparations: Mechanism of various reactions involved to be discussed.

Recrystallisation, determination of melting point and calculation of quantitative yield to be done.

(a) Bromination of Phenol/Aniline

(b) Benzoylation of amines/phenols

(c) Oxime and 2,4 dinitrophenylhydrazone of aldehyde/ketone

Recommended Books

1. A.I. Vogel: Textbook of Practical Organic Chemistry, 5th edition, Prentice-Hall.
2. F. G. Mann & B. C. Saunders, Practical Organic Chemistry, Orient Longman (1960).
3. B.D. Khosla, Senior Practical Physical Chemistry, R. Chand & Co.

SEMESTER-IV

PAPER CODE: CHEM-RCC/HGE-4016: Chemistry-4 **SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE,** **ELECTROCHEMISTRY & FUNCTIONAL GROUP** **ORGANIC CHEMISTRY**

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This course may be divided into two broad parts-physical and organic chemistry. In 1st part of this course students will be introduced to solutions, phase equilibrium and electrochemistry. The 2nd part contains carboxylic acid and derivatives, amines and diazonium salt and biochemistry.

Learning Outcome: After completion of this course the students learn solutions, phase rule and its application in specific cases, basics of conductance and electrochemistry. Students will also learn some important topics of organic and biochemistry- carboxylic acids, amines, amino acids, peptides, proteins and carbohydrates.

CONTENTS **THEORY**

UNIT 1: PHYSICAL CHEMISTRY-2 **(30 LECTURES)**

Solutions

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions. Vapour pressure-composition and temperature-composition

curves of ideal and non-ideal solutions. Distillation of solutions. Lever rule.

Azeotropes. Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Immiscibility of liquids- Principle of steam distillation. Nernst distribution law and its applications, solvent extraction.

Phase Equilibrium

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting

points (lead-silver, FeCl₃-H₂O and Na-K only).

Conductance

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch law of independent migration of ions.

Transference number and its experimental determination using Hittorf and Moving boundary methods. Ionic mobility. Applications of conductance measurements: determination of degree of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts,

ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acidbase).

Electrochemistry

Reversible and irreversible cells. Concept of EMF of a cell. Measurement of EMF of a cell. Nernst equation and its importance. Types of electrodes. Standard electrode potential. Electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG , ΔH and ΔS from EMF data.

Calculation of equilibrium constant from EMF data. Concentration cells with transference and without transference. Liquid junction potential and salt bridge.

pH determination using hydrogen electrode and quinhydrone electrode.

Potentiometric titrations -qualitative treatment (acid-base and oxidation-reduction only).

UNIT 2: ORGANIC CHEMISTRY (30 LECTURES)

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Carboxylic acids and their derivatives

Carboxylic acids (aliphatic and aromatic)

Preparation: Acidic and Alkaline hydrolysis of

esters.*Reactions:* Hell – Vohlard - Zelinsky

Reaction.

Carboxylic acid derivatives (aliphatic): (Upto 5 carbons)

Preparation: Acid chlorides, Anhydrides, Esters and Amides from acids and their interconversion.

Reactions: Comparative study of nucleophilicity of acyl derivatives.
Reformatsky Reaction, Perkin condensation.

(6 Lectures)

Amines and Diazonium Salts

Amines (Aliphatic and Aromatic): (Upto 5 carbons)

Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction.

Reactions: Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO_2 , Schotten – Baumann Reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation.

Diazonium salts: *Preparation:* from aromatic amines.

Reactions: conversion to benzene, phenol, dyes.

(6 Lectures)

Amino Acids, Peptides and Proteins:

Preparation of Amino Acids: Strecker synthesis using Gabriel's phthalimide synthesis. Zwitterion, Isoelectric point and Electrophoresis.

Reactions of Amino acids: ester of $-\text{COOH}$ group, acetylation of $-\text{NH}_2$ group, complexation with Cu^{2+} ions, ninhydrin test.

Overview of Primary, Secondary, Tertiary and Quaternary Structure of proteins.

