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Sustain with Green Chemistry

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Abstract – Ecological imbalance due to unmindful use of chemicals, careless disposal of chemical wastes and its detrimental consequences became a global threat causing concern to many. This led to the concept of "Green Chemistry" to Crystallize. Green chemistry reflects a shift away from the historic "command-and-control" approach to environmental problems that mandated waste treatment, control and clean up through regulation and towards preventing pollution at its source rather that accepting pollution at its source. Rather than accepting waste generation and disposal as unavoidable, green chemistry encourages judicious use of resources and seeks new technologies that are cleaner and economically competitive. Based on twelve principles such as atom economy, safer chemicals, energy efficiency, catalysis, reduced derivatization, utilizing green chemistry for pollution prevention demonstrates the power and beauty of chemistry: through careful design, society can enjoy the products on which we depend while benefiting the environment. But there exist barriers and challenges of economic, regulatory, technical, organizational and cultural nature to the implemention of green chemistry. To overcome these challenges some measures have already been taken place and some is to be done.

Keywords: Green Chemistry, Atom Economy, Reduced Derivatization

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INTRODUCTION

Chemical processes are as old as time, and over the centuries chemists have been trying to understand natural processes to develop methods based on the philosophies that are nature's very own. However, there lies a difference in that, while nature when working on any synthesis adopts methods following routes that eliminate almost completely the use and generation of substances hazardous to human health and the environment, chemists/technologists do not seem to rank the environment very high in their priorities. This is the reason why natural processes are 'green' while synthetic processes are often 'grey'. In fact, chemical technology has been rather malevolent in a number of cases. Some of the most infamous examples are: (a) DDT, an effective insecticide and also a stable suspected carcinogen; (b) The chemical accident in Bhopal in December 1984 that resulted in the deaths of several thousand people. In fact, substantial damage to the environment seems to have resulted from the actions of chemists and chemical technologists in the 20th century, for many of them paid little attention to investigating, publicizing and protecting against the risks of the chemicals which they produced or used. These and some related problems became a causes of concern which then led to the concept of 'Green Chemistry' to crystallize with an aim of sustainable development for achieving societal, economic and environmental objectives.

Green Chemistry, also known as **Clean Chemistry** and **Sustainable Chemistry** refers to the branch of Chemistry dealing with the use of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products and processes thus promoting the prevention of pollution at its source. It is based on certain principles and the principles are; **a)** Prevent waste. **b)** Design less hazardous chemical synthesis and safer chemicals and products with little or no toxicity to humans and the environment. **c)** Use renewable feedstocks rather than depleting. **d)** Use catalysts, not stoichiometric reagents and avoid chemical derivatives so as to minimize waste. **e)** Maximize atom economy which leads to the incorporation of all materials in the process into the final product. **f)** Avoid using solvents, separating agents or other auxiliary chemicals. If necessary, use innocuous chemicals. **g)** Run chemical reactions at ambient temperature and pressure so as to increase energy efficiency. **h)** Design chemical products to break down to innocuous substances after use so they do not accumulate in environment. **i)** Include real-time in-process monitoring and control during synthesis to minimize or eliminate the formation of hazardous by products. **j)** Minimize the potential for chemical accidents including explosion, fires, and releases to the environment.

APPLICATIONS

1. Production of allyl alcohol $CH_2 = CHCH_2OH$

Traditional route: Alkaline hydrolysis of allyl chloride, which generates the product and hydrochloric acid as a by-product

$CH_2=CHCH_2Cl+H_2O$ $CH_2=CHCH_2OH$ +HCL

Problem product

Greener route, to avoid chlorine: Two-step using propylene ($CH_2=CHCH_3$) acetic acid ($CH_3=COOH$) and oxygen (O_2)

$CH_2=CHCH_3+CH_3COOH+½ O2$

$CH_2=CHCH_2OCOCH_3+H_2O$

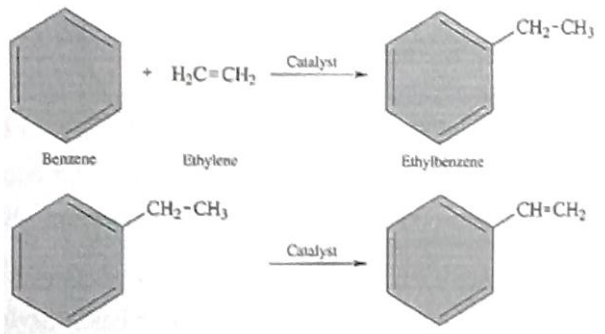
$CH2=CHCH_2OCOCH_3+H_2O$

$CH_2=CHCH_2OH+CH_3COOH$

Added benefit: The acetic acid produced in the 2^{nd} reaction can be recovered and used again for the 1^{st} reaction, leaving no unwanted by-product.

