

**UNIVERSITY DEPARTMENT OF CHEMISTRY**

**RADHA GOVIND UNIVERSITY**

**RAMGARH, JHARKHAND**



**COURSE CURRICULUM FOR UNDERGRADUATE COURSES UNDER  
CHOICE BASED CREDIT SYSTEM**

**B.Sc. (Honours in Chemistry)**

**With effect from 2018-2021**

**UNIVERSITY DEPARTMENT OF CHEMISTRY  
RADHA GOVIND UNIVERSITY  
RAMGARH**

# Course Structure (Chemistry-Major)

## Details of courses under B.Sc. (Honours)

Course	*Credits	
	Theory	Practical
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<b>I. Core Course</b>		
<b>(14 Papers)</b>	14x4= 56	
<b>Core Course Practical</b>		
<b>(07 Papers)</b>	04x4+02x06= 28	
<b>II. Elective Course</b>		
<b>(8 Papers)</b>		
A.1. Discipline Specific Elective	4x4=16	
<b>(4 Papers)</b>		
A.2. Discipline Specific Elective		
Practical/Tutorial*	2x4=8	
<b>(4 Papers)</b>		
B.1. Generic Elective/ Interdisciplinary	4x4=16	
<b>(4 Papers)</b>		
B.2. Generic Elective		
Practical/ Tutorial*	4x2=8	
<b>(4 Papers)</b>		
□ <b>Optional Dissertation or project work in place of one Discipline Specific Elective paper</b>		
<b>(6 credits) in 6<sup>th</sup> Semester</b>		
<b>III. Ability Enhancement Courses</b>		
<b>1. Ability Enhancement Compulsory</b>		
<b>(2 Papers of 2 credit each)</b>	2x2=4	
Environmental Science		
English Communication		
<b>2. Ability Enhancement Elective (Skill Based)</b>		
<b>(Minimum 2)</b>	2x2=4	
<b>(2 Papers of 2 credit each)</b>		
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<b>Total credit</b>	<b>140</b>	

**PROPOSED SCHEME FOR CHOICE BASED CREDIT SYSTEM IN  
B. Sc. Honours (Chemistry)**

Semester	CORE COURSE (14)	Ability Enhancement Compulsory Course (AECC) (2)	Ability Enhancement Elective Course (AEEC) (2) (Skill Based)	Elective: Discipline Specific DSE (4)	Elective: Generic (GE) (4)
I	Inorganic I: Atomic Structure & Chemical Bonding-I (4) Physical I: States of Matter & Ionic Equilibrium (4) Practical-I (4)	English Communication			GE-1
II	Organic I: Basics & Hydrocarbons (4) Physical II: Chemical Thermodynamics & its Applications (4) Practical-II (4)	Environmental Science			GE-2
III	Inorganic II: s- and p-Block Elements (4) Organic II: Oxygen Containing Functional Groups (4) Physical III: Phase Equilibria & Chemical Kinetics (4) Practical-III (6)		SEC -1		GE-3
IV	Inorganic III: Coordination Chemistry (4)		SEC -2		GE-4

	Organic Heterocyclic Chemistry (4)	III:				
	Physical Electrochemistry (4) Practical-IV(6)	IV:				
V	Organic Biomolecules (4)	IV:			DSE-1	
	Physical Quantum Chemistry & Spectroscopy (4) Practical-V(4)	V:			DSE -2	
VI	Inorganic Organometallic Chemistry (4)	IV:			DSE -3	
	Organic Chemistry Spectroscopy (4) Practical VI (4)	V:			DSE -4	

SEMESTER	COURSE OPTED	COURSE NAME	Credits
I	Ability Enhancement Compulsory Course-I	English Communications	2
	Core Course-I	Inorganic Chemistry-I	4
	Core Course-II	Physical Chemistry-I	4
	Core Course- Practical-I		4
	Generic Elective -1	GE-1	4
	Generic Elective -1 Practical		2
II	Ability Enhancement Compulsory Course-II	Environmental Science	2
	Core Course-III	Organic Chemistry-I	4
	Core Course-IV	Physical Chemistry-II	4
	Core Course Practical-II		4
	Generic Elective -2	GE-2	4
	Generic Elective -2 Practical		2
III	Core Course-V	Inorganic Chemistry-II	4
	Core Course-VI	Organic Chemistry-II	4
	Core Course -VII	Physical Chemistry-III	4
	Core Course Practical-III		6
	Skill Enhancement Course -1	SEC-1	2

	<b>Generic Elective -3</b>	<b>GE-3</b>	<b>4</b>
	<b>Generic Elective -3 Practical</b>		<b>2</b>
<b>IV</b>	<b>Core Course-VIII</b>	<b>Inorganic Chemistry-III</b>	<b>4</b>
	<b>Core Course-IX</b>	<b>Organic Chemistry-III</b>	<b>4</b>
	<b>Core Course-X</b>	<b>Physical Chemistry-IV</b>	<b>4</b>
	<b>Core Practical-IV</b>		<b>6</b>
	<b>Skill Enhancement Course -2</b>	<b>SEC -2</b>	<b>4</b>
	<b>Generic Elective -4</b>	<b>GE-4</b>	<b>4</b>
	<b>Generic Elective -4 Practical</b>		<b>2</b>
	<b>V</b>	<b>Core Course-XI</b>	<b>Organic Chemistry-IV</b>
<b>Core Course-XII</b>		<b>Physical Chemistry-V</b>	<b>4</b>
<b>Core Course Practical-V</b>			<b>4</b>
<b>Discipline Specific Elective -1</b>		<b>DSE-1</b>	<b>4</b>
<b>Discipline Specific Elective -2</b>		<b>DSE-2</b>	<b>4</b>
<b>Discipline Specific Elective Practical-I</b>			<b>4</b>
<b>VI</b>		<b>Core Course-XIII</b>	<b>Inorganic Chemistry-IV</b>
	<b>Core Course-XIV</b>	<b>Organic Chemistry-V</b>	<b>4</b>
	<b>Core Course Practical-VI</b>		<b>4</b>
	<b>Discipline Specific Elective -3</b>	<b>DSE-3</b>	<b>4</b>
	<b>Discipline Specific Elective-4</b>	<b>DSE-4</b>	<b>4</b>
	<b>Discipline Specific Elective Practical-II</b>		<b>4</b>
	<b>Total Credits</b>		<b>140</b>

