

Green chemistry



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Origins of Green Chemistry

The idea of green chemistry was initially developed as a response to the Pollution Prevention Act of 1990, which declared that U.S. national policy should eliminate pollution by improved design instead of treatment and disposal.

By 1991, the Environmental Protection Agency (EPA) Office of Pollution Prevention and Toxics had launched a research grant program encouraging redesign of existing chemical products and processes to reduce impacts on human health and the environment.

The Annual Presidential Green Chemistry Challenge Awards in 1996 was a bench mark.

The 12 Principles of Green Chemistry were published in 1998.

In 1999, the Royal Society of Chemistry launched its journal Green Chemistry.



The Benefits of Green Chemistry

- Economical
- Energy efficient
- Lower cost of production
- Less wastes
- Fewer accidents
- Safer products
- Healthier workplaces and communities
- Protects human health and the environment

Green chemistry or Green Synthesis

Green chemistry is the approach in chemical sciences that :

- Efficiently uses renewable raw materials,
- Eliminating waste and
- Avoiding the use of toxic and hazardous reagents and solvents in the manufacture and application of chemical products.

Green chemistry takes into account the environmental impact and prevents these impacts through certain principles.

The 12 key principles of green chemistry

1. Prevention: It is better to prevent waste formation than to treat it after it is formed.

2. Atom economy: Design synthetic methods to maximize incorporation of all material used into final product.

$$\text{Atom Economy} = \frac{\text{Mass of atom in product} \times 100\%}{\text{Mass of atom in reactant}}$$

$$\text{atom economy} = \frac{\text{molecular weight of desired product}}{\text{molecular weight of all products}} \times 100\%$$

3. Less hazardous Chemicals: Synthetic methods should use or generate materials of low human toxicity and environmental impact.



4. Safer chemicals: Chemical product should be of reduced toxicity.

5. Safer solvents: Avoid auxiliary materials - solvents, extractants - if possible, or otherwise make them harmless.

6. Energy efficiency: Energy requirements should be minimized: synthetic methods should be conducted at ambient temperature and pressure.

7. Renewable feedstocks: A raw material or feedstock should be renewable.

8. Reduce derivatives: Unnecessary derivatization should be avoided where ever possible.

9. Smart catalysis: Selectively catalyzed processes should be used

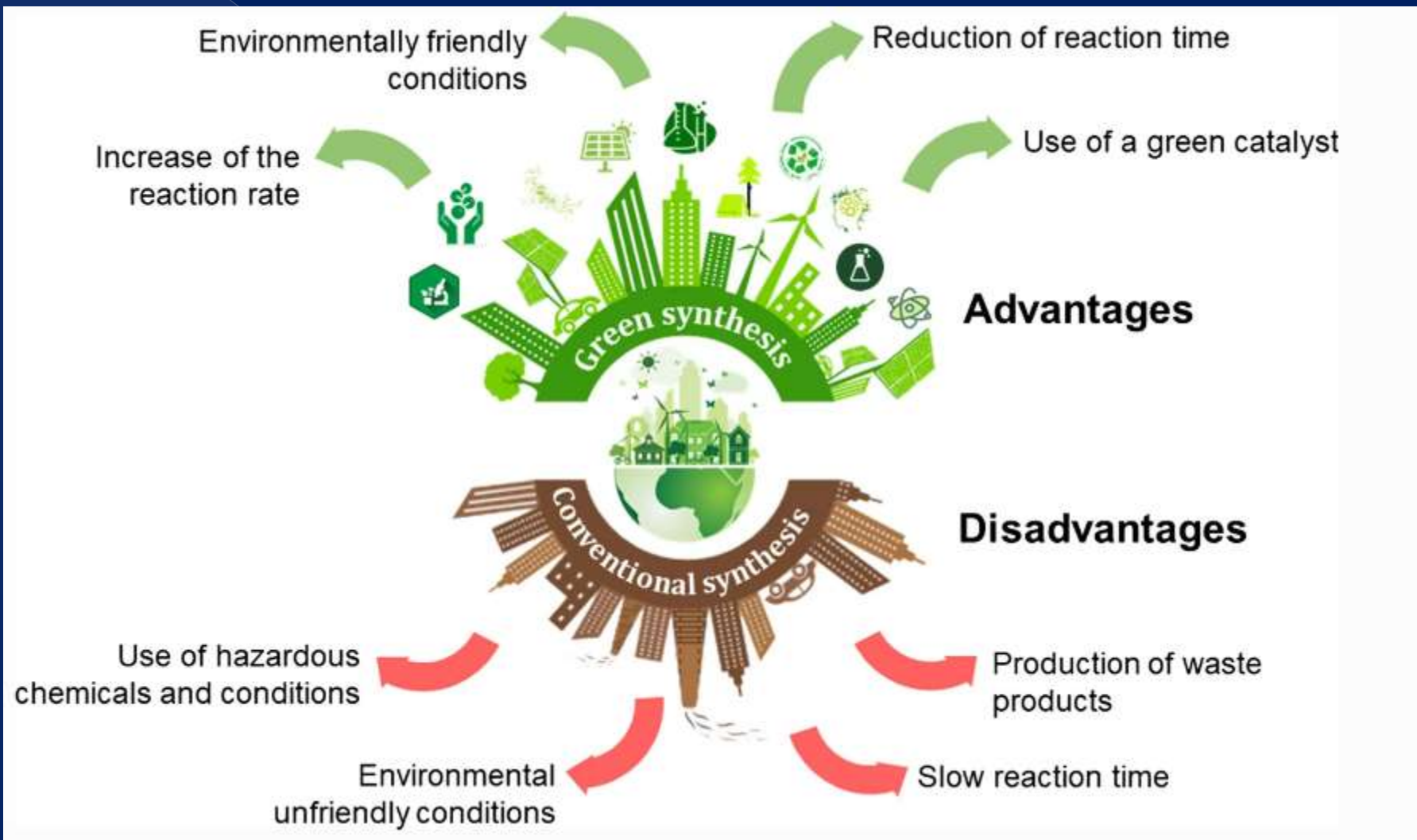
10. Degradable design: Chemical products should be designed to be degradable to safe products when disposed of and not be environmentally persistent.

