

# Green Chemistry – A Review

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## ABSTRACT

Green Chemistry is the utilization 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. Green Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. Often referred to as a form of molecular-level pollution prevention, Green Chemistry relies on a set of **12 principles** that can be used to design or re-design molecules, materials and chemical transformations to be safer for human health and the environment.

**Keywords:** Green Chemistry, Volatile Organic Compounds, PLA

## I. The 12 Principles of Green Chemistry:

### 1. Prevention

This principle is the most obvious and over-arches the other principles. It goes back to the old adage “an ounce of prevention is worth a pound of cure”. It is better to prevent waste than clean it up after-the-fact. Throughout history there have been many cases of environmental disasters that demonstrated this (Bopal, India; Love Canal; Times Beach; Cuyahoga River).

### 2. Atom Economy

This principle gets into the actual chemistry of how products are made. As chemists, atoms are assembled to make molecules. The molecules are assembled together to make materials. 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. The atom economy is a simple calculation that can be used when teaching stoichiometry and chemical reactions. The calculation is:  $A.E. = \frac{\text{Formula Weight (FW) of Product}}{\text{FW of all of the reactants}}$ . It is a simple measure of the amount of waste in a process.

### 3. Less Hazardous Chemical Synthesis

This principle is focused on how we make molecules and materials. The goal is to reduce the hazard of the

chemicals that are used to make a product (the reagents). Throughout the history of how we have invented products and developed the process for making them, chemists have traditionally not thought about what reagents they are using and the hazards that are associated with them. 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 and, many times they are made in a more efficient manner!

### 4. Designing Safer Chemicals

The previous principle was focused on the process. This principle focuses on the product that is made. Everyone wants safe products. Everyone also wants products that do what they are supposed to do (they have to work!). This principle is aimed at designing products that are safe, non-toxic and efficacious. A good example of this is pesticides; which are products that are designed to be toxic. Many researchers are focused on created pesticides that are highly specific to the pest organism, but non-toxic to the surrounding wildlife and ecosystems.

### 5. Safer Solvents and Auxiliaries

Many chemical reactions are done in a solvent. And, traditionally organic solvents have been used that pose hazards and many are highly toxic. They also create

volatile organic compounds (VOC's) which add to pollution and can be highly hazardous to humans. This principle focuses on creating products in such a way so that they use less hazardous solvents (such as water). We use solvents regularly in our daily lives (cleaning products, nail polish, cosmetics, etc.) and in the chemistry laboratory. An example that many can relate to is that of nail polish products. Have you walked by a nail salon and caught a smell of the solvents that are used? The solvents traditionally used have potential toxicity and are certainly not pleasant to smell. A water-based alternative polish would avoid the exposure that goes along with the nail products and reduce the hazards associated with traditional products.

## 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 the energy associated with creating the products, therefore 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.

## 8. Reduce Derivatives

This principle is perhaps the most abstract principle for a non-chemist. The methods that chemists use to make products are sometimes highly sophisticated. In addition, many involve the manipulation of molecules in

order to shape the molecules into what we want them to look like. This principle aims to simplify that process and to look at natural systems in order to design products in a simplified manner.

## 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 and it will be able to be used over-and-over again in the process. Enzymes are wonderful examples of catalysts that have been proven to perform amazing chemistry – our bodies are wonderful examples! Green chemists are investigating using enzymes to perform chemistry in the laboratory in order to obtain the desired product. Many times enzymes will have reduced toxicity, increased specificity and efficiency.

## 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 so that they perform their intended function and then, when appropriate, will degrade into safe, innocuous by-products when they are disposed of.

## 11. Real-time Analysis for Pollution Prevention

Imagine if you have never baked a cake before in your life and you did not have a cookbook to refer to. You mix the ingredients that you believe you need and you place the cake in the oven. But, for how long do you cook it and at what temperature? How will you know when the cake is done? What happens if you cook it too long or for not enough time? This process is similar to what chemists have to do when they make products.

## **12. Inherently 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.

### **Green Chemistry in day-to-day life:**

1. Dry Cleaning of Clothes.
2. Versatile Bleaching Agents.
3. Solution to Turbid Water Cleaning.

## **II. CONCLUSION**

Green Chemistry is new approach that through various application and extension of the principles of green chemistry can contribute to sustainable development. Presently it is easy to find in the literature many interesting examples of the use of green chemistry rules. Great efforts are still undertaken to design an ideal process that start from non-polluting materials. It is clear that the challenge for the future chemical industry is based on safer products and processes designed by utilizing new ideas in fundamental research.

## **III. REFERENCES**

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