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Review Paper

Green Technology a Must for Sustainable Future

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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 can simplify operations in chemical productions and seeking greener solvents that are inherently environmentally and ecologically benign. Sustainable development can be defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Current practices by society are not sustainable. Natural resources are being consumed faster than they are being replenished. Global population continues to rise and hazardous materials are being released into the environment in large quantities. Many companies adopt clean and green technologies because of favorable economy. This is only due to the fact that they are able to reduce material consumption, improve and go beyond compliance and significantly lower clean-up costs. Improvements are being made at both the processes, concepts and also at consumer levels.

Keywords: Atom economy, synthetic schemes, sustainable development, chemical feedstock.

INTRODUCTION

Green Chemistry is a relatively new emerging field that strives to work at the molecular level to achieve sustainability. The field has received widespread interest in the past decade due to its ability to harness chemical innovation to meet environmental and economic goals simultaneously. Green Chemistry has a framework of a cohesive set of Twelve Principles. This article covers the concepts of design and the scientific philosophy of Green Chemistry. Green technology is a philosophy with techniques that applies to all areas of chemistry. It is applied not in a single discipline of chemistry but also in innovative scientific solution to real world environmental problems. It is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry is the new and rapid emerging branch of chemistry.

Green chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances [1-2] in the design, manufacture and application of chemical products. This definition and the concept of Green Chemistry were first formulated at the beginning of the 1990s nearly 20 years ago [3]. Several programs and governmental initiatives on Green Chemistry around the world with initial leading

programs located in the U.S., U.K and Italy have played a significant role in informing sustainable design [4]. Green technologies are required essentially to protect our environment from pollution. The most important aspect of Green Chemistry is the concept of design. Design is a statement of human intention and one cannot do design by accident. It includes novelty, planning and systematic conception. The Twelve Principles of Green Chemistry are “design rules” to help chemists to achieve the intentional goal of sustainability. Green Chemistry is characterized by careful planning of chemical synthesis and molecular design to reduce adverse consequences. By utilizing atom economy, design rule, high yields can be achieved even on gram scale, while reaction times are considerably shortened. Growing poverty and income inequality in urban areas have compounded the sanitation problem and many Indian mega-cities have very large slum population. As per 2011 census one in six Indians lives in an urban slum. Urban sanitation sector has been facing a number of challenges in the state of Eastern India. This region faces very high population pressure, water quality issues such as arsenic, iron, bacteriological contamination, lack of proper solid – liquid waste management, climate change impact on water and sanitation infrastructure etc. Green technology is the solution not for waste water management rather for aerospace, automobile, cosmetic, electronics, energy, household products and pharmaceutical to agricultural technologies [5].

The Green Chemistry approach strives to achieve sustainability at the molecular level. 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.

Twelve Principles of Green Chemistry: In 1998, a set of principles to guide the practice of green chemistry was published [6]. The twelve principles address a range of ways to reduce the environmental and health impacts of chemical production and also indicate research priorities for the development of green chemistry technologies.

1. It is better to prevent waste than to treat or clean up waste after it is formed.
2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Chemical products should be designed to preserve efficacy of function while reducing toxicity.
5. The use of auxiliary substances should be made unnecessary wherever possible and innocuous when used.
6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable.
8. Reduce derivatives i.e. Unnecessary derivation should be avoided whenever possible.
9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.
11. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. Substances and the form of a substance used in a chemical process should be chosen to minimize potential for chemical accidents, including releases, explosions and fires.

Green Chemistry for Chemical Synthesis: Over the course of the past decade, green chemistry has demonstrated how fundamental scientific methodologies can protect human health and the environment in an economically beneficial manner. Significant progress is being made in several key research areas, such as catalysis, the design of safer chemicals and environmentally benign solvents and the development of renewable feedstock. Current and future chemists are being trained to design products and processes with

an increased awareness for environmental impact. Outreach activities within the green chemistry community highlight the potential for chemistry to solve many of the global environmental challenges we now face. The origins and basis of green chemistry chart a course for achieving environmental and economic prosperity inherent in a sustainable world. Green chemistry is increasingly seen as a powerful tool that researchers must use to evaluate the environmental impact of nanotechnology [7].

