**CHOICE BASED CREDIT SYSTEM**

 **B. Sc. WITH CHEMISTRY**

**Semester I**

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**CHEMISTRY-DSC 2A: ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS**

**(Credits: Theory-04, Practicals-02)**

**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.*

What is Quantum mechanics? Time independent Schrodinger equation and meaning of

various terms in it. Significance of *ψ* and *ψ*2, Schrödinger equation for hydrogen atom. Radial

and angular parts of the hydogenic wavefunctions (atomic orbitals) and their variations for

1*s*, 2*s*, 2*p*, 3*s*, 3*p* and 3*d* orbitals (Only graphical representation). Radial and angular nodes

and their significance. Radial distribution functions and the concept of the most probable

distance with special reference to 1*s* and 2*s* atomic orbitals. Significance of quantum

numbers, orbital angular momentum and quantum numbers *ml* and *ms*. Shapes of *s*, *p* and *d*

atomic orbitals, nodal planes. Discovery of spin, spin quantum number (*s*) and magnetic spin

quantum number (*ms*).

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

of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of

atomic orbitals, Anomalous electronic configurations. **(14 Lectures)**

**Chemical Bonding and Molecular Structure**

*Ionic Bonding:* General characteristics of ionic bonding*.* Energy considerations in ionic

bonding, lattice energy and solvation energy and their importance in the context of stability

and solubility of ionic compounds. Statement of Born-Landé equation for calculation of

lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability.

Fajan’s rules, ionic character in covalent compounds, bond moment, dipole moment and

percentage ionic character.

*Covalent bonding:* VB Approach: Shapes of some inorganic molecules and ions on the basis

of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar,

tetrahedral, trigonal bipyramidal and octahedral arrangements.

Concept of resonance and resonating structures in various inorganic and organic compounds.

MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their

characteristics for *s-s*, *s-p* and *p-p* combinations of atomic orbitals, nonbonding combination

10

of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods

(including idea of *s-p* mixing) and heteronuclear diatomic molecules such as CO, NO and

NO+. Comparison of VB and MO approaches. **(16 Lectures)**

***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. KMnO4)

and trans-addition (bromine), Addition of HX (Markownikoff’s and anti-Markownikoff’s

addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation.

**Alkynes**: (Upto 5 Carbons) *Preparation:* Acetylene from CaC2 and conversion into higher

alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides.

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*Reactions:* formation of metal acetylides, addition of bromine and alkaline KMnO4,

ozonolysis and oxidation with hot alk. KMnO4. **(12 Lectures)**

**Reference Books:**

 Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.

 Cotton, F.A., Wilkinson, G. & Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.

 Douglas, B.E., McDaniel, D.H. & Alexander, J.J. *Concepts and Models in Inorganic*

*Chemistry*, John Wiley & Sons.

 Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. *Inorganic Chemistry:*

*Principles of Structure and Reactivity*, Pearson Education India, 2006.

 Graham Solomon, T.W., Fryhle, C.B. & Dnyder, S.A. *Organic Chemistry,* John

Wiley & Sons (2014).

 McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India

Edition, 2013.

 Sykes, P. *A Guidebook to Mechanism in Organic Chemistry,* Orient Longman, New

Delhi (1988).

 Eliel, E.L. *Stereochemistry of Carbon Compounds*, Tata McGraw Hill education,

2000.

 Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.

 Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.

 Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry,* S. Chand, 2010.

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**CHEMISTRY LAB: DSC 2A LAB: 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 KMnO4.

3. Estimation of water of crystallization in Mohr’s salt by titrating with KMnO4.

4. Estimation of Fe (II) ions by titrating it with K2Cr2O7 using internal indicator.

5. Estimation of Cu (II) ions iodometrically using Na2S2O3.

***Section B: Organic Chemistry***

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing upto two

extra elements)

2. Separation of mixtures by Chromatography: Measure the Rf value in each case

(combination of two compounds to be given)

12

(a) Identify and separate the components of a given mixture of 2 amino acids (glycine,

aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography

(b) Identify and separate the sugars present in the given mixture by paper chromatography.

