 

**MIDDLE SCHOOL**

**Green Chemistry**

**Sustainability Bingo**

**Goal:** To provide students with reinforcement for the understanding of the concept of green chemistry and the scientific terminology used in the 12 Principles of Green Chemistry.

**Objectives:** Students will …

* Identify the 12 Principles of Green Chemistry in simplified terms

**Materials:**

* Bingo with Greg – Bingo Cards

**Time Required:** 45–60 minute class period

**Standards Met:**

* Abilities necessary to do scientific inquiry

**Green Chemistry Principles Addressed:** 1–12 (see Bingo Cards)

**Procedure:**

IN CLASS

* Pass out Bingo cards to students
* Read simplified principles or give examples (see teacher information sheet)
* Follow rules of Bingo

**Assessment:**

* Correctly identifying definitions on cards

**Sustainability Bingo – Card 1**

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| 1. **Prevention.** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up. | 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. | 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. |
| 2. **Atom Economy.** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms. | 6. **Design for Energy Efficiency.** Run chemical reactions at ambient temperature and pressure whenever possible. | 10. **Design for Degradation.** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment. |
| 3. **Less Hazardous Chemical Synthesis.** Design syntheses to use and generate substances with little or no toxicity to humans and the environment. | 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | 11. **Real-time Analysis for Pollution Prevention.** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts. |

**Sustainability Bingo – Card 2**

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| 1. **Prevention.** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up. | 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. | 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. |
| 2. **Atom Economy.** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms. | 6. **Design for Energy Efficiency.** Run chemical reactions at ambient temperature and pressure whenever possible. | 10. **Design for Degradation.** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment. |
| 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. | 8. **Reduce Derivatives.** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste. | 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. |

**Sustainability Bingo – Card 3**

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| 1. **Prevention.** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up. | 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. | 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. |
| 3. **Less Hazardous Chemical Synthesis.** Design syntheses to use and generate substances with little or no toxicity to humans and the environment. | 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | 11. **Real-time Analysis for Pollution Prevention.** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts. |
| 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. | 8. **Reduce Derivatives.** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste. | 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. |

**Sustainability Bingo – Card 4**

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| 2. **Atom Economy.** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms. | 6. **Design for Energy Efficiency.** Run chemical reactions at ambient temperature and pressure whenever possible. | 10. **Design for Degradation.** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment. |
| 3. **Less Hazardous Chemical Synthesis.** Design syntheses to use and generate substances with little or no toxicity to humans and the environment. | 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | 11. **Real-time Analysis for Pollution Prevention.** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts. |
| 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. | 8. **Reduce Derivatives.** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste. | 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. |

**Sustainability Bingo – Card 5**

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| 8. **Reduce Derivatives.** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste. | 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. | 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. |
| 2. **Atom Economy.** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms. | 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. | 10. **Design for Degradation.** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment. |
| 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. | 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | 11. **Real-time Analysis for Pollution Prevention.** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts. |

**Sustainability Bingo – Card 6**

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| 1. **Prevention.** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up. | 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. | 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. |
| 2. **Atom Economy.** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms. | 6. **Design for Energy Efficiency.** Run chemical reactions at ambient temperature and pressure whenever possible. | 10. **Design for Degradation.** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment. |
| 3. **Less Hazardous Chemical Synthesis.** Design syntheses to use and generate substances with little or no toxicity to humans and the environment. | 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | 11. **Real-time Analysis for Pollution Prevention.** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts. |
| 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. | 8. **Reduce Derivatives.** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste. | 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. |

**Sustainability Bingo – Card 7**

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| 1. **Prevention.** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up. | 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. | 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. |
| 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | 6. **Design for Energy Efficiency.** Run chemical reactions at ambient temperature and pressure whenever possible. | 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. |
| 3. **Less Hazardous Chemical Synthesis.** Design syntheses to use and generate substances with little or no toxicity to humans and the environment. | 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. | 11. **Real-time Analysis for Pollution Prevention.** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts. |

**Sustainability Bingo – Card 8**

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| 8. **Reduce Derivatives.** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste. | 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. | 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. |
| 2. **Atom Economy.** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms. | 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. | 10. **Design for Degradation.** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment. |
| 3. **Less Hazardous Chemical Synthesis.** Design syntheses to use and generate substances with little or no toxicity to humans and the environment. | 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. |

**12 Principles Demystified:**

**Teacher Information Sheet**

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| **Principle** | **Simplified Form** | **Examples** |
| 1. **Prevention.** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up. | Prevent waste so you don’t have to clean it up later | Only take as much food as you will eat |
| 2. **Atom Economy.** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms. | Avoid a process that creates waste.  How are products made? Atoms are assembled together to make materials. It is best to use all the atoms in a process. Those atoms that are not used end up as waste | Making a valentine’s day card. When you cut out the heart, you can use both the heart and the heart outline left by the blank space |
| 3. **Less Hazardous Chemical Synthesis.** Design syntheses to use and generate substances with little or no toxicity to humans and the environment. | Use less hazardous reagents and chemicals in the process to make products (focus on the process, not the product) | Hair dye. The process of dying hair can be toxic and actually burn the hair. There are less toxic ways to dye hair, like lemon juice & sunshine. The final product (hopefully) looks good |
| 4. **Designing Safer Chemicals.** Design chemical products to be fully effective, yet have little or no toxicity. | This principle focuses on the product, not the process. Make safe products that work. | DDT. Pesticides can be extremely toxic. We now have more benign choices |
| 5. **Safer Solvents & Auxiliaries.** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals. | Create products so that they use less hazardous solvents (such as water). | Imagine dissolving Kool Aid in acetone, instead of water |
| 6. **Design for Energy Efficiency.** Run chemical reactions at ambient temperature and pressure whenever possible. | Use less energy to create products. Run reactions at room temperature, don’t freeze or heat them. | Letting warm food sit on the countertop and come to room temperature before storing it in the refrigerator |
| 7. **Use of Renewable Feedstocks.** Use raw materials and feedstocks that are renewable. Renewable feedstocks = farm products or the wastes of other processes; depleting feedstocks = fossil fuels (petroleum, natural gas, or coal) or are mined. | Make products from renewable materials; things that are replaceable or can grow back. Don’t make products from fossil fuels, like gas.  (90-95% of the products we use in our everyday lives are made from petroleum.) | Start a fire. You could use gas (a petroleum product) to start it or newspaper (a renewable resource) |
| 8. **Reduce Derivatives.** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste. | Let the atoms & molecules be what they want to be. Don’t try to change their natural properties. | Imagine you are hosting a dinner party and short a chair. You could ask a guest to perform the duties of a chair. |
| 9. **Catalysis.** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once. | In a chemical process, catalysts make reactions happen more quickly. Just a little bit of a catalyst can be used over and over again so there is less waste. | Tennis racket that acts as a catalyst to move the ball. What if it didn’t have strings and was covered with plastic wrap. You would have to replace the racket each time. That is a stoichiometric reaction. |
| 10. **Design for Degradation.** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment. | Stop filling the landfill. Make products that will break down into safe substances after we finish using them. | What if there was stronger toilet paper that did not break down in water? What a waste! |
| 11. **Real-time Analysis for Pollution Prevention.** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts. | Pay attention to your chemical reaction and collect data while it is happening. That way, you won’t mess it up. | If you made pudding without stirring it and watching the temperature, it would burn and taste terrible. |
| 12. **Inherently Safer Chemistry for Accident Prevention.** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment. | Focus on safety for the worker. Explosions in the lab are bad. | Hand a teenager bleach and ammonia to clean the bathroom. |