11. Real-time analysis for pollution prevention:

Monitor processes in real time to avoid unnecessary formation of hazardous materials.

12. Hazard and accident prevention: Materials used in a chemical process should be chosen to minimize hazard and risk for chemical accidents, such as releases, explosions, and fires.

Green Synthesis Vs Conventional Conventional Synthesis



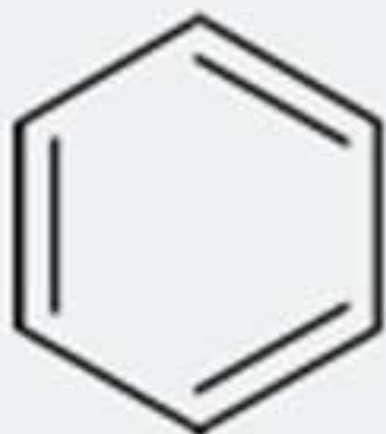
Synthesis of Adipic Acid (1,6-hexanedioic acid)

Adipic acid is one of the most widely used dicarboxylic acids in the chemical industry, and can be used for the manufacture of
Nylon 6,6 polyamide,
Polyurethanes,
Plasticizers
as well as other pharmaceutical chemicals.

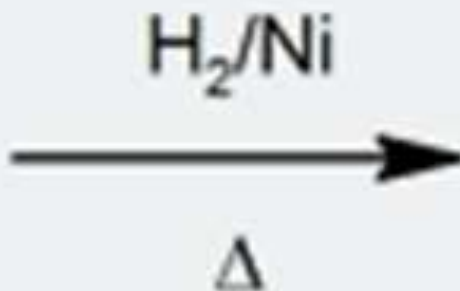
Synthesis of Adipic Acid (Conventional Method)

Adipic acid can be synthesised in laboratory in following steps

Step 1: Benzene is converted to cyclohexane by catalytic hydrogenation in presnce of Ni as a catalyst