**Reference Books:**

 Svehla, G. *Vogel’s Qualitative Inorganic Analysis*, Pearson Education, 2012.

 Mendham, J. *Vogel’s Quantitative Chemical Analysis*, Pearson, 2009.

 Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook*

*of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.

 Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

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**Semester II**

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**CHEMISTRY-DSC 2B: CHEMICAL ENERGETICS, EQUILIBRIA &**

**FUNCTIONAL ORGANIC CHEMISTRY**

**(Credits: Theory-04, Practicals-02)**

**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.

Statement of Third Law of thermodynamics and calculation of absolute entropies of

substances. **(10 Lectures)**

**Chemical Equilibrium:**

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical

equilibrium. Distinction between Δ*G* and Δ*G*o, Le Chatelier’s principle. Relationships

between *Kp, Kc* and *Kx* 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). **(8 Lectures)**

**Alkyl and Aryl Halides**

**Alkyl Halides** (Upto 5 Carbons) Types of Nucleophilic Substitution (SN1, SN2 and SNi)

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: KNH2/NH3 (or NaNH2/NH3).

Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl

halides. **(8 Lectures)**

**Alcohols, Phenols and Ethers** (Upto 5 Carbons)

**Alcohols:** *Preparation:* Preparation of 1о, 2о and 3о 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. KMnO4,

acidic dichromate, conc. HNO3). Oppeneauer oxidation *Diols:* (Upto 6 Carbons) oxidation of

diols. Pinacol-Pinacolone rearrangement.

**Phenols:** (Phenol case) *Preparation:* Cumene hydroperoxide method, from diazonium salts.

*Reactions:* Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-

Tiemann Reaction, Gattermann-Koch Reaction, Houben–Hoesch Condensation, Schotten –

Baumann Reaction.

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

**Aldehydes and ketones (aliphatic and aromatic):** (Formaldehye, acetaldehyde, acetone and

benzaldehyde)

*Preparation:* from acid chlorides and from nitriles.

*Reactions* – Reaction with HCN, ROH, NaHSO3, NH2-G derivatives. Iodoform test. Aldol

Condensation, Cannizzaro’s reaction, Wittig reaction, Benzoin condensation. Clemensen

reduction and Wolff Kishner reduction. Meerwein-Pondorff Verley reduction. **(14 Lectures)**

**Reference Books:**

 Graham Solomon, T.W., Fryhle, C.B. & Dnyder, S.A. *Organic Chemistry,* John

Wiley & Sons (2014).

 McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India

Edition, 2013.

 Sykes, P. *A Guidebook to Mechanism in Organic Chemistry,* Orient Longman, New

Delhi (1988).

 Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.

 Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.

 Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry,* S. Chand, 2010.

 Barrow, G.M. *Physical Chemistry* Tata McGraw‐Hill (2007).

 Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).

 Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning

India Pvt. Ltd., New Delhi (2009).

 Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).

 Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York

(1985).

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**CHEMISTRY LAB- DSC 2B LAB: CHEMICAL ENERGETICS, EQUILIBRIA &**

**FUNCTIONAL ORGANIC CHEMISTRY**

**60 Lectures**

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***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.

3. Determination of enthalpy of ionization of acetic acid.

4. Determination of integral enthalpy of solution of salts (KNO3, NH4Cl).

5. Determination of enthalpy of hydration of copper sulphate.

6. Study of the solubility of benzoic acid in water and determination of Δ*H*.

**Ionic equilibria**

pH measurements

a) Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos

and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass

electrode) using pH-meter.

b) Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

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

values.

***Section B: Organic Chemistry***

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

distillation.

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

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

Recrystallisation, determination of melting point and calculation of quantitative 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**

 Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook*

*of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.

 Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

 Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R.

Chand & Co.: New Delhi (2011).

