GREEN TECHNOLOGY

PREVENTING POLLUTION
SUSTAINING THE EARTH

MEANING OF GREEN TECHNOLOGY

- **Sustainable Development is defined as "Development to meet the needs of present without compromising with the abilities of the future generations to meet their own needs and a system of stable economic development that should improve the total quality of life on earth now and in future too, while maintaining the social and ecological integrity of the earth, upon which all life depends**

Green technology acts to reduce contaminants and harmful processes through directly counteracting them, or through altering the conditions that create them.

It is the technology which is environmentally friendly, developed and used in such a way so that it doesn't disturb our environment and conserves natural resources.

Expected Goals of Green Technology

- **Sustainability:** to meet the present needs of the society without compromising with needs of future generations
- **Cradle to cradle design:** Technology to have no toxic effects. By-products to be used in other processes
- **Source reduction:** Emphasis on minimization of waste generated
- **Innovation:** Technologies which are environmental friendly and benign
- **Viability:** Technology should be economical to enhance its implementation

- **All green environmental technologies for sustainable development have to be cost-effective, economically viable, ecologically sustainable and socially acceptable.**
- **Some common green technologies developed in past decades:**

❖ **Use of un-leaded petrol and sulphur free clean coal technology**

❖ **Genetically modified crops**

❖ **More efficient pollution control equipments and devices.**

❖ **Recycling of community waste**

Green technology promises mankind to

- Deliver clean, non polluting and renewable sources of energy.
- Work towards food security by developing safe and nutritive crops, which have short harvest cycles, are pest and disease resistant, without harming the natural ecosystems.
- Optimise the use of natural resources and improve the efficiency of resource use, specially of water and electricity.
- Manage all the wastes generated by their reduction, re-use and re-cycling and through cleaner production technologies which focus on zero-waste production.

Types of Green Technology

*Green Chemistry
*Green Nanotechnology
*Green Building
*Green Information Technology
*Green Energy


Green
Chemistry

Green chemistry, also called sustainable chemistry, is a philosophy of chemical research and engineering that encourages the design of products and processes that minimize the use and generation of hazardous substances.

Herbs used in cosmetic products.


is?
Nanotechnology
Green

GREEN Nano-Technology producing nanomaterials and products without harming the environment or human health.it is used to make nanomaterials and nano-products without toxic ingredients, at low temperatures using less energy and renewable inputs. manufacturing processes for non-nano materials and products more environmentally friendly .

Light-emitting diodes (LEDs)


Green Building

It refers to a structure and using process that is environmentally responsible and eco friendly too. It involves building's life-cycle: from design, construction, maintenance, renovation, and demolition.

green IT

The green IT or green computing, aims to reduce the carbon footprint generated by the Information Systems business. Green information technology and communication designs or uses products which can reduce the negative effects of human activity on the environment.

L.C.D. monitors by Samsung and Dell


Green Energy

Green energy is the energy produced by natural sources i.e. sunlight, wind, rain, tides, plants, algae and geothermal heat which put very small impact on the environment than fossil fuels i.e. oil, gas, coal.

Types of green energy

- Solar Power
- Wind Power
- Hydropower
- Geothermal Energy
- Biofuels

Green Chemistry Is About...

Reducing

- **Waste**
- **Materials**
- **Hazard**
- **Risk**
- **Energy**
- **Cost**

GREEN CHEMISTRY MEANS…

Works on the principle “ Prevention is better than cure”

Preventing pollution before it happens rather than cleaning up the mess later.

Saving companies money by using less energy and fewer/safer chemicals, thus reducing the costs of pollution control and waste disposal.

Father of Green Chemistry

The concept of green chemistry was formally established at the ENVIRONMENTAL PROTECTION AGENCY 15 years ago in response to the Pollution Prevention Act of 1990.

Paul T. Anastas for the first time in 1991 coined the term Green Chemistry. Though it is said that the concept was originated by Trevor Kletz in his 1978 paper where he proposed that chemists should seek alternative processes to those involving more dangerous substances and conditions.

GREEN CHEMISTRY

DEFINITION

Green chemistry or environmentally benign chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.

GREEN CHEMISTRY IS ABOUT

- **Waste Minimisation at Source**
- **Use of Catalysts in place of Reagents**
- **Using Non-Toxic Reagents**
- **Use of Renewable Resources**
- **Improved Atom Efficiency**
- **Use of Solvent Free or Recyclable Environmentally Benign Solvent systems**

12 Principles of Green Chemistry

1. Prevention. It is better to prevent waste than to treat or clean up waste after it is formed.

2. Atom Economy. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Synthesis. Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals. Chemical products should be designed to preserve

efficacy of the function while reducing toxicity.

5. Safer Solvents and Auxiliaries. The use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.

6. Design for Energy Efficiency. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

12 Principles of Green Chemistry

7. Use of Renewable Feedstocks. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

8. Reduce Derivatives. Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.

9. Catalysis. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for Degradation. Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

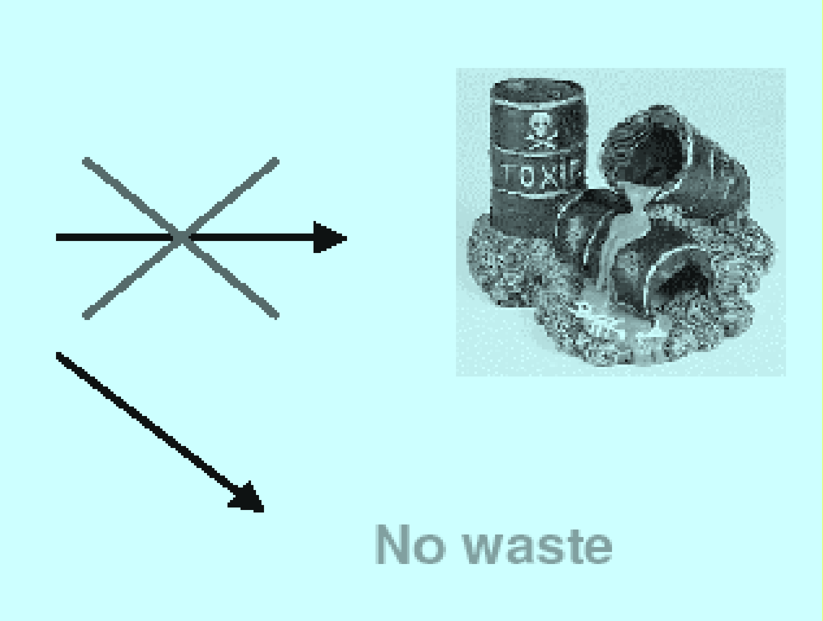
11. Real-time Analysis for Pollution Prevention. Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention. Substance and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

1. Prevention of waste

It is better to prevent waste than to treat or clean up waste after it is formed.

Chemical synthesis should be designed in such a way that the waste products are minimized



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2. Atom Economy

- Synthetic methods should be designed to maximize the incorporation of all the starting materials and reagents in the final products.
- The objective is to develop a methodology in which most of the reactant atoms become incorporated into the final desired product thus reducing the waste or the by-products.

Percentage yield of a reaction:

Percentage yield:

% yield = (actual yield/theoretical yield) x 100

What is missing?

What co-products are made?

How much waste is generated?

Is the waste benign waste?

Are the co-products benign and/or useable?

How much energy is required?

Are purification steps needed?

What solvents are used? (are they benign and/or reusable?

Is the "catalyst" truly a catalyst? (stoichiometric vs. catalytic?)

ATOM ECONOMY

Barry Trost, Stanford University

“Because an Atom is a Terrible Thing to Waste”

A Measure of the Efficiency of a Reaction

How many of the atoms of the reactant are incorporated into the final product and how many are wasted?