**Core Papers (C): (Credit: 04 each)** (1 period/week for tutorials or 4 periods/week for practical)

1. Inorganic Chemistry I: Atomic Structure & Chemical Bonding (4 )
2. Physical Chemistry I: States of Matter & Ionic Equilibrium (4 )
3. Practical -I (4)
4. Organic Chemistry I: Basics and Hydrocarbons (4 )
5. Physical Chemistry II: Chemical Thermodynamics and its Applications (4)
6. Practical-II (4)
7. Inorganic Chemistry II: s- and p-Block Elements (4)
8. Organic Chemistry II: Oxygen Containing Functional Groups (4)

9. Physical Chemistry III: Phase Equilibria and Chemical Kinetics (4)
10. Practical-III (6)
11. Inorganic Chemistry III: Coordination Chemistry (4 )
12. Organic Chemistry III: Heterocyclic Chemistry (4 )
13. Physical Chemistry IV: Electrochemistry (4 )
14. Practical-IV (6)
15. Organic Chemistry IV: Biomolecules (4 )
16. Physical Chemistry V: Quantum Chemistry & Spectroscopy (4)
17. Practical-V (4)
18. Inorganic Chemistry IV: Organometallic Chemistry (4)
19. Organic Chemistry V: Spectroscopy (4 )
20. Practical-VI (4)

**Discipline Specific Elective Papers: (4 papers)- DSE 1-4**

1. Applications of Computers in Chemistry (4) + Lab (4)
2. Analytical Methods in Chemistry (4) + Lab (4)
3. Green Chemistry (4) + Lab (4)
4. Industrial Chemicals & Environment (4) + Lab (4)

**Other Discipline (Four papers of any one discipline)- GE 1 to GE 4**

1. Mathematics (5) + Tut (1)
2. Physics (4) + Lab (2)
3. Economics (5) + Tut (1)
4. Computer Science (4) + Lab (2)
5. Zoology (4) + Lab (2)
6. Botany (4) + (2)
7. Geology (4) +(2)
8. Anthropology (4) +(2)

**Skill Enhancement Courses (02 papers ) (Credit: 02 each)- SEC1 to SEC-2**

1. Business Skills for Chemists
2. Intellectual Property Rights

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**Generic Elective Papers (GE) (Minor-Chemistry) (four papers) for other Departments/Disciplines: (Credit: 06 each)**

1. Atomic Structure, Bonding, General Organic Chemistry & Aliphatic Hydrocarbons (4)+ Lab (2)
2. Chemical Energetics, Equilibria & Functional Group Organic Chemistry-I (4) + Lab (2)
3. Solutions, Phase Equilibrium, Conductance, Electrochemistry & Functional Group Organic Chemistry-II (4) + Lab (2)
4. Chemistry of s- and p-block elements, States of matter and Chemical Kinetics (4) + Lab (2).

**CORE COURSE (HONOURS IN CHEMISTRY)**

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**Semester I**

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**CHEMISTRY-C I: INORGANIC CHEMISTRY-I**

**(Credits: Theory-04)**

**Theory: 60 Lectures**

**Atomic Structure:**

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of  $\psi$  and  $\psi^2$ . 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)**

**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.

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



(b) Atomic radii (van der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

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

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

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

**(16 Lectures)**

### **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  $N_2$ ,  $O_2$ ,  $C_2$ ,  $B_2$ ,  $F_2$ ,  $CO$ ,  $NO$ , and their ions;  $HCl$ ,  $BeF_2$ ,  $CO_2$ , (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and  $\sigma$  bond and  $\pi$  approach)  $\pi$  electrons, and bond multiple bonding (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) *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.

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

**(30 Lectures)**

### **Reference Books:**

- Lee, J.D. Concise Inorganic Chemistry, ELBS, 1991.

- Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, Oxford, 1970
- Atkins, P.W. & Paula, J. Physical Chemistry, Oxford Press, 2006.
- Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications 1962.

## CHEMISTRY -C II: PHYSICAL CHEMISTRY II

**(Credits: Theory-04)**

**Theory: 60 Lectures**

### **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,  $\sigma$  from  $\eta$ ; variation calculation of viscosity of with temperature and pressure.

Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor,  $Z$ , and its variation with pressure for different gases. Causes of deviation from ideal behaviour. van

der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dietrici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states.

**(25 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; 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.

**(35 Lectures)**

**Reference Books:**

- Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry Ed., Oxford University Press (2006).
- Ball, D. W. Physical Chemistry Thomson Press, India (2007).
- Castellan, G. W. Physical Chemistry 4<sup>th</sup> Ed. Narosa (2004).
- Mortimer, R. G. Physical Chemistry 3<sup>rd</sup> Ed. Elsevier: NOIDA, UP (2009).

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**CHEMISTRY PRACTICAL-I (4)**

**60 Lectures**

**Group-A**

**(A) Titrimetric Analysis**

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

**(B) Acid-Base Titrations**

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

**(C) Oxidation-Reduction Titrimetry**

- (i) Estimation of Fe(II) and oxalic acid using standardized  $\text{KMnO}_4$  solution.
- (ii) Estimation of oxalic acid and sodium oxalate in a given mixture.
- (iii) Estimation of Fe(II) with  $\text{K}_2\text{Cr}_2\text{O}_7$  using internal (diphenylamine, anthranilic acid) and external indicator.
- (iv) (iv)

**Group-B**

**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.

**Reference text:**

- 1. Vogel, A.I. A Textbook of Quantitative Inorganic Analysis, ELBS.

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

### CHEMISTRY-C III: ORGANIC CHEMISTRY I

**(Credits: Theory-04)**

**Theory: 60 Lectures**

#### **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.

**(6 Lectures)**

#### **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.

**(18 Lectures)**

#### **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 their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration-oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation). 1,2-and 1,4-addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination 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.

**(24 Lectures)**

## 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)**

## Reference Books:

- Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds; Wiley: London, 1994.
- Kalsi, P. S. Stereochemistry Conformation and Mechanism; New Age International, 2005.

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## CHEMISTRY -C IV: PHYSICAL CHEMISTRY II

**(Credits: Theory-04)**

**Theory: 60 Lectures**

**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.

*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  $T$ ,  $V$ ,  $P$ ; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

**(40 Lectures)**

### **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.

**(10 Lectures)**

### **Solutions and Colligative Properties:**

Dilute solutions;

- (i) Lowering of vapour pressure, Raoult's and Henry's Laws and their applications.
- (ii) Elevation of boiling point,
- (iii) Depression of freezing point,
- (iv) Osmotic pressure applications in calculating molar masses of normal, dissociated and associated solutes in solution.