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**Semester III**

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**CHEMISTRY-DSC 2C: SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE,**

**ELECTROCHEMISTRY & FUNCTIONAL GROUP ORGANIC CHEMISTRY-II**

**(Credits: Theory-04, Practicals-02)**

**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 temperaturecomposition

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. **(8 Lectures)**

**Phase Equilibrium**

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs

Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation

and its importance in phase equilibria. Phase diagrams of one-component systems (water and

sulphur) and two component systems involving eutectics, congruent and incongruent melting

points (lead-silver, FeCl3-H2O and Na-K only). **(8 Lectures)**

**Conductance**

Conductivity, equivalent and molar conductivity and their variation with dilution for weak

and strong electrolytes. Kohlrausch law of independent migration of ions.

Transference number and its experimental determination using Hittorf and Moving boundary

methods. Ionic mobility. Applications of conductance measurements: determination of degree

of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts,

ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acidbase). **(6 Lectures)**

**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: Δ*G*, Δ*H* and Δ*S* from EMF data.

Calculation of equilibrium constant from EMF data. Concentration cells with transference

and without transference. Liquid junction potential and salt bridge.

pH determination using hydrogen electrode and quinhydrone electrode.

Potentiometric titrations -qualitative treatment (acid-base and oxidation-reduction only). **(8 Lectures)**

***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 HNO2,

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 –COOH group, acetylation of –NH2 group, complexation

with Cu2+ ions, ninhydrin test.

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

Determination of Primary structure of Peptides by degradation Edmann degradation (Nterminal)

and C–terminal (thiohydantoin and with carboxypeptidase enzyme). Synthesis of

simple peptides (upto dipeptides) by N-protection (t-butyloxycarbonyl and phthaloyl) & Cactivating

groups and Merrifield solid-phase synthesis. **(10 Lectures)**

**Carbohydrates**: Classification, and General Properties, Glucose and Fructose (open chain

and cyclic structure), Determination of configuration of monosaccharides, absolute

configuration of Glucose and Fructose, Mutarotation, ascending and descending in

monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and

polysacharrides (starch and cellulose) excluding their structure elucidation. **(8 Lectures)**

**Reference Books:**

 Barrow, G.M. *Physical Chemistry* Tata McGraw‐Hill (2007).

 Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).

 Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry*, Cengage Learning

India Pvt. Ltd.: New Delhi (2009).

 Mahan, B.H. *University Chemistry*, 3rd Ed. Narosa (1998).

 Petrucci, R.H. *General Chemistry*, 5th Ed., 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 Bioch*emistry *7th Ed.,* W. H.

Freeman.

 Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.

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**CHEMISTRY LAB-DSC 2C LAB: SOLUTIONS, PHASE EQUILIBRIUM,**

**CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL ORGANIC**

**CHEMISTRY-II**

**60 Lectures**

***Section A: Physical Chemistry***

**Distribution**

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

I2(aq) + I-(aq) 􀖖 I3

-(aq)

Cu2+(aq) + *x*NH2(aq) 􀖖 [Cu(NH3)*x*]2+

**Phase equilibria**

a) Construction of the phase diagram of a binary system (simple eutectic) using

cooling curves.

b) Determination of the critical solution temperature and composition of the phenol

water system and study of the effect of impurities on it.

c) Study of the variation of mutual solubility temperature with concentration for the

phenol water system and determination of the critical solubility temperature.

**Conductance**

I. Determination of cell constant

II. Determination of equivalent conductance, degree of dissociation and dissociation

constant of a weak acid.

III. Perform the following conductometric titrations:

i. Strong acid vs. strong base

ii. Weak acid vs. strong base

**Potentiometry**

Perform the following potentiometric titrations:

i. Strong acid vs. strong base

ii. Weak acid vs. strong base

iii. Potassium dichromate vs. Mohr's salt

***Section B: Organic Chemistry***

**I** Systematic Qualitative Organic Analysis of Organic Compounds possessing

monofunctional groups (-COOH, phenolic, aldehydic, ketonic, amide, nitro, amines) and

preparation of one derivative.

