

12 PRINCIPLES OF GREEN CHEMISTRY

1. **Prevention:** it is better to prevent waste than to treat or clean up waste after it has been created;
2. **Atom Economy:** synthetic methods should be designed to maximize incorporation of all materials used in the process into the final product;
3. **Less Hazardous Chemical Synthesis:** wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment;
4. **Designing Safer Chemicals:** chemical products should be designed to preserved efficacy of function while reducing toxicity;
5. **Safer Solvents and Auxiliaries:** the use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever possible and, innocuous when used;
6. **Design for Energy Efficiency:** 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. **Use of Renewable Feedstocks:** a raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable;
8. **Reduce Derivatives:** Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste;
9. **Catalysis:** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents;
10. **Design for Degradation:** chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment;

11. **Real-time analysis for Pollution Prevention:** 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. **Inherently Safer Chemistry for Accident Prevention:** Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.