**(10 Lectures)**

## Reference Books

- Peter, A. & Paula, J. de. *Physical Chemistry* 9<sup>th</sup> Ed., Oxford University Press (2011).
- Castellan, G. W. *Physical Chemistry* 4<sup>th</sup> Ed., Narosa (2004).
- Engel, T. & Reid, P. *Physical Chemistry* 3<sup>rd</sup> Ed., Prentice-Hall (2012).
- McQuarrie, D. A. & Simon, J. D. *Molecular Thermodynamics* Viva Books Pvt. Ltd.: New Delhi (2004).
- Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. *Commonly Asked Questions in Thermodynamics*. CRC Press: NY (2011).
- Levine, I. N. *Physical Chemistry* 6<sup>th</sup> Ed., Tata Mc Graw Hill (2010).
- Metz, C.R. *2000 solved problems in chemistry*, Schaum Series (2006)

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## CHEMISTRY- C PRACTICAL II

### 60 Lectures

1. Checking the calibration of the thermometer

2. Purification of organic compounds by crystallization using the following solvents:

- a. Water
- b. Alcohol
- c. Alcohol-Water

3. Determination of the melting points of above compounds and unknown organic compounds (Kjeldahl method and electrically heated melting point apparatus)

4. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and capillary method)

### 5. 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  $\Delta$  of benzoic acid in water and determination of  $H$ .

Any other experiment carried out in the class.

### Reference Books

- Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
- Athawale, V. D. & Mathur, P. *Experimental Physical Chemistry* New Age International: New Delhi (2001).
- Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
- Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry*, 5<sup>th</sup> Ed., Pearson (2012)

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## Semester III

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### CHEMISTRY-C V: INORGANIC CHEMISTRY-II

(Credits: Theory-04)

Theory: 60 Lectures

#### 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.

(12 Lectures)

#### 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 nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogens and basic properties of halogens.

(36 Lectures)



## Noble Gases:

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF<sub>2</sub>, XeF<sub>4</sub> and XeF<sub>6</sub>; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF<sub>2</sub>). Molecular shapes of noble gas compounds (VSEPR theory).

(12 Lectures)

## Reference Books:

- Lee, J.D. *Concise Inorganic Chemistry*, ELBS, 1991.
- Douglas, B.E; Mc Danjel, D.H. & Alexander, J.J. *Concepts & Models of Inorganic Chemistry 3<sup>rd</sup> Ed.*, John Wiley Sons, N.Y. 1994.
- Greenwood, N.N. & Earnshaw. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.
- Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.
- Miessler, G. L. & Donald, A. Tarr. *Inorganic Chemistry 4<sup>th</sup> Ed.*, Pearson, 2010.
- Shriver & Atkins, *Inorganic Chemistry 5<sup>th</sup> Ed.*

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## CHEMISTRY-C VI: ORGANIC CHEMISTRY-II

(Credits: Theory-04)

Theory: 60 Lectures

### Chemistry of Halogenated Hydrocarbons:

*Alkyl halides*: Methods of preparation, nucleophilic substitution reactions – S<sub>N</sub>1, S<sub>N</sub>2 and S<sub>N</sub>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<sub>N</sub>Ar, 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)

### Alcohols, Phenols and Epoxides:

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

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

(16 Lectures)

## Carbonyl Compounds:

Structure, reactivity and preparation;

Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisan-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements,  $\alpha$  haloform reaction and Baeyer Villiger oxidation, -substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner,  $\text{LiAlH}_4$ ,  $\text{NaBH}_4$ , 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)

## 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.

(14 Lectures)

## Reference Books:

- Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.

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## CHEMISTRY-C VII: PHYSICAL CHEMISTRY-III

(Credits: Theory-04)

Theory: 60 Lectures

### 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 solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications.

Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent

and incongruent melting points, solid solutions.

Nernst distribution law: its derivation and applications.

**(28 Lectures)**

### **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 .

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.

**(18 Lectures)**

### **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)**

### **Surface chemistry:**

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

**(6 Lectures)**

### **Reference Books:**

- Peter Atkins & Julio De Paula, *Physical Chemistry* 9<sup>th</sup> Ed., Oxford University Press (2010).
  - Castellan, G. W. *Physical Chemistry*, 4<sup>th</sup> Ed., Narosa (2004).
  - McQuarrie, D. A. & Simon, J. D., *Molecular Thermodynamics*, Viva Books Pvt. Ltd.: New Delhi (2004).
  - Engel, T. & Reid, P. *Physical Chemistry* 3<sup>rd</sup> Ed., Prentice-Hall (2012).
    - Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. *Commonly Asked Questions in Thermodynamics*. CRC Press: NY (2011).
    - Zundhal, S.S. *Chemistry concepts and applications* Cengage India (2011).
    - Ball, D. W. *Physical Chemistry* Cengage India (2012).
    - Mortimer, R. G. *Physical Chemistry* 3<sup>rd</sup> Ed., Elsevier: NOIDA, UP (2009).
    - Levine, I. N. *Physical Chemistry* 6<sup>th</sup> Ed., Tata McGraw-Hill (2011).
  - Metz, C. R. *Physical Chemistry* 2<sup>nd</sup> Ed., Tata McGraw-Hill (2009).
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## CHEMISTRY - C III PRACTICAL (06)

### 75 Lectures

#### (Group-A)

##### (A) Iodo / Iodimetric Titrations

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

##### (B) Inorganic preparations

- (i) Cuprous Chloride,  $Cu_2Cl_2$
- (ii) Preparation of Aluminium potassium sulphate  $KAl(SO_4)_2 \cdot 12H_2O$  (Potash alum) or Chrome alum.

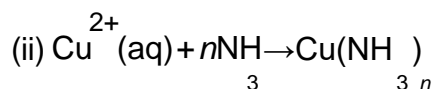
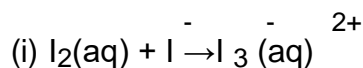
#### (Group – B)

1. Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group.
2. Organic preparations:
  - i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine) and phenols ( *o*-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 ( *o*-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.

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

#### Group-C

- I. Distribution of acetic/ benzoic acid between water and cyclohexane.
- II. Study the equilibrium of at least one of the following reactions by the distribution method:



III. Study the kinetics of the following reactions.

1. Integrated rate method:
  - a. Acid hydrolysis of methyl acetate with hydrochloric acid.
  - b. Saponification of ethyl acetate.

#### Reference Books:

- Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
- Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8<sup>th</sup> Ed.*; McGraw-Hill: New York (2003).
- Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3<sup>rd</sup> Ed.*; W.H. Freeman & Co.: New York (2003).
- *Chemistry: Preparation and Quantitative Analysis*, University Press (2000).
- Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).
- Vogel, A.I. *A Textbook of Quantitative Inorganic Analysis*, ELBS. 1978
- Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
- Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5<sup>th</sup> Ed.*, Pearson (2012)
- Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic*

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### Semester IV

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#### CHEMISTRY-VIII: INORGANIC CHEMISTRY-III

**(Credits: Theory-04)**

**Theory: 60 Lectures**

#### Coordination Chemistry:

Werner's theory, valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of  $10 Dq$  (weak and strong fields, pairing, t<sub>2g</sub> and e<sub>g</sub> energies, factors affecting the magnitude of  $10 Dq$  (Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspect of Ligand field and MO Theory.

IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Chelate effect, polynuclear complexes, Labile and inert complexes.

**(30 Lectures)**

### **Transition Elements:**

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, ability to form complexes. Difference between the first, second and third transition series.

Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy)

**(22 Lectures)**

### **Lanthanoids and Actinoids:**

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

**(8 Lectures)**

### **Reference Books:**

- Purcell, K.F & Kotz, J.C. Inorganic Chemistry W.B. Saunders Co, 1977.
- Huheey, J.E., Inorganic Chemistry, Prentice Hall, 1993.
- Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.
- Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. Wiley-VCH, 1999
- Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
- Greenwood, N.N. & Earnshaw A., Chemistry of the Elements, Butterworth-Heinemann, 1997.

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## **CHEMISTRY-C IX: ORGANIC CHEMISTRY-III**

**(Credits: Theory-04)**

**Theory: 60 Lectures**

### **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.

**(22 Lectures)**

## Polynuclear Hydrocarbons

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

(12 Lectures)

## 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, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction Derivatives of furan: Furfural and furoic acid.

(26 Lectures)

### Reference Books:

- Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Acheson, R.M. *Introduction to the Chemistry of Heterocyclic compounds*, John Welly & Sons (1976).
- Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
- Kalsi, P. S. *Textbook of Organic Chemistry 1<sup>st</sup> Ed.*, New Age International (P) Ltd. Pub.
- Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
- Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Parakashan (2010).

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## CHEMISTRY-C X: PHYSICAL CHEMISTRY-IV

(Credits: Theory-04)

Theory: 60 Lectures

### Conductance

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions.

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.

**(25 Lectures)**

### **Electrochemistry**

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

Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, 2 quinone-hydroquinone, 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).

**(35 Lectures)**

### **Reference Books:**

- Atkins, P.W & Paula, J.D. *Physical Chemistry*, 9<sup>th</sup> Ed., Oxford University Press (2011).
- Castellan, G. W. *Physical Chemistry* 4<sup>th</sup> Ed., Narosa (2004).
- Mortimer, R. G. *Physical Chemistry* 3<sup>rd</sup> Ed., Elsevier: NOIDA, UP (2009).
  - Barrow, G. M., *Physical Chemistry* 5<sup>th</sup> Ed., Tata McGraw Hill: New Delhi (2006).
- Engel, T. & Reid, P. *Physical Chemistry* 3<sup>rd</sup> Ed., Prentice-Hall (2012).
  - Rogers, D. W. *Concise Physical Chemistry* Wiley (2010).
  - Silbey, R. J.; Alberty, R. A. & Bawendi, M. G. *Physical Chemistry* 4<sup>th</sup> Ed., John Wiley & Sons, Inc. (2005).

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## **CHEMISTRY PRACTICAL-C IV (Credit- 06)**

### **75 Lectures**

#### **(Group-A)**

1. Detection of extra elements.
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)

### **Reference Books**

- Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
- Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry*, 5<sup>th</sup> Ed., Pearson (2012)



- Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, University Press (2000).
- Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).

### (Group-B)

#### Gravimetric Analysis:

- i. Estimation of nickel (II) using Dimethylglyoxime (DMG).
- ii. Estimation of copper as CuSCN

#### Inorganic Preparations:

- i. Tetraamminecopper (II) sulphate,  $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4 \cdot \text{H}_2\text{O}$
- ii. *Cis* and *trans*  $\text{K}[\text{Cr}(\text{C}_2\text{O}_4)_2 \cdot (\text{H}_2\text{O})_2]$  Potassium dioxalatodiaquachromate (III)
- iii. Tetraamminecarbonatocobalt (III) ion
- iv. Potassium tris(oxalate)ferrate(III)

#### Reference Book:

- 1. Vogel, A.I. A text book of Quantitative Analysis, ELBS 1986.
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### Group-C

#### Conductometry

- 1) 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

- 2) 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

#### Reference Books:

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

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### **CHEMISTRY-C XI: ORGANIC CHEMISTRY-IV**

**(Credits: Theory-04)**

**Theory: 60 Lectures**

#### **Nucleic Acids**

Components of nucleic acids, Nucleosides and nucleotides;

Structure, synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine; Structure of polynucleotides.

**(15 Lectures)**

#### **Amino Acids, Peptides and Proteins**

Amino acids, Peptides and their classification.

$\alpha$ -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

**(20 Lectures)**

#### **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).

**(10 Lectures)**

#### **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 (haldi), azadirachtin (neem), vitamin C and antacid (ranitidine).

**(15 Lectures)**

#### **Reference Books:**

- Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. VIth Edition. W.H. Freeman and Co.
- Nelson, D.L., Cox, M.M. and Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.

- 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.
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## **CHEMISTRY-C XII: PHYSICAL CHEMISTRY V**

**(Credits: Theory-04)**

**Theory: 60 Lectures**

### **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 and Heisenberg Uncertainty principle; wavefunctions, probability distribution functions, nodal properties, Extension to two and three dimensional boxes, separation of variables, degeneracy.

**(15 Lectures)**

### **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.

**(30 Lectures)**

### **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.

**(15 Lectures)**

### Reference Books:

- Banwell, C. N. & McCash, E. M. Fundamentals of Molecular Spectroscopy 4<sup>th</sup> Ed. Tata McGraw-Hill: New Delhi (2006).
  - Chandra, A. K. Introductory Quantum Chemistry Tata McGraw-Hill (2001).
  - House, J. E. Fundamentals of Quantum Chemistry 2<sup>nd</sup> Ed. Elsevier: USA (2004).
  - Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).
  - Kakkar, R. Atomic & Molecular Spectroscopy, Cambridge University Press (2015).
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## CHEMISTRY PRACTICAL- C V (Credit- 04)

### 60 Lectures

#### (Group-A)

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.
3. Saponification value of an oil or a fat.
4. Determination of Iodine number of an oil/ fat.

#### (Group-B)

### 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  $\text{KMnO}_4$  and  $\text{K}_2\text{Cr}_2\text{O}_7$  in a mixture.
- III. Determine the amount of iron present in a sample using 1,10-phenanthroline.