**II**

1. Separation of amino acids by paper chromatography

2. Determination of the concentration of glycine solution by formylation method.

3. Titration curve of glycine

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4. Action of salivary amylase on starch

5. Effect of temperature on the action of salivary amylase on starch.

6. Differentiation between a reducing and a nonreducing sugar.

**Reference Books:**

 Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook*

*of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.

 Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

 Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R.

Chand & Co.: New Delhi (2011).

 Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry,*

Universities Press.

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 **Semester IV**

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**CHEMISTRY-DSC 2D: COORDINATION CHEMISTRY, STATES OF MATTER &**

**CHEMICAL KINETICS**

**(Credits: Theory-04, Practicals-02)**

**Theory: 60 Lectures**

**Transition Elements (3d series)**

General group trends with special reference to electronic configuration, variable valency,

colour, magnetic and catalytic properties, ability to form complexes and stability of various

oxidation states (Latimer diagrams) for Mn, Fe and Cu.

Lanthanoids and actinoids: Electronic configurations, oxidation states, colour, magnetic

properties, lanthanide contraction, separation of lanthanides (ion exchange method only). **(12 Lectures)**

**Coordination Chemistry**

Valence Bond Theory (VBT): Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu

(coordination numbers 4 and 6). Structural and stereoisomerism in complexes with

coordination numbers 4 and 6.

Drawbacks of VBT. IUPAC system of nomenclature. **(8 Lectures)**

**Crystal Field Theory**

Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal

field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the

magnitude of D. Spectrochemical series. Comparison of CFSE for *Oh* and *Td* complexes,

Tetragonal distortion of octahedral geometry.

Jahn-Teller distortion, Square planar coordination. **(10 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 CO2.

Maxwell Boltzmann distribution laws of molecular velocities and molecular energies

(graphic representation – derivation not required) and their importance.

Temperature dependence of these distributions. Most probable, average and root mean square

velocities (no derivation). Collision cross section, collision number, collision frequency,

collision diameter and mean free path of molecules. Viscosity of gases and effect of

temperature and pressure on coefficient of viscosity (qualitative treatment only). **(8 Lectures)**

**Liquids**

Surface tension and its determination using stalagmometer. Viscosity of a liquid and

determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature on

surface tension and coefficient of viscosity of a liquid (qualitative treatment only). **(6 Lectures)**

**Solids**

Forms of solids. Symmetry elements, unit cells, crystal systems, Bravais lattice types and

identification of lattice planes. Laws of Crystallography - Law of constancy of interfacial

angles, Law of rational indices. Miller indices. X–Ray diffraction by crystals, Bragg’s law.

Structures of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals. Glasses

and liquid crystals. **(8 Lectures)**

**Chemical Kinetics**

The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on

reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations

for zero, first and second order reactions (both for equal and unequal concentrations of

reactants). Half–life of a reaction. General methods for determination of order of a reaction.

Concept of activation energy and its calculation from Arrhenius equation.

Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular

reactions. Comparison of the two theories (qualitative treatment only). **(8 Lectures)**

**Reference Books:**

 Barrow, G.M. *Physical Chemistry* Tata McGraw‐Hill (2007).

 Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).

 Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning

India Pvt. Ltd., New Delhi (2009).

 Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).

 Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York

(1985).

 Cotton, F.A. & Wilkinson, G. *Basic Inorganic Chemistry,* Wiley.

 Shriver, D.F. & Atkins, P.W. *Inorganic Chemistry*, Oxford University Press.

 Wulfsberg, G. *Inorganic Chemistry,* Viva Books Pvt. Ltd.

 Rodgers, G.E. *Inorganic & Solid State Chemistry,* Cengage Learning India Ltd.,

2008.