Determination of Primary structure of Peptides by degradation Edmann degradation (Nterminal) and C-terminal (thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (t-butyloxycarbonyl and phthaloyl) & Cactivating groups and Merrifield solid-phase synthesis.

(10 Lectures)

Carbohydrates: Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disaccharides (sucrose, cellobiose, maltose, lactose) and polysaccharides (starch and cellulose) excluding their structure elucidation.

(8 Lectures)

Recommended Books:

1. G. M. Barrow: *Physical Chemistry* Tata McGraw---Hill (2007).
2. G. W. Castellan: *Physical Chemistry* 4th Ed. Narosa (2004).
3. J. C. Kotz, P. M. Treichel, J. R. Townsend, *General Chemistry*, Cengage Learning India Pvt. Ltd.: New Delhi (2009).
4. B. H. Mahan: *University Chemistry*, 3rd Edn. Narosa (1998).
5. R. H. Petrucci, *General Chemistry*, 5th Edn., Macmillan Publishing Co.: New York (1985).
6. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Finar, I. L. *Organic Chemistry (Volume 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Nelson, D. L. & Cox, M. M. *Lehninger's Principles of Biochemistry 7th Ed.*, W. H. Freeman.
10. Berg, J. M., Tymoczko, J. L. & Stryer, L. *Biochemistry 7th Ed.*, W. H. Freeman

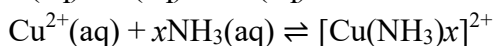
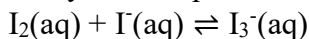
PRACTICAL: CHEMISTRY 4

SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL ORGANIC CHEMISTRY-II

Section A: Physical Chemistry

Distribution

Study of the equilibrium of one of the following reactions by the distribution method:



Phase equilibria

- a) Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.
- b) Determination of the critical solution temperature and composition of the phenol-water system and study of the effect of impurities on it.
- c) Study of the variation of mutual solubility temperature with concentration for the phenol-water system and determination of the critical solubility temperature.

Conductance

IV. Determination of cell constant

V. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

VI. Perform the following conductometric titrations:

1. Strong acid vs. strong base
2. Weak acid vs. strong base

Potentiometry

Perform the following potentiometric titrations:

1. Strong acid vs. strong base
2. Weak acid vs. strong base
3. Potassium dichromate vs. Mohr's salt

Section B: Organic Chemistry

I Systematic Qualitative Organic Analysis of Organic Compounds possessing monofunctional groups (-COOH, phenolic, aldehydic, ketonic, amide, nitro, amines) and preparation of one derivative.

II

1. Separation of amino acids by paper chromatography
2. Determination of the concentration of glycine solution by formylation method.
3. Titration curve of glycine
4. Action of salivary amylase on starch
5. Effect of temperature on the action of salivary amylase on starch.
6. Determination of the saponification value of an oil/fat.
7. Determination of the iodine value of an oil/fat
8. Differentiation between a reducing/nonreducing sugar.
9. Extraction of DNA from onion/ cauliflower

Recommended Books:

1. A.I. Vogel: Textbook of Practical Organic Chemistry, Prentice Hall, 5th Edn.
2. F. G. Mann & B. C. Saunders: Practical Organic Chemistry, Orient Longman, 1960.
3. B.D. Khosla: Senior Practical Physical Chemistry, R. Chand & Co.
4. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry*, Universities Press.

DISCIPLINE SPECIFIC ELECTIVE (DSE)

PAPER CODE: CHEM-RDS-5016: Analytical Methods in Chemistry

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This is an elective course designed to complement the needs of students who wish to learn more about the qualitative/quantitative characterization and separation techniques. The content of this course aims to cover some of the widely used instrumental techniques for characterization of samples. Experiments included aim at giving students hands on experience using different instrumental techniques and chemical analysis.

Learning outcome: On successful completion students will be have theoretical understanding about choice of various analytical techniques used for qualitative and quantitative characterization of samples. At the same time through the experiments students will gain hands on experience of the discussed techniques. This will enable students to take judicious decisions while analyzing different samples.