### Reference Books

- Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
- Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry* 8<sup>th</sup> Ed.; McGraw-Hill: New York (2003).
- Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry* 3<sup>rd</sup> Ed.; W.H. Freeman & Co.: New York (2003).
- Manual of Biochemistry Workshop, 2012, Department of Chemistry, University of Delhi.
- Arthur, I. V. *Quantitative Organic Analysis*, Pearson.
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## Semester VI

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## CHEMISTRY-C XIII: INORGANIC CHEMISTRY-IV

### (Credits: Theory-04)

### Theory: 60 Lectures

## Theoretical Principles in Qualitative Analysis (H<sub>2</sub>S 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.

(20 Lectures)

### Inorganic Polymers:

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

(10 Lectures)

### 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.

(15 Lectures)

### Catalysis by Organometallic Compounds

Study of the following industrial processes and their mechanism:

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

(15 Lectures)

### Reference Books:

#### Recommended Texts:

- Vogel, A.I. *Qualitative Inorganic Analysis*, Longman, 1972
- Svehla, G. *Vogel's Qualitative Inorganic Analysis*, 7th Edition, Prentice Hall, 1996-03-07.
- Cotton, F.A. G.; Wilkinson & Gaus, P.L. *Basic Inorganic Chemistry 3<sup>rd</sup> Ed.*; Wiley India,
- Huheey, J. E.; Keiter, E.A., & Keiter, R.L. *Inorganic Chemistry, Principles of Structure and Reactivity 4<sup>th</sup> Ed.*, Harper Collins 1993, Pearson, 2006.
- Sharpe, A.G. *Inorganic Chemistry*, 4<sup>th</sup> Indian Reprint (Pearson Education) 2005
- Douglas, B. E.; McDaniel, D.H. & Alexander, J.J. *Concepts and Models in Inorganic Chemistry 3<sup>rd</sup> Ed.*, John Wiley and Sons, NY, 1994.
- Greenwood, N.N. & Earnshaw, A. *Chemistry of the Elements, Elsevier 2<sup>nd</sup> Ed*, 1997 (Ziegler Natta Catalyst and Equilibria in Grignard Solution).
- Lee, J.D. *Concise Inorganic Chemistry 5<sup>th</sup> Ed.*, John Wiley and sons 2008.
- Powell, P. *Principles of Organometallic Chemistry*, Chapman and Hall, 1988.
- Shriver, D.D. & P. Atkins, *Inorganic Chemistry 2<sup>nd</sup> Ed.*, Oxford University Press, 1994.
- Basolo, F. & Person, R. *Mechanisms of Inorganic Reactions: Study of Metal Complexes in Solution 2<sup>nd</sup> Ed.*, John Wiley & Sons Inc; NY.
- Purcell, K.F. & Kotz, J.C., *Inorganic Chemistry*, W.B. Saunders Co. 1977

- Miessler, G. L. & Donald, A. Tarr, *Inorganic Chemistry 4<sup>th</sup> Ed.*, Pearson, 2010.
- Collman, James P. et al. *Principles and Applications of Organotransition Metal Chemistry*. Mill Valley, CA: University Science Books, 1987.
- Crabtree, Robert H. *The Organometallic Chemistry of the Transition Metals. j* New York, NY: John Wiley, 2000.
- Spessard, Gary O., & Gary L. Miessler. *Organometallic Chemistry*. Upper Saddle River, NJ: Prentice-Hall, 1996.

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## CHEMISTRY-C XIV: ORGANIC CHEMISTRY-IV

**(Credits: Theory-04 )**

**Theory: 60 Lectures**

### Organic Spectroscopy

General principles Introduction to absorption and emission spectroscopy.

*UV Spectroscopy:* Types of  $\lambda$  electronic transitions,  $\lambda_{max}$ , Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Application of Woodward

Rules  $\lambda_{max}$  for calculation for  $\alpha, \beta$  the unsaturated following aldehydes, systems: 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.

**(24 Lectures)**

### 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)**

### Dyes

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing; 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 –structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

**(8 Lectures)**

## Alkaloids

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

(6 Lectures)

## Terpenes

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

(6 Lectures)

### Reference Books:

- Kalsi, P. S. *Textbook of Organic Chemistry 1<sup>st</sup> Ed.*, New Age International (P) Ltd. Pub.
- Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Billmeyer, F. W. *Textbook of Polymer Science*, John Wiley & Sons, Inc.
- Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. *Polymer Science*, New Age International (P) Ltd. Pub.
- Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
- Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
- Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Prakashan (2010).
- Kemp, W. *Organic Spectroscopy*, Palgrave

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## CHEMISTRY PRACTICAL - C VI

### (Group-A)

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:

$\text{CO}_3^{2-}$ ,  $\text{NO}_2^-$ ,  $\text{S}^{2-}$ ,  $\text{SO}_3^{2-}$ ,  $\text{SO}_4^{2-}$ ,  $\text{CH}_3\text{COO}^-$ ,  $\text{F}^-$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ ,  $\text{NO}_3^-$ ,  $\text{BO}_3^{3-}$ ,  $\text{C}_2\text{O}_4^{2-}$ ,  $\text{PO}_4^{3-}$ ,  $\text{NH}_4^+$ ,  $\text{K}^+$ ,  $\text{Pb}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Bi}^{3+}$ ,  $\text{Sn}^{2+}$ ,  $\text{Sb}^{3+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Al}^{3+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$

Mixtures should preferably contain one interfering anion, or insoluble component ( $\text{BaSO}_4$ ,  $\text{SrSO}_4$ ,  $\text{PbSO}_4$ ,  $\text{CaF}_2$  or  $\text{Al}_2\text{O}_3$ ) or combination of anions e.g.  $\text{CO}_3^{2-}$  and  $\text{SO}_3^{2-}$ ,  $\text{NO}_2^-$  and  $\text{NO}_3^-$ ,  $\text{Cl}^-$  and  $\text{Br}^-$ ,  $\text{Cl}^-$  and  $\text{I}^-$ ,  $\text{Br}^-$  and  $\text{I}^-$ ,  $\text{NO}_3^-$  and  $\text{Br}^-$ ,  $\text{NO}_3^-$  and  $\text{I}^-$ .

Spot tests should be done whenever possible.

- i. Measurement of 10 Dq by spectrophotometric method
- ii. Verification of spectrochemical series.
- iii. Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs thermodynamic factors.
- iv. Preparation of acetylacetonato complexes of  $\text{Cu}^{2+}$  /  $\text{Fe}^{3+}$ . Find  $\lambda_{\text{max}}$  of the complex.
- v. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

## (Group-B)

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.

### Reference Books:

- Vogel, A.I. *Quantitative Organic Analysis*, Part 3, Pearson (2012).
- Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
- Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry*, 5<sup>th</sup> Ed., Pearson (2012)
- Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, University Press (2000).
- Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).
- Vogel's *Qualitative Inorganic Analysis*, Revised by G. Svehla.
- Marr & Rockett *Inorganic Preparations*.

