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Green Chemistry — Present and Future Issues

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Abstract

The basis of green chemistry is frequently considered as a response to the need to reduce the damage of the environment by man-made materials and the processes used to produce them. A quick view of green chemistry issues in the past decade demonstrates many methodologies that protect human health and the environment in an economically beneficial manner. This article presents selected examples of the implementation of green chemistry principles in everyday life in industry, the laboratory and in education. A brief history of green chemistry and future challenges are also mentioned.

Keywords: green chemistry, green analytical chemistry, hygienic chemistry, atom economy, sustainable development.

Introduction

Green chemistry is a pro-active approach to Pollution prevention. It targets pollution at the design stage, before it even begins. If chemists are taught to develop products and materials in a manner that does not use hazardous substances, then much waste, hazards and cost can be avoided. Green Chemistry is designing chemical products and processes that reduce or eliminate the use and/or the generation of hazardous substances. Green chemistry can be defined as the practice of chemical science and manufacturing in a manner that is sustainable, safe, and non-polluting and that consumes minimum amounts of materials and energy while producing little or no waste material.

The most important goals of sustainable development are reducing the adverse consequences of the substances that we use and generate. Foremost among the fundamental changes this calls for is the shifting of the production of energy and carbon-based chemicals from fossil fuels to renewable resources. While it is difficult to predict the exact date of the depletion of fossil fuels, the transition to renewable materials should be accelerated because of the frequently and unexpectedly changing political/economical environments resulting in limited access and rising costs. But perhaps of equal significance is the need to deal with toxicities that are threatening the welfare of essentially all living things in real time.

The concept of green chemistry has appeared in the United States as a common research program resulting from interdisciplinary cooperation of university teams, independent research groups, industry, scientific societies and governmental agencies, which each have their own programs devoted to decreasing pollution. Green chemistry incorporates a new approach to the synthesis, processing and application of chemical sub-stances in such a manner as to reduce threats to health and the environment. This new approach is also know 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[1]. The principles comprise instructions for professional chemists to implement new chemical compounds, new syntheses and new technological processes.

The first principle describes the basic idea of green chemistry — protecting the environment from pollution. The remaining principles are focused on such issues as atom economy, toxicity, solvent and other media using consump-tion of energy, application of raw materials from renewable sources and degradation of chemical products to simple, nontoxic substances that are friendly for the environment.

The 12 Laws of Green Chemistry

1. Prevention[2]

It's better to prevent waste than to treat or clean up waste afterwards.

2.Atom Economy

Design synthetic methods to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Syntheses

Design synthetic methods to use and generate substances that minimize toxicity to human health and the environment.

4. Designing Safer Chemicals[3]

Design chemical products to affect their desired function while minimizing their toxicity.

5. Safer Solvents and Auxiliaries

Minimize the use of auxiliary substances wherever possible make them innocuous when used.

6. Design for Energy Efficiency

Minimize the energy requirements of chemical processes and conduct synthetic methods at ambient temperature and pressure if possible.

7. Use of Renewable Feedstocks

Use renewable raw material or feedstock rather whenever practicable.

8. Reduce Derivatives

Minimize or avoid unnecessary derivatization if possible, which requires additional reagents and generate waste.

9. Catalysis

Catalytic reagents are superior to stoichiometric reagents.

10. Design for Degradation

Design chemical products so they break down into innocuous products that do not persist in the environment.

11. Real-time Analysis for Pollution Prevention

Develop analytical methodologies needed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention Choose substances and the form of a substance used in a chemical process to minimize the potential for chemical accidents, including releases, explosions, and fires.

Examples of Alternatives of Green Chemistry Laws into Practice

Conventional solvents can be hazardous in terms of toxicity, flammability and waste generation. Consequently, alternative solvents now form a substantial part of green chemistry.

Solvents are important in many areas of chemistry so the author has adopted a general approach encompassing of a wide range of solvents.