CONTENTS

THEORY

UNIT 1: QUALITATIVE AND QUANTITATIVE ASPECTS OF ANALYSIS:

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

(5 Lectures)

UNIT 2: OPTICAL METHODS OF ANALYSIS:

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of metal complex composition using Job's method of continuous variation and mole ratio method.

Infrared Spectroscopy: Basic principles of instrumentation (choice of source, monochromator & detector) for continuous wave and Fourier transform spectrometers; sampling techniques.

Structure elucidation through interpretation of data. Effect and importance of isotope substitution.

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and 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. Techniques for the quantitative estimation of trace level of metal ions from water samples.

UNIT 3: THERMAL METHODS OF ANALYSIS:

Theory of thermogravimetry (TG), basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

UNIT 4: ELECTROANALYTICAL METHODS:

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pK_a values.

(10 Lectures)

UNIT 5: SEPARATION TECHNIQUES:

Solvent extraction: Classification, principle and efficiency of the technique.

Mechanism of extraction: extraction by solvation and chelation.

Technique of extraction: batch, continuous and counter current extractions.

Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

Chromatography: Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange.

Development of chromatograms: frontal, elution and displacement methods.

Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral chromatographic techniques using chiral columns (GC and HPLC).

Role of computers in instrumental methods of analysis.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. CBS Publishers & Distributors, 2004.
3. Christian, Gary D: Analytical Chemistry, 6th Ed. Wiley India (P) Ltd., 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, 4th Ed. W. H. Freeman, 2008.
5. Khopkar, S.M.: Basic Concepts of Analytical Chemistry, 3rd Ed. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, 6th Ed. Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London. 1979
8. Ditts, R.V. *Analytical Chemistry: Methods of separation*. Van Nostrand, New York, 1974.

PRACTICAL: ANALYTICAL METHODS IN CHEMISTRY

1. Separation Techniques

I. Chromatography:

(a) Separation of mixtures

(i) Paper chromatographic separation of Fe^{3+} , Al^{3+} , and Cr^{3+} .

- (ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.
- (b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their R_f values.
- (c) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:

- (i) To separate a mixture of Ni²⁺ & Fe²⁺ by complexation with DMG and extracting the Ni²⁺- DMG complex in chloroform, and determine its concentration by spectrophotometry.
 - (ii) Solvent extraction of zirconium with amberliti LA-1, separation from a mixture of iron and gallium.
3. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.
 4. Determination of Na, Ca, Li in cola drinks and fruit juices using flame photometric techniques.

5. Analysis of soil:

- (i) Determination of pH of soil.
- (ii) Total soluble salt
- (iii) Estimation of calcium, magnesium, phosphate, nitrate

6. Ion exchange:

- (i) Determination of exchange capacity of cation exchange resins and anion exchange resins.
- (ii) Separation of metal ions from their binary mixture.
- (iii) Separation of amino acids from organic acids by ion exchange chromatography.

7. Spectrophotometry

- (i) Determination of pK_a values of indicator using spectrophotometry.
- (ii) Structural characterization of compounds by infrared spectroscopy.
- (iii) Determination of dissolved oxygen in water.
- (iv) Determination of chemical oxygen demand (COD).
- (v) Determination of Biological oxygen demand (BOD).

Recommended Books:

1. Vogel, Arthur I: A Text book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5th Ed. The English Language Book Society of Longman .
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed.

- Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, Gary D; Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
 4. Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
 5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age, International Publisher, 2009.
 6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.
 7. Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
 8. Ditts, R.V. *Analytical Chemistry: Methods of separation*. Van Nostrand, New York, 1974.

PAPER CODE: CHEM-RDS-5026: Polymer Chemistry

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course objective: This is an introductory level course in polymer chemistry. The aim of the course is to introduce the theory and applications of polymer chemistry to the students. Some industrially important polymers and conducting polymers, a promising class of polymeric materials for next generation devices will also be introduced in this course.

Learning outcome: After completion of this course the students will learn the definition and classifications of polymers, kinetics of polymerization, molecular weight of polymers, glass transition temperature, and polymer solutions etc. They also learn the brief introduction of preparation, structure and properties of some industrially important and technologically promising polymers.

