

12 Principles of Green Chemistry

1. Prevent Waste

Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.

2. Maximize Atom Economy

Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.

3. Design Less Hazardous Chemical Synthesis

Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.

4. Design Safer Chemicals and Products

Request chemical manufacturers to design safe chemicals.

5. Use Safer Solvents and Reaction Conditions

Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.

6. Increase Energy Efficiency

Run chemical reactions at room temperature and pressure whenever possible.

7. Use Renewable Energy

Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas or coal) or mining operations.

8. Avoid Chemical Derivatives

Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.

9. Use Catalysts instead of Stoichiometric Reagents

Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.

10. Design Chemicals and Products to Degrade

Design chemical products to break down to innocuous substances after use so that 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 physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires and releases to the environment.