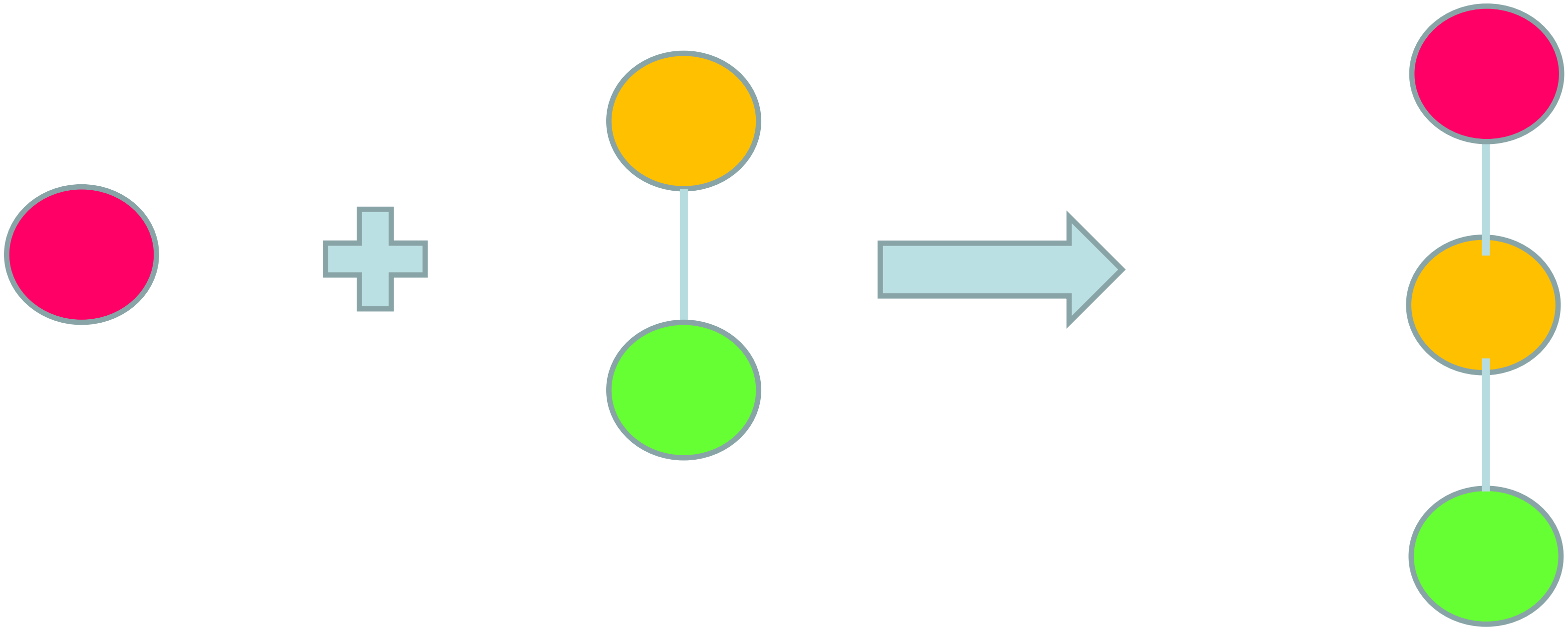
Atom Economy:

% Atom Economy

= (Mass of atoms in desired products/Mass of atoms of all reactants) X 100

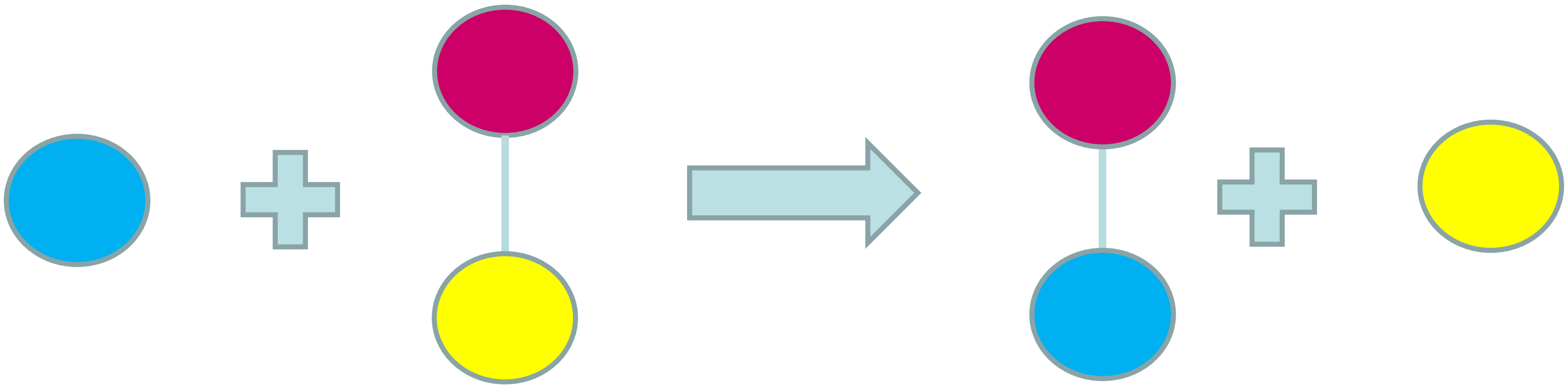
Trost, Barry M., The Atom Economy-A Search for Synthetic Efficiency. *Science* **1991**, *254*, 1471-1477.

High atom economy



All reactant atoms included in the desired product.

Low atom economy



Some reactant atoms not included in the desired product.

Step-by-step: How to calculate atom economy

Step 1. Write out the balanced equation

Step 2. Calculate the FW of each of the reactants (remember to account for stoichiometric coefficients)

Step 3. Calculate the FW of the product (remember to account for stoichiometric coefficients)

Step 4. Apply the formula

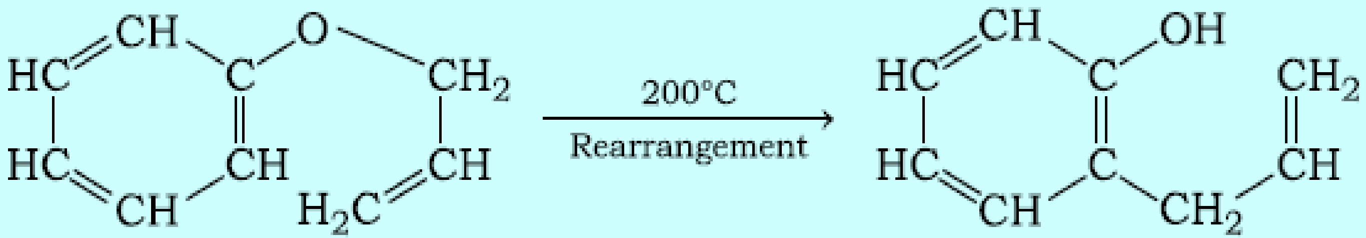
$$\%\ \text{atom economy} = \frac{\text{FW of all atoms utilized}}{\text{Total FW of all reactants}} \times 100$$

ATOM ECONOMY

Let us consider some common reactions and find which has more percentage of atom economy.

Rearrangement Reactions

Allyl phenyl ether gives O–Allyl phenol by heating at 200°C.



Allyl phenyl ether
(M.W = 134.175 g)

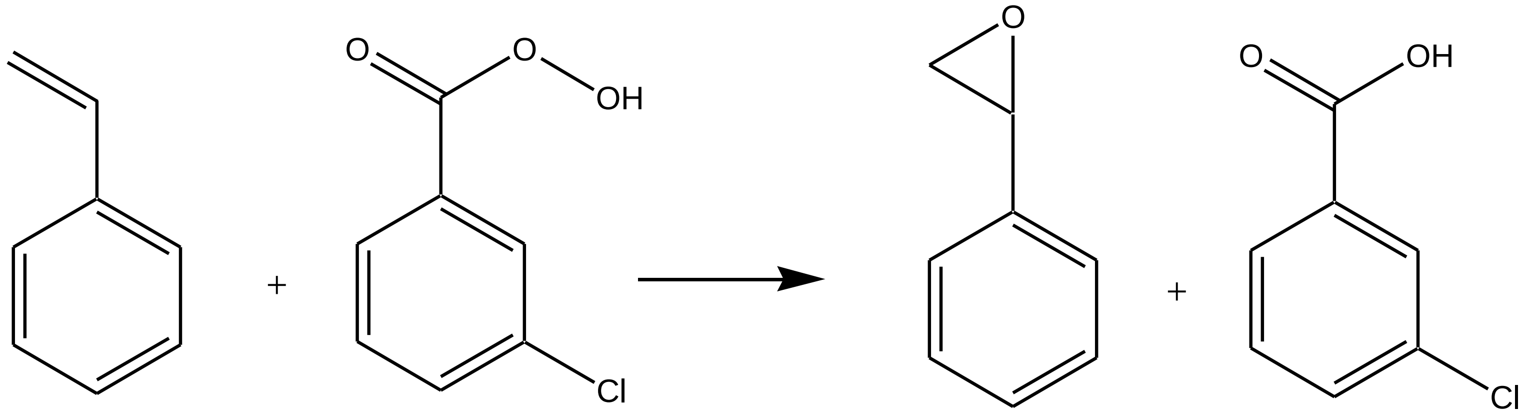
O–Allyl phenol
(M.W. = 134.175 g)
(desired product)

$$\% \text{ Atom economy} = \frac{134.175}{134.175} \times 100$$
$$= 100.$$

This is a 100% atom economical reaction.

Atom Economy

Balanced chemical reaction of the epoxidation of styrene

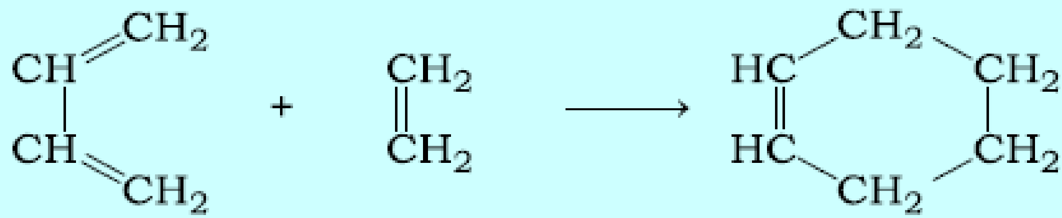


Assume 100% yield.
100% of the desired epoxide product is recovered.
100% formation of the co-product: m-chlorobenzoic acid
A.E. of this reaction is 23%.
77% of the products are waste.

