WEST BENGAL STATE UNIVERSITY

SYLLABUS IN CHEMISTRY (GENERAL)

UNDER CBCS

SEMESTER 1, 3 AND 5

(This is the modified syllabus only for the academic session 2020-21 for the above-mentioned semesters in view of the COVID pandemic as per resolution taken in the UGBOS meetings of the Department of Chemistry)

This document contains a total of 17 pages

SEMESTER-I

CEMGCOR01T: ATOMIC STRUCTURE, CHEMICAL PERIODICITY, ACIDS AND BASES,REDOX REACTIONS, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures Marks: 50

Section A: Inorganic Chemistry-I

(30 Lectures) Marks: 25

Atomic Structure (10 Lectures)

Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen and Bohr's model, ~~Sommerfeld's model,~~ quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many-electron atoms, *Aufbau* principle and its limitations.

Chemical Periodicity (05 Lectures)

Classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and ~~f-block~~ elements. Positions of hydrogen ~~and noble gases.~~ Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group-wise variation of above properties in respect of s- and p- block elements.

Acids and bases (10 Lectures)

Brönsted–Lowry concept, conjugate acids and bases, ~~relative strengths of acids and bases~~, ~~effects of substituent and solvent, differentiating and levelling solvents.~~ Lewis acid-base concept, classification of Lewis acids and bases, ~~Lux Flood concept and~~ solvent system concept. ~~Hard and soft acids and bases (HSAB concept), applications of HSAB process.~~

~~Redox reactions~~ Redox Reactions. ~~(05 Lectures)~~

~~Balancing of equations by oxidation number and ion electron method oxidimetry and reductimetry.~~ Balancing of equation by ion-electron method

Section B: Organic Chemistry-I

(30 Lectures) Marks: 25

Fundamentals of Organic Chemistry (5 Lectures)

Electronic displacements: inductive effect, resonance and hyperconjugation; cleavage of bonds: homolytic and heterolytic; ~~structure of organic molecules on the basis of VBT~~; nucleophiles electrophiles; reactive intermediates: carbocations, carbanions and free radicals.

Stereochemistry (8 Lectures)

Different types of isomerism; geometrical and optical isomerism; concept of chirality and optical activity (up to two carbon atoms); asymmetric carbon atom; elements of symmetry (plane and centre); interconversion of Fischer and Newman representations; enantiomerism and diastereomerism, *meso* compounds; ~~*threo* and *erythro*, D and L~~, *cis* and *trans* nomenclature; CIP Rules: *R/S* (upto 2 chiral carbon atoms) and *E/Z* nomenclature.

Nucleophilic Substitution and Elimination Reactions (5 Lectures)

Nucleophilic substitutions: S_N1 and S_N2 reactions; eliminations: E1 and E2 reactions (elementary mechanistic aspects); Saytzeff and Hofmann eliminations;~~elimination *vs* substitution~~.

Aliphatic Hydrocarbons (12 Lectures)

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

Alkanes:(up to 5 Carbons). *Preparation:* catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. *Reactions:* ~~mechanism forfree radical substitution~~: halogenation.

Alkenes:(up to 5 Carbons). *Preparation:* elimination reactions: dehydration of alcohols and dehydrohalogenation of alkyl halides; *cis* alkenes (partial catalytic hydrogenation) and *trans* alkenes (Birch reduction). *Reactions: cis*-addition (alkaline $KMnO_4$) and *trans*-addition (bromine) with mechanism, addition of HX [Markownikoff's (with mechanism) and antiMarkownikoff's addition], hydration, ozonolysis, ~~oxymercuration-demercuration and hydroboration-oxidation reaction~~.

Alkynes: (up to 5 Carbons). *Preparation:* ~~acetylene from~~ ~~CaC_2~~ and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides.

