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Implementation of Green Chemistry Principles into practice

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Abstract: Chemistry is really very helpful to us as its applications are used worldwide for several purposes. We cannot really imagine a world without chemistry and its applications such as medicines. However, we should now concentrate on green chemistry, or sustainable chemistry, which refers to reducing or stopping the damage done to the environment around us. Hence, green chemistry could include anything from reducing waste to even disposing of waste in the correct manner. Another way to save the environment through sustainable chemistry is to make use of renewable food stocks. Yet another good move is to make use of catalysts in experiments rather than using stoichiometric reagents. Chemical derivatives must be avoided as far as possible in any type of application as they often prove to be harmful. All chemical wastes should be disposed off in the best possible manner without causing any damage to the environment and living beings.This article presents selected examples of the implementation of green chemistry principles in everyday life in industry. A brief history of green chemistry are also mentioned.
Keywords: green chemistry, sustainable development.

Introduction to Green Chemistry

The term green chemistry[1] was first used in 1991 by Prof. Paul T. Anastas to implement sustainable development in chemistry and chemical technology by industry, academia and government. In 1995 the annual US Presidential Green Chemistry Challenge was announced. In 1996 the Working Party on Green Chemistry was created, acting within the framework of International Union of Applied and Pure Chemistry. One year later, the Green Chemistry Institute (**GCI**) was formed with chapters in 20 countries to facilitate contact between governmental agencies and industrial corporations with universities and research institutes to design and implement new technologies. The first conference highlighting green chemistry was held in Washington in 1997. Since that time other similar scientific conferences have soon held on a regular basis. The first books and journals on the subject of green chemistry were introduced in the 1990s, including the Journal of Clean Processes and Green Chemistry, sponsored by the Royal Society of Chemistry. Green chemistry embodies two main components. First, it addresses the problem of efficient utilisation of raw materials and the concomitant elimination of waste. Second, it deals with the health, safety and environmental issues associated with the manufacture, use and disposal or reuse of chemicals.

Green chemistry incorporates a new approach[2-7] to the synthesis, processing and application of chemical substances in such a manner as to reduce threats to health and the environment. This new approach is also known as:

- Environmentally benign chemistry
- Clean chemistry
- Atom economy
- Benign-by-design chemistry

Green chemistry is commonly presented as a set of twelve principles proposed by Anastas and Warner. The principles comprise instructions for professional chemists to implement new syntheses and new technological process. These principles are:

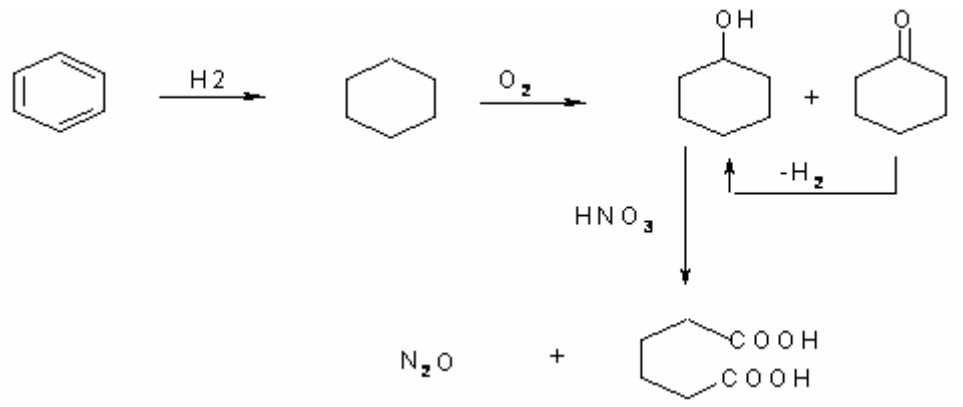
- It is better to prevent waste than treat or clean up waste after is formed.
- Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
- Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
- Chemical products should be designed to reduce toxicity.
- The use of solvents should be made unnecessary wherever possible.
- Energy requirements should be minimized. Synthetic methods should be conducted at low temperature and pressure.
- A raw material or feedstock should be renewable.
- Unnecessary derivatization (blocking group, protection/deprotection) should be[2-4] avoided whenever possible.
- Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
- Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into degradation products.
- Analytical methodologies need to be further developed to control the formation of hazardous substances.
- Substances 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.