Addition Reactions

(a) Cycloaddition reactions of Butadiene to Cyclohexene

$$\% \text{ Atom economy} = \frac{82}{82} \times 100$$
$$= 100$$



Butadiene [M.W. = 54 g]   Ethene [M.W. =28 g]   Cyclohexene [M.W. = 82 g] (desired product)

(b) Catalytic addition reaction

$$H_3C-CH=CH_2 + H_2 \xrightarrow{Ni} CH_3-CH_2-CH_3$$

Propene (M.W. = 42 g)   (M.W. = 2 g)   Propane [M.W. = 44 g] (desired product)

$$\% \text{ Atom economy} = \frac{44}{44} \times 100 = 100$$

Since Ni is used as a catalyst, it can be recovered fully after the reaction. Thus both type of addition reactions give an atom economy of 100%.

3. Less Hazardous Chemical Synthesis

Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

$$RNH_2 + COCl_2 \longrightarrow RNCO + 2HCl \xrightarrow[R'OH]{} RNHCOOR'$$

Amine Phosgene Isocyanate Urethane

$$RNH_2 + CO_2 \longrightarrow RNCO + H_2O \xrightarrow[R'OH]{} RNHCOOR'$$

4. Designing Safer Chemicals

Chemical products should be designed to preserve efficacy of the function while reducing toxicity.

eg., Nimulid (Nimesulide) is a banned drug in USA, Canada, Australia etc due to its severe side effects of liver failure

Thalidomide, a drug used for lessoning the effects of vomiting during pregnancy by expecting mothers resulted in birth defects

Designing Safer Chemicals

Case Study: Antifoulants (DCOI)

Antifouling agents: Used on boat hulls to reduce the build up of marine organisms . Tributyl Tin compounds are persistent and result in bioaccumulation. DCOI developed by Rohm and Hass is less persistent and products of metabolism are also non-toxic.

5. Safer Solvents and Auxilliaries

The use of auxiliary substances (solvents, separation agents, etc.) should be avoided.

- Solvent Substitution: Carbon tetrachloride, chloroform, perchloroethylene etc. used in Industries are very harmful and also explosive. Safer solvents like Water or liquid Carbon dioxide to be substituted
- Efforts to reduce the volume of solvent used. Eg. Claisen rearrangement: Allyl phenyl ether to O-Allyl phenol is done in solid phase without solvent.
- Solvent use can be reduced by using microwave irradiation
- Auxilliary supports like chromatographic supports etc. for purification be avoided

CHEMICALS FOR DRY CLEANING

- Perchloroethylene ("perc") is the solvent most widely used in dry cleaning clothing.
- Perc is suspected of causing cancer and its disposal can contaminate ground water.
- Liquid CO_2 can be used as a safer solvent if a wetting agent is used with it to dissolve grease.

6. Design for Energy Efficiency

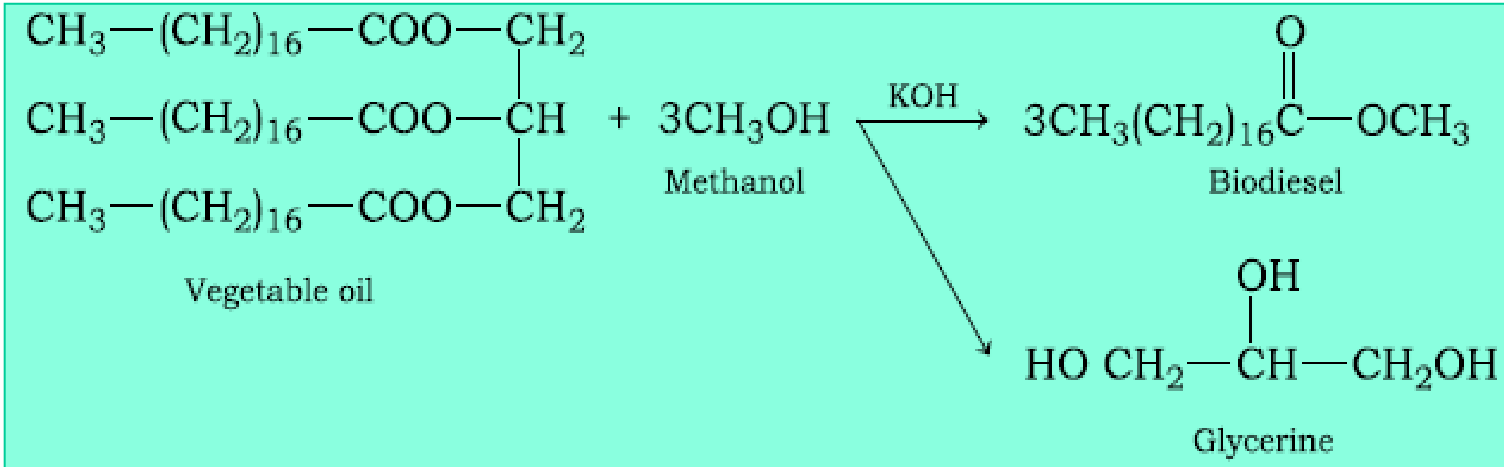
- Energy requirements should be recognized for their environmental and economic impacts and should be minimized.
- Synthetic methods should be conducted at ambient temperature and pressure.
- Process to be designed such that there is no need for separation or purification.
- Energy to a reaction can be supplied by photochemical means, microwave etc.

7. Use of Renewable Feedstocks

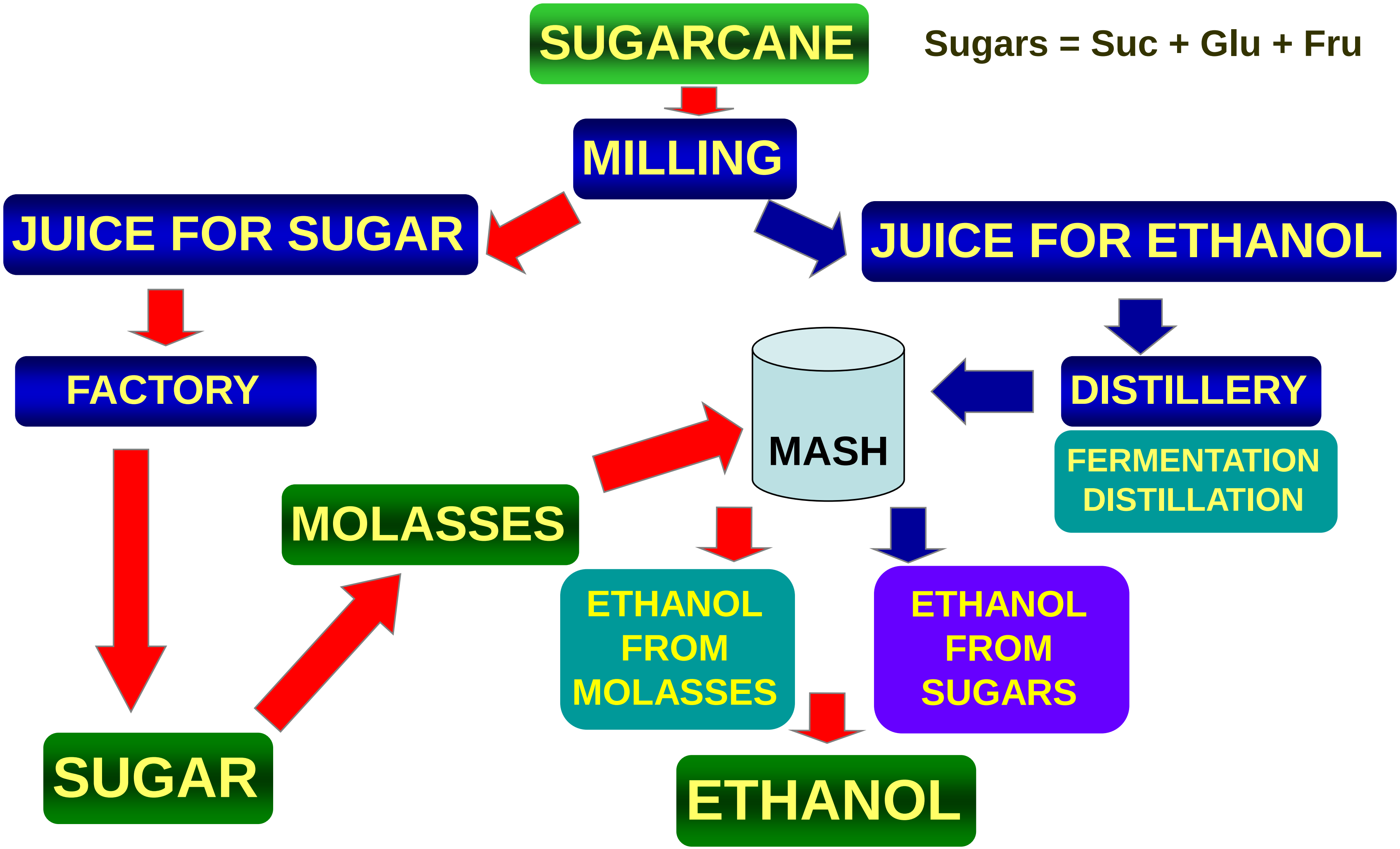
A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

Production of Bio-Diesel

Raw materials and feedstocks that are renewable should be preferred over that of depleting ones. Biodiesel which is Methyl or Ethyl ester of fatty acid is made from virgin or used vegetable oils (both edible and non-edible) and animal fats. It can be either used in its pure form as a fuel or it can be blended at any level with petroleum diesel to create a biodiesel blend. It is also considered as a clean fuel because it has no sulfur, no aromatics and has 10% built in oxygen, which helps it to burn completely.