CONTENTS

THEORY

UNIT 1: INTRODUCTION AND HISTORY OF POLYMERIC MATERIALS:

Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.

(4 Lectures)

UNIT 2: FUNCTIONALITY AND ITS IMPORTANCE:

Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems.

(8 Lectures)

UNIT 3: KINETICS OF POLYMERIZATION:

Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques.

(8 lectures)

UNIT 4: CRYSTALLIZATION AND CRYSTALLINITY:

Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.

(4 Lectures)

Nature and structure of polymers-Structure Property relationships.

(2 Lectures)

UNIT 5: DETERMINATION OF MOLECULAR WEIGHT OF POLYMERS (M_n , M_w , etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

(8 Lectures)

UNIT 6: Glass transition temperature (T_g) and determination of T_g, Free volume theory,

WLF equation, Factors affecting glass transition temperature (T_g).

Polymer Solution – Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

(8 Lectures)

UNIT 7: PROPERTIES OF POLYMERS (Physical, thermal, Flow & Mechanical Properties).

Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac),

polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphide polypyrrole, polythiophene)].

(10 Lectures)

Recommended Books:

6. *Seymour's Polymer Chemistry*, Marcel Dekker, Inc.
7. G. Odian: *Principles of Polymerization*, John Wiley.
8. F.W. Billmeyer: *Text Book of Polymer Science*, John Wiley.
9. P. Ghosh: *Polymer Science & Technology*, Tata Mcgraw-Hill.
10. R.W. Lenz: *Organic Chemistry of Synthetic High Polymers*.

PRACTICAL

3. Polymer synthesis

1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) /Methyl Acrylate (MA) / Acrylic acid (AA).
 - a. Purification of monomer
 - b. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bis-isobutyronitrile(AIBN)
4. Preparation of nylon 66/6
 2. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
 - a. Preparation of IPC
 - b. Purification of IPC
 - c. Interfacial polymerization
 8. Redox polymerization of acrylamide
 9. Precipitation polymerization of acrylonitrile
 10. Preparation of urea-formaldehyde resin
 11. Preparations of novalac resin/resold resin.
 12. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

6. Determination of molecular weight by viscometry:
 - (a) Polyacrylamide-aq. NaNO₂ solution
 - (b) (Poly vinyl propylidene (PVP) in water
7. Determination of the viscosity-average molecular weight of poly(vinyl alcohol)(PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
8. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG)(OH group).
9. Testing of mechanical properties of polymers.
10. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer analysis

6. Estimation of the amount of HCHO in the given solution by sodium sulphite method
7. Instrumental Techniques
8. IR studies of polymers
9. DSC analysis of polymers
10. Preparation of polyacrylamide and its electrophoresis.

*At least 7 experiments to be carried out.

Recommended Books:

1. Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed.
2. Harry R. Allcock, Frederick W. Lampe and James E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003)
3. Fred W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984)
4. Joel R. Fried, Polymer Science and Technology, 2nd ed. Prentice-Hall (2003)

8. Petr Munk and Tejraj M. Aminabhavi, Introduction to Macromolecular Science, 2nd ed. John Wiley & Sons (2002)
9. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005)
10. Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd ed. Oxford University Press (2005)

PAPER CODE: CHEM-RDS-6016: Industrial Chemicals and Environment

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objectives: This course provides an introduction to the various industrial gases and inorganic chemicals, their manufacturing processes, applications, storage and the hazards of handling them. Contribution of these industrial chemicals towards air and water pollution and their effects on living organisms and the environment has also been covered. Students are also expected to learn about metallurgy, energy generation industry and the pollution threat they pose. This course also discusses about management of the different kinds of wastes, their safe disposal and the importance of practicing green chemistry in chemical industry.

Learning Outcomes: After successful completion of the course, students would have learnt about the manufacture, applications and safe ways of storage and handling gaseous and inorganic industrial chemicals. Students will get to know about industrial metallurgy and the energy generation industry. Students will also learn about environmental pollution by

various gaseous, liquid wastes and nuclear wastes and their effects on living beings. Finally, the students will learn about industrial waste management, their safe disposal and the importance of environment friendly “green chemistry” in chemical industry.

