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Green Chemistry- A Potential tool for Chemical Synthesis

S. Ravichandran

Assistant Professor in Chemistry , Saveetha School of Engineering, Saveetha University, Thandalam,Chennai-602 105.

Corres.author: ravichanduru@yahoo.com

Abstract: Green chemistry for chemical synthesis addresses our future challenges in working with chemical processes and products by inventing novel reactions that can maximize the desired products and minimize by-products, designing new synthetic schemes that are seeking greener solvents and environmentally benign.The emerging area of Green chemistry is need in the design and attainment of sustainable development. Green chemistry is the utilization of a set of principles that will help reduce the use and generation of hazardous substances during the manufacture and application of chemical products.In this paper a brief description on Green chemistry, developments and some industrial applications are discussed.
Key words: Green Chemistry.

Introduction

Chemistry has provided valuable materials in the form of medicines, food products, cosmetics, dyes, paints, agrochemicals, biomolecules, high-tech substances like polymers, liquid crystals and nanoparticles. Chemists have used their knowledge and skill to prepare a large number of new materials which are far better and more useful than the natural products.

Over the past two centuries, fundamental theories in chemistry have been soundly established. Such theories have provided the foundations for the chemical enterprise that generates critical living needs such as food for the world's population, achieves various medical wonders that save millions of lives and improve people's health, and produces materials essential to the present and future needs of mankind. Just less than two centuries ago, organic compounds were believed to be only accessible[1] through biological processes under the influence of "vital forces". Today, many molecules of great complexity can be synthesized readily. However, despite such enormous achievements, we are facing great challenges in future chemical synthesis. The present state of the art processes for synthesizing chemical products are highly inefficient.

The processes on industrial scale involve many chemical reactions using huge quantities and wider varieties of smaller molecules, reagents, solvents, acids, alkali, etc. These chemical processes not only produce the required products but also large quantities of undesired and harmful substances in the form of solids, liquids and gases and have become the biggest challenge that chemistry has to face. So, the pressing need for the synthetic chemists is to minimize chemical pollution. During the last two decades much work has been going on in this direction. The term **Green Chemistry** was coined[2] in 1991 by **Prof. Paul T. Anastas**. The purpose is to design chemicals and chemical processes that will be less harmful to human health and environment. Green chemistry protects the environment, not by cleaning up, but by inventing new chemical processes that do not pollute.

The 12 principles of Green chemistry and their applications[3-8] to basic and applied research is briefly described below:

1.Prevention

It is better to prevent waste than to treat or clean up waste after it is formed. The ability of chemists to redesign chemical transformations to minimize

the generation of hazardous waste is an important first step in pollution prevention.
It goes back to the old saying "prevention is better than cure". It is better to prevent waste than clean it up after the fact.

2.Atom economy
This principle gets into the actual chemistry of how products are made. This principle states that it is best to use all the atoms in a process. And, those atoms that are not used end up as waste. Choosing transformations that incorporate most of the starting materials into the product are more efficient and minimize waste.

3.Less hazardous chemical synthesis
The goal is to reduce the hazard of the chemicals that are used to make a product.
Chemists have traditionally used whatever means necessary. Today we are finding
that less hazardous reagents and chemicals can be used in a process to make products. Synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and environment. Some toxic chemicals are replaced by safer ones for a green technology. For example, in the manufacture of polystyrene foam sheet packing material, chlorofluorocarbons which contribute to O3 depletion and global warming, have now been replaced by CO_2 as the blooming agent.

4.Designing safer chemicals
Everyone wants safe products. This principle is aimed at designing products that are safe, and non-toxic. Pharmaceutical products often consist of chiral molecules, and the difference between the two forms can be a matter of life and death – for example, racemic Thalidomide when administered during pregnancy, leads to horrible birth defects in many new borns. Evidence indicates that only one of the enantiomers has the curing effect while the other isomer is the cause of severe defects.

5. Safer solvents
We use solvents regularly in our daily lives (cleaning products, nail polish, cosmetics, etc.) and in the chemistry laboratory. Many chemical reactions are done in a solvent. And, traditionally organic solvents have been used that pose hazards and many are highly toxic. Solvents are extensively used in most of the syntheses. Widely used solvents in syntheses are toxic and volatile – alcohol, benzene (known carcinogenic), CCl_4, $CHCl_3$, perchloroethylene, CH_2Cl_2. Purification also utilize large amounts of solvents(e.g.,Chromatography) which add to pollution and can be highly hazardous to humans. The development of Green Chemistry redefines the role of a solvent: An ideal desirable green solvent should be natural, nontoxic, cheap, and readily available. This principle focuses on creating products in such a way that they use less hazardous solvents (such as water). It is obvious that water is the most inexpensive and environmentally benign solvent.