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## CHEMISTRY-DSE I-IV (ELECTIVES)

### CHEMISTRY-DSE-I : APPLICATIONS OF COMPUTERS IN CHEMISTRY

(Credits: Theory-04)

Theory: 60 Lectures

#### Basics:

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

(25 Lectures)



## Numerical methods:

*Roots of equations:* Numerical methods for roots of equations: Quadratic formula, iterative method, Newton-Raphson method, Binary bisection and Regula-Falsi.

*Differential calculus:* Numerical differentiation.

*Integral calculus:* Numerical integration (Trapezoidal and Simpson's rule), probability distributions and mean values.

*Simultaneous equations:* Matrix manipulation: addition, multiplication. Gauss-Siedal method.  
**(35 Lectures)**

## Reference Books:

- Harris, D. C. *Quantitative Chemical Analysis*. 6<sup>th</sup> Ed., Freeman (2007) Chapters 3-5.
  - Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
  - Noggle, J. H. *Physical chemistry on a Microcomputer*. Little Brown & Co. (1985).
  - Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).
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# PRACTICAL-DSE LAB- I : APPLICATIONS OF COMPUTERS IN CHEMISTRY

## 60 Lectures

Computer programs based on numerical methods for

1. Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).
2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).
3. Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values.

### Reference Books:

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

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# CHEMISTRY-DSE- II : ANALYTICAL METHODS IN CHEMISTRY

## (Credits: Theory-04)

### Theory: 60 Lectures

#### 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;

*Infrared Spectrometry*: Basic principles of instrumentation (choice of source, monochromator & detector) for single and double beam instrument; sampling techniques.

Structural illustration through interpretation of data, Effect and importance of isotope substitution.

*Flame Atomic Absorption and Emission Spectrometry*: Basic principles of

instrumentation (choice of source, monochromator, detector, choice of flame and Burner designs. Techniques of atomization and sample introduction; Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

**(25 Lectures)**

### **Thermal methods of analysis:**

Theory of thermogravimetry (TG), basic principle of instrumentation.

Techniques for quantitative estimation of Ca and Mg from their mixture.

**(10 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  $pK_a$  values.

**(10 Lectures)**

### **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.

**(15 Lectures)**

### **Reference Books:**

- Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5<sup>th</sup> Ed. The English Language Book Society of Longman .
- Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7<sup>th</sup> Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
- Christian, Gary D; Analytical Chemistry, 6<sup>th</sup> Ed. John Wiley & Sons, New York, 2004.
- Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
- Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age,

- International Publisher, 2009.
- Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.
- Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
- Ditts, R.V. Analytical Chemistry – Methods of separation.

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## **PRACTICALS- DSE LAB-II (2): ANALYTICAL METHODS IN CHEMISTRY**

### **60 Lectures**

#### **I. Separation Techniques**

##### 1. Chromatography:

Separation of mixtures

3+ 3+ 3+  
 (i) Paper chromatographic separation of Fe<sup>3+</sup>, Al<sup>3+</sup> and Cr<sup>3+</sup>

(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R<sub>f</sub> values.

#### **2. Solvent Extractions:**

To separate a mixture of Ni<sup>2+</sup> & Fe<sup>2+</sup> by complexation with DMG and extracting the Ni<sup>2+</sup>-DMG complex in chloroform, and determine its concentration by spectrophotometry. Solvent extraction of zirconium with amberliti LA-1, separation from a mixture of irons 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:

Determination of pH of soil.

#### **Reference Books:**

- Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5<sup>th</sup> Ed. The English Language Book Society of Longman .
- Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7<sup>th</sup> Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
- Christian, Gary D; Analytical Chemistry, 6<sup>th</sup> Ed. John Wiley & Sons, New York, 2004.

- Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
- Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age, International Publisher, 2009.
- Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.
- Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
- Ditts, R.V. Analytical Chemistry – Methods of separation.

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## **CHEMISTRY-DSE - III: GREEN CHEMISTRY**

**(Credits: Theory-04)**

**Theory: 60 Lectures**

### **Introduction to Green Chemistry**

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

**(4 Lectures)**

### **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.

**(36 Lectures)**

### **Examples of Green Synthesis/ Reactions**

Green Synthesis of the following compounds: adipic acid, catechol, BHT, methyl methacrylate, urethane, aromatic amines (4-aminodiphenylamine), benzyl bromide, acetaldehyde, disodium iminodiacetate (alternative to Strecker synthesis), citral, ibuprofen, paracetamol, furfural.

**(10 Lectures)**

### **Future Trends in Green Chemistry**

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; oncovalent derivatization; Green chemistry in sustainable development.

**(10 Lectures)**

### **Reference Books:**

- V.K. Ahluwalia & M.R. Kidwai: New Trends in Green Chemistry,
- Anamalaya Publishers (2005).

- P.T. Anastas & J.K. Warner: Oxford Green Chemistry- Theory and Practical, University Press (1998).
- A.S. Matlack: Introduction to Green Chemistry, Marcel Dekker (2001).
- M.C. Cann & M.E. Connely: Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).
- M.A. Ryan & M. Tinneland, Introduction to Green Chemistry, American Chemical Society, Washington (2002).

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## CHEMISTRY PRACTICAL – DSE- III (2) LAB: GREEN CHEMISTRY

### 60 Lectures

#### 1. Using renewable resources

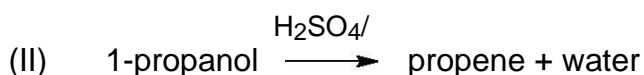
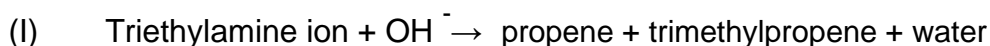
Preparation of biodiesel from vegetable oil.

#### 2. 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 any one method can be studied



#### 3. Diels Alder reaction in water

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

4. Extraction of D-limonene from orange peel using liquid CO<sub>2</sub> prepared from dry ice.

#### Reference Books:

- Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press (1998).
- Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).
- Ryan, M.A. *Introduction to Green Chemistry*, Tinneland; (Ed), American Chemical Society, Washington DC (2002).
- Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. I.K. *Green Chemistry Experiment: A monograph International Publishing House Pvt Ltd. New Delhi. Bangalore* ISBN 978-93-81141-55-7 (2013).