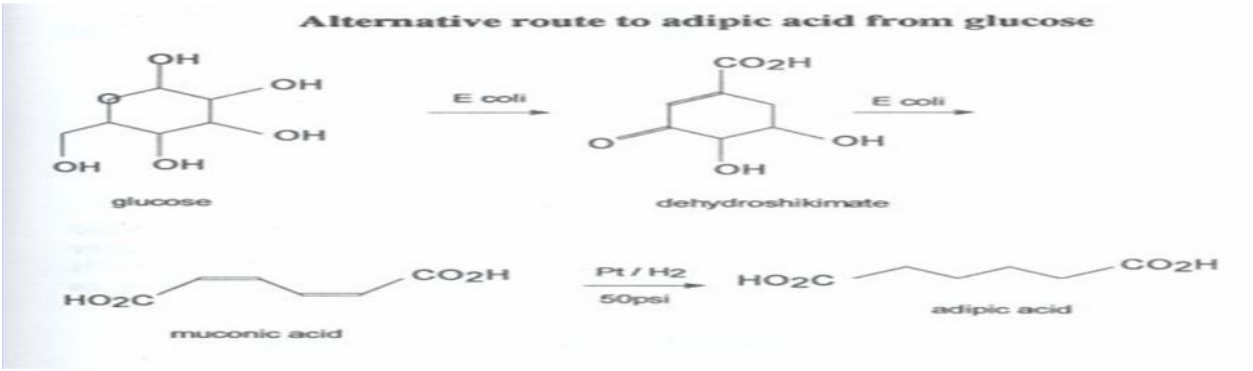
These principles can motivate chemistry at all levels: research, reduction to practice, education and public perception. The first principle describes the basic idea of green chemistry in protecting the environment from pollution. The remaining principles are focused on such issues as atom economy, toxicity, solvent and other media using consumption of energy, application of raw materials from renewable sources and degradation of chemical products to simple, nontoxic substances that are friendly for the environment.

Green Chemistry principles - in action

In some industrial chemical processes, not only waste products but also the reagents used for the production, may cause a threat to the environment. According to the principles of green chemistry, a threat can be eliminated in a simpler way, by applying safe raw materials for production process. Large amounts of adipic acid[8] are used each year for the production of nylon, polyurethanes, lubricants and plasticizers. Benzene (a compound with carcinogenic properties) is a standard substrate for the production of this acid. Chemists from State University of Michigan developed green synthesis of adipic acid using a less toxic substrate. Furthermore, the natural source of this raw material, glucose is almost inexhaustible. The glucose can be converted into adipic acid by an enzyme discovered in genetically modificated bacteria. Such a manner of production of this acid guards the workers and the environment from exposure to hazardous chemical compounds.

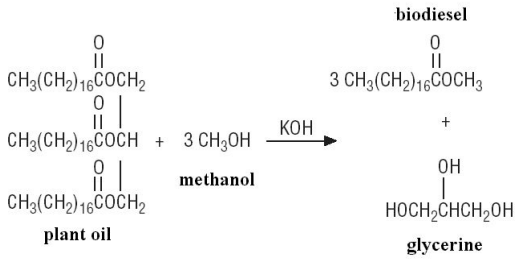
Conventional route to Adipic acid from Benzene





Green chemistry tries, when possible, to utilize benign, renewable feedstocks as raw materials. From the point view of green chemistry, combustion of fuels obtained from renewable feedstocks is more preferable than combustion of fossil fuels from depleting finite sources. For example, many vehicles around the world are fueled with diesel oil, and the production of biodiesel oil is a promising possibility. As the name indicates, biodiesel oil is produced from cultivated plants oil, e.g. from soya beans. It is synthesized from fats embedded in plant oils by removing the glycerine molecule. The advantages of using biodiesel oil are obvious. It's fuel from renewable resources and contrary to normal diesel oil.

Reaction for biodiesel oil production



The great threats to the environment are organic solvents applied in many syntheses. They are released into the environment by a volatilization process, especially in the case of volatile organic compounds (**VOCs**) and as a result of leakage. The emission of such compounds is significant because in many syntheses their amounts exceeds the amount of reagents. The new solutions for practical synthesis aim at complete elimination of solvents or to substitute the compounds belonging to VOCs by cheap technological media, harmless for humans and the environment. The use of supercritical fluids[9,10] (**SCFs**) in chemical processes is becoming more and more prevalent. Carbon dioxide as a supercritical fluid is most frequently used as medium for reactions. It is inflammable, easily available (from natural sources) and cheap. The discovery of supercritical carbon dioxide opened a way to new processes in textile and metal industries and for dry cleaning of clothes. Micell Technologies Company offers technology for removal of stains using liquid carbon dioxide instead of the perchloroethylene (**PERC**) more commonly applied.

Conclusions

Green chemistry is not a new branch of science. It is a new philosophical approach that through 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 starts from non-polluting materials. It is clear that the challenge for the future chemical industry is based on production of safer products and processes designed by utilizing new ideas in fundamental research. If companies are able to meet the needs of society, people will influence their own governments to foster those industries attempting such environmental initiatives. In this context, chemical sciences will play a key role in the realization of the conditions for a sustainable development with green chemistry strategies. Furthermore, the success of green chemistry depends on the training and education of a new generation of chemists. Student at all levels have to be introduced to the philosophy and practice of green chemistry.

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