

# SEMESTER-IV

<b>Program:</b> B.Sc. (Sem-IV)	<b>Type:</b> Theory
<b>Subject: DSC-7-Physical Chemistry-II: Chemical Kinetics &amp; Thermodynamics</b>	
<b>Credit:</b> 04 (T) + 02 (P)	<b>Total learning hours:</b> 60
<b>Course description:</b>  This Course Paper proposes to teach about: The chemical kinetics, order of reaction, theories of reaction rate, kinetics of complex and chemical reactions, applications of chemical kinetics, thermodynamics equilibrium and processes, work and energy, entropy, enthalpy, free energy, laws of thermodynamics, important equations their derivations and applications.	
<b>Student learning outcome:</b>  After completing this course, the students will be able to learn: Order, molecularity, rate of chemical reactions – factors affecting it, kinetics and theories of complex and chemical reactions and applications in various fields, objectives and limitations of thermodynamic processes, laws of thermodynamics and its' significance, enthalpy, entropy, free energy, various isotherms, equations and their applications.	

### **Unit 1: Introduction to Chemical Kinetics**

**(06Hrs)**

- 1.1 Chemical kinetics and its scope
- 1.2 Macroscopic and microscopic kinetics
- 1.3 Slow and fast reactions
- 1.4 Rate of reaction
- 1.5 Factors affecting rate of reaction
- 1.6 Velocity constant or rate constant

### **Unit 2: Order & Molecularity of Chemical Reaction**

**(06Hrs)**

- 2.1 Molecularity of reaction
- 2.2 Order of reaction with examples
  - 2.2.1 Zero order reactions and Kinetics
  - 2.2.2 Pseudo first order reaction
  - 2.2.3 First order reactions and Kinetics
  - 2.2.4 Second order reactions and Kinetics
  - 2.2.5 Third order reactions and Kinetics
  - 2.2.6 Kinetics of N<sup>th</sup> order reactions
- 2.3 Half-life and mean life.
- 2.4 Order and molecularity of simple reactions
- 2.5 Order and molecularity of complex reactions
- 2.6 Numerical

### **Unit 3: Theories of Reaction Rate**

**(10Hrs)**

- 3.1 Collision theory of reaction rate and limitation
- 3.2 Effect of increase of temperature on reaction rate
- 3.3 Transition state theory
- 3.4 Activation energy and catalyst
- 3.5 Lindemann mechanism
- 3.6 Numerical

**Unit 4: Kinetics of Complex and Chemical Reactions** (10Hrs)

- 4.1 Consecutive reactions
- 4.2 Parallel or side reactions
- 4.3 Reversible or opposing reactions
- 4.4 Michaelis-Menten relationship for Enzyme reaction
- 4.5 Chain reactions
- 4.6 Branching reactions
- 4.7 Explosive reactions
- 4.8 Influence of ionic strength
- 4.9 Numerical

**Unit 5: Applications of Chemical Kinetics** (04 Hrs)

- 5.1 Polymer Science
- 5.2 Chemical Engineering
- 5.3 Environment Science
- 5.4 Biological Science

**Unit 6: Thermodynamics-I** (06 Hrs)

- 6.1 Introduction
- 6.2 Objectives and limitations
- 6.3 Types of systems and properties
- 6.4 State functions and thermodynamics equilibrium
- 6.5 Thermodynamic processes
- 6.6 The nature of energy, work, heat and temperature
- 6.7 Internal energy: characteristics
- 6.8 Exothermic and endothermic reactions

**Unit 7: Thermodynamics-II** (12 Hrs)

- 7.1 The Zeroth law of thermodynamics
- 7.2 First law of thermodynamics and its' significance
- 7.3 P-V work and Enthalpy
- 7.4 Standard heat enthalpy and enthalpy of formation
- 7.5 Applications of first law of thermodynamics
- 7.6 Bond energy and enthalpy
- 7.7 The spontaneous process and criterion of spontaneity
- 7.8 The Entropy and entropy change
- 7.9 Second law of thermodynamics
- 7.11 Free energy and standard free energy changes and significance
- 7.12 Absolute entropies and third law of thermodynamics