Ethanol (Power Alcohol) from Molasses and Juice



Power Alcohol from Molasses and Juice

Production of Power Alcohol (Bio-fuel):

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{invertase}]{} 2C_6H_{12}O_6$$

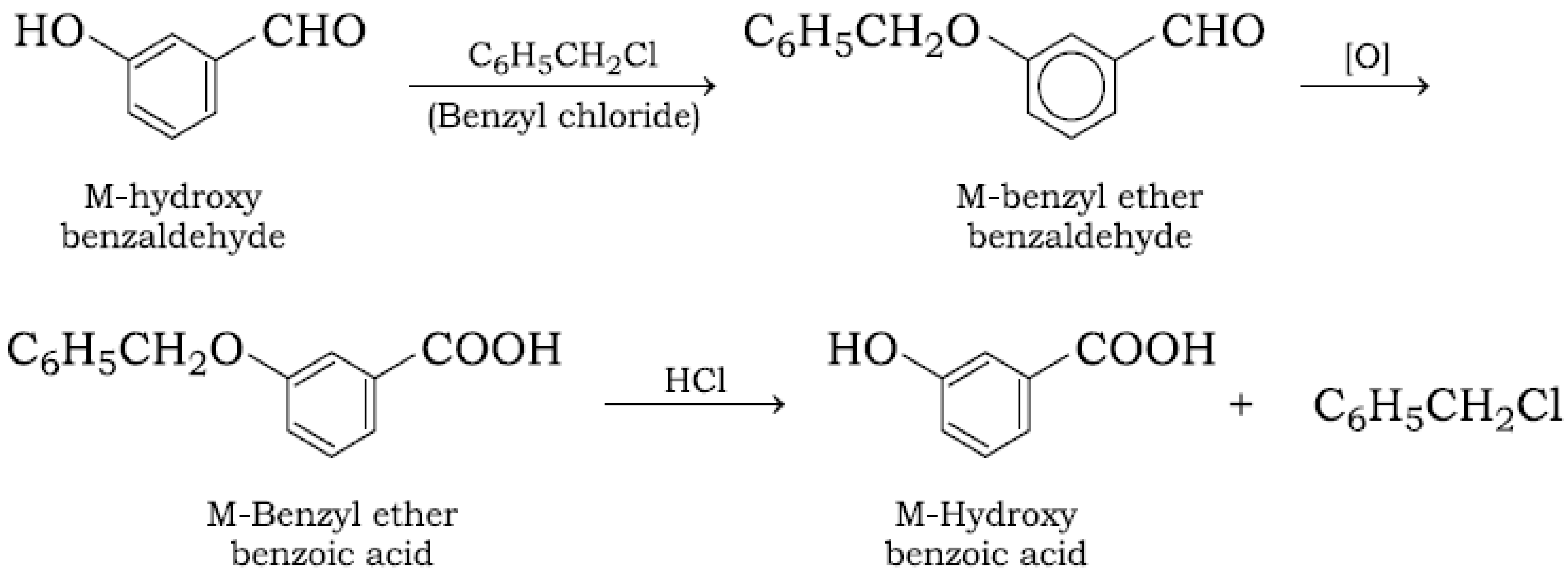
$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow[\text{zymase}]{} \underset{\text{Ethanol (Power Alcohol)}}{2C_2H_5OH} + 2CO_2 \quad \Delta H = -31.2 \text{ kcal}$$

Polymers from Renewable Resources: Poly(lactic acid)

http://www.natureworksllc.com/corporate/nw_pack_home.asp

8. Avoid Chemical Derivatives

Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.



The waste generated after the deprotection should be handled properly. This reaction is less atom economical since a lot of waste is generated.

9. Use of Catalysts

- Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
- Catalytic reactions are highly specific and catalysts are needed in very small amounts
- Catalytic reactions are also energy efficient

Few advantages of catalytic reactions are as follows:

1. Reaction is feasible with a catalyst which is otherwise not possible under ordinary conditions.

$$\underset{\text{Acetylene}}{CH{\equiv}CH} + H_2O \xrightarrow[H_2SO_4]{HgSO_4} \underset{\text{Acetaldehyde}}{CH_3CHO}$$

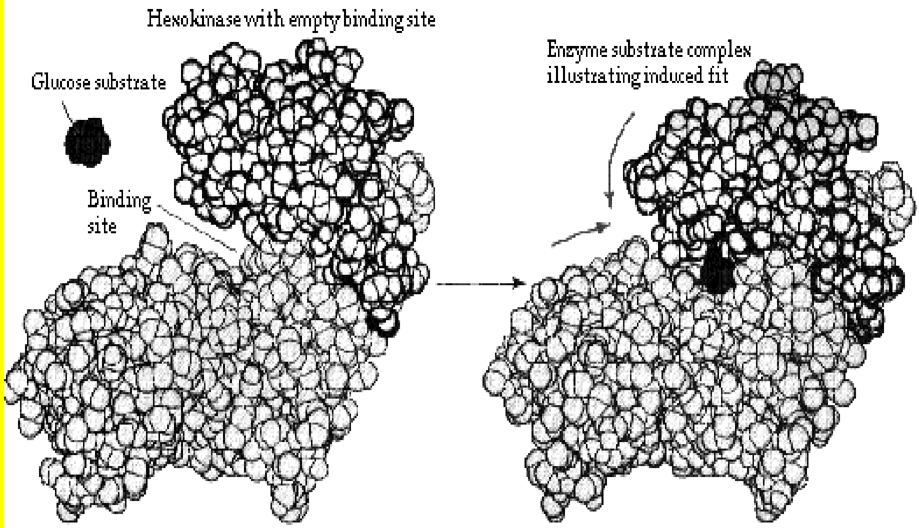
2. *Selectivity is increased*

   Hydrogenation of propynes to propenes

$$\underset{\text{Propyne}}{CH_3C{\equiv}CH} + H_2 \xrightarrow{\text{Pd-BaSO}_4} \underset{\text{Propene}}{H_3C{-}CH{=}CH_2}$$

Biocatalysis

- Enzymes or whole-cell microorganisms
- Benefits
  - Fast rxns due to correct orientations
  - Orientation of site gives high stereospecificity
  - Substrate specificity
  - Water soluble
  - Naturally occurring
  - Moderate conditions
  - Possibility for tandem rxns (one-pot)



10. Design for Degradation

Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

It is now possible to place functional groups and other features in a molecule which will facilitate degradation. Eg., carbonyl group, ester group etc.

Persistent Chemicals

- Early examples:
- Sulfonated detergents
  - Alkylbenzene sulfonates – 1950’s & 60’s
  - Foam in sewage plants, rivers and streams
  - Persistence was due to long alkyl chain
  - Introduction of alkene group into the chain increased degradation
- Chlorofluorocarbons (CFCs)
  - Do not break down, persist in atmosphere and contribute to destruction of ozone layer
- DDT
  - Bioaccumulate and cause thinning of egg shells

Degradation of Polymers: Polylactic Acid

- Manufactured from renewable resources
  - Corn or wheat; agricultural waste in future
- Uses 20-50% fewer fossil fuels than conventional plastics
- PLA products can be recycled or composted

11. Strengthening of Analytical Techniques for Pollution Prevention

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

Real time analysis for a chemist is the process of "checking the progress of chemical reactions as it happens."

Knowing when your product is "done" can save a lot of waste, time and energy!

Placement of sensors to monitor generation of hazardous by-products, minimum usage of chemicals in a reaction and recycling of unused reagents

12. Inherently Safer Chemistry for Accident Prevention

Substance and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

Bhopal Gas Tragedy

- December 3, 1984 – poison gas leaked from a Union Carbide factory, killing thousands instantly and injuring many more (many of who died later of exposure). Up to 20,000 people have died as a result of exposure (3-8,000 instantly). More than 120,000 still suffer from ailments caused by exposure

What happened?

- Methyl isocyanate – used to make pesticides was being stored in large quantities on-site at the plant
- Methyl isocyanate is highly reactive, exothermic molecule
- Most safety systems either failed or were inoperative
- Water was released into the tank holding the methyl isocyanate
- The reaction occurred and the methyl isocyanate rapidly boiled producing large quantities of toxic gas.

Simple precaution of breathing through a wet towel could have saved many lives

TOOLS OF GREEN CHEMISTRY

The objectives of green chemistry is to reduce the toxicity in the environment. The areas where improvements could be made are termed as tools for Green Chemistry:

1. **Green starting materials**
2. **Green reagents**
3. **Green reactions**
4. **Green chemical products**
5. **Green methodologies**

1.Green Starting Materials

- The starting material is said to be green when it is non toxic, preferably renewable and does not degrade the quality of the environment.
- Adipic acid which is an important chemical used in the synthesis of nylon, plasticisers and lubricants is conventionally prepared from benzene which is carcinogenic.
- An environmentally benign synthesis of adipic acid is from D-glucose (a nontoxic and renewable source) and the solvent used is water instead of organic solvents.