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

Reference Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. *Concepts and Models in InorganicChemistry*, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. *Inorganic Chemistry:Principles of Structure and Reactivity*, Pearson Education India, 2006.
5. Sethi, A. *Conceptual Organic Chemistry;* New Age International Publisher.
6. Parmar, V. S. *A Text Book of Organic Chemistry*, S. Chand & Sons.
7. Madan, R. L. *Organic Chemistry*, S. Chand & Sons.

8. Wade, L. G., Singh, M. S., *Organic Chemistry*.
9. Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Eliel, E. L. & Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
12. Sen Gupta, Subrata. *Basic Stereochemistry of Organic molecules.*
13. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, Eighth edition, New Age International, 2014.
14. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.

CEMGCOR01P: ATOMIC STRUCTURE, CHEMICAL PERIODICITY, ACIDS AND BASES, REDOX REACTIONS, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS LAB

(60 Lectures/Contact Hours) Marks: 25

Section A: Inorganic Chemistry –LAB ***(30 Lectures)***

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.

2. Estimation of oxalic acid by titrating it with $KMnO_4$.

3. ~~Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.~~

4. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.

5. ~~Estimation of Cu (II) ions iodometrically using $Na_2S_2O_3$.~~

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

Qualitative Analysis of Single Solid Organic Compound(s)

Experiment A: Detection of special elements (N, Cl, ~~and S~~) in organic compounds.

Experiment B: Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH)

Experiment C: Detection of functional groups: Aromatic-NO_2, Aromatic -NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), ~~-OH (phenolic)~~ in solid organic compounds.

Experiments A - C with unknown (at least ~~6~~ 2) solid samples containing not more than two of the above type of functional groups should be done.

Reference Books:

1. *University Hand Book of Undergraduate Chemistry Experiments*, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Das, S. C., Chakraborty, S. B., *Practical Chemistry*.
3. Mukherjee, K. S. *Text book on Practical Chemistry*, New Oriental Book Agency.
4. Ghosal, Mahapatra & Nad, *An Advanced course in practical Chemistry*, New Central Book Agency.
5. Vogel, A. I. *Elementary Practical Organic Chemistry*, Part 2: *Qualitative Organic Analysis*, CBS Publishers and Distributors.
6. 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.
7. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

SEMESTER-III

CEMGCOR03T: CHEMICAL ENERGETICS, EQUILIBRIA, ORGANIC CHEMISTRY-II

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures Marks: 50

Section A: Physical Chemistry-II

(30 Lectures) Marks: 25

Chemical Energetics (14 Lectures)

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics; Concept of heat, work, internal energy 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

Standard states; Heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; Laws of thermochemistry; bond energy, bond dissociation energy ~~and resonance energy from thermochemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions; Adiabatic flame temperature; explosion temperature~~

Statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine, ~~refrigerator and efficiency; Entropy change of systems and surroundings for various processes and transformations; Auxiliary state functions (G and A) and Criteria for spontaneity and equilibrium.~~

Chemical Equilibrium: (08 Lectures)

~~Thermodynamic conditions for equilibrium, degree of advancement; Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs' free energy change;~~ Definitions of K_P, K_C and K_X and relation among them; ~~van't Hoff's reaction isotherm, isobar and isochore from different standard states;~~ Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant with addition to inert gas; Le Chatelier's principle

Ionic Equilibria: (08 Lectures)

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water; Ionization of weak acids and bases, pH scale, 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

Reference Books:

1. Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
2. Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
5. Ekambaram, S. *General Chemistry*, Pearson.
6. Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
7. Chugh, K.L., Agnish, S.L. *A Text Book of Physical Chemistry* Kalyani Publishers8.Bahl, B.S., Bahl, A., Tuli, G.D., *Essentials of Physical Chemistry* S. Chand & Co. ltd.
9. Palit, S. R., *Elementary Physical Chemistry* Book Syndicate Pvt. Ltd.
10. Mandal, A. K. *Degree Physical and General Chemistry* Sarat Book House
11. Pahari, S., *Physical Chemistry* New Central Book Agency
12. Pahari, S., Pahari, D., *Problems in Physical Chemistry* New Central Book Agency