CONTENTS

THEORY

UNIT 1: INDUSTRIAL GASES AND INORGANIC CHEMICALS

Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.

Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

(10 Lectures)

UNIT 2: INDUSTRIAL METALLURGY

Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

(4 Lectures)

UNIT 3: ENVIRONMENT AND ITS SEGMENTS

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur.

Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution.

Pollution by SO₂, CO₂, CO, NO_x, H₂S and other foul smelling gases. Methods of estimation of CO, NO_x, SO_x and control procedures.

Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.

Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems.

Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment:

electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc.
Sludge disposal.

Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

(30 Lectures)

UNIT 4: ENERGY & ENVIRONMENT

Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.

Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

(10 Lectures)

UNIT 5: BIOCATALYSIS

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

(6 Lectures)

Recommended Books:

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

PRACTICAL: INDUSTRIAL CHEMICALS & ENVIRONMENT

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Determination of Biological Oxygen Demand (BOD)
4. Percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by simple titrationmethod (AgNO₃ and potassium chromate).
6. Estimation of total alkalinity of water samples (CO₃²⁻, HCO₃⁻) using double titrationmethod.
7. Measurement of dissolved CO₂.
8. Study of some of the common bio-indicators of pollution.

9. Estimation of SPM in air samples.
10. Preparation of borax/ boric acid.

Recommended Books:

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

PAPER CODE: CHEM-RDS-6026: Green Chemistry

PAPER CREDIT: 06 (4T+2P)

Total no. of Lectures: 60+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: The learners will be taught about the emerging discipline of green chemistry particularly to differentiate as to how the principles of green chemistry may be applied to organic synthesis.

Learning Outcome: Apart from introducing learners to the principles of green chemistry, this course will make them conversant with applications of green chemistry to organic synthesis. Students will be prepared for taking up entry level jobs in the chemical industry. They also will have the option of studying further in the area.

UNIT 1: INTRODUCTION TO GREEN CHEMISTRY

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

(4 Lectures)

UNIT 2: PRINCIPLES OF GREEN CHEMISTRY AND DESIGNING A CHEMICAL SYNTHESIS

Twelve principles of Green Chemistry with their explanations and examples; Designing a Green Synthesis using these principles; Prevention of Waste/ byproducts; maximum

incorporation of the materials used in the process into the final products (Atom Economy); prevention/ minimization of hazardous/ toxic products; designing safer chemicals – different basic approaches to do so; selection of appropriate auxiliary substances (solvents, separation agents), green solvents, solventless processes, immobilized solvents and ionic liquids; energy requirements for reactions - use of microwaves, ultrasonic energy; selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups; use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; designing of biodegradable products; prevention of chemical accidents; strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

(24 Lectures)

UNIT 3: EXAMPLES OF GREEN SYNTHESIS/ REACTIONS

1. Green Synthesis of the following compounds: adipic acid, catechol, BHT, methylmethacrylate, urethane, citral, ibuprofen, paracetamol, furfural.
2. Microwave assisted reactions in water: Oxidation of toluene, alcohols.
Microwave assisted reactions in organic solvents: Esterification, Fries rearrangement, Diels-Alder Reaction.
Microwave assisted solid state reactions: Deacetylation, Deprotection. Saponification of esters, Alkylation of reactive methylene compounds, reductions, benzimidazoles.
3. Selective methylation of active methylene group using dimethylcarbonate: Solid-state polymerization of amorphous polymers using diphenylcarbonate; Use of “Clayan”, a nonmetallic oxidative reagent for various reactions; Free Radical Bromination; Role of Tellurium in organic syntheses; Biocatalysis in organic syntheses.

(24 Lectures)

UNIT 4: FUTURE TRENDS IN GREEN CHEMISTRY

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Solventless reactions; Green chemistry in sustainable development.