**Unit 8: Thermodynamics-III** (06 Hrs)

- 8.1 Free Energy:
  - 8.1.1 Helmholtz Free Energy
  - 8.1.2 Gibbs Free Energy
- 8.2 Free Energy Functions:
  - 8.2.1 Helmholtz Free Energy Functions
  - 8.2.2 Gibbs Free Energy Functions
- 8.3 Van't Hoff Isotherm
  - 8.3.1 Derivation of the relation between  $\Delta G$  and  $K_p$
- 8.4 Clapeyron Equation: Derivation

- 8.4.1 Solid-liquid equilibrium
- 8.4.2 Liquid-gas equilibrium
- 8.5 Clapeyron-Clausius Equation: Integration form
  - 8.5.1 Applications: Determination of M.W. from
    - 8.5.1.1 Molal elevation constant
    - 8.5.1.2 Molal depression constant
- 8.6 Numerical

### Reference Books:

1. Advanced Physical Chemistry; Gurdeep Raj, 20<sup>th</sup> Edition, 2017, Krishna Prakashan
2. Essentials of Physical Chemistry, Arun Bahl, B.S. Bahi, G.D. Tuli; 1<sup>st</sup> Revised Edition 2008, Reprint 2016, S. Chand and Company Limited.
3. Textbook of Physical Chemistry, K.K. Sharma and L.K. Sharma, 4<sup>th</sup> Edition, 2005, Vikas Publication,
4. Physical Chemistry for S.Y.B.Sc. Sem-4, Dr. Hemangi Desai, et.al, 1<sup>st</sup> Edition, (2017), New Popular Prakashan,
- 5 Text Book of Chemistry, P. Bahadur and P. Bahadur, 6<sup>th</sup> Edition, 2001, Krishna Prakashan Media (P) Ltd.
6. Textbook of Physical Chemistry, M.V. Sangaranarayanan, V. Mahadevan, 1<sup>st</sup> Edition, 2011, University Press (India) Pvt. Ltd.
7. Principles of Physical Chemistry, Late B.R. Puri, L.R. Sharma, Madan S. Pathania, 1<sup>st</sup> Revised Edition, 2013, Vishal Publishing Company.
8. Text Book of Engineering Chemistry, P.C. Jain and Monica Jain, 2016, Dhanpatrai Publishing Company.
9. Text Book of Engineering Chemistry, Dr. Rajshree Khare, Katson Books.
10. Molecular Thermodynamics, Mc Quarrie, D. A. & Simon, J. D., 1<sup>st</sup> Edition, 2004, Viva Books.

<b>Program:</b> B.Sc. (Sem-IV)	<b>Type:</b> Theory
<b>Subject:</b> DSC-8- Inorganic Chemistry-III	
<b>Credit:</b> 04 (T) + 02 (P)	<b>Total learning hours:</b> 60
<b>Course description:</b> <p>This course provides an overview of d and f-block elements, many important aspects of coordination compounds, inorganic polymers, non-aqueous solvents and some ceramics.</p> <p>Course comprises of information about coordination compounds and organometallic compounds as well as basics of inorganic polymers and cages.</p>	
<b>Student learning outcome:</b> <p>Upon completion of this course, students will:</p> <ul style="list-style-type: none"> <li>• Have a deep knowledge regarding lanthanide and actinide elements</li> <li>• Be able to understand various theories related to coordination compounds</li> <li>• Have systematic understanding organometallic compounds</li> <li>• Come to know about pros and cons of radioactivity</li> <li>• Get an idea regarding inorganic cages and metal clusters</li> <li>• Be familiar with solvent other than water</li> </ul>	

## **Unit-1 Chemistry of d- and f- Block Elements**

**(10 Hrs)**

### **1.1 Transition Elements:**

**1.1.1** General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry

### **1.2 Lanthanide and Actinides:**

**1.2.1** General Comparison on Electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (ion-exchange method only)

## **Unit-2 Coordination Chemistry-II**

**(11 Hrs)**

**2.1** Elementary Crystal Field Theory: splitting of  $d^n$  configurations in octahedral, square planar and tetrahedral fields

