

Green Chemistry

Green chemistry

Definition → ① Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.

② Green chemistry is defined by IUPAC as follows:

The invention, design and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances.

③ Hence Green chemistry focuses on the development of processes and technologies that results in more efficient chemical reactions that generate or produce little waste.

④ Green chemistry is defined as the design, development and implementation of chemical products and processes to reduce or eliminate the use and generation of substances which are hazardous to human health and the environment.

Twelve principles of Green Chemistry

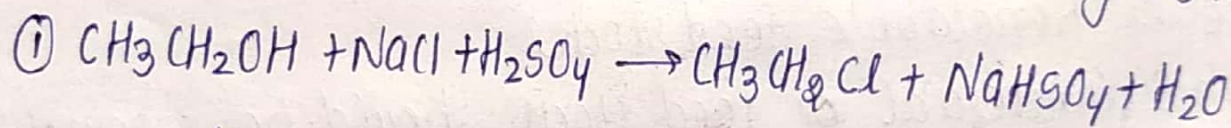
1. Prevention → It is better to prevent waste than to treat or clean up waste after it has been created.
2. Atom economy → Synthetic methods should be designed to maximize the utilisation of all materials used in the process into the final product.

* What is Atom Economy → (it can be asked in 2 marks question)

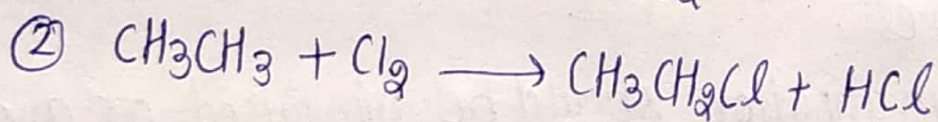
Atom economy is a method of determining the efficiency with which raw materials are used.

$$\text{Atom economy} = \frac{\text{Formula weight of all reactants utilised}}{\text{Formula weight of all reactants}} \times 100\%$$

ex- There are two methods / reaction for producing $\text{CH}_3\text{CH}_2\text{Cl}$



$$\text{Atom economy} = \frac{64}{202} \times 100 = 32\%$$



$$\text{Atom economy} = \frac{64}{101} \times 100 = 63\%$$

Hence atom economy is one of most useful tools for design of reaction with minimum waste.

3. Less Hazardous Chemical Synthesis:

Synthetic methods should be designed to use and generate substances that possess little or no toxicity to people or the environment.

4. Designing Safer Chemicals

Chemical products should be designed to perform their desired function while minimizing their toxicity.

5. Safer Solvents and Auxiliaries

The use of auxiliary substances (e.g. solvents or other agents) should be made unnecessary.

They should be used only when they are required to use.

6. Design for Energy Efficiency

Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized.

7. Use of Renewable feedstocks

A raw material or feed stock should be renewable rather than depleting.

8. Reduce Derivatives

Unnecessary derivatization should be minimized, or avoided because these steps require extra reagents and can generate waste.

9. Catalysis

catalytic reagents are superior to stoichiometric reagents.

10. Design for Degradation

Chemical products should be designed so that at the end of their function they break down into innocuous (harmless) degradation products.

11. Real time Analysis for Pollution Prevention →

Analytical methodologies need to be further developed to allow for real time, in process monitoring and control to the ~~has~~ formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention

Substances ~~used~~ used in the chemical process should be chosen to minimise the potential for chemical accidents including explosions, fires etc.

Importance of Green Chemistry / Green synthesis

① Environmental preservation →

- Green chemistry aims to reduce the use and generation of hazardous substances, thus minimizing pollution and environmental degradation.
- It helps to protect ecosystem, biodiversity and health of our planet.

2. Health & Safety →

- It promotes the use of safer chemicals and processes.
- By reducing exposure to toxic substances it improve the health & safety of workers & consumers.

3. Resource efficiency →

- It encourages the efficient use of raw material and energy.
- This contribute to sustainable resource management and reduces the depletion of natural resources.

4. Innovation →

- It promotes innovation in product design and manufacturing processes.
- Lead to development of novel, more sustainable products.

5. Economic benefits →

- Green chemistry can lead to cost savings in industries.
- It results in reduced waste disposal and increased energy efficiency.
- It can open up new markets for sustainable products and technologies.

6. Education & Awareness →

- Green Chemistry also plays a role in educating the next generation of scientists, engineers and consumers for understanding the importance of protecting the planet.

