Quadrant II – Notes

Programme: B.Sc.

Subject: Chemistry

Paper Code: CHD 102

Paper Title: Green Methods and Safety Aspects in Chemistry

Unit: 1

Module Name: Designing Less Hazardous Materials and Reducing Toxicity

Module No: 02

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Designing of Less Hazardous Materials

- **Principle**: "Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to the human health and the environment."
- **Illustration**: This principle aims to develop the methodologies that will minimize the use and formation of toxic and hazardous materials and aim for the formation of non-toxic ecofriendly substances.
- In case, hazardous materials are formed, their effects on the workers must be minimized by the use of Protective clothing, respirators, etc. which will add to the cost of production.

- **<u>Example: Production of Chlorine</u>**
- Chlorine has been produced industrially from around 19th century and is being widely used in the textile as well as the paper industry.
- Earlier the Production of Chlorine was done by Chlor-Alkali process using the Mercury Cell method and now it is produced by using the Membrane cell method.
- Now that Mercury is proved to have tragic health and environmental effects causing heavy metal accumulation which caused Minamata disease in Ontario.
- Now, Membrane cell is preferred over the other Chlor-Alkali processes.
- **<u>Chlor-Alkali Process</u>:**

1. <u>Mercury Cell Method</u>:
    - Consists of a Mercury cathode.
- Saturated Brine (NaCl) solution is used which forms Mercury-Sodium amalgam at the cathode and Chlorine is produced at the anode.
- Known as the Castner-Kellner Process.

2. **<u>Membrane Cell Process:</u>**
- Consists of a cellulose based technology with membrane made up of either Nafion, Flemion or Aciplex and cell made up of an Anode (-) and Cathode (+).
- High Conc. Solution of Salt i.e. NaCl (Brine) is used.
- The anode oxidizes the Chloride ion which loses an electron to become free chlorine gas.

- The Main products formed here are Chlorine and Caustic Soda (NaOH).
- **Reducing toxicity (Designing Safer Chemicals)**
- **Principle**: "**Chemical Products should be designed to preserve efficacy of function while reducing toxicity**".
- **Illustrations**: In many industries, not only the waste product but the starting materials are also quite hazardous to the workers and the environment sometimes.
- Eg. Adipic acid is widely used in the polymer industry for the manufacture of Nylon, Polyurethane, lubricants, etc.
- Benzene is the starting material which is volatile organic compound (VOC's) and carcinogenic; also pollutes the air.
- Preparation of Nylon-6,6
- Adipic Acid + Hexamethylene Diammine ⟶ Nylon-6,6
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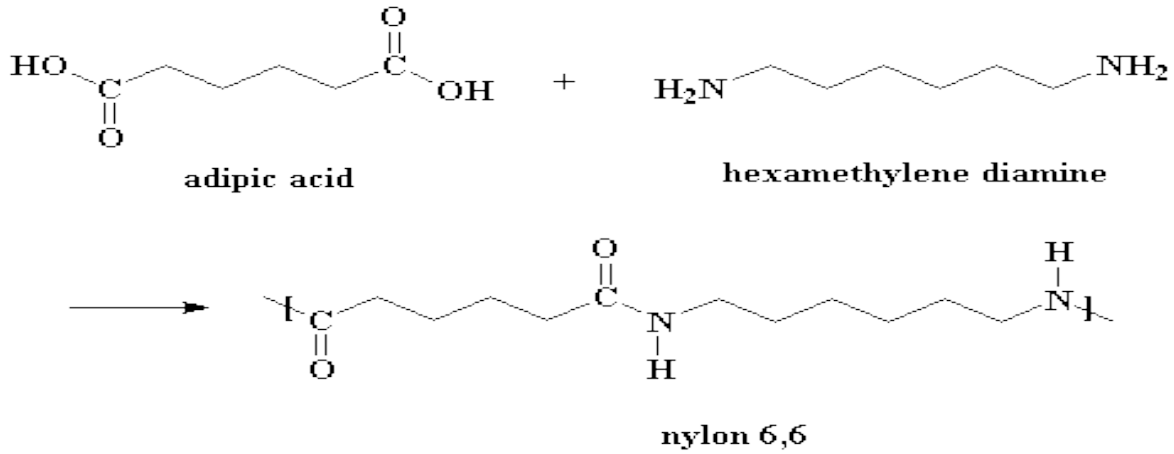
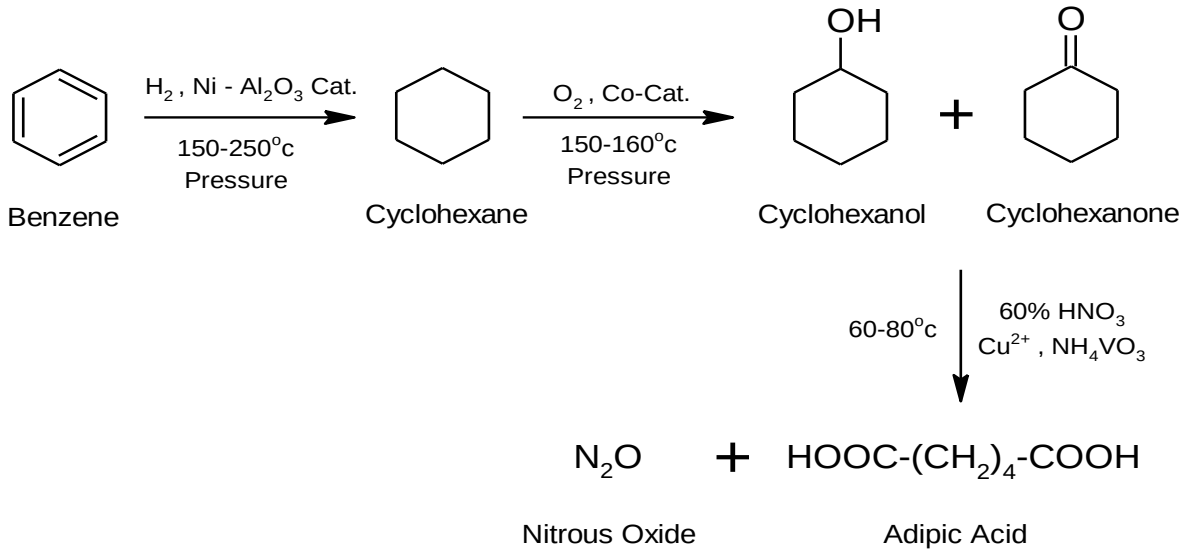