2. Production of styrene

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 xylenes (cheapest source of aromatics and environmentally safer than benzene).

Another option, still under development, is to start with toluene (benzene decay and can be easily separated from the product mix and recycled back into the process.)

3. Biocatalysis

(Use cell as miniature chemical plants) In biocatalysis, enzymes and antibodies are used to mediate reactions. Biocatalysis may involve the use of whole living micro-organisms or only of enzymes that are separated from the cell and immobilized in a support medium. In order words, entire cells or cell components are used as microengines.

Reactions that use biocatalysis often proceed with exceptionally high selectivity. In some cases, they have also been shown to increase reaction rates between 9 and 15 orders of magnitude in comparison with uncatalyzed reactions. Therefore, biotechnology offers much hope for progress in green chemistry.

Applications in industrial sector:

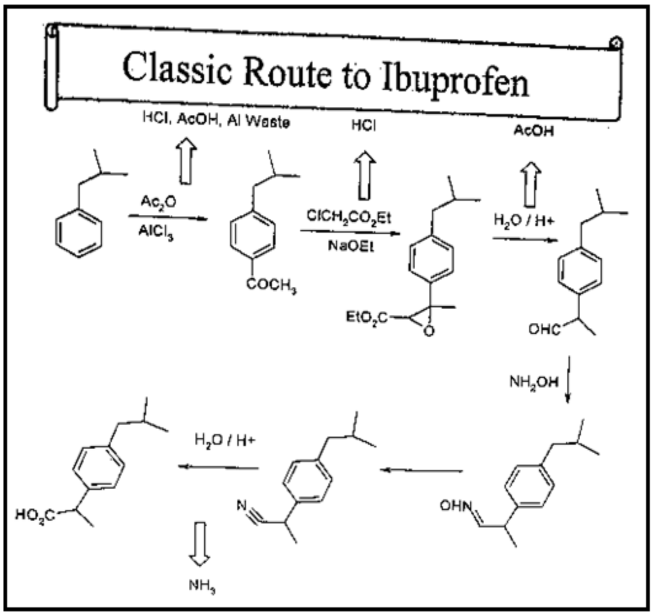
1) **Green starting materials –** Commodity chemicals from glucose. Glucose in an excellent feed-stock to synthesize a variety of commodity chemicals using the biochemical pathway. This route helps to minimize the use of carcinogenic starting materials such as benzene. Moreover the synthesis is performed with water instead of organic solvents e.g. conversion of glucose to adipic acid- a raw material in the manufacture of nylon66 fibre.

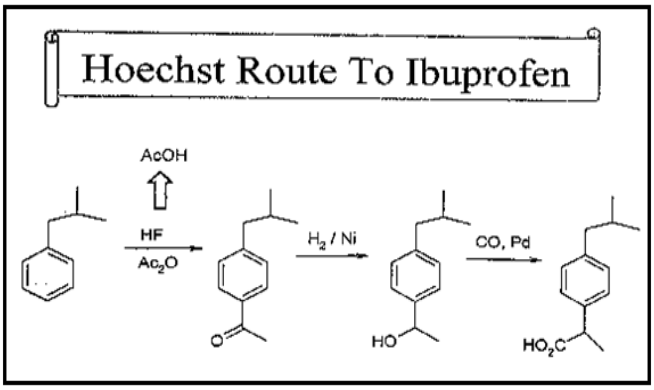
2) **Green solvents –** Use to super critical carbon dioxide. The traditional solvents used in organic synthesis such as chlorinated hydrocarbons have a number of environmental problems due to which benign solvents which are eco-friendly have been developed. One such solvent is super critical carbon dioxide. The solvent is non-toxic, non-flammable, renewable and inexpensive.

3) **Green chemical products –** Synthesis of thermal polyaspartates. Thermal polyaspartates is an economically viable, effective and biodegradable alternative to polyacrylic acid used in many industrial applications.