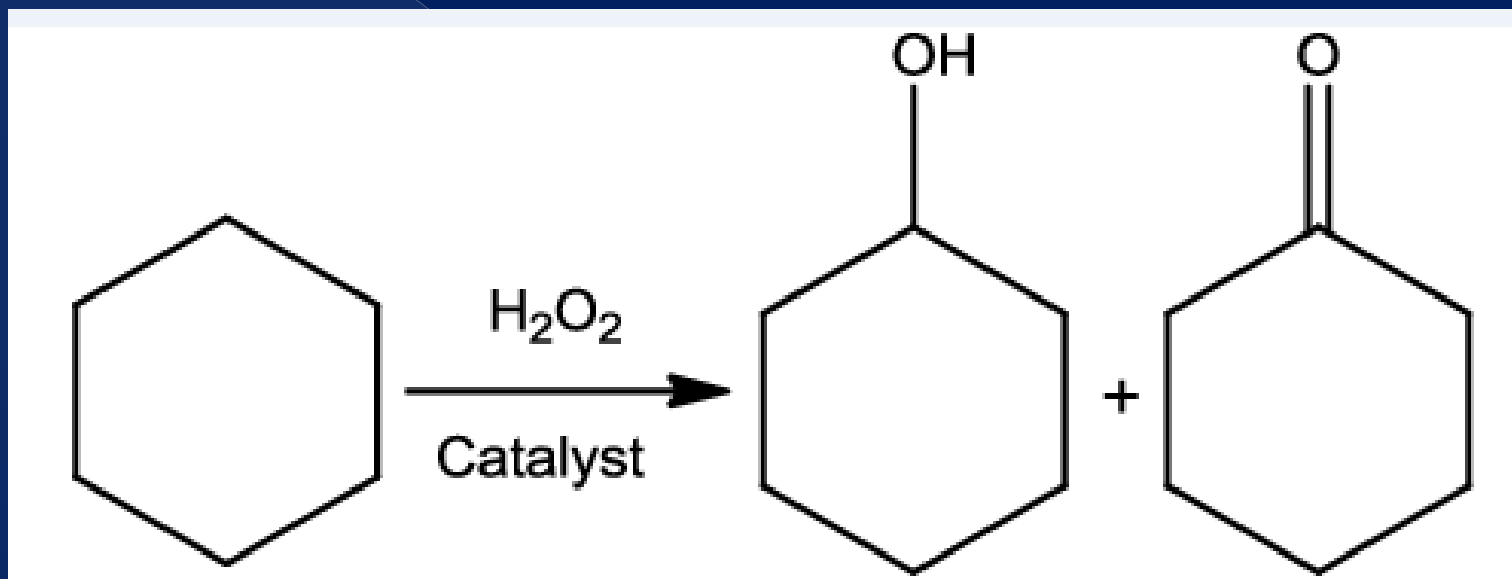


Benzene

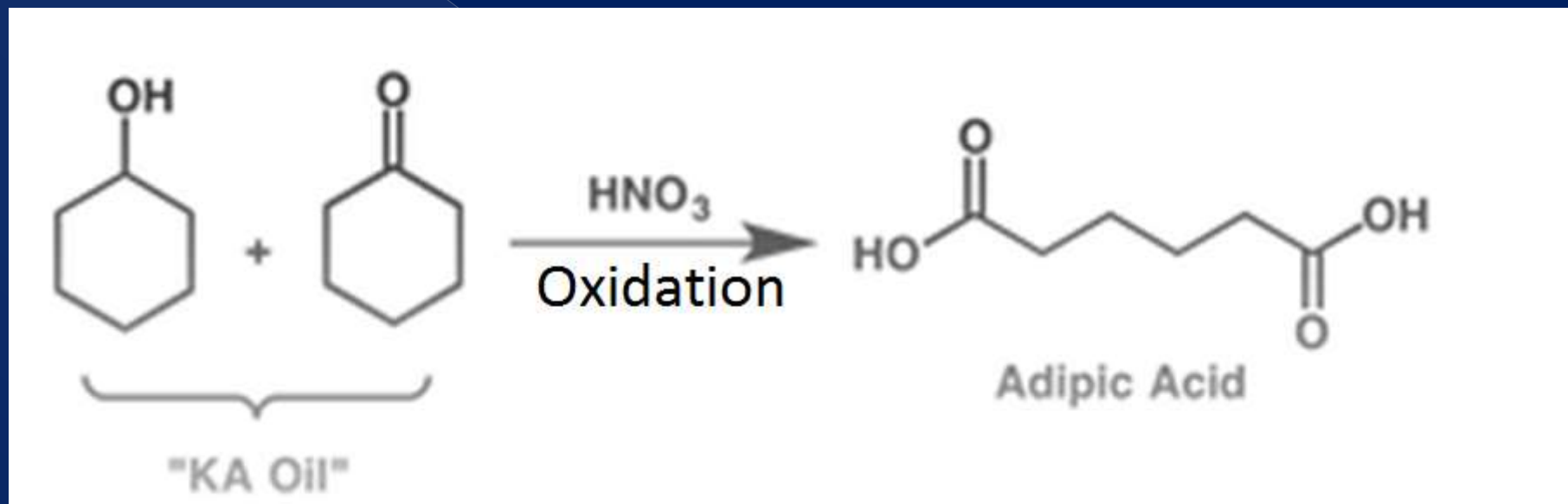


Cyclohexane

Step 2: Catalytic Oxidation of Cyclohexane to Cyclohexanol & cyclohexanone in presence of Fe_2O_3 or Co_3O_4 as catalyst