- Consider the synthesis of adipic acid ($HOOC(CH_2)_4COOH$).

- Adipic acid is the essential feedstock for making synthetic fibres such as nylon.

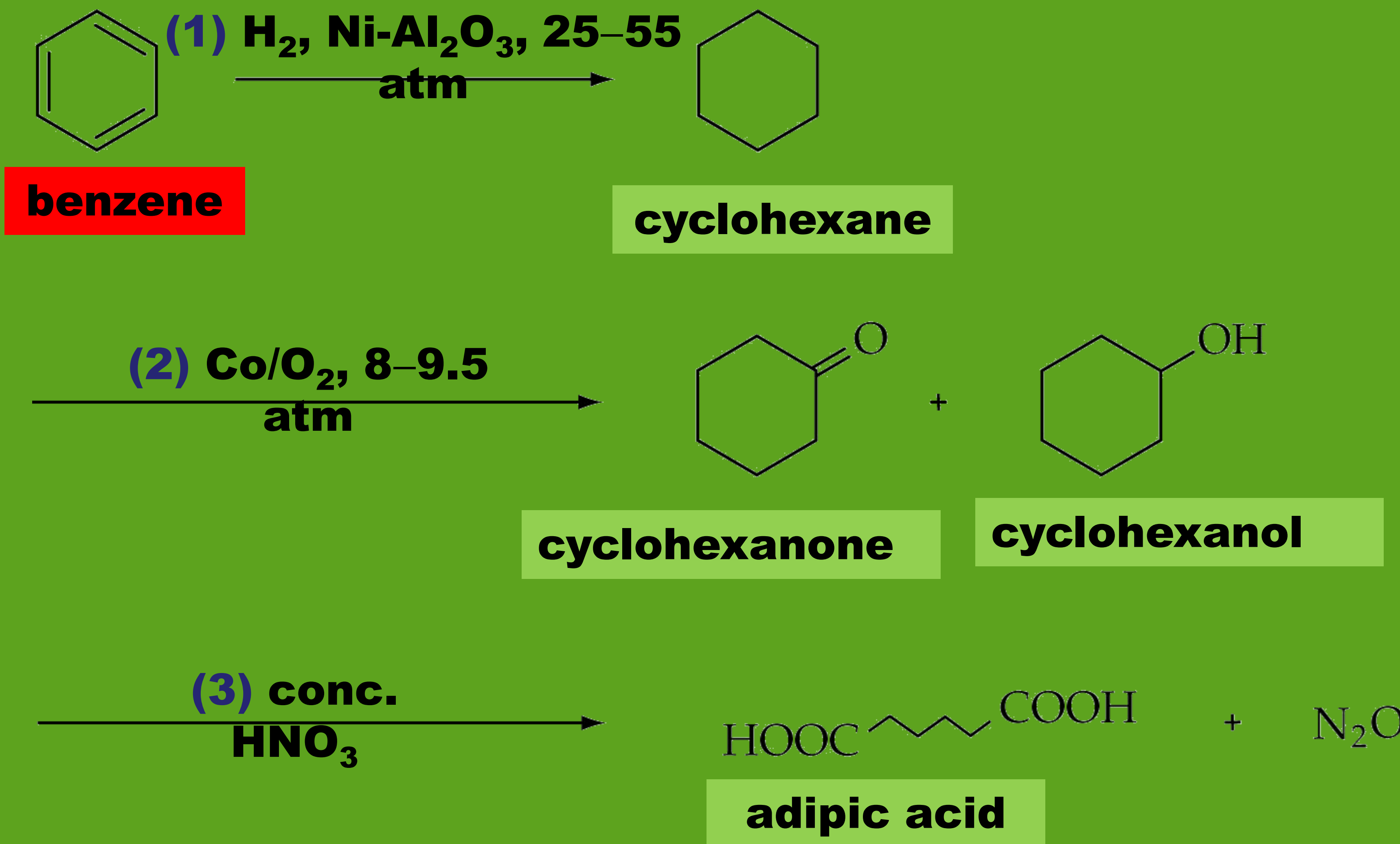
Traditional method

$$C_6H_6 \longrightarrow HOOC(CH_2)_4COOH$$

New method

$$C_6H_{12}O_6 \longrightarrow HOOC(CH_2)_4COOH$$

Traditional Method



Traditional Method

- The synthesis has the following risks and hazards:

- In step 1, the starting material for the synthesis is benzene, which is a known carcinogen.

Traditional Method

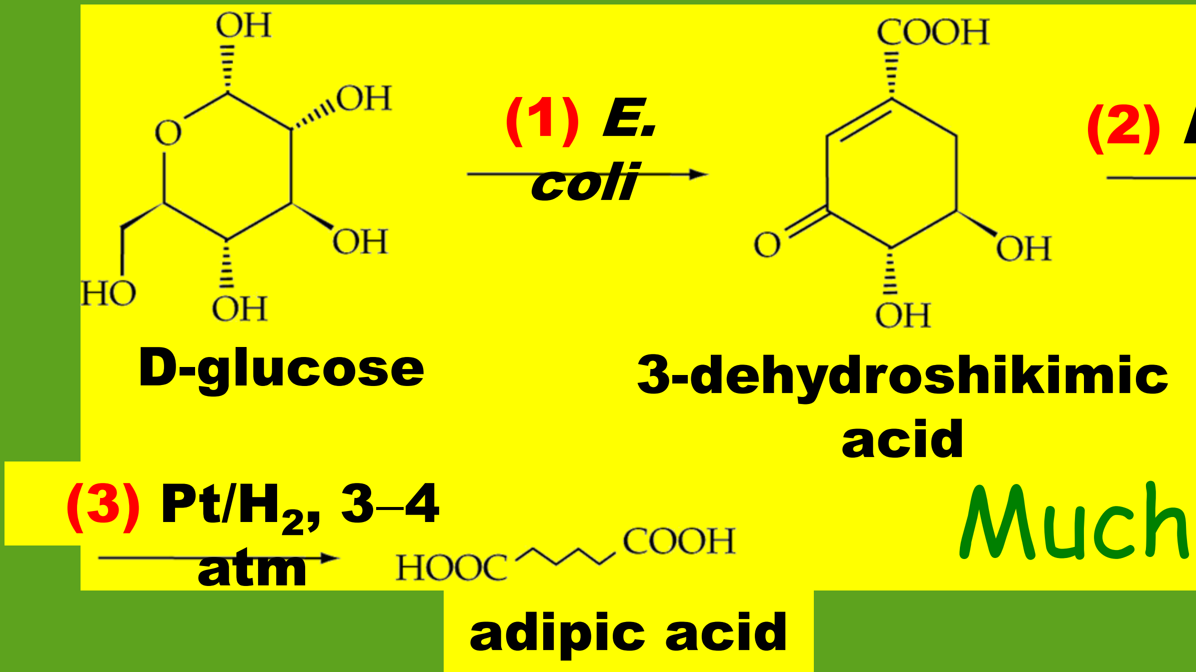
- In step 2, the oxidation of cyclohexane with air may lead to an uncontrolled reaction. It has the risk of explosion.

- Not all of the cobalt catalysts can be recovered. This may lead to the disposal of a heavy metal to the environment.

Traditional Method

- In step 3, dinitrogen oxide or nitrous oxide (N_2O) gas is produced as a by-product. It is a greenhouse gas with an effect which is 200 times the effect of carbon dioxide.

