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THE TWELVE PRINCIPLES OF GREEN CHEMISTRY: A MINI REVIEW

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Abstract
This mini review deals with the introduction to green chemistry and describing the 12 principles established. Green Chemistry is a branch of chemistry that deal with keeping environment and economic profits on the same balance. Better and more environment-friendly resources can be employed while manufacturing various chemical product which could not only reduce harm to the environment but also increase efficiency and yield. Adhering to these twelve principles can also make the manufacturing processes more efficient in turn help in achieving sustainability.

Green Chemistry: The need of the hour
Green chemistry is an emerging field of chemistry that works at the molecular level to achieve sustainability. This field has received a lot of recognition due to its ability to utilization innovation in the field of chemical science to merge with economical as well as environmental goals. Green chemistry can be defined as study that could help in utilizing a set of principles that reduces or eliminates the use or generation of hazardous substance in the design, manufacture and applications of chemical products.
The idea behind it actually calls for the development of new chemical processes and reaction conditions that can potentially provide benefits for chemical syntheses in terms of resource and energy efficiency, product selectivity, operational simplicity, as well as health and environmental safety.
The idea of green chemistry was first conceptualized and defined in the early 1900s. Since then, these principles are adopted internationally leading to creation of government schemes and initiatives around the globe. One of the early crucial initiatives include US Presidential Green Chemistry Challenge Awards established in 1995.
Because of the approach of the subject, it has been applied to all the sectors including aerospace, automobile, cosmetic, electronics, energy, household products, pharmaceutical, to agriculture.

The 12 Principles of Green Chemistry
Paul Anastas and John Warner were the first ones to introduce these twelve principles in the year 1998.
They are a guiding framework for the design of new chemical products and/or processes, applicable to all aspects of the process life-cycle from the raw materials used to the efficiency and safety of the transformation, the toxicity and biodegradability of products and reagents used.
Following are the principles established by Anastas and Warner:
1. Prevention of Waste: . It is better to prevent waste than to treat orclean up waste after it is formed.It is better to prevent the waste production than to clean it up after. The generation of any material that does not have realized value or the loss of unutilized energy can be considered a waste. It can take various forms and can impact environment differently depending on its toxicity, nature, disposal or even quantity. E-Factor is one of metric used to quantify the amount of waste generate per kg and assess the "environmental acceptability" of a manufacturing process.

2. Atom Economy. Synthetic methods should be designed tomaximize the incorporation of all materials used in theprocess into the final product.
Atom Economy or Atom Efficiency was the concept of synthetic efficient introduced by Barry Frost in the year 1990. It refers to the concept of maximizing the use of raw materials so that the final product contains the maximum number of atoms from the reactants.
3.Less HazardousChemical Synthesis.Wheneverpracticable, synthetic methodologies should be designed touse and generate substances that pose little or no toxicityto human health and the environment.
4. Designing Safer Chemicals. Chemical products should bedesigned to preserve efficacy of the function whilereducing toxicity.
There has been significant focus on designing chemicals on various aspects ranging from medicines to materials but there has also been a surprising lack of interest in taking into consideration hazard in the design process. Understanding the properties of a molecule that have an impact on the environment and the transformations that take place in the biosphere is essential to environmental sustainability. For example, the existing understanding of medicinal chemistry can already help to establish some ground rules for designing less toxic chemicals *via* incorporation of specific design features that block their access into humans and many animal organisms.
5.Safer Solvents and Auxiliaries. The use of auxiliarysubstances (e.g. solvents, separation agents, etc.) shouldbe made unnecessary whenever possible and, when used,innocuous.
Solvents are one of the most active areasod research in green chemistry and impose a crucial challenge because of the mass wasted in the syntheses and processes. Not only that conventional solvents are known to be toxic, flammable and /or corrosive. Because of their volatile and soluble nature, they are contributors to air, water as well as land pollution. Recovery and reuse, when possible, is often associated with energy-intensive distillation and sometimes cross contamination. In an effort to address all those shortcomings, chemists started a search for safer solutions. If possible, the ideal situation would be to not use any chemical solvents. Water being a non- hazardous and easily available solvent is often referred to as benign universal solvent. Using water as solvent can be safer and can be proven as useful in large scale process chemistry.
Apart from certain solventless systems, the new improved green solvents remain auxiliaries and therefore must be isolated from the desired product. If their use cannot be avoided then the issue of separation must be taken into consideration when choosing the appropriate solvent.
6. Design for Energy Efficiency. Energy requirements ofchemical processes should be recognized fortheirenvironmental and economic impacts and should beminimized. If possible, synthetic methods should beconducted at ambient temperature and pressure.
Rising concerns over the depletion of petroleum feedstocks and the increase in energy consumption have pushed the development of more energy efficient processes and for the search for renewable energies; non-depleting resources in a time frame relevant to human scale. Reducing the energy barrier of a chemical reaction or choosing appropriate reactants so that the transformation may proceed at room temperature is one of the examples to reduce energetic requirements. Alternative energies can also be employed. Solar power, wind power, hydro power, geothermal energy are the common sources of renewable energy identified for biofuel production
7. Use of Renewable Feedstocks. A raw material or feedstockshould be renewable rather than depleting whenevertechnically and economically practicable.
The depletion of exhaustible resources will affect aspects of our consumer life and our economy. Turning towards renewable feedstocks both for material and fuel has now become more urgent. The major renewable feedstock on the planet both for material and energy is bio-mass, which can be procured from living organisms. Examples include