**2.2** Crystal field stabilization energy (CFSE) in weak and strong fields, pairing energy

**2.3** Spectrochemical series

**2.4** Jahn- Teller distortion

**2.5** Octahedral site stabilization energy (OSSE)

**2.6** Metal-ligand bonding (MO concept, elementary idea)

## **Unit-3 Organometallic Compounds-II**

**(10 Hrs)**

**3.1** Metal Alkyls: Important structural features of methyl lithium (tetramer) and Trialkyl Aluminium (dimer)

**3.2** Concept of multicentre bonding in these compounds

**3.3** Ferrocene: Preparation, physical properties and reactions (acetylation, alkylation,

- metallation, Mannich Condensation
- 3.4 Structure and aromaticity of ferrocene
- 3.5 Comparison of aromaticity of ferrocene and reactivity with that of Benzene

**Unit-4 Inorganic Polymers (06 Hrs)**

- 4.1 Overview of polymers
- 4.2 Types of inorganic polymers
- 4.3 Comparison with organic polymers
- 4.4 Synthesis, structural aspects and applications
- Silicones and siloxanes
- Borazines,
- Phosphazenes
- Polysulphates

**Unit-5 Radioactivity (08 Hrs)**

- 5.1 Nuclear stability and nuclear binding energy
- 5.2 Nuclear forces: meson exchange theory
- 5.3 Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers
- 5.4 Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation
- 5.5 Nuclear energy and power generation
- 5.6 Hazards of radiation and safety measures

**Unit-6 Cages and Metal Clusters (05 Hrs)**

- 6.1 Cages
- 6.2 Boron cage compounds
- 6.3 Metal clusters: Metal-metal bonds
- 6.4 Framework bonding in metal clusters
- 6.5 Synthesis of metal clusters
- 6.6 Types of clusters viz. carbonyl clusters, Halide type clusters, Boron clusters and their applications

**Unit-7 Non-aqueous Solvents (05 Hrs)**

- 7.1 Classification of solvents
- 7.2 Physical properties of a solvent for functioning as an effective reaction medium
- 7.3 General characteristics of solvents
- 7.4 Study of solvents such as liquid  $\text{NH}_3$ , liquid  $\text{SO}_2$  and DMSO

**Unit-8 Ceramics (05 Hrs)**

- 8.1 Important clays and feldspar, ceramic, their types and manufacture
- 8.2 High technology ceramics and their applications
- 8.3 Superconducting and semiconducting oxides

**Reference books:**

1. Advanced Inorganic Chemistry, Satya Prakash Tuli, Basu & Madan 6<sup>th</sup> Edn, 2000, S. Chand and Company Limited.
2. Calculation of Analytical Chemistry, Hamilton, Simpson & Ellis 7<sup>th</sup> Edn., 1969, ACS publication
3. Quantitative Inorganic Analysis, A.I Vogel, 5<sup>th</sup> Edn., 1989, Longman scientific and technical Publication
4. Theoretical Inorganic Chemistry, Day, M.C. and Selbin, J., 2008, East-West Press
5. Concise Inorganic Chemistry, Lee J. D., Wiley India, 5<sup>th</sup> Edn., 2008, Oxford University Press
6. Inorganic Chemistry – Principles of structure and reactivity, Huheey J. E., Keiter E. A. and Keiter R. L., 4<sup>th</sup> Edn., 1997, Pearson
7. Principles of Inorganic Chemistry by Puri, Sharma, Kalia 33<sup>rd</sup> Edn., 2020, Vishal Publishing Co.
8. Selected Topic in Inorganic Chemistry, Malik, Tuli, Madan, 17<sup>th</sup> Edn., 2010, S. Chand
9. Basic Inorganic Chemistry, Cotton and Wilkinson, 3<sup>rd</sup> Edn., 1994, A John Wiley and Sons
10. Inorganic and organometallic polymers, Randal D. Archer, 2001 A John Wiley and Sons, Inc. publication (USA)
11. Nuclear and Radiation Chemistry, Sharma B. K, 1987, Goel Publishing House

<b>Program:</b> B.Sc. (Sem-IV)	<b>Type:</b> Theory
<b>Subject: SEC-2: Green Chemistry</b>	
<b>Credit:</b> 04 (T) + 02(P)	<b>Total learning hours:</b> 60
<p><b>Course description:</b> This course provides an overview of fundamental topics in green chemistry. Green Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. While there are many mechanisms and tools available to <i>assess</i> the impact of materials and processes on human health and the environment, there are few tools available to help design and create products as such.</p> <p>This course will present the fundamentals of the 12 principles of green chemistry, and explore relevant examples of their practical use in commercial applications.</p> <p>This course will explore examples from a wide spectrum of industrial sectors including construction, personal care, pharmaceuticals and electronics.</p> <p>Through examples, students will be presented with the premise that green chemistry offers organizations a boost to innovation and faster time to market.</p>	
<p><b>Student learning outcome:</b> Upon completion of this course, Students learn the basic principles of green and sustainable chemistry They must be able to do and understand stoichiometric calculations and relate them to green process metrics. They learn alternative solvent media and energy sources for chemical processes.</p>	