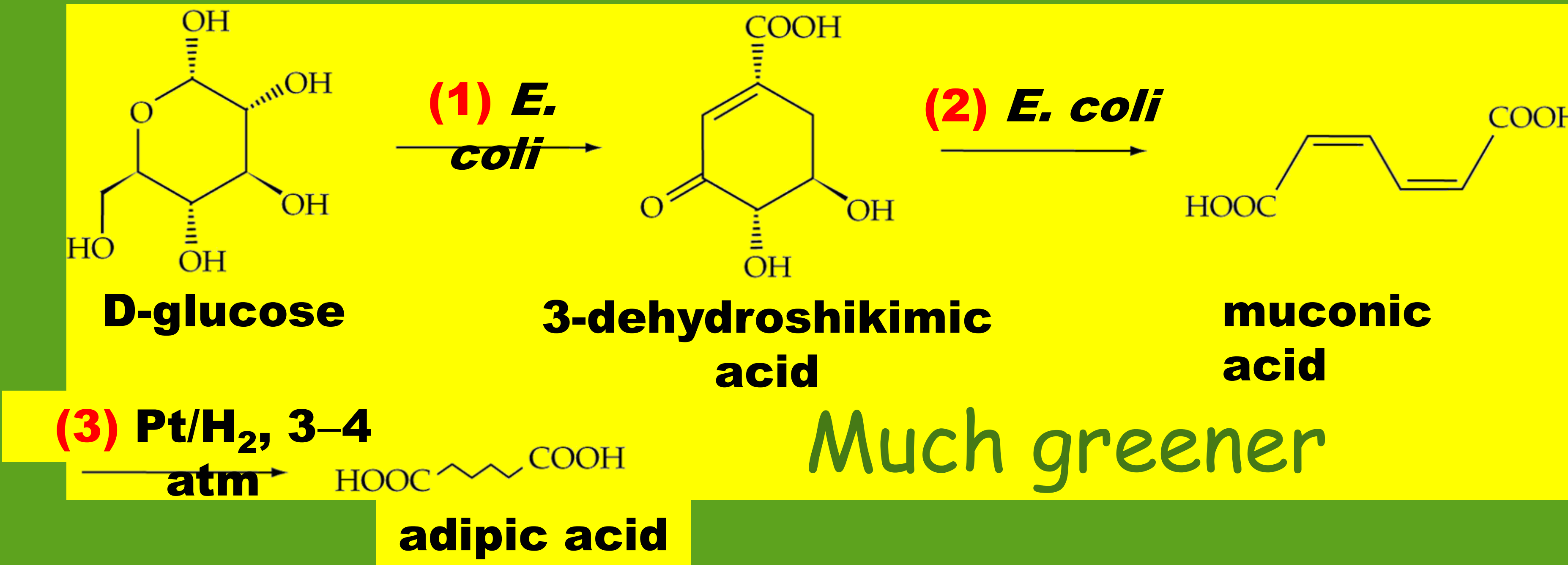
biosynthetic pathway



Much greener

1. The starting material, glucose, is harmless.

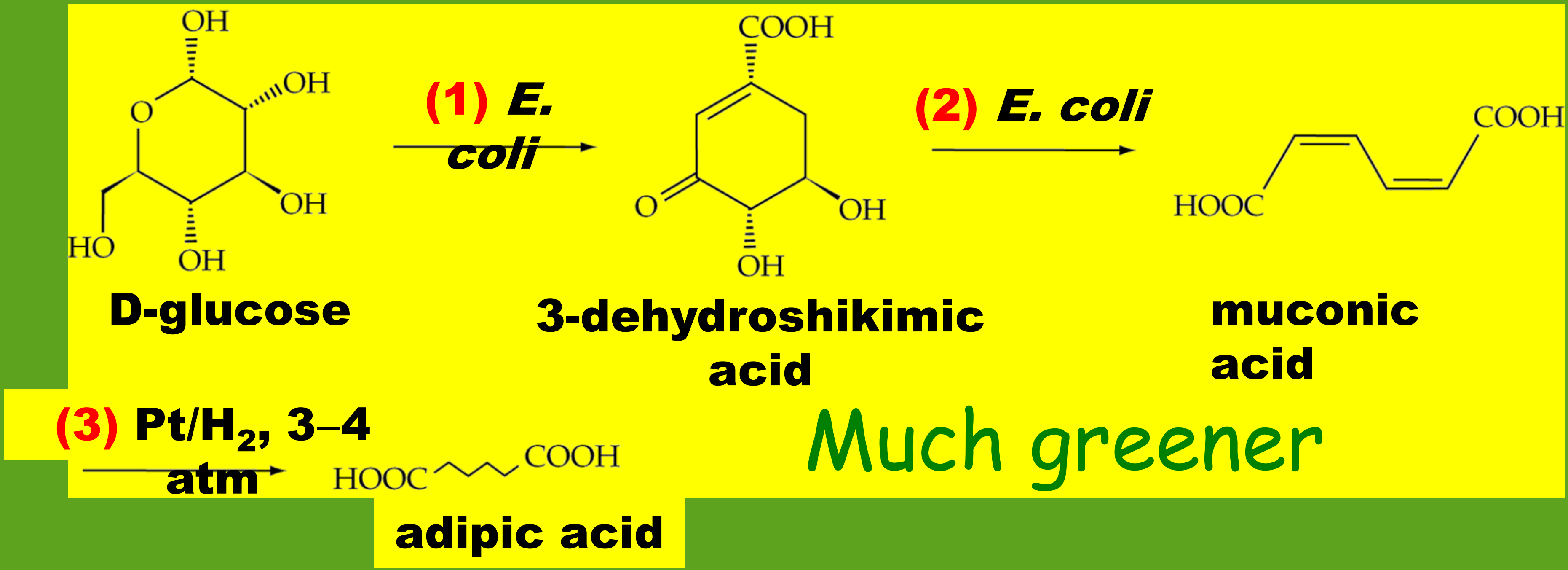
biosynthetic pathway



Much greener

2. E. coli is used to catalyse two steps of the reaction. This reduces the use of certain chemical reagents with significant toxicity.

biosynthetic pathway



Much greener

3. there are no by-products generated during the synthesis.

2. Green reagents

- **The reagents are said to be green when they are easily available (preferably from natural renewable resources), non toxic, give maximum atom economy and the waste products formed (if any) are non toxic and biodegradable.**

Green reagents-examples

$RNH_2 + COCl_2 \longrightarrow RNCO + 2HCl \longrightarrow RNHCOOR'$

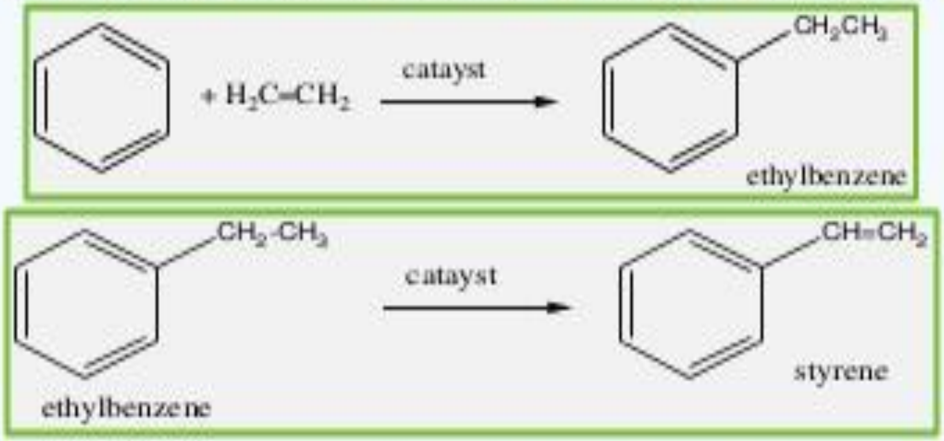
Amine Phosgene Isocyanate Urethane

$RNH_2 + CO_2 \longrightarrow RNCO + H_2O \longrightarrow RNHCOOR'$

2. Synthesis of Adipic acid with D-Glucose

Production of styrene (benzene ring with $CH=CH_2$ tail)

- *Traditional route*: Two-step method starting with benzene, which is carcinogenic) and ethylene to form ethylbenzene, followed by dehydrogenation to obtain styrene



- *Greener route*: To avoid benzene, start with xylene (cheapest source of aromatics and environmentally safer than benzene).

- **Another option**, still under development, is to start with toluene (benzene ring with CH_3 tail).

3.Green Reactions

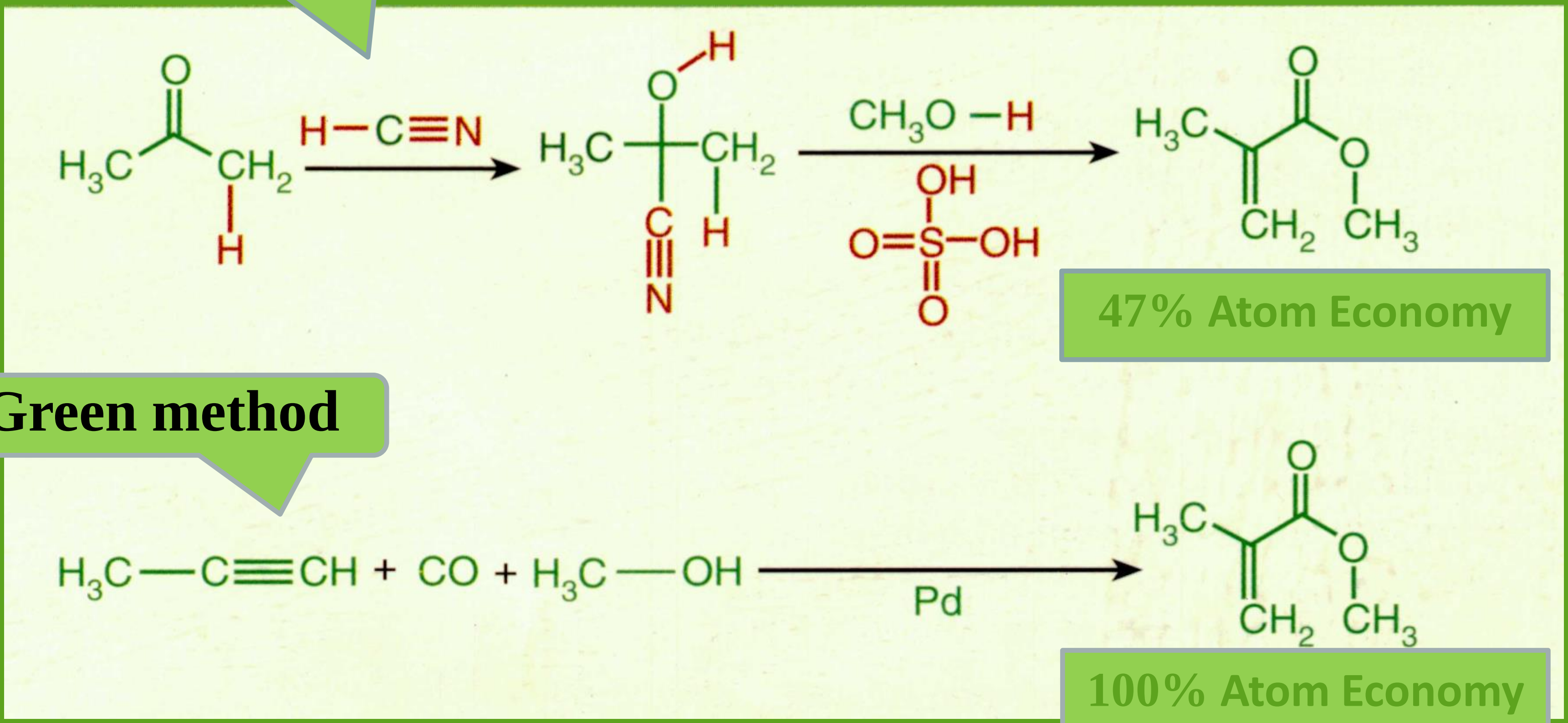
- **Green reactions is based on the "Concept of Atom Economy". Few examples of green reactions are given below:**
- **Synthesis of Methyl Methacrylate (used for manufacture of polymers)**
- **Synthesis of ibuprofen***

