GREEN CHEMISTRY

Chemistry plays an important role to improve the quality of our life. But unfortunately due to this achievement our health and global environment are under threat. Also, due to Increase in human population and the industrial revolution, energy crisis and environmental pollution are highlighted the major global problems in 21st century. To minimize the problems of energy crisis and pollution, we have to adapt Green Chemistry.

Paul T. Anastas is known as Father of Green Chemistry

Definition :- Green Chemistry is the use of Chemistry for pollution prevention by environmentally concious design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.

To reduce the impact of energy crisis, pollution and to save natural resources, we need to implement 12-principles of Green Chemistry. By adapting these principles, we can achieve Sustainable development too.

[Sustainable Development :- The development that meets the needs of the present, without compromising the ability of future generations to meet their own needs.]

Principles of Green Chemistry :-

1. Prevention of waste or by products :-

To give priority for the prevention of waste rather than cleaning up and treating waste after it has been created.

→ To develop the zero waste technology (ZWT), in a chemical synthesis, waste product should be zero or minimum.

→ It also aims to use the waste product of one system as the raw material for other system.

For e.g. Bottom ash of thermal power stations can be used as a raw material for cement and brick industry.

e.g. effluents coming from the cleaning of machinery parts may be used as coolant water in thermal power station.

2- Atom economy :- Atom economy is the measure of the amount of atoms from the starting materials that are present in the useful products at the end of the chemical process.

$$\% \text{ Atom economy} = \frac{\text{Formula Wt of the desired product}}{\text{Sum of the F.W. of all the reactants}} \times 100$$

For e.g. Conversion of Butan-1-ol to 1-Bromobutane

$$CH_3CH_2CH_2CH_2OH + NaBr + H_2SO_4 \rightarrow CH_3CH_2CH_2CH_2-Br + NaHSO_4 + H_2O$$

$$\% \text{ Atom economy} = \frac{\text{mass of } 4C + 9H + 1\text{-}Br \text{ atoms}}{\text{mass of } 4C + 12H + 5O + 1\text{-}Br + 1\text{-}Na + 1\text{-}S \text{ atom}} \times 100$$

$$= \frac{137\,u}{275\,u} \times 100 = 49.81\%$$

3. Less Hazardous Chemical Synthesis :- Desired chemical reactions and synthesis routes should be as safe as possible, so that hazardous waste formation can be avoided during chemical processes.

e.g. DDT was used as insecticide for controlling diseases like typhoid, malaria carrying mosquitoes, it was very harmful to living beings. Now a days ~~BHC~~ γ-isomer of BHC (Gammaxene / Lindane) is used

[DDT → Dichloro diphenyl trichloro ethane; BHC → Benzene hexa chloride]

4- Designing Safer Chemicals! - To develop products that are less toxic or which require less toxic raw materials.

* In chemical industries, to prevent the workers from the exposure of toxic environment.

For e.g. Adipic acid can be prepared by benzene as a starting material which is a carcinogenic and volatile (i.e. hazardous to human health as well as pollutes air), but by green route it is prepared enzymatically from glucose.

5- use safer solvents and auxillaries! - Choose the safer solvent available for any given ~~rea~~ step of reaction. Minimize the total amount of solvents & auxillary substances used as these ~~ma~~ make up ~~th~~ a large amount of total wastage.

→ Main aim is to use green solvents.
For e.g. use of water (H_2O), supercritical CO_2 in place of volatile halogenated solvents like CH_2Cl_2, $CHCl_3$, CCl_4 etc. which are hazardous