Green Chemicals: Alternate solvents

a) Use of safer solvents

To avoid the use of some carcinogenic solvents like benzene, chlorinated organic solvents, some safer solvents are used and these are:

- a) α -Butanol
- b) 1-Butanol
- c) α -Ethylhexanol
- d) Propionic acid
- e) Ethylene glycol

Another class of safer solvents is the Green solvents. Green solvents are environmentally friendly solvents, or biosolvents which are derived from the processing of agricultural crops.

Ethyl lactate is green solvent derived from processing corn. Ethyl lactate is the ester of lactic acid.

Lactate ester solvents are commonly used solvents in paints and coating industry.

- Advantages \rightarrow
- (i) 100% biodegradable
 - (ii) easy to recycle
 - (iii) non corrosive
 - (iv) non carcinogenic

(b) Use of water as solvent

- \rightarrow Use of water as solvent for organic reactions is one of the finest solutions to the problem of solvent toxicity.
- \rightarrow Chemical Reaction in natural systems is based on water.
- \rightarrow Use of water as solvent provides less hazardous production of chemicals.

(c) Solvent free conditions

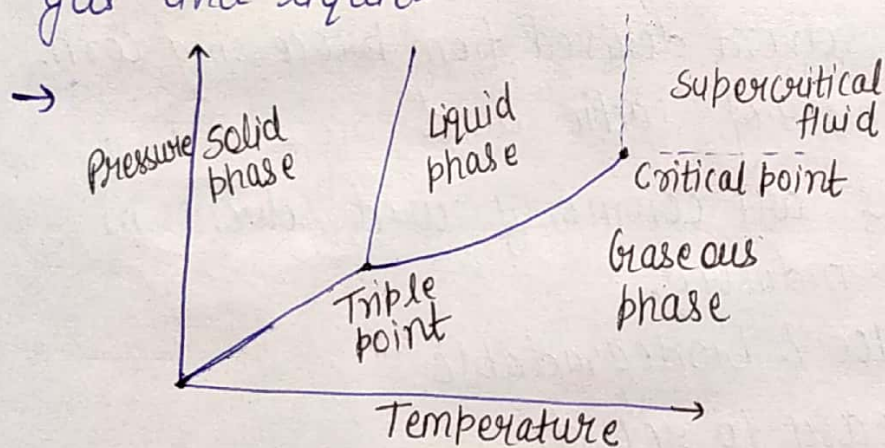
Solvent free conditions over the use of organic solvent provide the following advantages.

- Lesser Reaction time
- Increase in yield of product
- lower energy usage
- No need of special equipment.

(d) Use of supercritical liquids

Supercritical liquid is any substance at a temperature and pressure above its critical point (where gas and liquid phase can coexist)

Supercritical fluids exhibits properties between those of gas and liquid.



→ Due to this supercritical fluids are able to dissolve many compounds with different polarity.

Two supercritical fluids used in green chemistry

(i) Supercritical carbon dioxide ($SCCO_2$)

- It has low critical temperature 304K and critical pressure 73bar.
- CO_2 as supercritical fluid ^{used} as a medium for reaction because:
 - It is inflammable, easily available & cheap

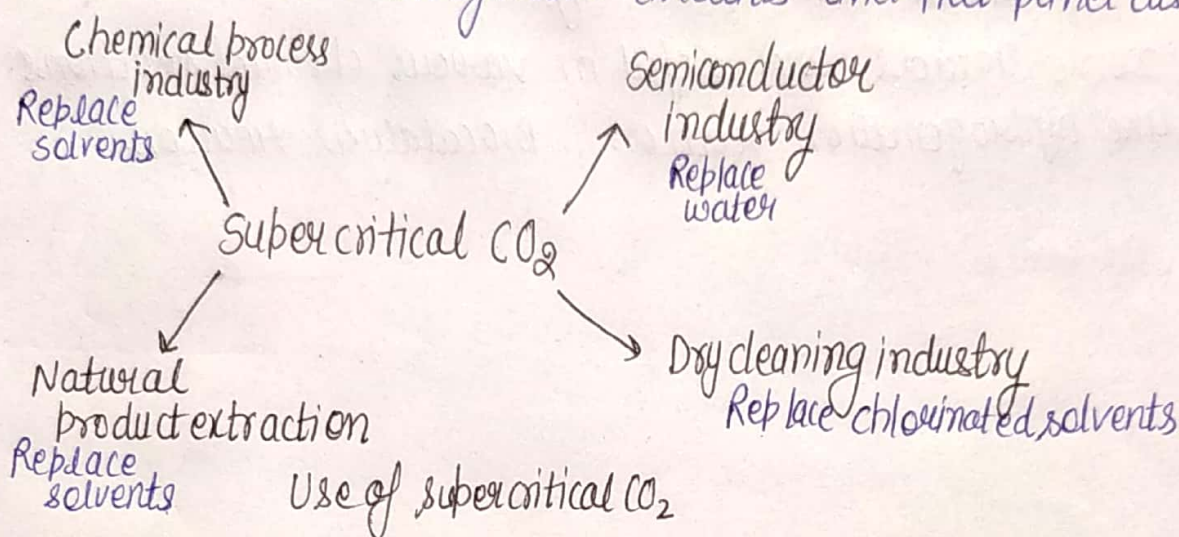
→ CO_2 as supercritical fluid dissolves non polar compounds and some polar solvents also.