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**CHEMISTRY LAB-DSC 2D LAB: COORDINATION CHEMISTRY, STATES OF**

**MATTER & CHEMICAL KINETICS**

**60 Lectures**

***Section A: Inorganic Chemistry***

Semi-micro qualitative analysis using H2S of mixtures - not more than four ionic species (two

anions and two cations and excluding insoluble salts) out of the following:

Cations : NH4

+, Pb2+, Ag+, Bi3+, Cu2+, Cd2+, Sn2+, Fe3+, Al3+, Co2+, Cr3+, Ni2+, Mn2+, Zn2+,

Ba2+, Sr2+, Ca2+, K+

Anions : CO32– , S2–, SO2–, S2O32–, NO3–, CH3COO–, Cl–, Br–, I–, NO3–,SO42-, PO43-, BO33-,C2O42-, F-

*(Spot tests should be carried out wherever feasible)*

1. Estimate the amount of nickel present in a given solution as bis(dimethylglyoximato)

nickel(II) or aluminium as oximate in a given solution gravimetrically.

2. Draw calibration curve (absorbance at λmax vs. concentration) for various

concentrations of a given coloured compound (KMnO4/ CuSO4) and estimate the

concentration of the same in a given solution.

3. Determine the composition of the Fe3+-salicylic acid complex solution by Job’s

method.

4. Estimation of (i) Mg2+ or (ii) Zn2+ by complexometric titrations using EDTA.

5. Estimation of total hardness of a given sample of water by complexometric titration.

6. Determination of concentration of Na+ and K+ using Flame Photometry.

***Section B: Physical Chemistry***

(I) Surface tension measurement (use of organic solvents excluded).

a) Determination of the surface tension of a liquid or a dilute solution using 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.

(III) Chemical Kinetics

Study the kinetics of the following reactions.

1. Initial rate method: Iodide-persulphate reaction

2. Integrated rate method:

a. Acid hydrolysis of methyl acetate with hydrochloric acid.

b. Saponification of ethyl acetate.

c. Compare the strengths of HCl and H2SO4 by studying kinetics of hydrolysis of

methyl acetate

**Reference Books:**

 Svehla, G. *Vogel’s Qualitative Inorganic Analysis*, Pearson Education, 2012.

 Mendham, J. *Vogel’s Quantitative Chemical Analysis*, Pearson, 2009.

 Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R.

Chand & Co.: New Delhi (2011).

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 **Semester V**

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**Discipline Specific Electives (Two papers)**

**CHEMISTRY-DSE: ANALYTICAL METHODS IN CHEMISTRY**

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

**Qualitative and quantitative aspects of analysis:**

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their

expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and

t test, rejection of data, and confidence intervals. **(5 Lectures)**

**Optical methods of analysis:**

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and

selection rules, validity of Beer-Lambert’s law.

*UV-Visible Spectrometry:* Basic principles of instrumentation (choice of source,

monochromator and detector) for single and double beam instrument;

*Basic principles of quantitative analysis:* estimation of metal ions from aqueous solution,

geometrical isomers, keto-enol tautomers. Determination of composition of metal complexes

using Job’s method of continuous variation and mole ratio method.

*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**. (5 Lectures)**

**Electroanalytical methods:**

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and

conductometric titrations. Techniques used for the determination of equivalence points.

Techniques used for the determination of pKa values. **(10 Lectures)**

**Separation techniques:**

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

Mechanism of extraction: extraction by solvation and chelation.

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

Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from

aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

**Chromatography:** Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange.

Development of chromatograms: frontal, elution and displacement methods.

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

TLC and HPLC.

Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of

Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of

enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral

chromatographic techniques using chiral columns (GC and HPLC).

Role of computers in instrumental methods of analysis. **(15 Lectures)**

**Reference Books:**

 Jeffery, G.H., Bassett, J., Mendham, J. & Denney, R.C. *Vogel’s Textbook of*

*Quantitative Chemical Analysis*, John Wiley & Sons, 1989.

 Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of*

*Analysis*, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA,

1988.

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 Christian, G.D; *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.

 Harris, D. 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. & Nieman, T.A. *Principles of Instrumental Analysis*,

Cengage Learning India Ed.

 Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles

Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.