- ***Won the Presidential Green Chemistry Challenge award in 1996**

Synthesis of Methyl Methacrylate

Traditional method

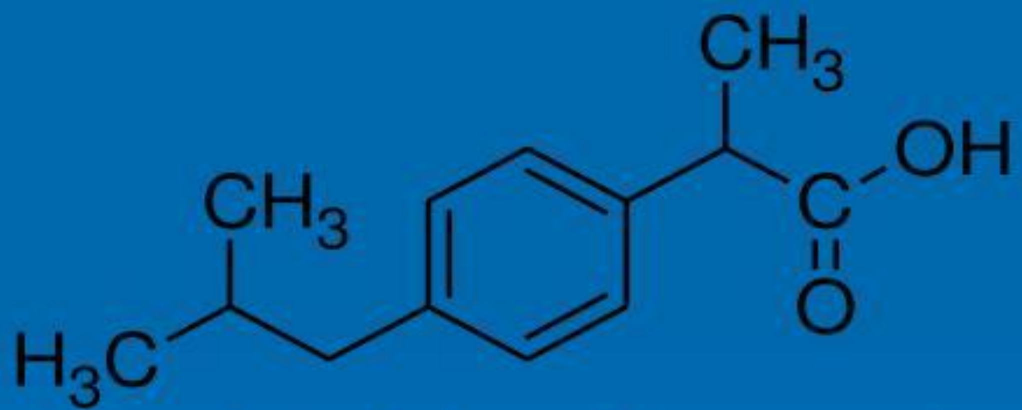
Green method



47% Atom Economy

100% Atom Economy

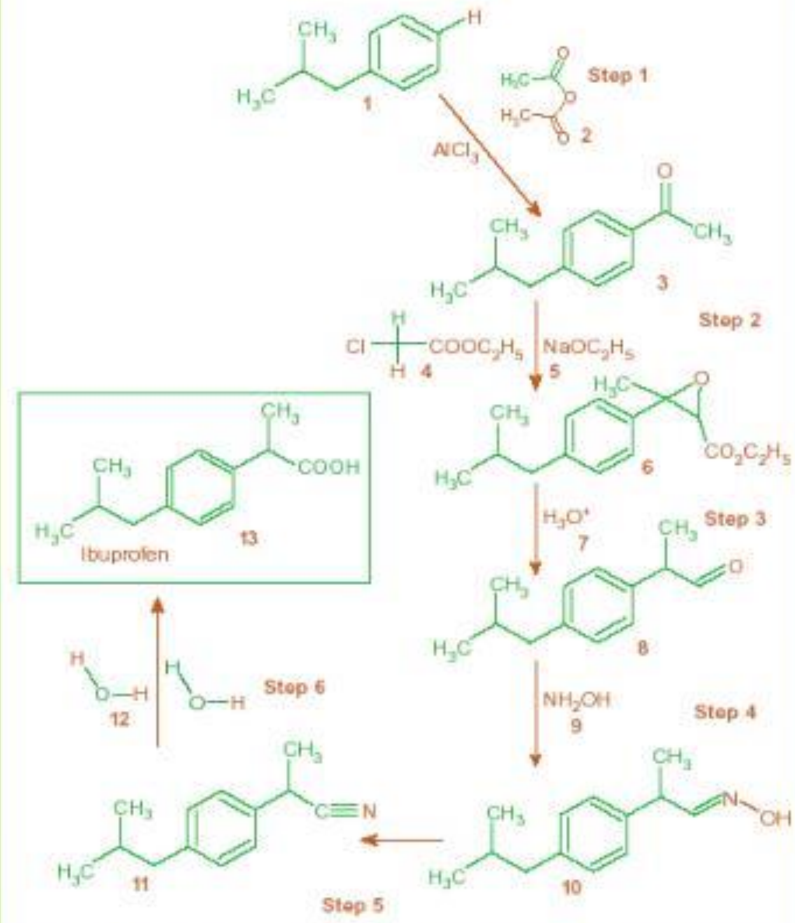
STRUCTURE OF IBUPROFEN



2-(4-isobutylphenyl)propanoic acid

BROWN SYNTHESIS OF IBUPROFEN

Atom Economy: 40%

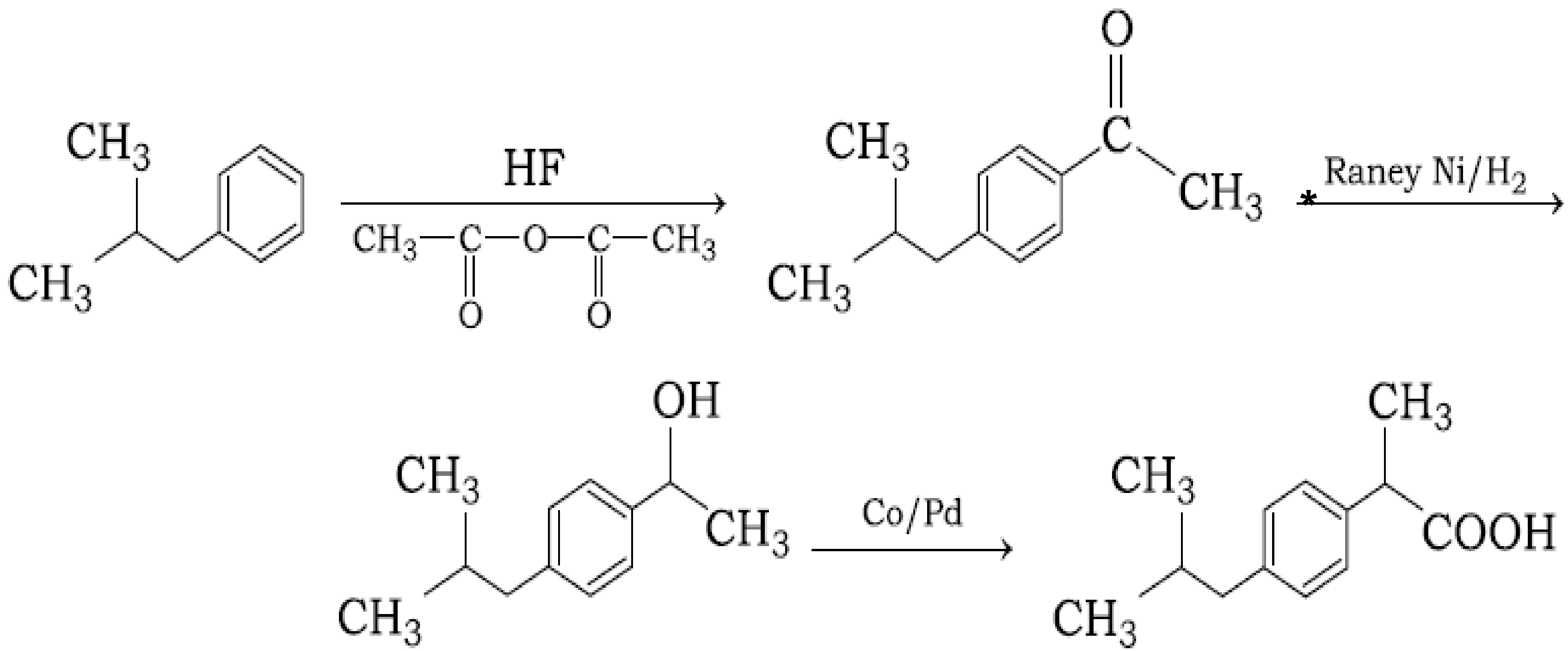


SCHEME 1. The Boots Company Synthesis of Ibuprofen—The Brown Synthesis

Green Synthesis
(Atom Economy= 77.4%)

Green Synthesis

Atom Economy by this process is 77.4%.