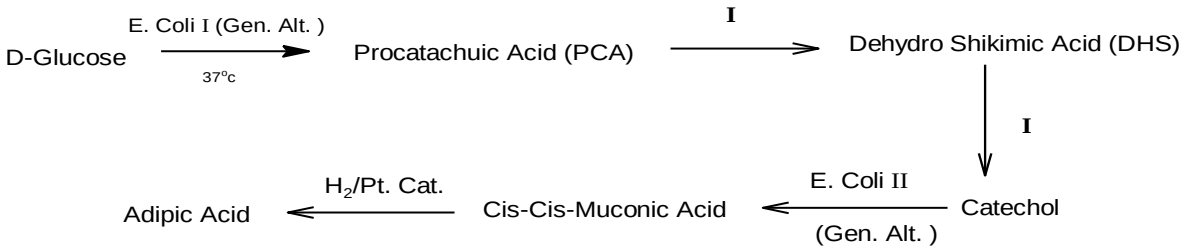
1. Conventional Route for Synthesis of Adipic Acid



❖ 2. Green Method for Synthesis of Adipic Acid

❖ Developed by Drath and Frost.

❖ Adipic acid can be enzymatically prepared by using D-Glucose as the starting material.



I = E. Coli I (Genetically Altered)

❖ Another example is about a greener firefighting foam.

❖ Fluorinated surfactants are critical components of firefighting foams, but they are persistent chemicals and have the potential for environmental impacts.

❖ RE-HEALING™ Foam concentrates are a blend of hydrocarbon surfactant(s), water, solvent, sugars, a preservative, and a corrosion inhibitor.

- The presence of complex carbohydrates gives the foam significantly more capacity to absorb heat than fluorine-containing foam.
- The main advantage of the RE-HEALING™ is that it shows 93% degradation in 28 days, and complete degradation by day 42.
- RE-HEALING™ Foam (RF) is a very effective firefighting foam concentrate for
    - flame knockdown,
    - fire control,
    - extinguishment, and
    - Burnback resistance.
- Control, extinguishing time, and burnback resistance are paramount to the safety of firefighters everywhere, and RF has excellent performance in each.
- Another Example is the drug Thalidomide (1961) used for reducing the effects of Nausea and Vomiting during pregnancy (Morning Sickness).
- It was later banned because the children born to the women taking it suffered from severe birth defects like limbs, eyes, ears, etc. fail to develop properly.
- (+)(R)-thalidomide is an effective sedative, whereas the (-)(S)-thalidomide is a teratogen (a substance affecting the development of the foetus and causing structural or functional disability).