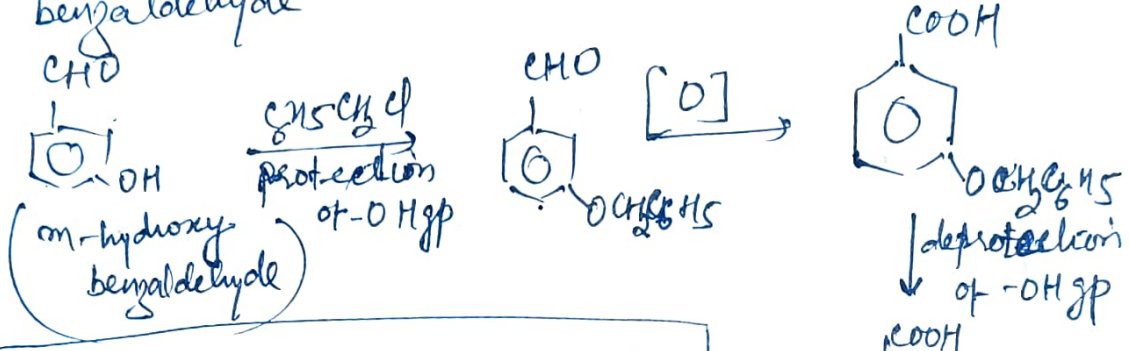
6- Design for energy efficiency! - chemical ~~re~~ synthesis should be designed to minimize the use of energy by carrying out the reactions at room temp. & pressure. This can be achieved by the use of proper catalyst, use of microorganisms for organic synthesis, use of renew~~a~~able materials etc.

→ For e.g. Biocatalysts can work at the ambient condition, refluxing require less energy, improving the technology of ~~wat~~ heating system, use microwave heating etc.

7. Use of renewable feedstocks :- Use chemicals which are made from renewable sources (plant based) rather than other (for e.g. crude oil). Over exploitation of non-renewable feed stocks deplete the resources and also put the burden on the environment.

8- Reduce Derivatives (Minimization of Steps) :- A commonly used technique in the organic synthesis is the use of protecting or blocking gp. Such steps require additional reagents and can generate waste. In such cases atom economy is also less.

e.g. Synthesis of m-hydroxybenzoic acid from m-hydroxy benzaldehyde



Green Chemistry aims to avoid unnecessary steps, wherever possible, biocatalytic reactions can be performed and they need no protection of selective gp.

9- Use of Catalysis :- Use of a catalyst speeds up the reaction rate. Catalyst helps to increase selectivity, minimize waste and reduce reaction times and energy demands.

e.g. Hydrogenation of oil (hardening) → Catalyst: Nikel catalyst
Haber's process of NH_3 formation → Iron "
etc.

10. Design for Degradation!- Design chemicals that degrade and can be discarded easily. Ensure that both chemicals and their degradation products are not toxic, bioaccumulative or environmentally persistent.

→ The aim is that the waste product should degrade automatically to clean the environment. Thus, biodegradable polymers and pesticides are always preferred.

→ To make seperation easier for the consumer an international plastic recycle mark is printed on layer items.

11. Real-Time Analysis Pollution prevention!- Analytical methods need to be further developed to allow for real-time, in process monitoring and control prior to the formation of hazardous substance.

→ Analytical methodologies should be developed or modified, so that continuous monitoring of the manufacturing and processing units become possible. It's very imp. for chemical industries & nuclear reactors.

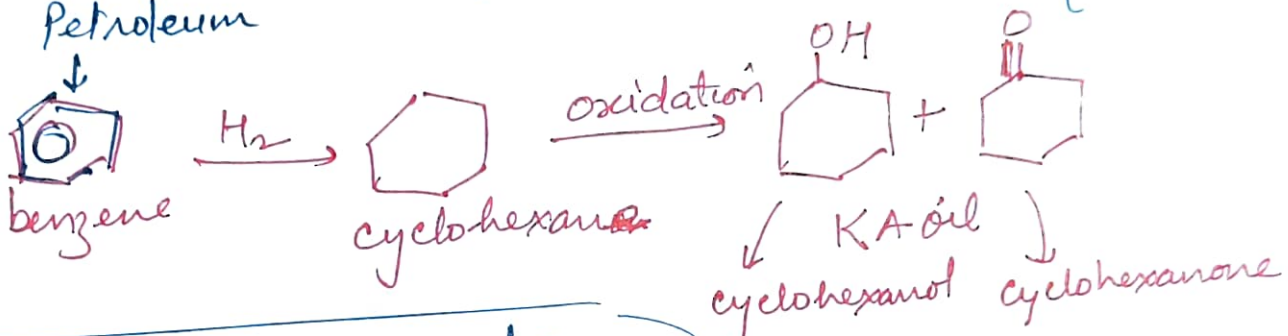
12- Safer Chemistry for Accident Prevention!- We need to develop chemical processes that are safer and minimize the risk of accidents.