Section-B: Organic Chemistry-II

(30 Lectures) Marks: 25

~~Functional group app roach for the following reactions (preparations & reactions) to be studied in context to their structures.~~

Aromatic Hydrocarbons 06 Lectures)

Benzene:~~Preparation~~: ~~from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid~~. *Reactions*: electrophilic substitution (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), ~~sulphonation~~ and Friedel-Craft's reaction (alkylation and acylation) (up to 4 carbons on benzene); ~~side chain oxidation of alkyl benzenes (up to 4 carbons on benzene)~~.

Organometallic Compounds (2 Lectures)

Introduction; *Grignard reagents*: *Preparations* (from alkyl and aryl halide); concept of *umpolung;* ~~Reformatsky reaction.~~

Aryl Halides (3 Lectures)

~~*Preparation:* (chloro-, bromo- and iodobenzene): from phenol~~, Sandmeyer reactions. *Reactions (Chlorobenzene):* nucleophilic aromatic substitution (replacement by –OH group) and effect of nitro substituent (activated nucleophilic substitution).

Alcohols, Phenols and Ethers (11 Lectures)

Alcohols:(up to 5 Carbons). *Preparation:* 1°-, 2°- and 3°- alcohols: using Grignard reagent, reduction of aldehydes, ketones, carboxylic acid and esters; *Reactions:* With sodium, HX (Lucas test), ~~oxidation (alkaline $KMnO_4$, acidic dichromate, concentrated HNO_3);~~ ~~Oppenauer oxidation;~~

Diols: ~~Preparation~~ ~~(with OsO_4);~~ pinacol- pinacolone rearrangement (with mechanism) (*with symmetrical diols* only).

Phenols:Preparation: ~~cumene hydroperoxide method,~~ from diazonium salts; acidic nature of phenols; *Reactions:* electrophilic substitution: ~~nitration~~ and halogenations; Reimer -Tiemann reaction, ~~Houben–Hoesch condensation, Schotten –Baumann reaction~~, Fries rearrangement and Claisen rearrangement.

Ethers:Preparation: Williamson's ether synthesis; ~~*Reaction*: cleavage of ethers with HI~~.

Carbonyl Compounds (08 Lectures)

Aldehydes and Ketones (aliphatic and aromatic):(Formaldehye, acetaldehyde, acetone and benzaldehyde): *Preparation:* from acid chlorides, from nitriles and from Grignard reagents; ~~general properties of aldehydes and ketones~~; *Reactions:* with HCN, ROH, $NaHSO_3$, NH_2-G derivatives and with Tollens' and Fehling's reagents; iodoform test; aldol condensation (with mechanism); Cannizzaro reaction (with mechanism), ~~Wittig reaction,~~ ~~benzoin condensation~~; Clemmensen reduction, Wolff- Kishner reduction and ~~Meerwein-Pondorff-Verley (MPV) reduction.~~

Reference Books:

1. Sethi, A. *Conceptual Organic Chemistry;* New Age International Publisher.
2. Parmar, V. S. *A Text Book of Organic Chemistry*, S. Chand & Sons.
3. Madan, R. L. *Organic Chemistry*, S. Chand & Sons.
4. Wade, L. G., Singh, M. S., *Organic Chemistry, Pearson*.
5. Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry,* S. Chand, 2010.

