

# 12 Principles of Green Chemistry\*



**MILLIPORE SIGMA**

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## 1 Waste Prevention



It is better to prevent waste than to treat or clean it up after it's been created.

## 2 Atom Economy



Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product

## 3 Less Hazardous Chemical Syntheses



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 affect their desired function while minimizing their 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 of chemical processes should be minimized. If possible, 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. Such steps require additional reagents and can generate waste.

## 9 Catalysis



Catalytic reagents (as selective as possible) should be used in place of 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

For more information, visit: [Beyond Benign](#)



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\*Anastas, Paul T., and John Charles Warner. Green Chemistry: Theory and Practice. Oxford University Press, 1998