→ The substances used in chemical reactions should be selected which can minimize the occurence of chemical accidents, explosions, fire and emissions. For eg. for gaseous substance danger of explosion is high than liq/solid.

Synthesis of Adipic Acid - Conventional Route

In conventional method Adipic Acid is prepared from benzene, which is extracted from Petroleum, a non-renewable source. For oxidation, HNO_3 is used, which releases N_2O and pollute air. Inhalation of N_2O causes breathing issues and throat etching.

(KA oil → Ketone-alcohol oil)

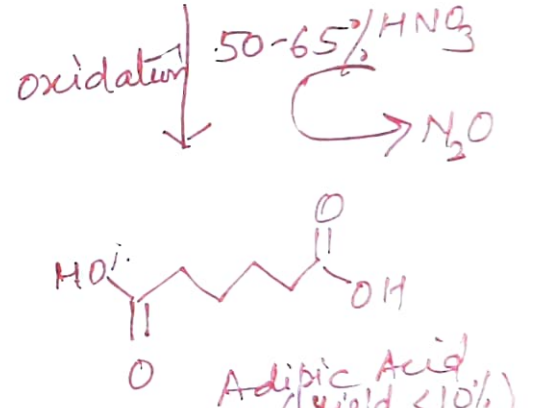


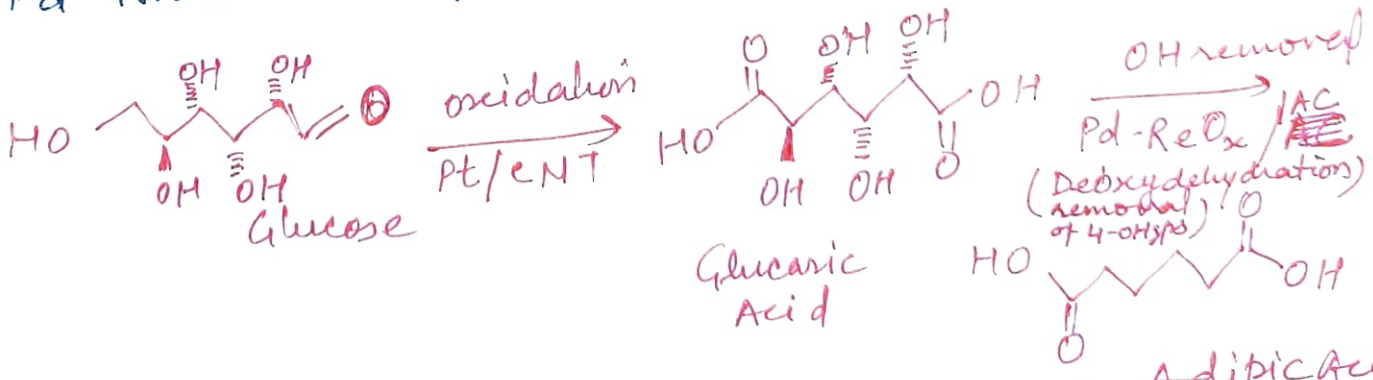
Synthesis by Green-route

→ In this method, cellulose derived glucose is converted into Adipic Acid via Glucaric acid.