#### **Unit-1 Introduction to Green Chemistry**

**(02Hrs)**

- 1.1 What is green chemistry?
- 1.2 Need for Green Chemistry
- 1.3 Goals of Green Chemistry
- 1.4 Limitation/Obstacles in the pursuit of the goals of Green Chemistry

#### **Unit-2 Tools and Principles of Green Chemistry**

**(03Hrs)**

- 2.1 Principles of Green chemistry with their explanations
- 2.2 Tools green chemistry
  - 2.2.1 Green starting materials & Reaction Media.
  - 2.2.2 Green catalysts
  - 2.2.3 Green reactions
  - 2.2.4 Green Reaction conditions
  - 2.2.5 Green chemical products
  - 2.2.6 Use of Renewable feed stock

#### **Unit-3 Principles of Green Chemistry & Designing a Chemical synthesis-I**

**(04Hrs)**

- 3.1 Principles of Green Chemistry special emphasis on: Designing a Green Synthesis using these principles;
- 3.2 Prevention of Waste/ by products; 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
- 3.3 Green solvents supercritical fluids, water as a solvent for organic reactions, ionic liquids



#### **Unit-4 Principles of Green Chemistry and Designing a Chemical synthesis-II (12Hrs)**

- 4.1** Energy requirements for reactions alternative sources of energy: use of microwaves and ultrasonic energy.
- 4.2** Selection of starting materials; avoidance of unnecessary derivatization careful use of blocking/protecting groups
- 4.3** Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, bio catalysis, asymmetric catalysis and photo catalysis.
- 4.4** Prevention of chemical accidents designing greener processes, inherent safer design, principle of ISD What you dont have cannot harm you, greener alternative to Bhopal Gas tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to and limitation.
- 4.5** Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes

#### **Unit-5 Principles of Green Chemistry-II (12Hrs)**

- 5.1** Fluorous biphasic solvent, PEG, solvent less processes, immobilized solvents and how to compare greenness of solvents
- 5.2** Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy
- 5.3** 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, bio catalysis, asymmetric catalysis and photo catalysis. subdivision of hazardous substances in chemical processes.
- 5.4** Ionic liquids as green solvents and use of bio-catalysis
  - a) Ionic liquids as green solvents-green solvents, reactions in acidic ionic liquids and in neutral ionic liquids (Hydrogenation, Diels-Alder reaction, O-alkylation and N-alkylation).
  - b) Biocatalysts in organic synthesis: Introduction,
    - i) Biochemical Oxidation and reduction (microbial)-production of fine chemicals, vitamins and amino acids.
    - ii) By microorganisms- production of penicillins, streptomycin and chloramphenic

#### **Unit-6 Waste Management & Application of Green Technology (03Hrs)**

- 6.1** Sources and types of waste.
- 6.2** Waste treatment and disposal: Integrated waste Management & supercritical oxidation of waste
- 1.1** Integrated waste management of plastics: Illustration of 4R's

#### **Unit-7 Examples of Green Synthesis/Reactions & Real World Cases-I (15Hrs)**

- 7.1** Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis)
- 7.2** Microwave assisted reactions in water: Hoffmann elimination, hydrolysis,

oxidation, saponification reactions

- 7.3 Microwave assisted reactions in organic solvents: Esterification reactions, Fries rearrangement, Ortho ester Claisen rearrangement, Diels-Alder reaction, decarboxylation.
- 7.4 Microwave solvent free reactions (Solid state reactions): Deacetylation, deprotection, saponification of ester, alkylation of reactive methylene compounds, synthesis of nitriles from aldehydes, reductions.
- 7.5 Ultrasound assisted reactions: Introduction, substitution reactions, addition, oxidation, reduction reactions sono chemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine).
- 7.6 Surfactants for carbon dioxide replacing smog producing and ozone depleting solvents with CO<sub>2</sub> for precision cleaning and dry cleaning of garments.
- 7.7 Designing of environmentally safe marine antifoulant