→ easily recovered after processing.

Use of SCCO_2 :

→ used for dry cleaning, metal cleaning and textile processing.

→ used to clean integrated circuits and flat panel displays.



(ii) Supercritical water (SCH_2O):

→ It has critical temperature 647K and critical pressure 220 bar.

→ At critical temperature water lose Hydrogen bonding and water molecules can dissolve chemicals which were insoluble previously.

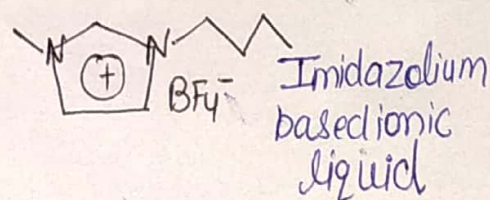
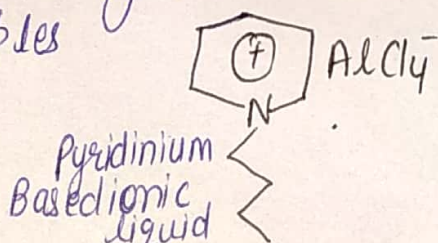
→ It can dissolve paraffins (combustible hydrocarbon liquid that burnt as a fuel), aromatic compounds.

(c) Room-temperature ionic liquid

→ Ionic liquid is salt in liquid state.

→ Ionic liquid is defined as compound composed of ions with melting point below 100°C .

→ examples



→ It is used as green solvent because:

• easy to reuse

• nonvolatility → offers lower toxicity as compared to other solvents

• thermal stability

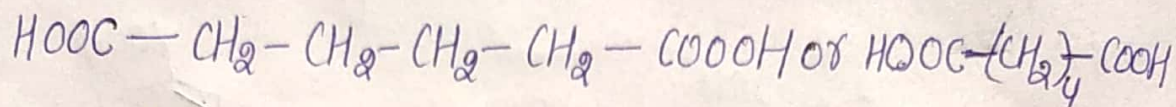
• ability to dissolve variety of organic compounds and organometallic compounds.

• high electrical conductivity

→ Ionic liquids are useful in various chemical reactions like hydrogenation reaction, Biocatalysis reaction.

Synthesis of Typical organic compounds by Conventional and Green route.

(i) Adipic acid

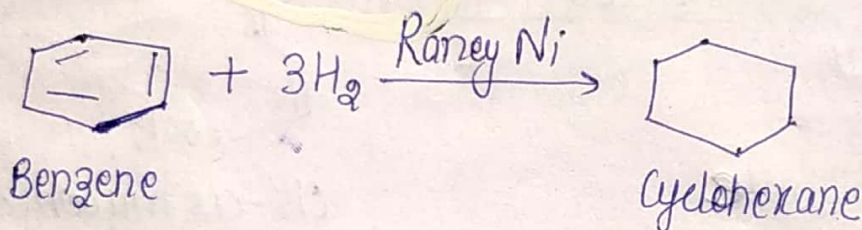


- Adipic acid is used as monomer for production of nylon 6,6.