1.Old and New Synthesis of Ibuprofen

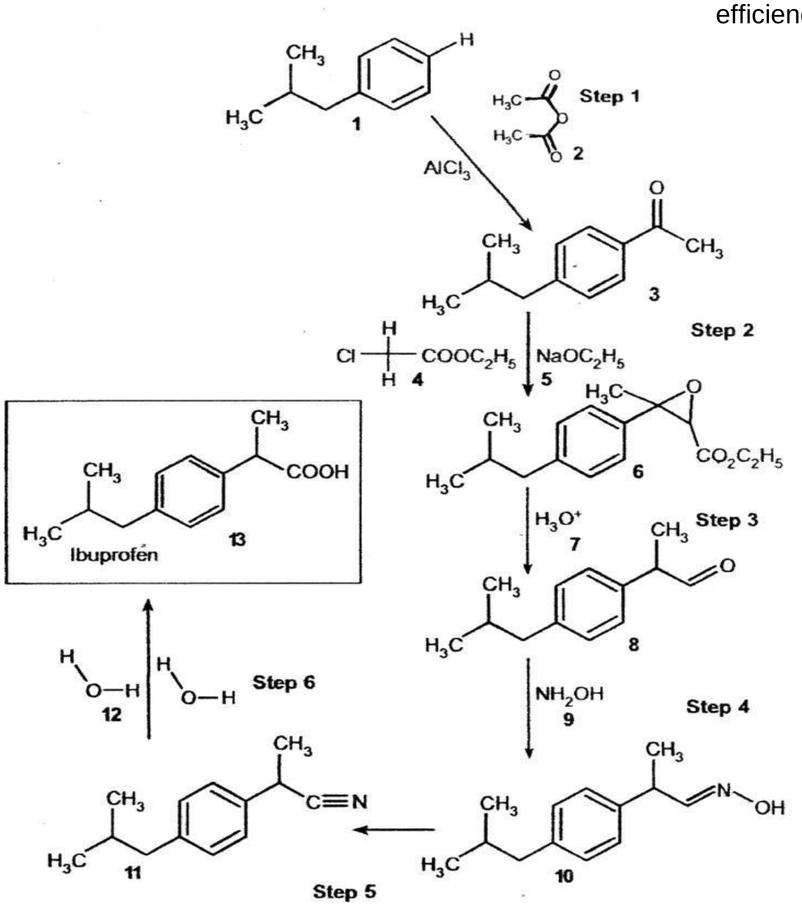
The pharmaceutical industry is considered now as the most dynamic sector of the chemical industry for the 21st century. Sales of medicines and other pharmaceutical products have increased fourfold from 1985[4]. The analgetic and anti-inflammatory drugs is a category of medicines which are produced in vast amounts every year. Some of the most important are : **Aspirin** (acetylosalicilic acid), **Acetaminophen** (Tylenol, paracetamol) and **Ibuprofen[5].** Ibuprofen belongs to non-steroidal anti-inflammatory drugs with very high sales.

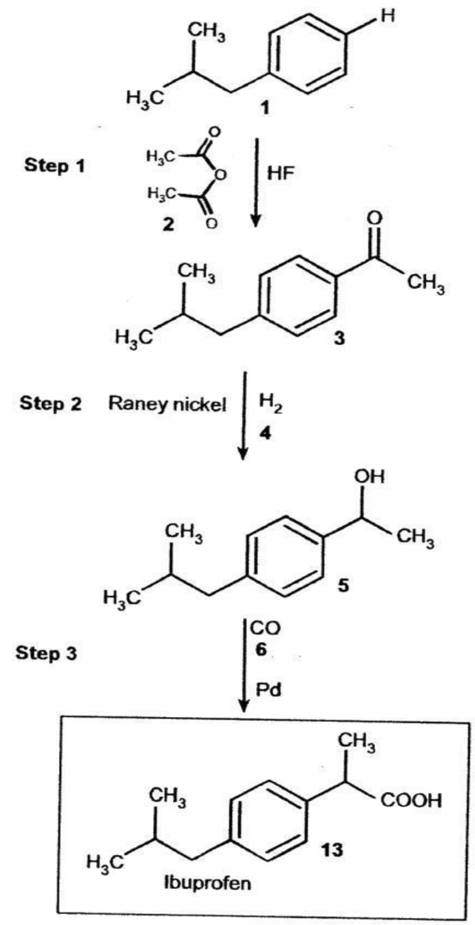
Ibuprofen was synthesized in 1960 by the pharmaceutical company Boot (England) and sold under the commercial name Aspro, Panadol and Nurofen. The synthesis of Ibuprofen was performed in six steps with the production of secondary by-products and waste. The main problem according to the scientists at the time was that this synthesis had a very “poor atom economy”.