## **Unit-8 Examples of Green Synthesis & Some Real World Cases-II (09Hrs)**

- 8.1 Right fit 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.
- 8.2 Healthier Fats and oil by Green Chemistry: Enzymatic Inter etherification for production of no Trans Fats and Oils
- 8.3 Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting.
- 8.4 Future Trends in Green Chemistry Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solvent less reactions; co-crystal controlled solid state synthesis (C2S3); Green chemistry in sustainable development

### **Reference Books:**

1. New Trends in Green Chemistry, V.K. Ahluwalia & M.R. Kidwai, 2005, Anamalaya Publishers
2. Introduction to Green Chemistry, A.S. Matlack, 2001, Marcel Dekker
3. Real-World cases in Green Chemistry, . M.C. Cann & M.E. Connely, 2000, American Chemical Society, Washington
4. Introduction to Green Chemistry, M.A. Ryan & M. Tinnesand, 2002, American Chemical Society, Washington
5. Green Chemistry Theory and Practice, P.T. Anatas and J.C. Warner, 1998, University Press
6. Green Chemistry, V.K. Ahluwalia, 2012, Narosa, New Delhi.
7. Real world cases in Green Chemistry, M.C. Cann and M.E. Connelly, 2000, American Chemical Society
8. Green Chemistry: Introductory Text, M.Lancaster, 2010, Royal Society of Chemistry (London)
9. Green Chemistry: Environmental friendly alternatives, R S Sanghli and M.M Srivastava, 2012, Narosa Publication

<b>Program:</b> B.Sc. (Sem-IV)	<b>Type:</b> Theory
<b>Subject:</b> DSE-4-Nanoscience and Nanotechnology	
<b>Credit:</b> 02 (T)	<b>Total learning hours:</b> 30
<p><b>Course description:</b> Nanoscience is the study of structures and molecules on the scale of nanometers and the technology which utilizes it in practical applications is called nanotechnology. Today, engineers and researchers are finding a wide variety of methods to deliberately make nanoscale materials to take the advantages of their enhanced properties such as higher strength, lighter weight, high chemical reactivity, etc. also the nanotechnology offers more advances in disease treatments, in imaging and diagnostics equipment, in energy efficient products such as fuel and solar cells, etc. so in order to move towards the advanced materials and devices, students should have the knowledge of nanoscience.</p>	
<p><b>Student learning outcome:</b> After learning the course, students should be able :</p> <ul style="list-style-type: none"> <li>• To understand the difference between bulk and nanoscale materials.</li> <li>• To understand the basics of nanoscale science.</li> <li>• To understand the synthesizing technique and difficulties to synthesize the nanomaterials so they can get interest in the search of new composition techniques of nanomaterials.</li> <li>• To understand the various applications of nanoscience and nanotechnology.</li> </ul>	

### **Unit-1 Fundamentals of Nanoscience and Nanotechnology**

**(03 Hrs)**

- 1.1 Introduction to the world of Nanoscience
- 1.2 Nano and Nature: Nanoscopic colors, Bioluminescence, Tribiology.
- 1.3 Introduction to hydrophilic and hydrophobic materials.
- 1.4 Time line of Nanotechnology in different centuries.

### **Unit-2: Nano scale Science (The big world of Nano scale)**

**(4 Hrs)**

- 2.1 Interconversion of Units.
- 2.2 Introduction to surface area to volume ratio and aspect ratio.
- 2.3 Difference between surface area to volume ratio of bulk materials and nano materials (sphere, rods, cubes)
- 2.4 Difference in aspect ratio of bulk wire and nanowire.
- 2.5 Nanomaterial and wavelength of light.

### **Unit-3: Classification of Nano structured materials**

**(4 Hrs)**

- 3.1 Small things can make a big difference.
- 3.2 Classification of nanostructured materials (3D, 2D, 1D, 0D).
- 3.3 Relationship between dimension and shape of nanomaterials (Quantum dots, Quantum wires, carbon nanotubes, Fullerenes).
- 3.4 Effect of size on electronic and optical properties.