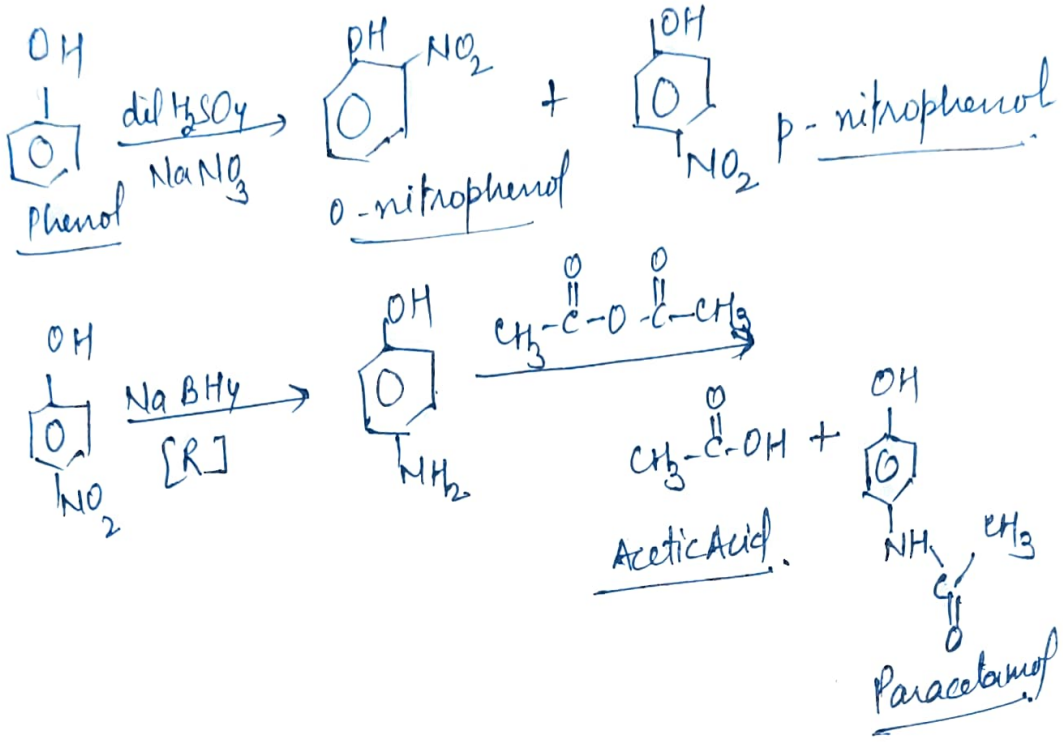
→ CNT support Pt nanoparticles efficiently oxidize glucose to glucaric acid

→ Pd-Rh oxide composite effectively remove hydroxyl gp.

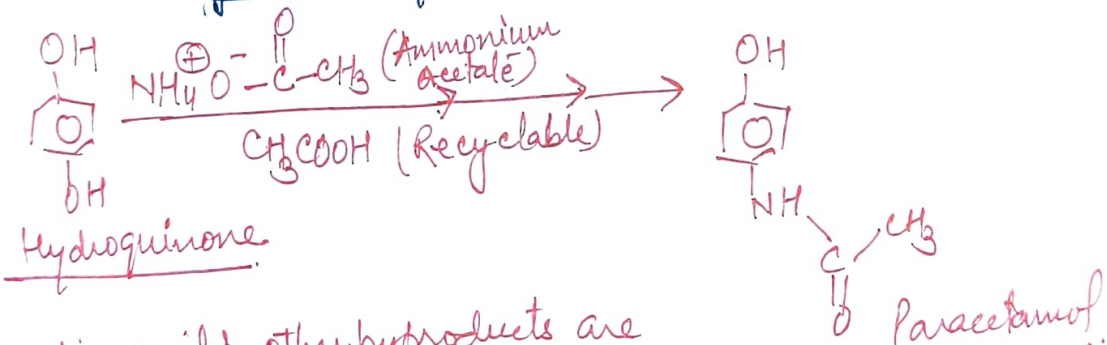




Synthesis of Paracetamol - Conventional Route :



Synthesis of Paracetamol - Green Route.



(N-(4-Hydroxyphenyl) acetamid)

(yield >95%)

Acetic acid & other byproducts are recyclable & reusable. This method is metal-free, additive-free & ~~high~~ has high yield and high selectivity.

Environmental Impact of Green chemistry

Environment-

1- Green chemicals either degrade to harmless products or are recovered for further.

2- Plants and animals suffer less harm from toxic chemicals in the environment.

3- Lower chance for global warming, ozone depletion & smog formation.

4- Less chemical dissruption of eco-systems.

Humain Health.

1- High yields for chemical reactions, consuming smaller amounts of precursor to obtain the same amount of product.

2- Fewer synthetic steps, faster manufacturing of products, increasing plant capacity saving energy & water.

3- Reduced use of petroleum products, slowing their depletion.

4- Reduced generation of waste, eliminating costly disposals methods of the hazardous chemicals.

5- Increased consumerism by displaying a safer product label..