Ibuprofen

* Raney Ni is Spongy Ni

*Won the Presidential Green Chemistry Challenge award in 1996

4. Green Methodologies

- New methodologies are designed as an alternative to the existing methods, so that toxic materials, reagents, catalysts, by products or intermediate are either limited or totally eliminated. Few methods for the environmentally benign synthesis are:
- Use of Biocatalysts
- Use of Aqueous Medium as Solvents

Use of Biocatalysts

- Enzymes are also known as biocatalysts. The use of biocatalysts have the following advantages.
  - The reactions are performed at ambient temperatures and pressures.
  - Most of the reactions are carried out in aqueous medium.
  - The conversions are normally single step conversions.
  - Conversion are stereospecific.

Use of Aqueous Medium as Solvents

The advantage of using water as a solvent instead of organic solvents is it is cheaply available, safe (non-inflammable), non-carcinogenic and simple in operation. It has the highest value of specific heat. The few reaction carried out in aqueous medium are:

- *Diels Alder reaction*: Heterocyclic compounds with Nitrogen or Oxygen containing dienophiles are synthesised using this reaction.

- ***Claisen Rearrangement*: The thermal rearrangement of allyl vinyl ether to give aldehyde in pure water.**
- ***Michael Reactions*: 2-Methyl-cyclopentane-1,3-dione when reacted with vinyl ketone in water gave a 5-6 fused ring system without using a basic catalyst (as in conventional method).**
- ***Aldol Condensation:* Vinyl ketones can be obtained by the reaction of 2-alkyl-1,3 diketones with aqueous formaldehyde using 6-10 M aqueous potassium carbonate as base.**

- **Some of the solid phase reactions** which are already carried out successfully are halogenation, hydrohalogenation (addition of HBr), Michael Addition, Dehydration of Alcohols to Alkenes, Aldol condensation, Grignard reactions, Claisen rearrangement.

5. Green Chemical Products

- The green products are those which serve the same function without themselves being toxic or breaking down into toxic substances.
- For examples many insecticides use organochlorines, organophosphates, or carbamates.

Green Chemical Products

- **Organochlorine compounds (like aldrin, dieldrin) are readily incorporated into the food chain, whereas organophosphates and carbamates although are less persistent in the environment (DDT), but they readily decompose in the environment and tend to be toxic to human beings and other non target organisms.**
- **A new class of insecticides (diacetyl hydrazine) developed by Rohm and Hass is non-toxic.**

Green Chemical Products

- **The conventional antifouling agent used on boats is Tributyltin (TBT) compounds.**
- **Antifouling agents are used on boat nulls to reduce the build up marine organisms, such as algae, plants, diatoms etc.**
- **TBT compounds are persistant in the environment and result in bioaccumulation in various microorganisms.**

Green Chemical Products

- **Rohm and Hass developed DCOI {4, 5 dichloro-2-n-octyl-4-iso thiazolin-3-one) as antifouling agent which is less persistent in marine environment as well as the product of metabolism are also non toxic.**

Zero Waste Technology

- Zero Waste is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use.
- Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them.
- Implementing Zero Waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health.

Why Zero Waste

- Landfills – No space, filled to maximum capacity
- No space or area for new landfills or dumping sites
- Landfills – Sources of GHG emissions
- Technology research and development
- Improves health and environment
- Reduce GHGs
- Improve aesthetic value
- Reduces nuisances
- Reduction in transportation
- Green jobs
- Green Economy
- Green industries
- New initiative
- Policy research
- Target based reduction of waste
- Incentives

Steps in Zero Waste

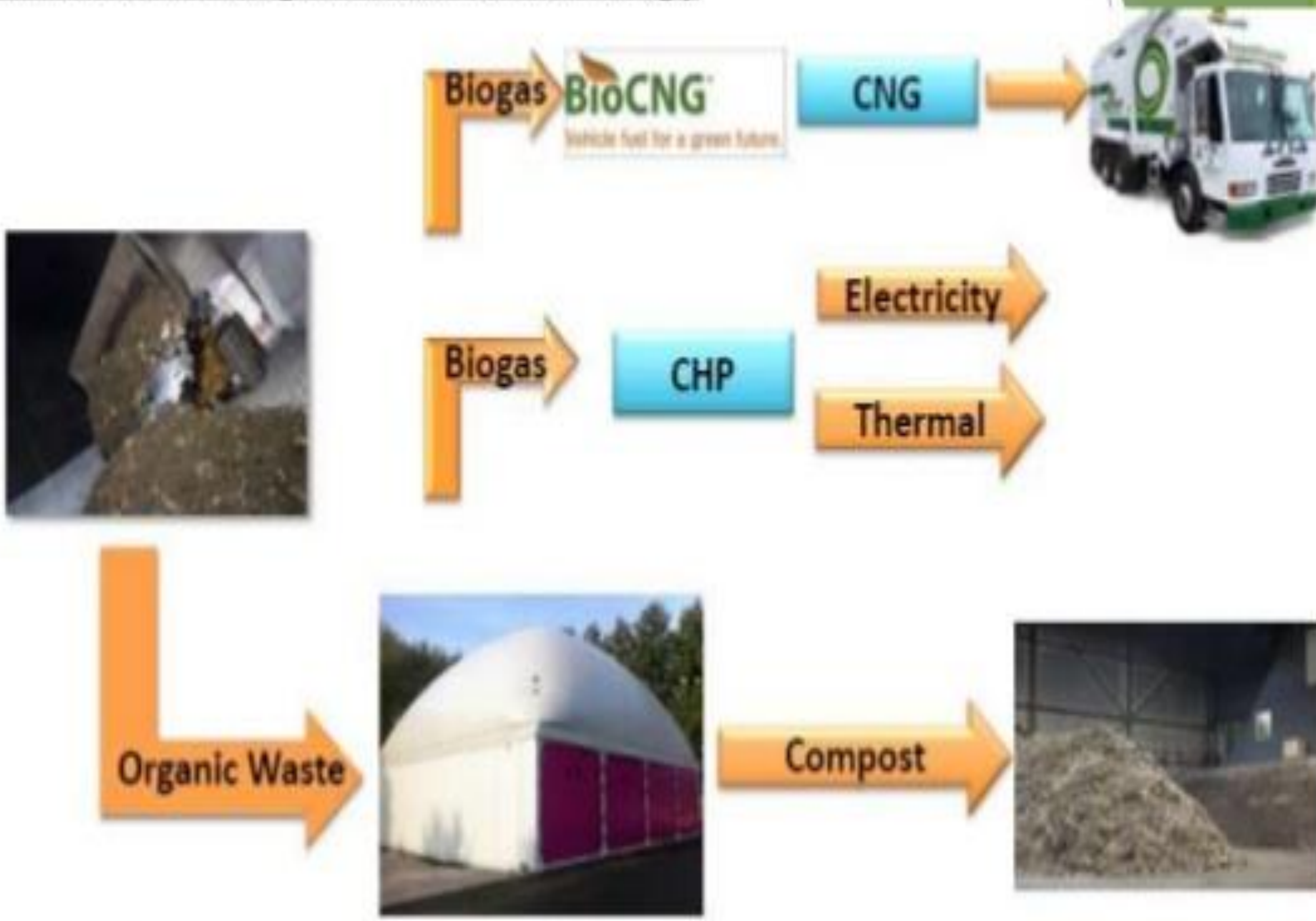
EXAMPLES OF ZERO WASTE

- Carbon dioxide which is formed as a by-product from ammonia manufacturing and natural gas units is used as a blowing agent for making extruded polystyrene foam sheet
- Earlier chlorofluorocarbons (CFCs) and hydrochloro fluorocarbons (HCFCs) were used instead of liquid and supercritical CO_2.
- The use of supercritical CO_2 as blowing agent in making polystyrene foam sheet (green synthesis) has the following advantages:
-

EXAMPLES OF ZERO WASTE

- From the ammonia manufacturing units, the by product formed i.e. CO_2 is removed, hence it does not contribute to green house effect.
- It replaces CFCs (which results in ozone depletion) thus reducing the adverse impact on the environment.
- Apart from other advantages, CO_2 is economical, easy to handle, and neither forms smog nor depletes the ozone layer

Convertion of Organic waste into energy



ZERO WASTE MANAGEMENT IN INDIA

India's first zero waste toilet system inaugurated

TIRUCHIRAPALLI: Aiming to encourage public to follow environment-friendly solid waste management practices and end open defecation, a Zero Waste Toilet System (ZWTS), claiming to be the first in the country,

People from Bangalore, Pune and Tamil Nadu and other places are major buyers of this dry waste. The zero waste management units at Kumbarkoppal are earning thousands of rupees through manufacturing the compost manure and also from segregating waste. There is a big demand for this manure from farmers and also from companies. The cost of this compost manure ` five per kilo.

VIJAYAWADA: Concepts like 'waste to energy' and 'waste to manure' play a crucial role in the solid waste management. As part of this, the Vijayawada Municipal Corporation (VMC) has promoted Shriram Energy Systems and Excel Industries at Ajit Singh Nagar for recycling of solid waste and vegetable waste. A biomethanisation plant was also set up to process the vegetable and slaughter house waste.

IN SUMMARY, GREEN CHEMISTRY IS…

- Scientifically sound,
- Cost effective, and
- Leads toward a sustainable civilization.