(8 Lectures)

Recommended Books:

1. V.K. Ahluwalia & M.R. Kidwai: New Trends in Green Chemistry, Anamalaya Publishers (2005).
2. P.T. Anastas & J.K. Warner: Oxford Green Chemistry- Theory and Practical, University Press (1998).
3. A.S. Matlack: Introduction to Green Chemistry, Marcel Dekker (2001).
4. M.C. Cann & M.E. Connely: Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).
5. M.A. Ryan & M. Tinnesand, Introduction to Green Chemistry, American Chemical Society, Washington (2002).

PRACTICAL: GREEN CHEMISTRY

1. Safer starting materials

The Vitamin C clock reaction using Vitamin C tablets, tincture of iodine, hydrogen peroxide and liquid laundry starch.

- (i) Effect of concentration on clock reaction
- (ii) Effect of temperature on clock reaction.

2. Using renewable resources

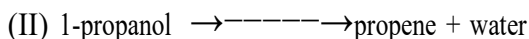
Preparation of biodiesel from vegetable oil.

3. Avoiding waste

Principle of atom economy.

Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.

Preparation of propene by two methods can be studied



The other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.

4. Use of enzymes as catalysts

Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide

Alternative Green solvents

5. Diels Alder reaction in water

Reaction between furan and maleic acid in water and at room temperature rather than in benzene and reflux.

6. Extraction of D-limonene from orange peel using liquid CO₂ prepared from dry ice.

7. Mechanochemical solvent free synthesis of azomethines

8. Co-crystal controlled solid state synthesis (C₂S₃) of N-organophthalimide using phthalicanhydride and 3-aminobenzoic acid.

Alternative sources of energy

9. Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper(II).

10. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Recommended Books:

1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate*

- chemistryexperiment*. American Chemical Society, Washington DC (2002).
3. Ryan, M.A. *Introduction to Green Chemistry*, Tinneland; (Ed), American Chemical Society, Washington DC (2002).
 4. Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. *Green Chemistry Experiment: A monograph*, I.K International Publishing House Pvt Ltd. New Delhi. Bangalore ISBN 978-93-81141-55-7 (2013).

SKILL ENHANCEMENT COURSE (SEC)

PAPER CODE: CHEM-SEC-3014: Basic Analytical Chemistry

PAPER CREDIT: 04 (2T+2P)

Total no. of Lectures: 30+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: To familiarize students with different micro and semimicro analytical techniques and help develop the ability to use modern instrumental methods for chemical analysis of food, soil, air and water.

Learning Outcome: Upon completion of this course, students shall be able to explain the basic principles of chemical analysis, design/implement microscale and semimicro experiments, record, interpret and analyze data following scientific methodology.

CONTENTS

THEORY

UNIT 1: INTRODUCTION: Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results, from the point of view of significant figures.

UNIT 2: ANALYSIS OF SOIL: Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators

- a. Determination of pH of soil samples.
- b. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

UNIT 3: ANALYSIS OF WATER: Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

- a. Determination of pH, acidity and alkalinity of a water sample.
- b. Determination of dissolved oxygen (DO) of a water sample.

UNIT 4: ANALYSIS OF FOOD PRODUCTS: Nutritional value of foods, idea about food processing and food preservations and adulteration.

- a. Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.
- b. Analysis of preservatives and colouring matter.

Chromatography: Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

- a. Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).
- b. To compare paint samples by TLC method.

Ion-exchange: Column, ion-exchange chromatography etc.

Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

UNIT 5: ANALYSIS OF COSMETICS: Major and minor constituents and their function

- a. Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.
- b. Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration.

PRACTICAL

Suggested Applications (Any one):

- a. To study the use of phenolphthalein in trap cases.
- b. To analyze arson accelerants.
- c. To carry out analysis of gasoline.

Suggested Instrumental demonstrations:

- a. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.
- b. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.
- c. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drink.

Recommended Books:

1. Willard, H. H. *Instrumental Methods of Analysis*, CBS Publishers.
2. Skoog & Lerry. *Instrumental Methods of Analysis*, Saunders College Publications, New York.
3. Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6th Ed.*, Saunders College Publishing, Fort Worth (1992).
4. Harris, D. C. *Quantitative Chemical Analysis*, W. H. Freeman.
5. Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
6. Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7th Ed.*, Prentice Hall.
7. Vogel, A. I. *Vogel's Quantitative Chemical Analysis 6th Ed.*, Prentice Hall.

