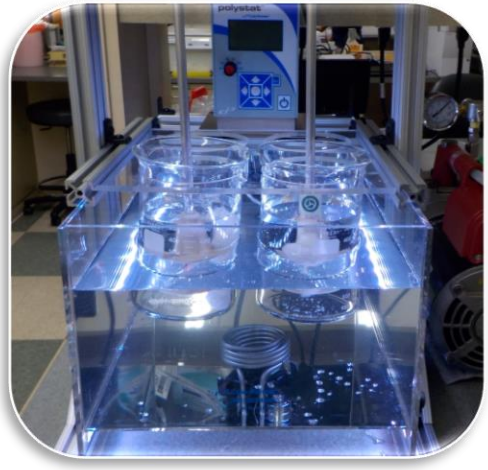
What Is Green Chemistry and Green Engineering?

Almost everything around us is made from materials that humans changed, or modified, from how they were created in nature. In some cases, these changes can be small, such as cutting down a tree to use the wood to build a cabin or using a waterwheel to make electricity from moving water. Sometimes the changes are very big, as when minerals are separated from rocks to make computer chips or specific molecules are extracted from oil to make medicines. All of these changes use energy, make waste, and **might** use or produce materials that are harmful to humans and to the environment.

The goal of any chemist is to develop new ways to make and produce chemicals and materials. Green chemists, and the field of green chemistry, work to make sure these discoveries and materials are also safe for humans and the environment. To accomplish this, they developed 12 guidelines—like rules, but not as strict—called the 12 Principles of Green Chemistry. These principles help green chemists keep the environment in mind as they develop new materials and are grouped into two main categories: safer chemicals and lower waste production.



Safer chemicals and processes

What does safety and a safer environment mean to you? When most people think about being safe they worry about getting hurt in a way you can see right away, like by a fall. Green chemists worry about people, animals, and plants getting hurt too. They think about how the materials they use, the products they make, and the way they make them will affect the people, animals, and plants around them. They try to do things that are safer, more sustainable, for everyone.

You may wonder why it is important to have safe chemicals—can't we just make sure that dangerous chemicals don't get into the environment? Well, we can try really hard, but it doesn't always work. Just look at the Exxon Valdez spill, the Deepwater Horizon accident, or the Great Smog of 1952. Those were all times when we thought we were protected from harmful chemicals but something unexpected happened and in the end plant, animal, and human communities all suffered.

Less waste

When thinking about the environment, it is always good practice to think about making—or generating—less waste. Waste comes in many forms, including making unwanted side products (unwanted extra products), getting less out for what you put in (lower yields), and using extra energy. All of that waste means more inputs—ingredients, energy, etc.—are used to make each product or output.

As green chemists continue to discover and to invent new materials to make our lives better, they need to make sure they never forget how those materials might affect the Earth and its environment. This doesn't mean they should stop inventing. Rather, they need to keep in mind that the need for greener, safer materials is good for the environment and is a source of endless opportunity.

12 Principles of Green Chemistry

Principle Number	Principle of Green Chemistry Official Language	Principle of Green Chemistry Everyday Language
1	**Prevention** It is better to prevent waste than to treat or clean up waste after it has been created.	It is better not to make a mess than to have to clean it up.
2	**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.	Use ingredients, or input materials, that are safe and good for/harmless to the environment.
3	**Designing Safer Chemicals** Chemical products should be designed to affect their desired function while minimizing their toxicity.	When designing new chemicals or materials, make sure they are safe.
4	**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.	If you need to mix everything in a liquid to make your new chemical or material, make sure that liquid is not harmful. When possible, use water.
5	**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.	Develop tools and instruments to measure pollution and waste AS IT IS MADE (real-time) instead of having to take samples to the lab to test later.
6	**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.	Use ingredients, or input materials, and recipes, or chemical processes, that are safe and less likely to cause an accident.
7	**Atom Economy** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product	Try to make all the different ingredients you have all useful, so you don't have to throw them away.
8	**Design for Energy Efficiency** Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.	Deign new chemicals or materials that can be made under mild conditions, for example, at room temperature (versus very high or very low temperature) or at normal pressure (versus high or low pressure).
9	**Catalysis** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.	If you need to use an ingredient, or input, that you will end up throwing away, design your process and choose an ingredient of which you will only need to use a little bit.
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.	Design new materials and chemicals that are compostable and biodegradable.
11	**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.	When possible, use simple ingredients, input chemicals, and ways to make things.
12	**Use of Renewable Feedstocks** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.	Use input materials that are renewable, i.e., that can be quickly replaced. One example is bamboo. Another example is hemp.