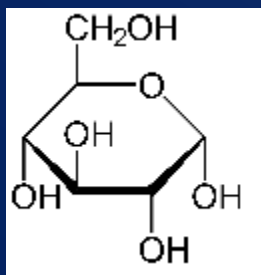
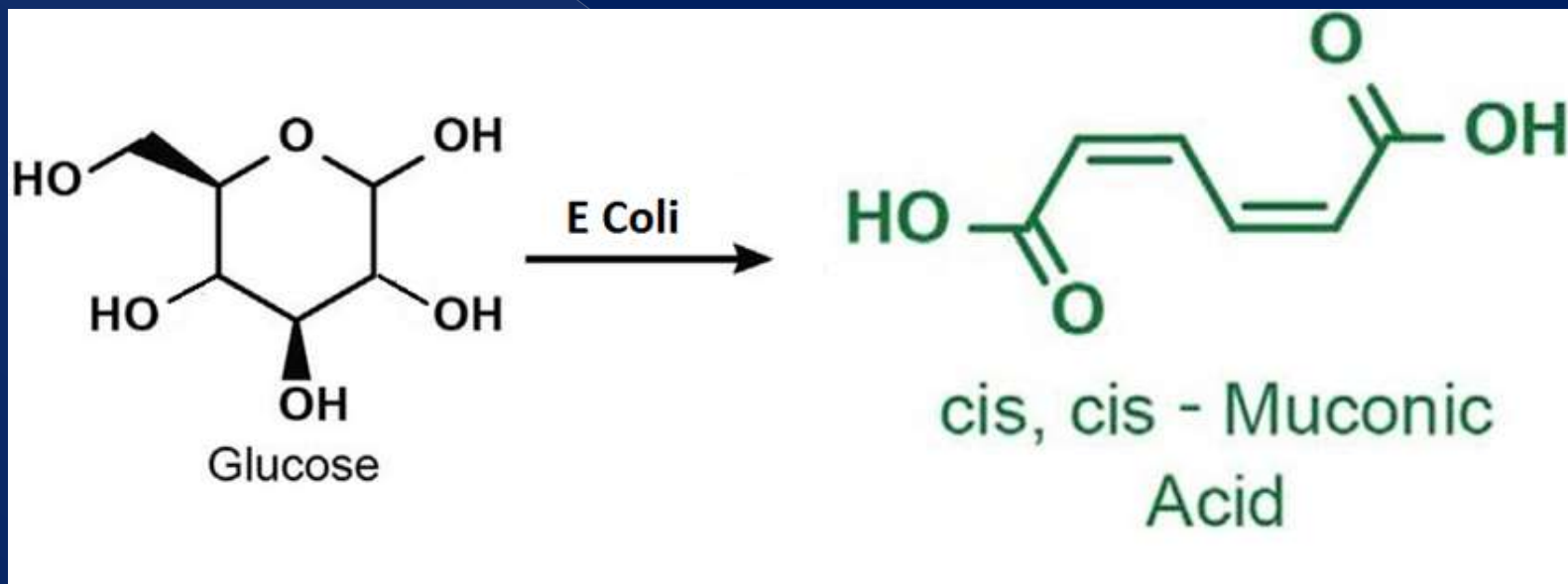
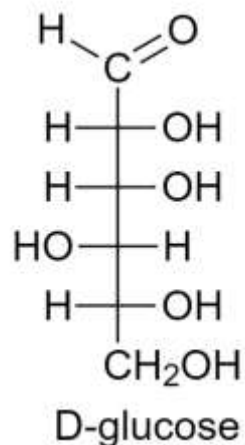
Step 3: Oxidation and ring opening reaction of cyclohexanone in presence of conc. nitric acid (KA oil stands for Ketone-Alcohol oil)



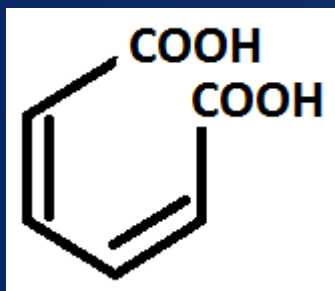
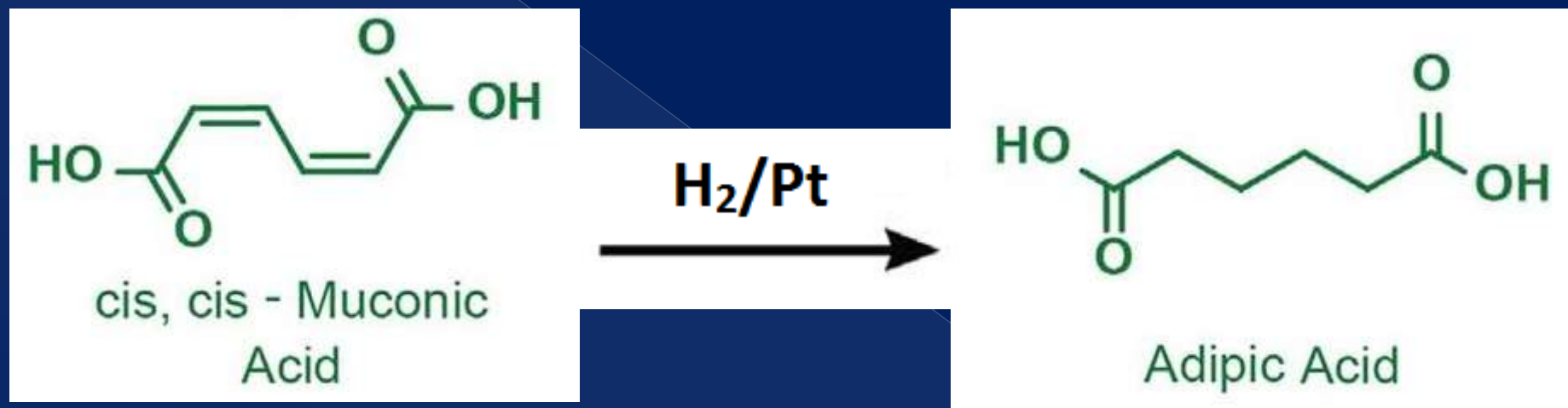
Green Approach to Synthesis of Adipic Acid