**Unit-4: Fundamental of atomic structure and Bonding (3 Hrs)**

- 4.1 Bohr's atomic structure.
- 4.2 Bohr's atomic radii, comparative size of nanomaterials and atomic size, electronic configuration.
- 4.3 Types of energy levels
- 4.4 Bonding and electronic structures of solids.

**Unit-5: Concept of solid state physics and crystal structure (4 Hrs)**

- 5.1 Introduction.
- 5.2 Planes in the crystals and crystallographic directions.
- 5.3 Types of crystal structures.
- 5.4 Reciprocal lattice

**Unit-6: Synthesis techniques (4 Hrs)**

- 6.1 Introduction
- 6.2 Top-Down fabrication methods(concepts with examples only)
- 6.3 Bottom-Up fabrication methods(concepts with examples only)
- 6.4 Chemical,Biological and Self-assembly methods of synthesis

**Unit-7: Properties of Nano materials (4 Hrs)**

- 7.1 Introduction
- 7.2 Mechanical & Optical properties
- 7.3 Electrical & Magnetic properties
- 7.4 Structural and Thermal properties

**Unit-8: Applications and Future perspective of Nanoscience and Nanotechnology. (4 Hrs)**

- 8.1 Introduction
- 8.2 Cosmetics & Domestic appliances
- 8.3 Nanobiotechnology and Medical fields
- 8.4 Environmental development
- 8.5 Food and Agriculture

**Reference Books:**

1. Nanoscience and Nanotechnology Fundamentals to Frontiers, M.S. Ramachandra Rao, Shubra Singh 2013, Wiley
2. Nanotechnology Principles and practicals, S.K. Kulkarni, 2017, Capital Publishing Company

3. Bio-nanotechnology: concepts and applications, Madhuri Sharon ,Maheshwar Sharon, 2013, CRC Press
4. Introduction to nanoscience and nanotechnology, Boca Raton, G.L. Hornyak, H.F. Tibbals, J. Dutta , J. Moore, CRC Press
5. A textbook of Nanoscience and Nanotechnology, B.S. Murty, 2012, Orient Blackswan Private Limited - New Delhi
6. Environmental Nanotechnology, M. H. Fulekar, Bhawana Pathak, 2018, CRC Press
7. A textbook of Nanoscience and Nanotechnology, T. Pradeep, 2012, Tata McGraw Hill Education Private Limited.

# Chemistry Lab-Semester-IV

1. Determination of the rate-constant (K) for the hydrolysis of methyl acetate catalysed by HCl.
2. Determination of the order of reaction and rate-constant(K) for the hydrolysis of ester (ethyl acetate) by NaOH
3. To determine the Heat of solution of organic acid (benzoic acid/ phthalic acid) by finding the solubility of the acid at two different temp
4. Vitamin-C clock reaction using vitamin-C tablet, tincture, hydrogen peroxide and liquid laundry starch
5. Preparation of biodiesel from waste vegetable oil
6. Detection of elements in organic compounds by green method (Sodium carbonate method)
7. **Qualitative inorganic analysis (Minimum five)**  
Analysis of mixture salt containing two anions and two cations (From two different groups) from the following:  
**Anions:** Carbonate, Sulphate, Chloride, Bromide, Nitrate, Borate, Phosphate  
**Cations:** Copper, Iron, Aluminium, Zinc, Manganese, Calcium, Strontium, Barium, Potassium and Ammonium.

## Reference Books:

1. Advanced Physical Chemistry, J.B. Yadav, 14<sup>th</sup> Edition, 1995, Goel Publishing House.
2. Experiments in Physical Chemistry 8<sup>th</sup> Ed.; Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. McGraw-Hill: New York (2003).
3. A Text Book on Chemistry Practical; 1<sup>st</sup> Edition, Bidhan Chandra Ray, Satyanarayan Das, Reprint 2017, NCBA.
4. Vogel, A.I. Quantitative Organic Analysis, Part 3, ,2012, Pearson
5. Greener approaches to undergraduate chemistry experiment., Kirchoff, M.; Ryan, M.A. 2002, American Chemical Society, Washington DC.
6. Green Chemistry Experiments: A monograph, Sharma, R.K.; Sidhwani, I.T.; Chaudhari, M.K. 2013, I.K. International Publishing House Pvt Ltd. New Delhi.