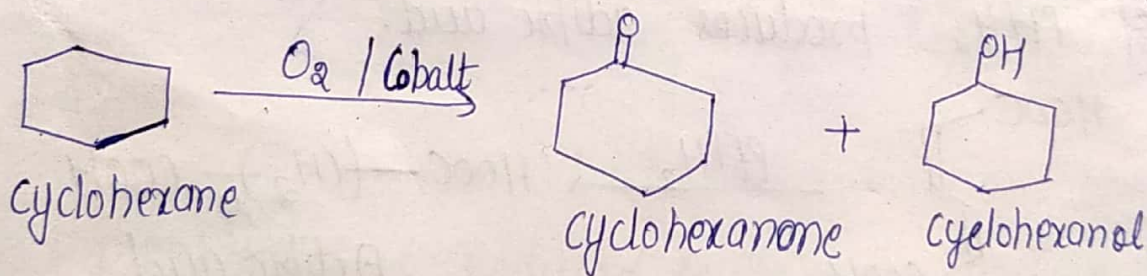
9) Synthesis of Adipic acid by Conventional method:

Adipic acid is synthesised traditionally with benzene as starting material.

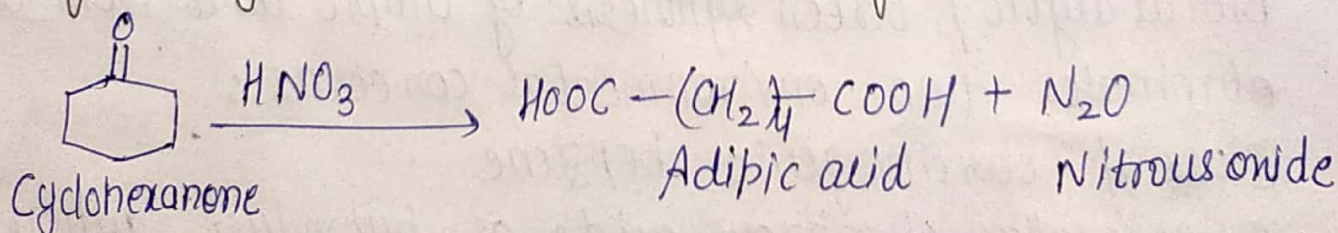
Step 1: Benzene is reduced to cyclohexane using H_2 and Raney Ni.



Step 2: Cyclohexane is oxidised to cyclohexanone in presence of cobalt



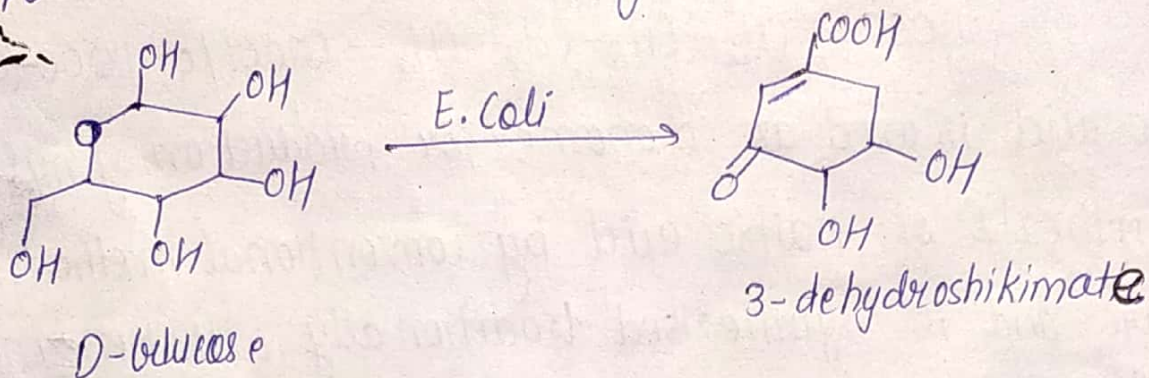
Step 3: Cyclohexanone is oxidised with nitric acid resulting in ring opening reaction and production of adipic acid.



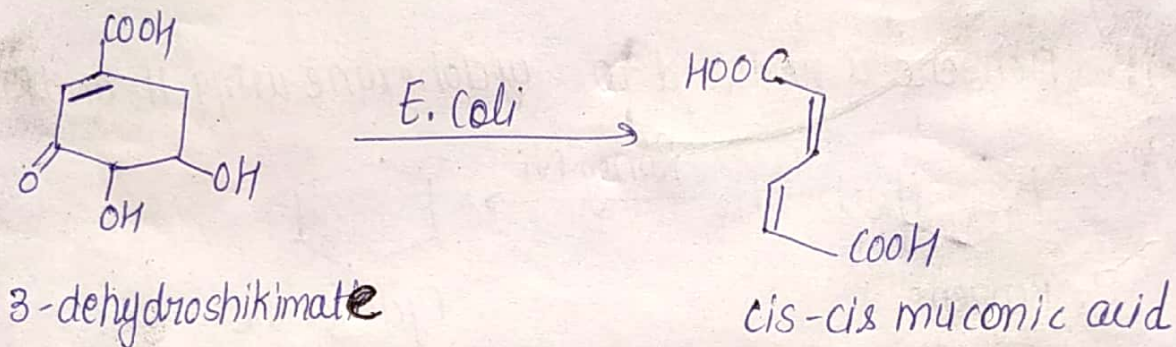
(b) Synthesis of Adipic Acid by Green Chemistry:

Green synthesis of adipic acid uses a completely safe compound, Glucose as starting molecule.

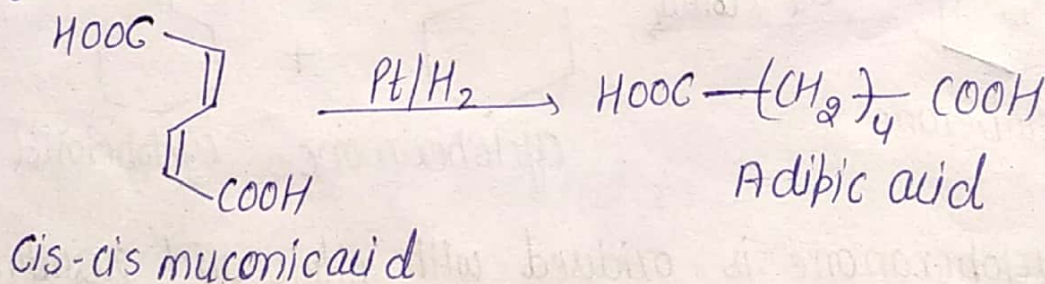
Step 1:



Step 2:



Step 3: Cis-cis muconic acid on reduction reaction in presence of Pt/H_2 produces adipic acid.



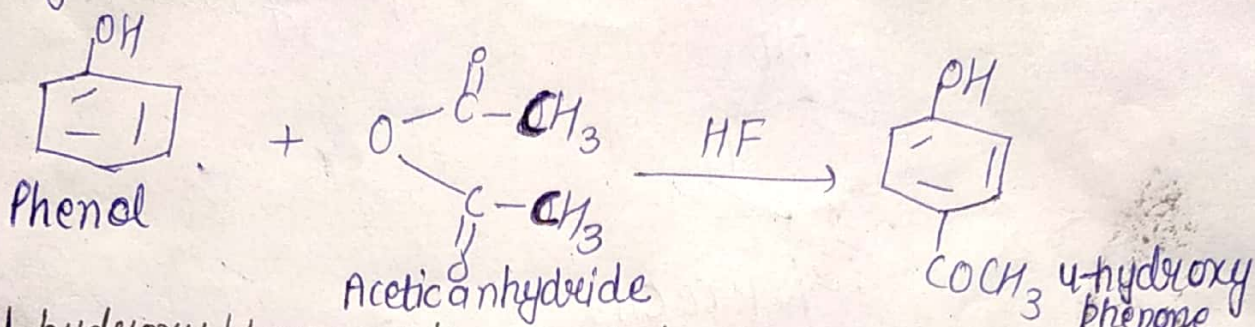
Biocatalytic / Green synthesis of adipic acid from Glucose eliminates two environmental concerns:

- ① use of carcinogenic benzene
- ② generation of nitrous oxide as byproduct when adipic acid synthesised by conventional method

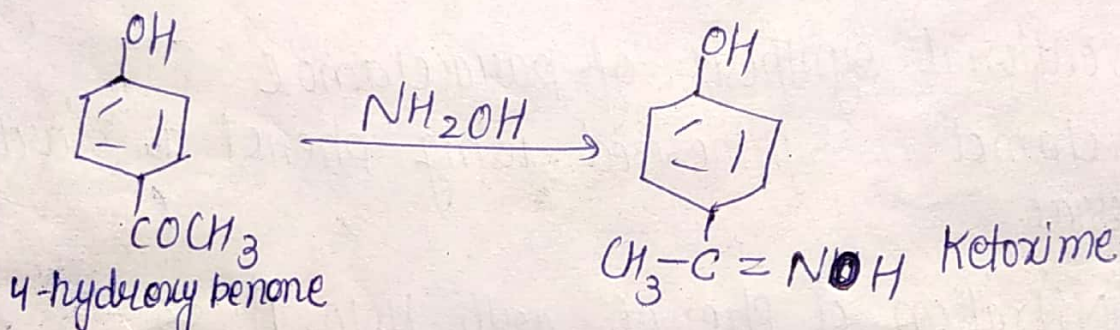
(b) Green route for synthesis of paracetamol