Robinson, J.W. *Undergraduate Instrumental Analysis 5th Ed.*, Marcel Dekker, Inc., New York (1995).

PAPER CODE: CHEM-SEC-4014: Pesticide Chemistry

PAPER CREDIT: 04 (2T+2P)

Total no. of Lectures: 30+30(L+P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Tutorial, P: Practical T: Theory, IA: Internal Assessment, P: Practical

Course Objective: This is a brief and introductory course on pesticides, through which the students will be introduced to various classes of pesticides, their synthesis, applications and possible hazards of their uses.

Learning Outcome: Students will be able to explain or describe and critically examine different types of pesticides, their activity/toxicity and their applications and the need for the search of an alternative based on natural products.

CONTENTS

THEORY

Definition of pesticides, general introduction to pesticides (natural and synthetic), benefits and adverse effects of pesticides. Classification, mode of action, toxicity and methods of pesticides residue analysis. Synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene); organophosphate (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor)

PRACTICALS:

1. To calculate acidity/alkalinity in given sample of pesticides formulations as per BIS specifications.
2. Preparation of simple organophosphates, phosphonates and thiophosphates.

Recommended Book:

1. R. Cremllyn: Pesticides, Preparation and Mode of Action, John Wiley & Sons, New York, 1978
2. R.P. Bateman, Pesticide Applications, AAB Press, 2004
3. Principles of Pesticide chemistry: S K Handa, Ed. by Agrobios (India), 2008
4. Pesticide Science & Biotechnology: R Greenhalgh and T R Robers, IUPAC, Blackwell Scientific Publications, 1987
5. The Chemical Process Industries: D N Shreve
6. Pesticide Chemistry : G Matolesy, M. Nadasy, V. Andriska, Elsevier Sc. Publisher, USA, 1988

PAPER CODE: CHEM-SEC-5014: Chemical Technology and Society

PAPER CREDIT: 04 (2T+2P)

Total no. of Lectures: 60 (30L+30P) Total Marks: 100 (T60+IA20+P20)

L: Lecture, T: Theory, IA: Internal Assessment P: Presentation

Course Objective: The objective of the course is to enable students to have a firsthand understanding of different types of equipments needed in chemical technology and offer them concepts regarding some important parameters. The syllabus also emphasizes the dynamic nature of the relations between society on one hand and technological achievement from chemical industries on the other hand. In other words, it tries to explore societal and technological issues from a chemical perspective.

Learning Outcome: Students shall be familiarized with processes and terminologies in chemical industry, like mass balance, energy balance etc... Learners will be able to use chemical and scientific literacy as a means to better understand the topics related to the society.

CONTENTS

THEORY

UNIT 1: CHEMICAL TECHNOLOGY

Different types of equipments needed in chemical technology, including reactors, distillation columns, extruders, pumps, mills, emulgators. Scaling up operations in chemical industry. Introduction to clean technology.

Concept of relative humidity, molal humidity, dew point, partial saturation.

Material Balance: Recycle, bypass in batch, stage wise and continuous operations in systems with and without chemical reactions.

Energy balance: Energy balance of systems with and without chemical reactions.

UNIT 2: SOCIETY

Social issues related to soil, air and water pollution.

Energy crisis of modern society and search for alternatives such as energy from natural sources (i.e. solar and renewable forms), and from nuclear fission, biofuel etc.

Pros and cons of use of materials like plastics and polymers and their natural analogues, Genetic engineering and the manufacture of drugs (proteins and nucleic acids, and molecular reactivity and interconversions)

UNIT 3: Presentation on related topics.

Recommended Book:

1. John W. Hill, Terry W. McCreary & Doris K. Kolb, *Chemistry for changing times* 13th Ed.
2. E.J. Hackett, O. Amsterdamska, M. Lynch and J. Wajcman (eds.), *The Handbook of Science and Technology Studies*, The MIT Press, 2008.
3. D. MacKenzie and J. Wajcman (eds.), *The Social Shaping of Technology*, The Open University Press, 1999.