Ibuprofen as a non-steroid anti-inflammatory drug was very successful and its sales were increased substantially in the last decades.

The initial synthesis, observed under the “green” principles, had many disadvantages. The starting chemical could not be incorporated into the product, producing lots of by-products and waste. The six steps of the synthetic route was consuming chemicals and energy while lowering the yield of the final product.

In 1990 the company BHC after prolonged research on the subject discovered a new synthetic route with only three steps and increased efficiency. The atoms of the starting chemicals are incorporated into the products of the reactions and waste is minimized. In both synthetic routes the starting chemical is 2-methylpropylbenzene, which is produced from the petrochemical industry. The innovation in the new method was in the second step. A catalysts of Nickel (Raney nickel) [6]was used thus decreasing substantially the steps of the synthesis.

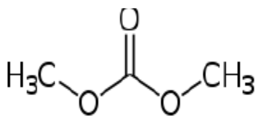




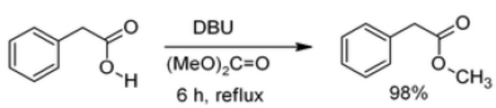
The two synthetic routes of Ibuprofen. In the old method the synthetic route comprised of six steps and in the second was reduced to three steps. The efficiency of the reaction increased substantially. In the old synthetic route, each step had a yield of 90% so that the final product came to be 40% yield compared to the starting chemical. This resulted in the increased production of by-products as waste. The drug was produced annually (only in Great Britain) in 3.000 tones and we understand that substantial amounts of chemicals were lost as waste. Energy also was lost by the low efficiency of the reaction method. In the “greener’ method of three steps the final yield is 77%, whereas the Raney nickel catalyst CO/Pt) can be recycled and reused. In the old synthetic route, the $AlCl_3$ used as a catalyst had to be thrown away as waste. The energy requirements of the second method were much lower than the first.

The new synthetic route of Ibuprofen is a classic example of how Green Chemistry ideas can influence to the better the industrial synthetic methods, not only from the point of economic efficiency, but also from the point of more effective science and technology methods.

2.Carbonic ester, such as DMC,dimethyl carbonate are considered a new class of green chemistry solvent in many organic reactions. they can replace methylchloride and dimethyl sulfate ester which are toxic and hazardous[6]



DMC can be used in methylation reaction of phenols ,anilines, carboxylic acids DBU is an alternatives solvents that can be for methyalation reaction of phenols, indoles and benzimidazoles



GREEN CHEMISTRY IN EDUCATION

Convincing chemists to think in an environmentally friendly manner begins with education. The idea of including Green Chemistry in chemistry education was first put forward in 1994. Few Green chemistry textbooks have also been published. Graduates, post graduates, teachers and researchers will find these books of immense use. Both Environmental Protection Agency (EPA) and American Chemical Agency (ACS) [2] have recognized the importance of bringing Green Chemistry to the class room and the laboratory. Together they have launched a significant campaign to develop Green Chemistry educational materials and to encourage the 'greening' of the chemistry curriculum Student involvement in Green Chemistry principles and practices is essential to the integration the environmentally benign technologies in academia and industry [1]

CONCLUSION

The expansion of Green Chemistry over the course of the past decade needs to increase at an accelerated pace if molecular science is to meet challenges of sustainability. It has been said that the revolution of one day becomes the new orthodoxy of the next Green Chemistry is applied and must involve the successful implementation of more environmentally friendly chemical processes and product design. Most importantly we need the relevant scientific, engineering, educational and other communities to work together for sustainable future through Green Chemistry

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