CEMGCOR03P: CHEMICAL ENERGETICS, EQUILIBRIA, ORGANIC CHEMISTRY LAB

(60 Lectures/Contact Hours) Marks: 25

Section A: Physical Chemistry-LAB **(15x2=30 Lectures)**

(Minimum **five** experiments to complete)

(I) Thermochemistry (Any **three**)

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 enthalpy of hydration of copper sulphate

(II) Ionic Equilibria (Any **two**)

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 and compare it with the indicator method

b) Preparation of buffer solutions and find the pH of an unknown buffer solution by colour matching method (using following buffers)

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

c)Study of the solubility of benzoic acid in water

Reference Books:

1. *University Hand Book of Undergraduate Chemistry Experiments*, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Palit, S.R., *Practical Physical Chemistry* Science Book Agency
3. Mukherjee, N.G., *Selected Experiments in Physical Chemistry* J. N. Ghose & Sons
4. Dutta, S.K., *Physical Chemistry Experiments* Bharati Book Stall

Section B: Organic Chemistry-LAB

Identification of a pure organic compound

Solid compounds: oxalic acid, tartaric acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.

Liquid Compounds: methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene

Reference Books:

1. Bhattacharyya, R. C, *A Manual of Practical Chemistry*.
2. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbookof Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
3. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

Discipline Specific Electives

CHEMISTRY-DSE I-IV (ELECTIVES)

CEMGDSE01T: POLYMER CHEMISTRY

(Credits: Theory-06, Practicals-02)

Theory: 60 Lectures Marks:50

Introduction and history of polymeric materials:

(4 Lectures) Marks:04

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

Functionality and its importance:

(8 Lectures) Marks:06

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

Kinetics of Polymerization:

(8 lectures) Marks:06

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

Crystallization and crystallinity:

(4 Lectures) Marks:04

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

Nature and structure of polymers-

(2 Lectures) Marks:04

Structure Property relationships.

Determination of molecular weight of polymers

(8 Lectures) Marks:06

(M_n, M_w, etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

Glass transition temperature (Tg) and determination of Tg,

(8 Lectures) Marks:06

Free volume theory, WLF equation, Factors affecting glass transition temperature (Tg).

Polymer Solution –

(8 Lectures) Marks:06

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

Properties of Polymers

(10 Lectures) Marks:08

(Physical, thermal, flow & mechanical properties).

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

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

Reference Books:

- Seymour, R.B.& Carraher, C.E. *Polymer Chemistry: An Introduction*, Marcel Dekker, Inc. New York, 1981.
- Odian, G. *Principles of Polymerization*, 4th Ed. Wiley, 2004.
- Billmeyer, F.W. *Textbook of Polymer Science*, 2nd Ed. Wiley Interscience, 1971. Ghosh, P. *Polymer Science & Technology*, Tata McGraw-Hill Education, 1991.
- Lenz, R.W. *Organic Chemistry of Synthetic High Polymers.* Interscience Publishers, New York, 1967.

CEMGDSE01P: POLYMER CHEMISTRY

(60 Lectures/Contact Hours) Marks: 25

1. **Polymer synthesis**

1.Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).

   a. Purification of monomer
   b. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bisisobutylonitrile (AIBN)

2. Preparation of nylon 66/6

1.Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein

   a. Preparation of IPC
   b. Purification of IPC
   c. Interfacial polymerization

3. Redox polymerization of acrylamide
4. Precipitation polymerization of acrylonitrile
5. Preparation of urea-formaldehyde resin
6. Preparations of novalac resin/resold resin.
7. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry:
   (a) Polyacrylamide-aq.$NaNO_2$ solution
   (b) (Poly vinyl proplylidine (PVP) in water
2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).
4. Testing of mechanical properties of polymers.
5. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer analysis

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method
2. Instrumental Techniques
3. IR studies of polymers
4. DSC analysis of polymers
5. Preparation of polyacrylamide and its electrophoresis *at least 7 experiments to be carried out.

