

GREEN CHEMISTRY PRINCIPLES

Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. Green chemistry relies on a set of 12 principles that can be used to design or re-design molecules, materials, and chemical transformations to be safer for human health and the environment.

The 12 principles identified by the [American Chemical Society](#) (ACS) Green Chemistry web site include:

1. **Prevent waste:** Design chemical synthesis to prevent waste, leaving no waste to treat or clean up.
2. **Design safer chemicals and products:** Design chemical products to be fully effective yet have little or no toxicity.
3. **Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to humans and the environment.
4. **Use renewable feedstocks:** Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are waste or other processes; depleting feedstocks are made of fossil fuels (petroleum, natural gas, or coal) or are mined.
5. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.
6. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
7. **Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
8. **Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.

9. Increase energy efficient: Run chemical reactions at ambient temperatures and pressure whenever possible.
10. Design chemicals and products to degrade after use” Design chemicals products to break down to innocuous substances after use so they do not accumulate in the environment.
11. Analyze in real time to prevent pollution. Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. Minimize the potential for accidents: Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

EHRS will continue to promote green chemistry principals during education sessions (formal or informal training), resources (such as manuals, guides, and guidelines) as well as during period audits or site visits.

Any questions regarding this program, please contact EHRS at (215) 707-2520.