



The principles of green chemistry: How does PureTemp fare?

Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Unlike most phase change materials, PureTemp products are well-aligned with the principles of green chemistry.

Developed by Paul Anastas and John Warner*, the following list outlines an early conception of what would make a greener chemical, process or product. Their principles became the guiding force in the practice of green chemistry, also known as sustainable chemistry.

Our chemists have always kept these guidelines in mind during their research and development efforts. Dr. William R. Sutterlin, Entropy Solutions' chief chemical officer, is a recipient of the prestigious Presidential Green Chemistry Challenge Award based on the 12 principles. Green chemistry concepts apply across the entire life cycle of a chemical product and we keep these goals in mind through design, sourcing, manufacturing, use and end-of-life disposal considerations.

Here's how PureTemp measures up:

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. PureTemp chemical syntheses are designed to prevent waste. In fact, the main byproduct is water.

2. **Atom Economy**

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product. Our chemists estimate that, on average, the manufacture of PureTemp products realize 95% atom utilization.

- 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. Feedstock raw materials and byproducts of PureTemp manufacturing have little or no toxicity to humans and the environment.
- 4. Designing Safer Chemicals**
Chemical products should be designed to affect their desired function while minimizing their toxicity. PureTemp products generally have little or no 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. Solvents are not used in the production of PureTemp.
- 6. 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. While some PureTemps are produced at ambient temperatures and pressures, others do require higher amounts of each. Generally, the temperatures and pressures used are considered very moderate.
- 7. Use of Renewable Feedstocks**
A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable. All PureTemp products originate from renewable feedstocks. We are actively researching ways to use materials considered to be waste of other processes.
- 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. Chemical derivatives are not used in the production of PureTemp products.
- 9. Catalysis**
Catalytic reagents (as selective as possible) are superior to stoichiometric reagents. Small amounts of catalysts are used in PureTemp production. Stoichiometric reagents are not.
- 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. Testing has shown that PureTemp materials are readily biodegradable, often in months.

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. This is not necessary for production of PureTemp materials since the byproduct of the synthesis is typically water.

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. Safety has always been a focus of PureTemp production and handling processes.

Unlike most phase change materials, PureTemp products are strongly aligned with the principles of green chemistry. That alignment reflects our continuing commitment to developing chemical processes and earth-friendly products that reduce demand on diminishing resources.

** Anastas, P.T.; Warner, J. C., "Green Chemistry: Theory and Practice," Oxford University Press: New York, 1998, p. 30.*