6.Design for energy efficiency
Today there is a focus on renewable energy and energy conservation. We use energy for transportation purposes and to provide electricity to our homes and businesses. Traditional methods for generating energy have been found to contribute to global environmental problems such as Global Warming and the energy used can also be a significant cost. This principle focuses on creating products and materials in a highly efficient manner and reducing associated pollution and cost.

7. Use of renewable feedstocks
90-95% of the products we use in our everyday lives are made from petroleum. Our society not only depends on petroleum for transportation and energy, but also for making products. This principle seeks to shift our dependence on petroleum and to make products from renewable materials that can be gathered or harvested locally. *Biodiesel* is one example of this where researchers are trying to find alternative fuels that can be used for transportation. Another example is alternative, bio-based plastics. PLA (polylactic acid) is one plastic that is being made from renewable feedstocks such as corn and potato waste. Benzene used in the commercial sythesis of adipic acid which is required in the manufacture of nylon, placticizers and lubricants, has been replaced to some extent by the renewable and nontoxic glucose and the reaction is carried out in water.

8. Reduce derivatives
Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible, because such steps require additional re- agents and can generate more waste.

9. Catalysis
In a chemical process catalysts are used in order to reduce energy requirements and to make reactions happen more efficiently (and many times quicker). Another benefit of using a catalyst is that generally small amounts (catalytic amount versus a stoichiometric amount) are required to have an effect. And, if the catalyst is truly a "green" catalyst it will have little to no toxicity in the process. Enzymes are wonderful examples of catalysts. Biocatalysed

reactions are advantageous as they are performed in aqueous medium, all conversions are single step, protection and deprotection of functional groups are not necessary. Such transforma tions are either impossible or extremely difficult to achieve by conventional chemical methods.

10. Design for degradation

Not only do we want materials and products to come from renewable resources, but we would also like them to not persist in the environment. There is no question that many products we use in our daily lives are far too persistent. Plastics do not degrade in our landfills and pharmaceutical drugs such as antibiotics build up in our water streams. This principle seeks to design products in such a way that they perform their intended function.

11. Pollution prevention

This process is similar to what chemists have to do when they make products. How long do they allow the reaction to run for? When do they know it will be "done"? If there was a way to see inside the reaction and to know exactly when it would be
done, then this would reduce waste in the process.

12. Safer Chemistry for Accident Prevention

This principle focuses on safety for the worker and the surrounding community where an industry resides. It is better to use materials and chemicals that will not explode, light on fire, ignite in air, etc. when making a product. There are many examples where safe chemicals were not used and the result was disaster. The most widely known and perhaps one of the most devastating disaster was that of Bhopal, India in 1984 where a chemical plant had an accidental release that resulted in thousands of lives lost and many more injuries. The chemical reaction that occurred was an exothermic reaction that went astray and toxic fumes were released to the surrounding community. When creating products, it is best to avoid highly reactive chemicals that have potential to result in accidents. When explosions and fires happen in industry, the result is often devastating.

Some examples of green chemistry in the use of industrial synthesis:

Commercial applications of green chemistry have led to novel academic research to examine alternatives to the existing synthetic methods.

- The use of phosgene and methylene chloride in the synthesis of polycarbonates has been replaced by diphenylcarbonate.
- The most polluting reaction in industry is oxidation. Implementation of green chemistry has led to the use of alternative less polluting reagents viz., metal ion contamination is minimized by using molecular O_2 as the primary oxidant and use of extremely high oxidation state transition metal complexes.
- A convenient green synthesis of acetaldehyde is by Wacker oxidation of ethylene with O_2 in presence of a catalyst, in place of its synthesis by oxidation of ethanol or hydration of acelylene with H_2SO_4.
- Conventional methylation reactions employing toxic alkyl halides or methylsulfate leading to environmental hazard are replaced by dimethylcarbonate with no deposit of inorganic salts.

Conclusion

Our future challenges in resource, environmental, and societal sustainability demand more efficient and benign scientific technologies for working with chemical processes and products. Green chemistry addresses such challenges by inventing novel reactions that can maximize the desired products and minimize by-products, designing new synthetic schemes and seeking greener solvents that are inherently environmentally benign. Together, such fundamental innovations in chemical sciences will lead us to a new generation of chemical syntheses.

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