Green Solvents for Sustainable Organic Synthesis: Solvents are consumed in large quantities in many chemical syntheses as well as for cleaning and degreasing. Traditional solvents are often toxic or are chlorinated. Green solvents, on the other hand, are generally derived from renewable resources and biodegrade to innocuous, often naturally occurring product [8-9]. The growing awareness of the pressing need for greener, more sustainable technologies has focused attention on the use of atom efficient catalytic methodologies for the manufacture of fine chemicals and pharmaceuticals. Another aspect which is receiving increasing attention is the use of alternative reaction media that circumvent the problems associated with many of the traditional volatile organic solvents.

The use of nonconventional reaction media also provides opportunities for facilitating the recovery and recycling of the catalyst. The state of the art in the use of alternative reaction media for green, sustainable organic synthesis is reviewed. "The best solvent is no solvent" but if a solvent is needed then water has a lot to recommend it and catalysis in aqueous biphasic systems is an industrially attractive methodology which has found broad application. Similarly, supercritical carbon dioxide is an interesting reaction medium in the context of green chemistry and catalysis in various mono- and biphasic systems involving this solvent are reviewed. It has been found that supercritical carbon dioxide works equally as a blowing agent, without the need for hazardous substances, allowing the polystyrene to be more easily recycled. The CO₂ used in the process is reused from other industries, so the net carbon released from the process is zero. The ultimate in clean catalytic technologies is to telescope multistep syntheses into one-pot in the form of catalytic cascade processes. Examples of such catalytic cascades involving both chemo- and bio-catalytic conversions are presented. Bio-catalysis has a distinct advantage in this context in that the reactions all take place at or close to ambient temperature and pressure.

Green Chemistry Tools to Influence A Medicinal Chemistry: Influencing and improving the environmental performance of a large multi-national pharmaceutical company can be achieved with the help of electronic education tools, backed up by site champions and strong site teams. This paper describes the development of two of those education tools. Ceric Ammonium Nitrate (CAN) has been found to be an efficient catalyst for the solid phase green synthesis of amide derivatives of substituted carboxylic acids with urea in excellent yields under microwave irradiation conditions. The success of the pharmaceutical industry is, in large part, built on the towering achievements of organic chemistry, a mature science which emerged as a distinct discipline well over 150 years ago. This long history is both a blessing and a curse. Many of our most reliable strategies for assembling target molecules employ reactions which are fifty to one hundred years old and often named in honor of their discoverer. During these early years, the chronic toxicological properties of chemicals were often completely unknown and many unwittingly became indispensable tools of the trade. Infamously, benzene was widely employed as a solvent, a hand-cleaner and even as an aftershave, decades before its carcinogenicity [10] became appreciated. Today chemists are still taught the efficacy of chromium, osmium and lead compounds as oxidants, the virtues of chlorinated solvents and the use of atom-inefficient methodologies, while the curricula in most undergraduate chemistry programs provide little or no training in toxicology [11] environmental science [12] or sustainable technology.

Early pioneers in green chemistry included Trost (who developed the atom economy principle) [13] and Sheldon (who developed the E-Factor) [14]. These measures were introduced to encourage the use of more sustainable chemistry and provide some benchmarking data to encourage scientists to aspire to more benign synthesis. Later, green chemistry became formalized by the publication by Warner and Anastas

[15] of a holistic set of principles designed to raise awareness of the safe, environmentally sensitive and sustainable practice of chemistry. While many of these principles were second nature to process development chemists and their manufacturing colleagues in the wake of the pollution control legislation over the last 30 years, the same cannot be said of their medicinal chemistry colleagues. The modern practice of drug discovery relies heavily on speed of execution, which in turn relies on robust methodologies emphasizing reliability rather than environmental impact. While the scale of the reactions conducted at the early stages of a program is usually small, the cumulative footprint generated by tens or hundreds of laboratories in a pharmaceutical company becomes significant. Moreover, the delay that may be incurred by the necessity to reengineer a 'discovery route' to achieve a scalable process impacts the development timeline, as well as its cost. This paper describes ongoing initiatives in Pfizer to equip its medicinal chemists with a working knowledge of the principles of green chemistry, favoring restraint over constraint, and providing access to tools which guide the selection of greener solvents and reagents. We believe the success of these initiatives will reduce our environmental impact, improve worker safety and reduce the time taken to deliver important new medicines addressing major unmet medical needs.

