

COMMENT

# 25 years of green chemistry

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In its simplest form, green chemistry may be defined as the design of chemical products and processes that reduce or eliminate the generation of hazardous substances. Green chemistry was born out of the Pollution Prevention Act of 1990, and although the “12 Principles of Green Chemistry” how-to guide was not published until 1998, it’s fair to say that green chemistry is roughly at the quarter-century mark, and it is an appropriate time to step back and look at how it has developed.

Not surprisingly, the ACS Committee on Environmental Improvement (CEI) has been linked to green chemistry from the beginning. The vision of CEI is “a sustainable world enabled through the sustainable practice and use of chemistry.” We work to accomplish this through our mission to “advance sustainability thinking and practice across ACS and society for the benefit of Earth and its people.”

Green chemistry has aimed primarily to reduce the use of toxic chemicals and production of waste in industrial processes. Other aspects place the principles in a systems approach and focus on factors such as energy and water usage, as well as minimization of critical materials usage. Green chemistry looks to achieve pollution prevention through molecular design. This strategy minimizes the negative impacts of industrial chemistry on the environment through cooperation among academia, government, and industry.

Unfortunately, green chemistry means different things to different people. I have rarely found it a good thing when different people use the same term to mean different things. Part of the problem is that some people see green chemistry as a social movement. Some associate it with a political movement. Some have tried to define green chemistry as a separate discipline of chemistry. Quite simply, I believe that green chemistry should be synonymous with chemistry. It’s the way all chemists, regardless of discipline, should be thinking.

As chemists, we should be looking at

the complete life cycle of our products and associated processes. Green chemistry is better for the environment. Although chemists and the chemical enterprise have become more environmentally aware and responsible over the past few decades, significant challenges remain. Sustainability is a key principle, and we need to put sustainability front and center in the practices of the chemical enterprise.



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Green chemistry is about redesigning chemical processes from the ground

up, and it goes hand in hand with the sustainable practice of chemistry. If you calculate the total cost of a product, green chemistry is better for the bottom line.

In many ways, the chemical enterprise continues to wrestle with a shallow, limited environmental awareness. Although significant improvements have been made, we still have a long way to go. I would echo the arguments of those who believe that this can be traced, at least in part, to the academic training system for chemists. We tend to focus on specialization for most candidates earning advanced degrees, and only rarely does the established academic framework reward researchers who anticipate environmental harm associated with their work.

Practitioners throughout the chemical enterprise are looking to make their current processes greener. In industry, this is often associated with cost-cutting and efficiency efforts, which brings us to another reality: Cost-benefit analysis will be a key driver in the greening of any given process. Green chemistry doesn’t automatically win; it has to make economic sense. It has often been noted that industry is ahead of academia in the area of green chemistry because there are often larger and more obvious economic drivers for industry. Having said that, it is also frequently noted that the adoption of green chemistry

in industry to date has been focused primarily on incremental improvements in existing processes to increase efficiency. We have a long way to go to see processes redesigned from scratch and plants rebuilt from the ground up, and that is a matter of economics as well as chemistry. The vast majority of all organic chemicals in commerce are still derived from petroleum, which presents a host of other challenges, which I believe can be solved through the

practice of green chemistry throughout the chemical enterprise.

The brief history of green chemistry is marked with extraordinary creativity and accomplishments in meeting the “triple bottom line” of sustainability in economic, social, and environmental performance. This has generally been accomplished by improving a single crucial element or characteristic, such as toxicity, persistence, or energy consumption. Green chemists and engineers are working to get their research and innovations into everyday products and processes, redesigning the basic building blocks of our economy in sustainable ways.

The ACS Green Chemistry Institute continues to be a catalyst for information, networking, and research sharing through the *Nexus* newsletter and blog, the annual Green Chemistry & Engineering Conference, industrial roundtables, and a growing number of educational and research programs.

As we look back at a quarter century of green chemistry, I invite you to join me in celebrating this milestone by recognizing that green chemistry is good chemistry.

I hope that each of you embrace green chemistry in your own discipline and continue to work toward the sustainable practice and use of chemistry for the benefit of Earth and its people.

Views expressed are those of the author and not necessarily those of C&EN or ACS.