- Cann, M.C. & Connelly, M. E. *Real world cases in Green Chemistry*, American Chemical Society (2008).
- Cann, M. C. & Thomas, P. *Real world cases in Green Chemistry*, American Chemical Society (2008).
- Pavia, D. L. Lamponan, G. H. & Kriz, G.S. *W B Introduction to organic laboratory*

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## **CHEMISTRY-DSE - IV: INDUSTRIAL CHEMICALS AND ENVIRONMENT (Credits: Theory-04)**

### **Theory: 60 Lectures**

#### **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.

**(14 Lectures)**

#### **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 SO<sub>2</sub>, CO<sub>2</sub>, CO, NO<sub>x</sub>, H<sub>2</sub>S and other foul smelling gases. Methods of estimation of CO, NO<sub>x</sub>, SO<sub>x</sub> 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.

**(30 Lectures)**

## 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)

## Biocatalysis

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

(6 Lectures)

## Reference Books:

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

### 60 Lectures

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Percentage of available chlorine in bleaching powder.
4. Measurement of chloride, sulphate and salinity of water samples by simple titration method ( $\text{AgNO}_3$  and potassium chromate).
5. Estimation of total alkalinity of water samples ( $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ ) using double titration method.

## Reference Books:

- E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
- R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
- J. A. Kent: *Riegel's Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.



- S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.
  - K. De, *Environmental Chemistry*. New Age International Pvt., Ltd, New Delhi.
  - S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.
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## **Skill Enhancement Course (any two) (Credit: 02 each)- SEC1 to SEC4**

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### **BUSINESS SKILLS FOR CHEMISTS (Credits: 02) Theory: 30 Lectures**

#### **Business Basics**

Key business concepts: Business plans, market need, project management and routes to market.

#### **Chemistry in Industry**

Current challenges and opportunities for the chemistry-using industries, role of chemistry in India and global economies.

#### **Making money**

Financial aspects of business with case studies

#### **Intellectual property**

Concept of intellectual property, patents.

#### **Reference**

[www.rsc.org](http://www.rsc.org)

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### **INTELLECTUAL PROPERTY RIGHTS (IPR) (Credits: 02) Theory: 30 Lectures**

*In this era of liberalization and globalization, the perception about science and its practices has undergone dramatic change. The importance of protecting the scientific discoveries, with commercial potential or the intellectual property rights is being discussed at all levels – statutory, administrative, and judicial. With India ratifying the WTO agreement, it has become obligatory on its part to follow a minimum acceptable standard for protection and enforcement of intellectual property rights. The purpose of this course is to apprise the students about the multifaceted dimensions of this issue.*

#### **Introduction to Intellectual Property:**

Historical Perspective, Different Types of IP, Importance of protecting IP.

#### **Copyrights**

Introduction, How to obtain, Differences from Patents.

## **Trade Marks**

Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, Trade names, etc.

Differences from Designs.

## **Patents**

Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Healthcare – balancing promoting innovation with public health, Software patents and their importance for India.

## **Different International agreements**

### **(a) World Trade Organization (WTO):**

(i) General Agreement on Tariffs & Trade (GATT), Trade

Related Intellectual Property Rights (TRIPS) agreement

(ii) General Agreement on Trade related Services (GATS)

(iii) Madrid Protocol

(iv) Berne Convention

(v) Budapest Treaty

### **(b) Paris Convention**

**WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity**

**IP Infringement issue and enforcement** – Role of Judiciary, Role of law enforcement agencies – Police, Customs etc. Economic Value of Intellectual Property – Intangible assets and their valuation, Intellectual Property in the Indian Context – Various laws in India Licensing and technology transfer.

## **Reference Books:**

- N.K. Acharya: *Textbook on intellectual property rights*, Asia Law House (2001).
- Manjula Guru & M.B. Rao, *Understanding Trips: Managing Knowledge in Developing Countries*, Sage Publications (2003).
- P. Ganguli, *Intellectual Property Rights: Unleashing the Knowledge Economy*, Tata McGraw-Hill (2001).
- Arthur Raphael Miller, Micheal H.Davis; *Intellectual Property: Patents, Trademarks and Copyright in a Nutshell*, West Group Publishers (2000).
- Jayashree Watal, *Intellectual property rights in the WTO and developing countries*, Oxford University Press, Oxford.

**Generic Elective Papers (GE) (Minor-Chemistry) (any four) for other Departments/Disciplines: (Credit: 06 each)**

**GE: ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS  
(Credits: Theory-04)  
Theory: 60 Lectures**

**Section A: Inorganic Chemistry-1 (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.

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.

**(16 Lectures)**

**Section B: Organic Chemistry-1 (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<sub>4</sub>) and *trans* -addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymercuration-demercuration, Hydroboration-oxidation.

**Alkynes:** (Upto 5 Carbons) *Preparation:* Acetylene from CaC<sub>2</sub> 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<sub>4</sub>, ozonolysis and oxidation with hot alk. KMnO<sub>4</sub>.

**(12 Lectures)**

### **Reference Books:**

- J. D. Lee: *A new Concise Inorganic Chemistry*, E L. B. S.
- F. A. Cotton & G. Wilkinson: *Basic Inorganic Chemistry*, John Wiley.
- Douglas, McDaniel and Alexander: *Concepts and Models in Inorganic Chemistry*, John Wiley.
- James E. Huheey, Ellen Keiter and Richard Keiter: *Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Publication.
- T. W. Graham Solomon: *Organic Chemistry*, John Wiley and Sons.
- Peter Sykes: *A Guide Book to Mechanism in Organic Chemistry*, Orient Longman.

- E. L. Eliel: *Stereochemistry of Carbon Compounds*, Tata McGraw Hill.
  - I. L. Finar: *Organic Chemistry* (Vol. I & II), E. L. B. S.
  - R. T. Morrison & R. N. Boyd: *Organic Chemistry*, Prentice Hall.
  - Arun Bahl and B. S. Bahl: *Advanced Organic Chemistry*, S. Chand
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## **GE LAB - I: ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS**

### **60 Lectures**

#### ***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  $\text{KMnO}_4$ .
3. Estimation of water of crystallization in Mohr's salt by titrating with  $\text{KMnO}_4$ .
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)

#### **Reference Books:**

- Vogel's Qualitative Inorganic Analysis, A.I. Vogel, Prentice Hall, 7th Edition.
  - Vogel's Quantitative Chemical Analysis, A.I. Vogel, Prentice Hall, 6th Edition.
  - Textbook of Practical Organic Chemistry, A.I. Vogel, Prentice Hall, 5th edition.
  - Practical Organic Chemistry, F. G. Mann. & B. C. Saunders, Orient Longman, 1960.
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## **GE- II :CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY-I**

**(Credits: Theory-04)**

**Theory: 60 Lectures**

#### ***Section A: Physical Chemistry-1 (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 – Kirchhoff's equation.

**(10 Lectures)**

### **Chemical Equilibrium:**

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between  $G$  and  $G^\circ$ , 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)**

### **Section B: Organic Chemistry-2 (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 benzene sulphonic 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).