Development of the Solvent Selection Tool: A number of companies have previously published solvent selection guides, more recently Fischer et.al. published a detailed and comprehensive approach to the environmental selection of solvents, though in our view this assessment is too generous to volatile solvents. Volatile solvents have more potential for environmental release and may also have more flammability issues (e.g. pentane or diethyl ether). In reviewing previous work, it was felt that because of the challenges and time pressures associated with the medicinal chemistry job, any tool needed to be extremely simple for the end user scientist. However, this does not mean that the information behind the tool is simple. The work to produce a tool was initiated in our environment, health and safety (EHS) group and solvents were assessed in a thorough and systematic way in three general areas.

(i) Worker safety-including carcinogenicity, mutagenicity, reprotoxicity, skin absorption/sensitization and toxicity.

(ii) Process safety – including flammability, potential for high emissions through high vapour pressure, static charge, potential for peroxide formation and odor issues.

(iii) Environmental and regulatory considerations - including ecotoxicity and ground water contamination, potential EHS regulatory restrictions, ozone depletion potential, photoreactive potential. Of course, compliance with regulations and company guidelines provide the baseline of Pfizer's environmental policy.

REFERENCES

- [1] P. T. Anastas, J. C. Warner, in *Green Chemistry: Theory and Practice*, Oxford University Press, New York, **1998**, I. Horvath and P. T. Anastas, *Chem. Rev.*, **2007**, 107, 2167.
- [2] P. T. Anastas and T. C. Williamson, in *Green Chemistry: Designing Chemistry for the Environment*, American Chemical Series Books, Washington, DC, **1996**, pp. 1–20.
- [3] T. J. Collins, in *Green Chemistry*, Macmillan Encyclopedia of Chemistry, Simon and Schuster Macmillan, New York, **1997**, 2, 691–697.
- [4] W. McDonough, M. Braungart, P. T. Anastas and J. B. Zimmerman, *Environ. Sci. Technol.*, **2003**, 37, 434A.
- [5] Office of Pollution Prevention and Toxics, The Presidential Green Chemistry Challenge, Award Recipients, 1996–2009, US Environmental Protection Agency, Washington, DC, **2009**.
- [6] T. Paul, Warner, C. John, *Green chemistry: theory and practice*, Oxford [England], New York: Oxford University Press, **1998**.
- [7] D. Prat, O. Pardigon, H.W. Flemming, S. Letestu, V. Ducandas, P. Isnard, E. Guntrum, T. Senac, S. Ruisseau, P. Cruciani, P. Hosek, "Sanofi's Solvent Selection Guide: A Step Towards More Sustainable Processes", *Org. Proc. Res. Devel*, **2013**, 17, 1517-1525.
- [8] Sherman J, Chin B, Huibers P. D. T, Garcia-Valls R, Hatton T. A, "Solvent Replacement for Green Processing", *Environ. Health Persp*, **1998**, 106, 253-271.

- [9] The Nobel Prize in Chemistry 2005", The Nobel Foundation. Retrieved 2006-08-04.
- [10] A.S. Matlack, Introduction to Green Chemistry, Marcel Dekker, New York, **2001**.
- [11] Tavakoli, M. Adeli, M. Vossoughi, Nanomedicine, *Nanotechnology, Biology, Medicine*, **2010**, 6, 556.
- [12] H. Ye, L.Jin, R. Hu, Z.Yi, *Biometaterials*, **2006**, 27, 5958.
- [13] J.H.Clark, Green Chemistry: challenges and opportunities, *Green Chem*, **1999**, 1(1), 1-8.
- [14] P.T. Anastas, T.C. Williamson, Green Chemistry: Designing Chemistry for the Environment, ACS publications, Washington DC, **1996**.
- [15] P.T. Anastas, J.C. Warner, Green Chemistry: Theory and Practice, Oxford Science Publications, Oxford, **1998**.

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