 Ditts, R.V. *Analytical Chemistry; Methods of Separation*, van Nostrand, 1974.

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**PRACTICALS- DSE LAB: ANALYTICAL METHODS IN CHEMISTRY(60 Lectures)**

**I. Separation Techniques**

1. Chromatography:

(a) Separation of mixtures

(i) Paper chromatographic separation of Fe3+, Al3+, and Cr3+.

(ii) Separation and identification of the monosaccharides present in the given mixture

(glucose & fructose) by paper chromatography. Reporting the Rf values.

(b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them

on the basis of their Rf values.

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

II. Solvent Extractions:

(i) To separate a mixture of Ni2+

& Fe2+

by complexation with DMG and extracting the Ni2+-

DMG complex in chloroform, and determine its concentration by spectrophotometry.

(ii) Solvent extraction of zisconium 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:

(i) Determination of pH of soil.

(ii) Total soluble salt

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(iii) Estimation of calcium, magnesium, phosphate, nitrate

6. Ion exchange:

(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

(ii) Separation of metal ions from their binary mixture.

(iii) Separation of amino acids from organic acids by ion exchange chromatography.

III Spectrophotometry

1. Determination of pKa values of indicator using spectrophotometry.

2 Structural characterization of compounds by infrared spectroscopy.

3 Determination of dissolved oxygen in water.

4 Determination of chemical oxygen demand (COD).

5 Determination of Biological oxygen demand (BOD).

6 Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by

Job’s method.

**Reference Books:**

 Jeffery, G.H., Bassett, J., Mendham, J. & Denney, R.C. *Vogel’s Textbook of*

*Quantitative Chemical Analysis*, John Wiley & Sons, 1989.

 Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of*

*Analysis*, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA,

1988.

 Christian, Gary D; Analytical Chemistry, 6th 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. & Nieman, T.A. *Principles of Instrumental Analysis*,

Cengage Learning India Ed.

 Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles

Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.

 Ditts, R.V. *Analytical Chemistry; Methods of Separation*, van Nostrand, 1974.

**DSE: ORGANOMETALLICS, BIOINORGANIC CHEMISTRY, POLYNUCLEAR**

**HYDROCARBONS AND UV, IR SPECTROSCOPY**

**(Credits: Theory-04, Practicals-02)**

**Theory: 60 Lectures**

***Section A: Inorganic Chemistry-4* (30 Lectures)**

**Chemistry of 3d metals**

Oxidation states displayed by Cr, Fe, Co, Ni and Co.

A study of the following compounds (including preparation and important properties);

Peroxo compounds of Cr, K2Cr2O7, KMnO4, K4[Fe(CN)6], sodium nitroprusside,

[Co(NH3)6]Cl3, Na3[Co(NO2)6]. **(6 Lectures)**

**Organometallic Compounds**

Definition and Classification with appropriate examples based on nature of metal-carbon

bond (ionic, s, p and multicentre bonds). Structures of methyl lithium, Zeiss salt and

ferrocene. EAN rule as applied to carbonyls. Preparation, structure, bonding and properties of

mononuclear and polynuclear carbonyls of 3d metals. p-acceptor behaviour of carbon

monoxide. Synergic effects (VB approach)- (MO diagram of CO can be referred to for

synergic effect to IR frequencies). **(12 Lectures)**

**Bio-Inorganic Chemistry**

A brief introduction to bio-inorganic chemistry. Role of metal ions present in biological

systems with special reference to Na+, K+ and Mg2+ ions: Na/K pump; Role of Mg2+ ions in

energy production and chlorophyll. Role of Ca2+ in blood clotting, stabilization of protein

structures and structural role (bones). **(12 Lectures)**

***Section B: Organic Chemistry-4* (30 Lectures)**

**Polynuclear and heteronuclear aromatic compounds:**

Properties of the following compounds with reference to electrophilic and nucleophilic

substitution: Naphthalene, Anthracene , Furan, Pyrrole, Thiophene, and Pyridine. **(6 Lectures)**

**Active methylene compounds:**

*Preparation:* Claisen ester condensation. Keto-enol tautomerism.

