

## The 12 Principles of Green Chemistry

Green chemistry- maximising efficiency and minimising hazardous effects on human health and the environment

### 1. Waste prevention:

Prioritise the prevention of waste, rather than cleaning up and treating waste after it has been created. Plan ahead to minimise waste at every step.

### 2. Atom economy:

Reduce waste at the molecular level by maximising the number of atoms from all reagents that are incorporated into the final product. Use atom economy to evaluate reaction efficiency.

### 3. Less hazardous chemical synthesis:

Design chemical reactions and synthetic routes to be as safe as possible. Consider the hazards of all substances handled during the reaction, including waste.

### 4. Designing safer chemicals:

Minimise toxicity directly by molecular design. Predict and evaluate aspects such as physical properties, toxicity, and environmental fate throughout the design process.

### 5. Safer solvents and auxiliaries:

Choose the safest solvent available for any given step. Minimise the total amount of solvents and auxiliary substances used, as these make up a large percentage of the total waste created.

### 6. Design for energy efficiency:

Choose least energy-intensive chemical route. Avoid heating and cooling, as well as pressurised and vacuum conditions (i.e. ambient temperature and pressure are optimal).

### 7. Use of renewable feedstocks:

Use chemicals which are made from renewable (i.e. plant-based) sources, rather than other, equivalent chemicals originating from petrochemical sources.

#### 8. Reduce derivatives:

Minimise the use of temporary derivatives such as protecting groups. Avoid derivatives to reduce reaction steps, resources required, and waste created.

#### 9. Catalysis:

Use catalytic instead of stoichiometric reagents in reactions. Choose catalysts to help increase selectivity, minimise waste, and reduce reaction times and energy demands.

#### 10. Design for degradation:

Design chemicals that degrade and can be discarded easily. Ensure that both chemicals and their degradation products are not toxic, bio-accumulative, or environmentally persistent.

#### 11. Real-time pollution prevention:

Monitor chemical reactions in real-time as they occur to prevent the formation and release of any potentially hazardous and polluting substances.

#### 12. Safer chemistry for accident prevention:

Choose and develop chemical procedures that are safer and inherently minimise the risk of accidents. Know the possible risks and assess them beforehand.