4) **Ibuprofen Manufacture –** An elegant example of a process with high atom efficiency is provided by the manufacture of the over-the-counter, non-steroidal anti-inflammatory drug, ibuprofen. Two routes for the production of ibuprofen via the common intermediate, *p-* isobutylacetophenone. The classical route, developed by the Boots Pure Drug Company (the discoverers of ibuprofen), entails 6 steps with stoichiometric reagents, relatively low atom efficiency and substantial inorganic salt formation. In contrast, the elegant alternative, developed by the Boots – Hoechst – Celanese (BHC) company, involves only three catalytic steps. The first step involves the use of anhydrous hydrogen fluoride as both catalyst and solvent in a Friedel – Crafts acylation. The hydrogen fluoride is recyclable and waste is essentially eliminated. This is followed by two catalytic steps (hydrogenation and carbonylation),

both of which are 100% atom efficient. The BHC ibuprofen process was commercialized in 1992 in Texas. The process was awarded the Kirkpatrick Achievement Award for outstanding advances in chemical engineering technology in 1993 and a Presidential Green Chemistry Challenge Award in 1996. It represents a benchmark in environmental excellence in chemical processing technology that revolutionized bulk pharmaceutical manufacturing. It provides an innovation and excellent solution to the prevalent problem of the large volumes of waste associated with the traditional stoichiometric use of auxiliary chemicals. The anhydrous hydrogen fluoride is recovered and recycled with greater than 99.9% efficiency. No other solvent is used in the process, simplifying product recovery and minimizing fugitive emissions. This combined with the almost complete atom utilization of this streamlined process truly makes it a waste – minimizing, environmentally friendly technology and a source of inspiration for other pharmaceutical manufacturers.





NEW RESEARCH INVESTIGATES POTATO BIOPLASTIC AND CORN-BASED GLUE

Separate research initiatives in the U.S. and Canada are turning potato starch into high performance Bioplastic packaging and using corn germ to reduce the amount of resin in glue. Agriculture and Agri-Food Canada will look at developing potatoes with enhanced starch properties in order to better produce the industrial starch needed to make Bioplastic. The project's researchers also hope to find additional potato-based bioplastic applications and improve bioplastic's water resistance and other properties.

CHALLENGES:

Although USA has been a forerunner in the promotion of the awareness of green chemistry. Realizing that an incentive was also required in order to bring about a more effective implementation, there are awards given at the presidential level, pronounced as the Presidential green Chemistry Challenge (PGCC) Awards, which are presented annually at the National Academy of Science in Washington DC to promote the design of chemical products and manufacturing processes that prevent pollution and are economically competitive. Some other developed nations have already identified the need to promote green chemistry but still the rest world is dealing with multiple challenges i.e.

- Lack of sensitivity and awareness in the industry about environmental issues & green chemistry.
- Lack of incentives and "Green Friendly" policies.
- No eco-system for "enviropreneurs" to show up.
- Academic and research institutions not working on solving real-life problems.

MEASURES:

To overcome the challenges;

- Educate operations people in the industry about green chemistry.
- Acknowledge & appreciate individuals & companies taking initiatives & contributing to Green Chemistry.
- Bring solution providers & industry together to enable Collaboration.

- Interaction with government & regulatory bodies.
- Organize biomimicry (innovation inspired from nature) camps for R&D Teams.
- Participation in exhibitions, conferences & workshops to learn from others.

CONCLUSION:

While Green chemistry offers principles for the development of 'greener' reagents and alternatives and more benign routes to synthetic methodologies, it does not have the capacity to bring about a radical change. A consensus has to be arrived at between the policy makers, chemical practitioners, industry persons in order to give Green chemistry the power it rightly deserves and a doctrine needs to be framed to guide so that overall efficiency, environmental cleanliness and sustainability are achieved. It is reiterated that the espouses for green chemistry must involve not only the academic intelligentsia but also the science and technology agencies and the S & T administrators, since it is only a synchronized movement of these apparently segregated entities that can bring about a reform movement in chemistry and chemical technology.

Though it is true that many industries and research organizations are yet to implement the principles of Green chemistry, nevertheless some of them have begun to realize that the 'think green' culture is more than just a fashion. In fact the winds of changes have already started blowing and the more successful chemistry researchers and chemical technologists will like to appreciate and apply the value of Green chemistry in innovation, application and teaching.

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