Reference Books:

- M.P. Stevens, *Polymer Chemistry: An Introduction*, 3rd Ed., Oxford University Press, 1999.
- H.R. Allcock, F.W. Lampe & J.E. Mark, *Contemporary Polymer Chemistry*, 3rd ed. Prentice-Hall (2003)
- F.W. Billmeyer, *Textbook of Polymer Science*, 3rd ed.Wiley-Interscience (1984)
- J.R. Fried, *Polymer Science and Technology*, 2nd ed.Prentice-Hall (2003)
- P. Munk & T.M. Aminabhavi, *Introduction to Macromolecular Science*, 2nd ed.John Wiley & Sons (2002)
- L. H. Sperling, *Introduction to Physical Polymer Science*, 4th ed.John Wiley & Sons (2005)
- M.P. Stevens, *Polymer Chemistry: An Introduction* 3rd ed.Oxford University Press (2005).
- Seymour/ Carraher's Polymer Chemistry, 9th ed.by Charles E. Carraher, Jr. (2013).

CEMGDSE02T: GREEN CHEMISTRY

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures Marks: 50

Introduction to Green Chemistry

(4 Lectures) Marks: 05

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

Principles of Green Chemistry and Designing a Chemical synthesis

(30 Lectures) Marks: 25

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:

- 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, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.

- Prevention/ minimization of hazardous/ toxic products reducing toxicity.
  risk = (function) hazard × exposure; waste or pollution prevention hierarchy.

- Green solvents– supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents.
- Energy requirements for reactions – alternative sources of energy: use of microwaves and 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; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, ~~asymmetric catalysis and photocatalysis.~~
- Prevention of chemical accidents designing greener processes, inherent safer design, ~~principle of ISD "What you don't have cannot harm you",~~ greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) a~~nd Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation.~~
- Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

Examples of Green Synthesis/ Reactions and some real world cases

(16 Lectures) Marks: 12

1. Green Synthesis of the following compounds: adipic acid, catechol, ~~disodium iminodiacetate (alternative to Strecker synthesis)~~
2. Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents ~~Diels-Alder reaction and Decarboxylation reaction~~
3. ~~Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)~~

4 Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments.

5 ~~Designing of Environmentally safe marine antifoulant.~~

6 ~~Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.~~

7 An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.

8 ~~Healthier fats and oil by Green Chemistry: Enzymatic interesterification for production of no Trans Fats and Oils~~

9 ~~Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting~~

Future Trends in Green Chemistry

(10 Lectures) Marks: 08

Biomimetic, multifunctional reagents

Oxidation reagents and catalysts; ~~Biomimetic, multifunctional reagents; Combinatorial green chemistry;~~ Proliferation of solventless reactions; ~~co crystal controlled solid state synthesis (C^2S^3);~~ Green chemistry in sustainable development.

Reference Books:

- Ahluwalia, V.K. & Kidwai, M.R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).
- 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).
- Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.

CEMGDSE02P: GREEN CHEMISTRY

(60 Lectures/Contact Hours) Marks: 25

1. ~~Safer starting materials~~

- ~~Preparation and characterization of nanoparticles of gold using tea leaves~~.

2. ~~Using renewable resources~~

- ~~Preparation of biodiesel from vegetable/ waste cooking oil.~~

3. Avoiding waste

Principle of atom economy.

- Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.
- Preparation of propene by two methods can be studied

(I) Triethylamine ion + OH^- → propene + trimethylpropene + water

(II) 1-propanol $\xrightarrow{H_2SO_4/\square}$ propene + water

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

4. ~~Use of enzymes as catalysts~~

- ~~Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide.~~

5. Alternative Green solvents

Extraction of D-limonene from orange peel using liquid CO_2 prepared form dry ice.

Mechanochemical solvent free synthesis of azomethines

6. Alternative sources of energy

- ~~Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).~~
- Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

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*, Tinnesand; (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 CISBN 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).
- Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.
- Pavia, D.L., Lampman, G.M., Kriz, G.S. & Engel, R.G. *Introduction to Organic Laboratory Techniques: A Microscale and Macro Scale Approach*, W.B.Saunders, 1995.

CEMGDSE03T: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures Marks: 50

Silicate Industries

(16 Lectures) Marks: 12