*Reactions:* Synthetic uses of ethylacetoacetate (preparation of non-heteromolecules having

upto 6 carbon). **(6 Lectures)**

**Application of Spectroscopy to Simple Organic Molecules**

Application of visible, ultraviolet and Infrared spectroscopy in organic molecules.

Electromagnetic radiations, electronic transitions, *λ*max & εmax, chromophore, auxochrome,

bathochromic and hypsochromic shifts. Application of electronic spectroscopy and

Woodward rules for calculating l max of conjugated dienes and α,β – unsaturated

compounds.

Infrared radiation and types of molecular vibrations, functional group and fingerprint region.

IR spectra of alkanes, alkenes and simple alcohols (inter and intramolecular hydrogen

bonding), aldehydes, ketones, carboxylic acids and their derivatives (effect of substitution on

>C=O stretching absorptions). **(18 Lectures)**

**Reference Books:**

 James E. Huheey, Ellen Keiter & Richard Keiter: *Inorganic Chemistry: Principles of*

*Structure and Reactivity,* Pearson Publication.

 G.L. Miessler & Donald A. Tarr: *Inorganic Chemistry,* Pearson Publication.

 J.D. Lee: *A New Concise Inorganic Chemistry,* E.L.B.S.

 F.A. Cotton & G. Wilkinson: *Basic Inorganic Chemistry*, John Wiley & Sons.

 I.L. Finar: *Organic Chemistry* (Vol. I & II), E.L.B.S.

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 John R. Dyer: *Applications of Absorption Spectroscopy of Organic Compounds,*

Prentice Hall.

 R.M. Silverstein, G.C. Bassler & T.C. Morrill*: Spectroscopic Identification of*

*Organic Compounds*, John Wiley & Sons.

 R.T. Morrison & R.N. Boyd: *Organic Chemistry,* Prentice Hall.

 Peter Sykes: *A Guide Book to Mechanism* in *Organic Chemistry,* Orient Longman.

 Arun Bahl and B. S. Bahl: *Advanced Organic Chemistry,* S. Chand.

**DSE LAB**

**60 Lectures**

***Section A: Inorganic Chemistry***

1. Separation of mixtures by chromatography: Measure the *Rf* value in each case.

(Combination of two ions to be given)

Paper chromatographic separation of Fe3+, A13+ and Cr3+ or

Paper chromatographic separation of Ni2+, Co2+, Mn2+ and Zn2+

2. Preparation of any two of the following complexes and measurement of their conductivity:

(i) tetraamminecarbonatocobalt (III) nitrate

(ii) tetraamminecopper (II) sulphate

(iii) potassium trioxalatoferrate (III) trihydrate

Compare the conductance of the complexes with that of M/1000 solution of NaCl, MgCl2 and

LiCl3.

***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: Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.

 A.I. Vogel: Quantitative Chemical Analysis, Prentice Hall, 6th Edn.

 Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook*

*of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.

 Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

**SKILL ENHANCEMENT COURSE**

**BASIC ANALYTICAL CHEMISTRY**

**(Credits: 02)**

**30 Lectures**

**Introduction:** Introduction to Analytical Chemistry and its interdisciplinary nature. Concept

of sampling. Importance of accuracy, precision and sources of error in analytical

measurements. Presentation of experimental data and results, from the point of view of

significant figures.

**Analysis of soil**: Composition of soil, Concept of pH and pH measurement, Complexometric

titrations, Chelation, Chelating agents, use of indicators

a. Determination of pH of soil samples.

b. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric

titration.

**Analysis of water:** Definition of pure water, sources responsible for contaminating water,

water sampling methods, water purification methods.

a. Determination of pH, acidity and alkalinity of a water sample.

b. Determination of dissolved oxygen (DO) of a water sample.

**Analysis of food products:** Nutritional value of foods, idea about food processing and food

preservations and adulteration.

a. Identification of adulterants in some common food items like coffee powder, asafoetida,

chilli powder, turmeric powder, coriander powder and pulses, etc.

b. Analysis of preservatives and colouring matter.