Adipic acid can be prepared by eco-friendly routes in following steps

Step 1: D-Glucose on reaction with E Coli gives Cis-Muconic Acid (Bio synthesis with microbial enzyme)



Step 2: Reduction of Cis Cis Muconic Acid in presence of Catalyst Pt gives Adipic Acid



Draw backs of Conventional Route

Benzene is the starting material which is carcinogenic (Volatile Organic Compound (VOC))

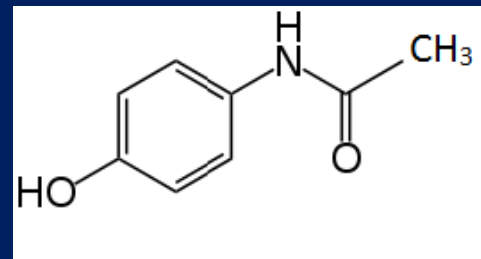
Benefit of Green Approach

Glucose is the starting material and enzyme catalyzed reaction takes place which is non toxic

Paracetamol $C_8H_9NO_2$

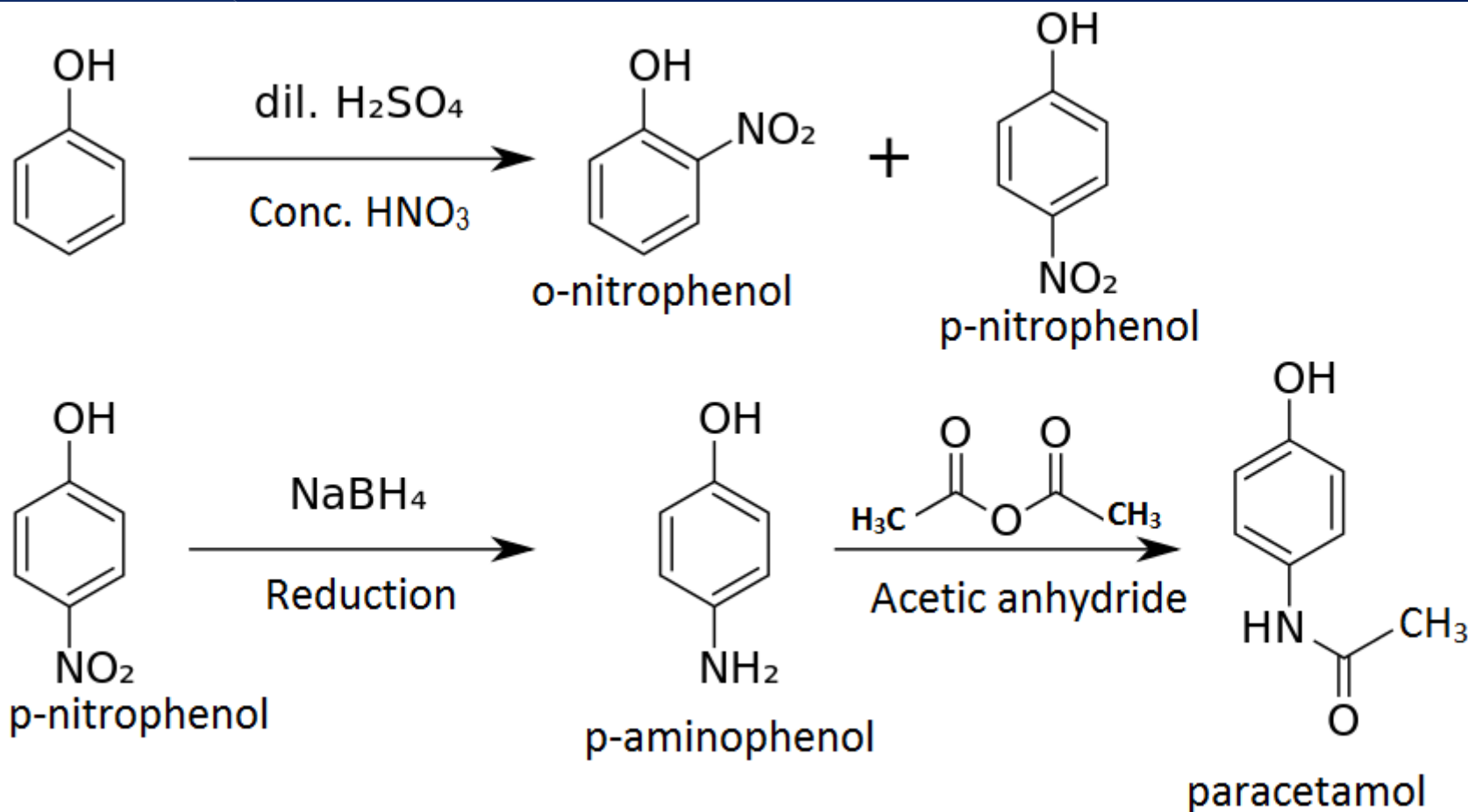
N-acetyl-para-aminophenol or
Acetaminophen