**(10 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:  $\text{KNH}_2/\text{NH}_3$  (or  $\text{NaNH}_2/\text{NH}_3$ ).

**(10 Lectures)**

### Alcohols and Phenols (Upto 5 Carbons)

**Alcohols: Preparation:** Preparation of  $1^\circ$ ,  $2^\circ$  and  $3^\circ$  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.  $\text{KMnO}_4$ , acidic dichromate, conc.  $\text{HNO}_3$ ). 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.

**(10 Lectures)**

### Reference Books:

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

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## GE LAB- II: CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY-I

**60 Lectures**

**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 sodium hydroxide.

### **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:  
Recrystallisation, determination of melting point and calculation of quantitative yields to be done.
  - (a) Bromination of Phenol/Aniline
  - (b) Benzoylation of amines/phenols
  - (c) Oxime and 2,4 dinitrophenylhydrazone of aldehyde/ketone

### **Reference Books**

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

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## **GE-III : SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL GROUP ORGANIC CHEMISTRY-II**

**(Credits: Theory-04) Theory:**

**60 Lectures**

### **Section A: 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)

### **Conductance**

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch law of independent migration of ions. Conductometric titrations (only acid-base).

### **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:  $G$ ,  $H$  and  $S$  from EMF data.

### **Section B: Organic Chemistry-3 (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  $\text{HNO}_2$ , 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  $\text{Cu}^{2+}$  ions, ninhydrin test.

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

**(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).

**(8 Lectures)**

## Reference Books:

□ G. M. Barrow: *Physical Chemistry* Tata McGraw-Hill (2007).

□ G. W. Castellan: *Physical Chemistry* 4th Ed. Narosa (2004).

□ J. C. Kotz, P. M. Treichel, J. R. Townsend, *General Chemistry*, Cengage Learning India Pvt. Ltd.: New Delhi (2009).

□ B. H. Mahan: *University Chemistry*, 3rd Edn. Narosa (1998).

□ R. H. Petrucci, *General Chemistry*, 5th Edn., Macmillan Publishing Co.: New York (1985).

□ Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

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

□ Finar, I. L. *Organic Chemistry (Volume 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

□ Nelson, D. L. & Cox, M. M. *Lehninger's Principles of Biochemistry* 7<sup>th</sup> Ed., W. H. Freeman.

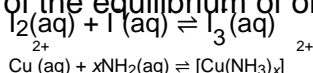
## GE LAB- III: SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL ORGANIC CHEMISTR-II

### 60 Lectures

#### Section A: Physical Chemistry

##### Distribution

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



##### 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:
  - v. Strong acid vs. strong base
  - vi. Weak acid vs. strong base
  - vi. Weak acid vs. strong base

#### Section B: Organic Chemistry

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

##### Reference Books:

- A.I. Vogel: Textbook of Practical Organic Chemistry, Prentice Hall, 5th Edn.
  - F. G. Mann & B. C. Saunders: Practical Organic Chemistry, Orient Longman, 1960.
  - B.D. Khosla: Senior Practical Physical Chemistry, R. Chand & Co.
  - Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry*, Universities Press.
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## GE- IV:CHEMISTRY OF S- AND P-BLOCK ELEMENTS, STATES OF MATTER & CHEMICAL KINETICS

(Credits: Theory-04)

Theory: 60 Lectures

#### General Principles of Metallurgy

Chief modes of occurrence of metals based on standard electrode potentials.  
Ellingham diagrams for reduction of metal oxides using carbon as reducing agent.

**(4 Lectures)**

### **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.

### **Compounds of s- and p-Block Elements**

Hydrides and their classification (ionic, covalent and interstitial), structure and properties with respect to stability of hydrides of p- block elements.

Concept of multicentre bonding (diborane).

Structure, bonding and their important properties like oxidation/reduction, acidic/basic nature of the following compounds and their applications in industrial, organic and environmental chemistry.

Hydrides of nitrogen ( $\text{NH}_3$ ,  $\text{N}_2\text{H}_4$ ,  $\text{N}_3\text{H}$ ,  $\text{NH}_2\text{OH}$ )

**(26 Lectures)**

## **Section B: Physical Chemistry-3 (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  $\text{CO}_2$ .

### **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.

## 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).

### Reference Books:

- G. M. Barrow: *Physical Chemistry* Tata McGraw-Hill (2007).
- G. W. Castellan: *Physical Chemistry* 4th Edn. Narosa (2004).
- J. C. Kotz, P. M. Treichel & J. R. Townsend: *General Chemistry* Cengage Lening India Pvt. Ltd., New Delhi (2009).
- B. H. Mahan: *University Chemistry* 3rd Ed. Narosa (1998).
- R. H. Petrucci: *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
- J. D. Lee: *A New Concise Inorganic Chemistry*, E.L.B.S.
- F.A. Cotton & G. Wilkinson: *Basic Inorganic Chemistry*, John Wiley.
- D. F. Shriver and P. W. Atkins: *Inorganic Chemistry*, Oxford University Press.
- Gary Wulfsberg: *Inorganic Chemistry*, Viva Books Pvt. Ltd.

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## GE LAB- IV: CHEMISTRY OF S- AND P-BLOCK ELEMENTS, STATES OF MATTER & CHEMICAL KINETICS

### 60 Lectures

#### Section A: Inorganic Chemistry

Semi-micro qualitative analysis using H<sub>2</sub>S of mixtures- not more than four ionic species (two anions and two cations and excluding insoluble salts) out of the following:

Cations :  $\text{NH}_4^+$ ,  $\text{Pb}^{2+}$ ,  $\text{Ag}^+$ ,  $\text{Bi}^{3+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Sn}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Al}^{3+}$ ,  $\text{Co}^{2+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{K}^+$

Anions :  $\text{CO}_3^{2-}$ ,  $\text{S}^{2-}$ ,  $\text{SO}_4^{2-}$ ,  $\text{S}_2\text{O}_3^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{CH}_3\text{COO}^-$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ ,  $\text{NO}_2^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{PO}_4^{3-}$ ,  $\text{BO}_3^{3-}$ ,  $\text{C}_2\text{O}_4^{2-}$ ,  $\text{F}^-$

(Spot tests should be carried out wherever feasible)

#### 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 a 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.

**Reference Books:**

- A.I. Vogel, Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.
- A.I. Vogel, Quantitative Chemical Analysis, Prentice Hall, 6th Edn.
- B.D. Khosla, Senior Practical Physical Chemistry, R. Chand & Co.