**Chromatography:** Definition, general introduction on principles of chromatography, paper

chromatography, TLC etc.

a. Paper chromatographic separation of mixture of metal ion (Fe3+ and Al3+).

b. To compare paint samples by TLC method.

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

Determination of ion exchange capacity of anion / cation exchange resin (using batch

procedure if use of column is not feasible).

**Analysis of cosmetics:** Major and minor constituents and their function

a. Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.

b. Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc

oxide and Calcium carbonate by complexometric titration.

**Suggested Applications (Any one)**:

a. To study the use of phenolphthalein in trap cases.

b. To analyze arson accelerants.

c. To carry out analysis of gasoline.

**Suggested Instrumental demonstrations:**

a. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame

photometry.

b. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.

c. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft

Drink.

**Reference Books:**

 Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of*

*Analysis*. 7th Ed. Wadsworth Publishing Co. Ltd., Belmont, California, USA, 1988.

 Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*,

Cengage Learning India Ed.

 Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6th*

*Ed.,* Saunders College Publishing, Fort Worth (1992).

 Harris, D. C. *Quantitative Chemical Analysis*, W. H. Freeman.

 Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.

 Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India.

 Freifelder, D. *Physical Biochemistry 2nd Ed.,* W.H. Freeman and Co., N.Y. USA

(1982).

 Cooper, T.G. *The Tools of Biochemistry,* John Wiley and Sons, N.Y. USA. 16 (1977).

 Vogel, A. I. *Vogel’s Qualitative Inorganic Analysis 7th Ed.,* Prentice Hall.

 Vogel, A. I. Vogel’s *Quantitative Chemical Analysis 6th Ed.,* Prentice Hall.

 Robinson, J.W. *Undergraduate Instrumental Analysis 5th Ed.,* Marcel Dekker, Inc., New

York (1995).

**GREEN METHODS IN CHEMISTRY**

**(Credits: 02)**

**Theory: 30 Lectures**

*Theory and Hand-on Experiments*

Introduction: Definitions of Green Chemistry. Brief introduction of twelve principles of

Green Chemistry, with examples, special emphasis on atom economy, reducing toxicity,

green solvents, Green Chemistry and catalysis and alternative sources of energy, Green

energy and sustainability

**The following Real world Cases in Green Chemistry should be discussed:**

 Surfactants for carbon dioxide – Replacing smog producing and ozone depleting

solvents with CO2 for precision cleaning and dry cleaning of garments.

 Designing of environmentally safe marine antifoulant.

 Rightfit pigment: Synthetic azo pigments to replace toxic organic and inorganic

pigments.

 An efficient, green synthesis of a compostable and widely applicable plastic (poly

lactic acid) made from corn.

**Practicals**

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 Preparation and characterization of biodiesel from vegetable oil.

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

 Mechano chemical solvent free synthesis of azomethine.

 Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of

copper(II).

**Reference Books:**

 Anastas, P.T. & Warner, J.K. *Green Chemistry- Theory and Practical*, Oxford

University Press (1998).

 Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).

 Cann, M.C. & Connely, M.E. *Real-World cases in Green Chemistry*, American

Chemical Society, Washington (2000).

 Ryan, M.A. & Tinnesand, M. *Introduction to Green Chemistry*, American

Chemical Society, Washington (2002).

 Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. *Green Chemistry Experiments:*

*A monograph* I.K. International Publishing House Pvt Ltd. New Delhi, Bangalore.

 Lancaster, M. *Green Chemistry: An introductory text* RSC publishing, 2nd

Edition.

 Sidhwani, I.T., Saini, G., Chowdhury, S., Garg, D., Malovika, Garg, N. Wealth

from waste: A green method to produce biodiesel from waste cooking oil and

generation of useful products from waste further generated *“A Social Awareness*

*Project”, Delhi University Journal of Undergraduate Research and Innovation*,

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