cellulose, lignin, suberin and other wood compounds, polyhydroxyalkanoates, lactic acid, chitin, starch, glycerol and oil. Using these could be a good and effective replacement for the current petroleum feedstocks.

8. Reduce Derivatives. Unnecessary derivatization (use ofblocking groups,protection/ deprotection, temporarymodification of physical/chemical processes) should beminimized or avoided, if possible, because such stepsrequire additional reagents and can generate waste.

9. Catalysis. Catalyst (as selective as possible) aresuperior to stoichiometric reagents.

Switching from stoichiometric methodologies to catalytic processes is perceived as one major way to improve the efficiency of the synthetic toolbox. Catalysis can improve the efficiency of a reaction by lowering the energy input required, by avoiding the use of stoichiometric amount of reagents, and by greater product selectivity. This stich would mean less energy, less feedstock and less waste.

Biocatalysis is yet another example of “green” chemistry as it is a biomimetic approach relying on natural or modified enzymes. It usually employs direct use of purified chemicals and the transformations accomplished by engineered living organisms.

10. Design for Degradation. Chemical products should bedesigned so that at the end of their function they breakdown into innocuous degradation products and do notpersist in the environment.

Designing biodegradable materials and chemicals is not a simple task as illustrated by continuing problems of environmental pollution.

11. Real-Time Analysis for Pollution Prevention. Analyticalmethodologies need to be further developed to allow forreal-time, in-process monitoring and control prior to theformation of hazardous substances. The environmental issues associated with analytical chemistry are usually linked to the analytical approach itself.

12. Inherently Safer Chemistry for Accident Prevention.Substances and the form of a substance used in a chemicalprocess should be chosen to minimize the potential forchemical accidents, including releases, explosions,and fires.

Accident prevention can be done by identifying and assessing hazards.

Future challenges

Few of the challenges are listed below:

1. The twelve principles framed are not meant to be implemented independently rather should be employed as one cohesive system. Only through the applications of all principles can one hope to achieve a truly sustainable process.
2. Catalysts are still designed to act on one transformation and still there is little known about multi- functional catalyst. By using the same catalyst on a series of transformations, various independent reactions can be achieved in a single pot which could help us achieve the goal of environmental sustainability.

Conclusion

The concept of Green Chemistry has had a large impact due to the fact that it goes beyond the research laboratory in isolation and has touched industry, education, environment, and the general public. The field of Green Chemistry has demonstrated how chemists can design next generation products and processes so that they are profitable while being good for human health and the environment. Following the scientific enthusiasm of Green Chemistry, teaching initiatives, governmental funding, and the establishment of Green Chemistry Research Centers have multiplied in the past two decades and will increase in future as well.

Green Chemistry is ensuring that the creative ability of various companies in the field of chemistry is practised in a way that creates impact on people and the planet as a design criterion as well as keeping environment sustainability in mind.

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