In green route paracetamol is produced from phenol and acetic anhydride in presence of strong acid HF

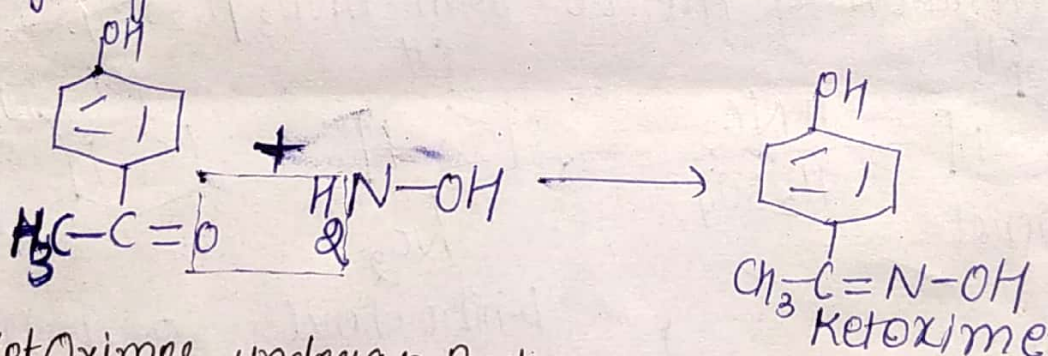
Step 1:



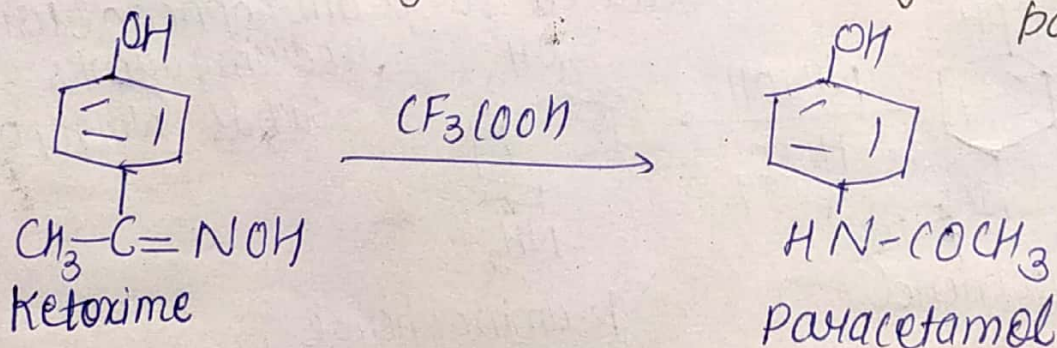
Step 2: 4-hydroxyphenone is reacted with hydroxylamine



OR



Step 3: Ketoximes undergo Beckmann rearrangement to produce paracetamol



Atom economy of green method of synthesis of paracetamol is 56%. while with conventional method it is only 36%.

Environmental impact of Green Chemistry On society

1. Reduced pollution → Green Chemistry focuses on designing process that produces less harmful byproducts.
→ This helps to reduce air, water and soil pollution which leads to cleaner healthier environment for society.
2. Lower Resource consumption → Green chemistry promotes the efficient use of resources, such as raw materials, energy and water.
→ It helps in conserving natural resources and reduces the environment impact like their extraction, processing and transportation
3. Safer Chemicals → Green chemistry encourages the development of safer chemicals and materials and reduces the risk of hazardous chemical for both consumer and workers in chemical industry.
→ Safer chemicals reduce the risk of chemical accidents which contribute to healthier society.
4. Energy efficiency → It focuses on reducing energy requirements which reduces green house emission and this contribute to improvement in climate change.
5. Sustainable Agriculture → It promotes the development of environmentally friendly pesticides, fertilizers and crop protection method in agriculture.
→ This helps in reducing ground water contamination and ensure food security for society.
6. Waste reduction → It focuses on reduction of waste generation, and use of recyclable material.
→ This leads to reduction in environmental burden of waste management on society.

7. Public Awareness:- It initiates in providing the awareness to public about environmental impact of chemical processes and products and encourage environmentally responsible behaviour in society.