4-hydroxyphenylethanamide



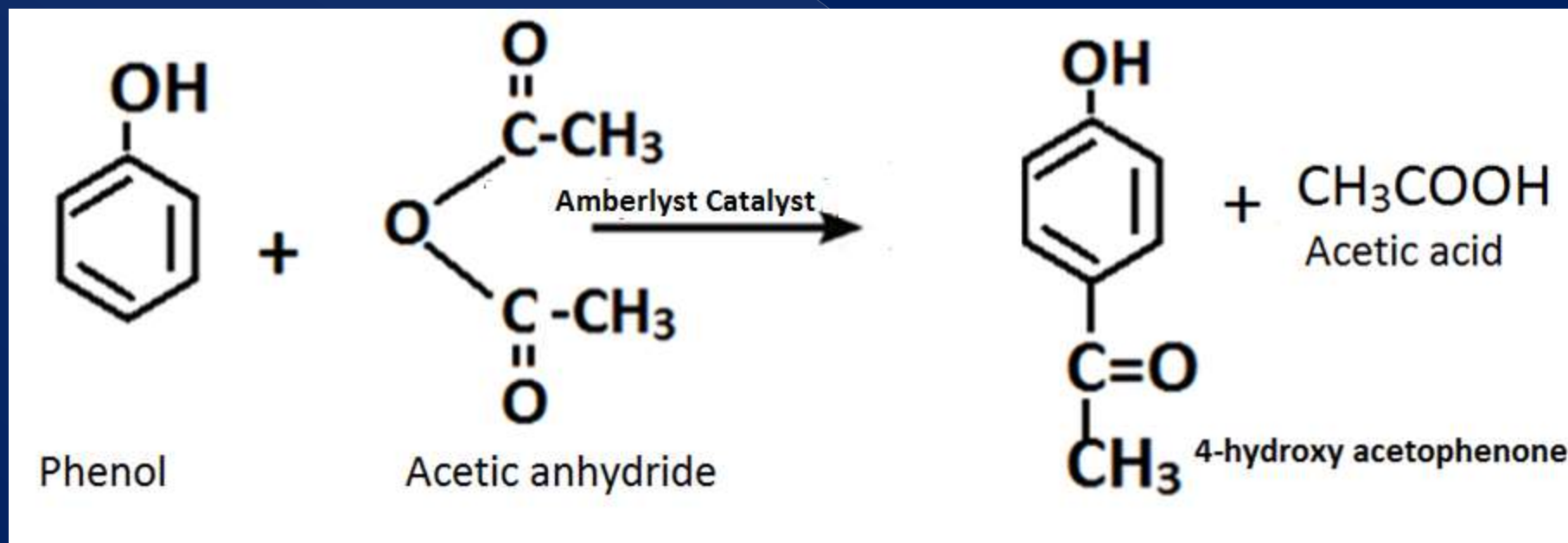
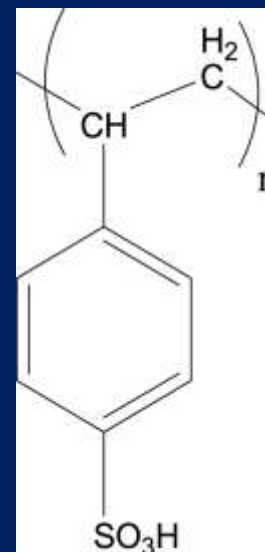
Paracetamol can be synthesized from phenol in three steps.

- Step I - involved electrophilic aromatic substitution on phenol with nitric acid to form 4-nitrophenol or p-nitrophenol.
- Step II - hydrogenation in presence of Fe catalyst in produced p-aminophenol.
- Step III - Finally, Paracetamol was formed by acylation of the aminophenol.

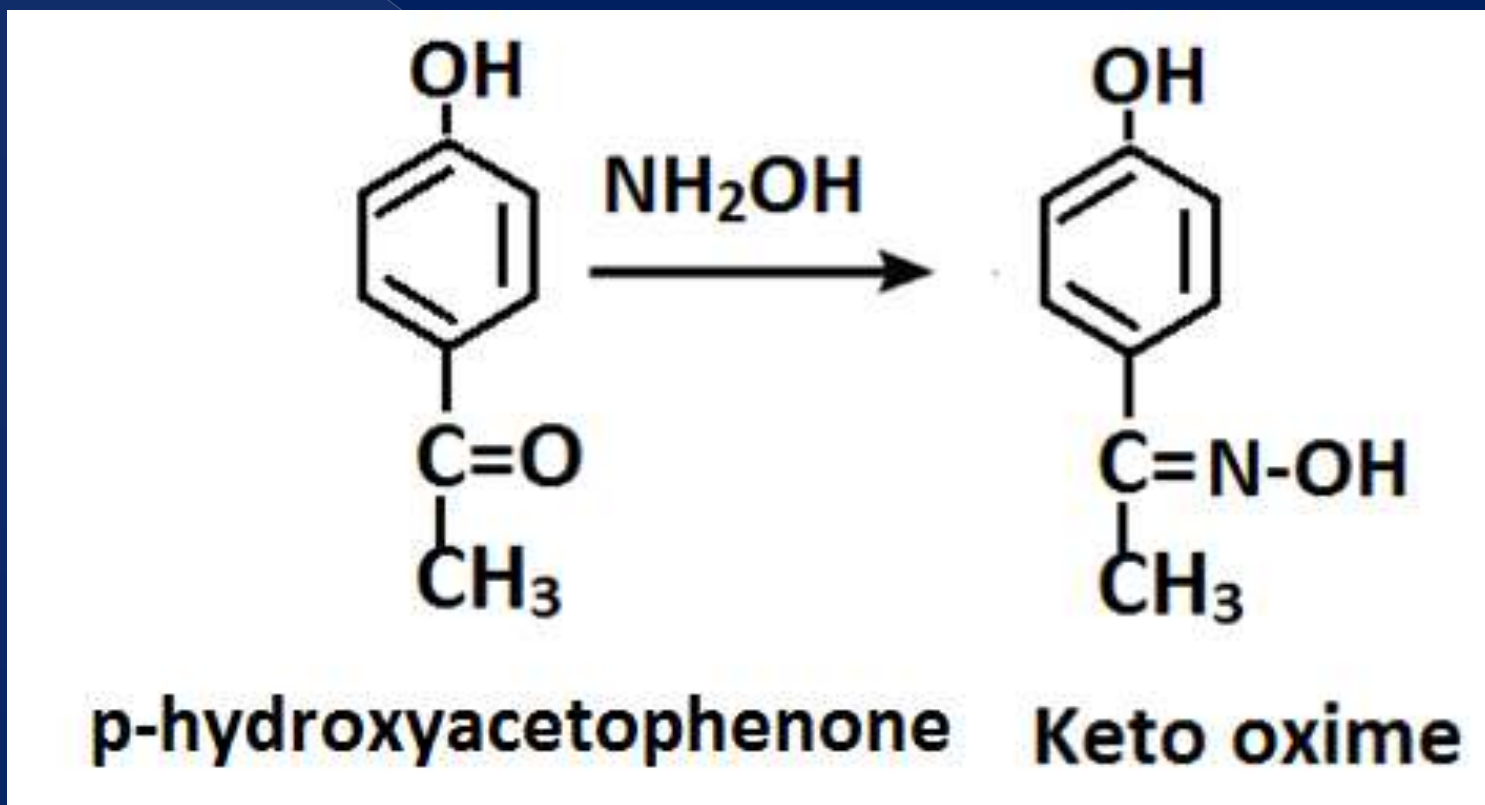


Green Approach for synthesis of Paracetamol

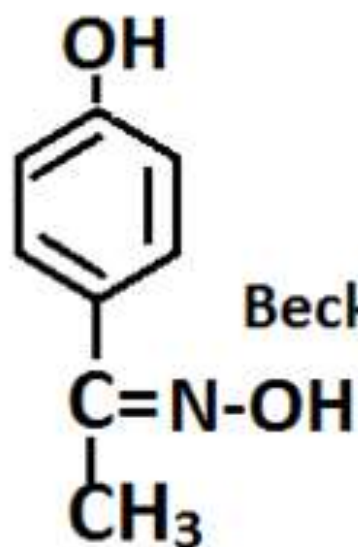
Step-1: Acylation of Phenol to form p-hydroxy acetophenone in presence of strong acid HF and green catalyst Amberlyst



Step-2: Reacton with hydroxylamine to give corresponding Ketoxime



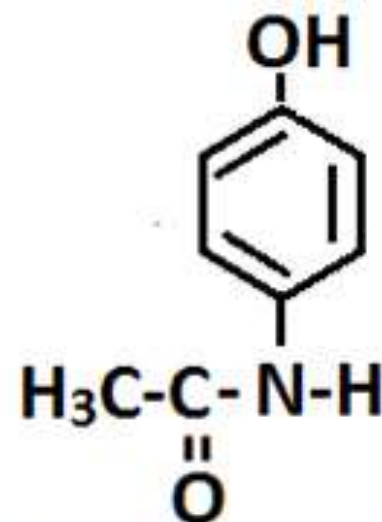
Step-3: Oxime in strong acid undergo Beckman's Rearrangement to give substituted amide (Paracetamol)



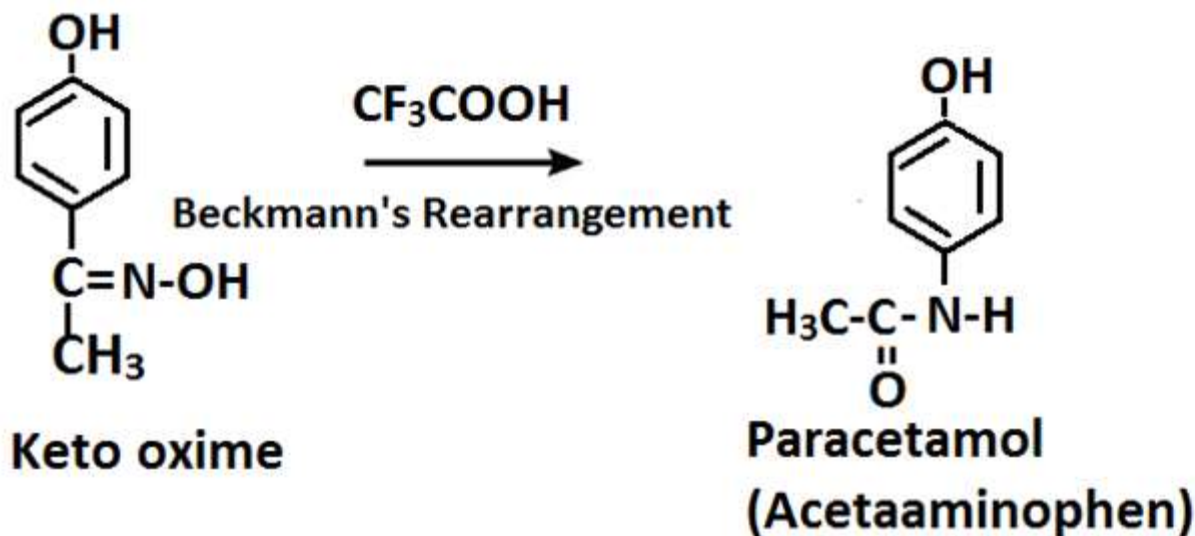
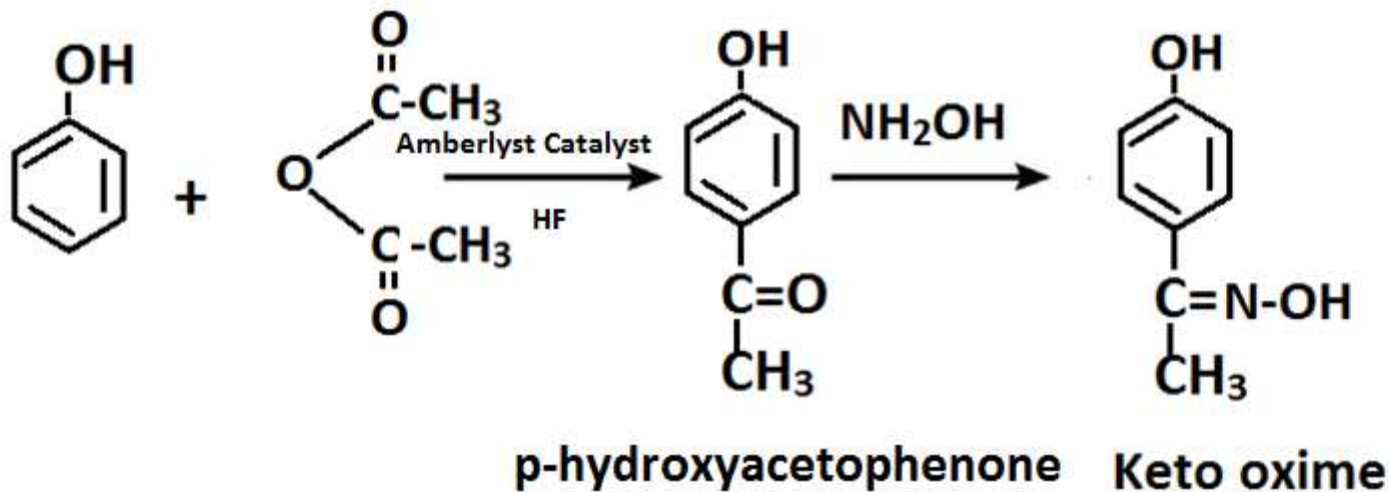
Keto oxime



Beckmann's Rearrangement



**Paracetamol
(Acetaminophen)**



Environmental Impact of Green Chemistry on Society

Environment

1. Green chemicals degrade to non-toxic products
2. Plants and animals suffer less harm from toxic chemicals in the environment.
3. Lower potential for global warming, ozone depletion, and smog formation Less chemical disruption of ecosystems
4. Less use of landfills, especially hazardous waste landfills

Human Health

1. Cleaner air: Less release of hazardous chemicals to
2. Cleaner water: less release of hazardous chemical wastes to water
3. Increased safety for workers in the chemical industry; less use of toxic materials; less personal protective equipment required; less potential for accidents (e.g., fires or explosions)
4. Safer consumer products of all types:
5. Safer food: elimination of persistent toxic chemicals
6. Less exposure to toxic chemicals.

Economy and business:

1. Higher yields for chemical reactions, consuming smaller amounts of feedstock to obtain the same amount of product
2. Fewer synthetic steps
3. faster manufacturing of products,
4. increasing plant capacity, and saving energy and water
5. Reduced waste, hazardous waste disposal
6. Better performance so that less product is needed to achieve the same function
7. Reduced use of petroleum products
8. Reduced manufacturing plant size
9. Increased consumer sales



Thank You