**Extend the Learning:**

**What are the Principles of Green Chemistry**

Green Chemistry has 12 specific rules, or **principles**, it follows. These principles ensure that scientists will follow the core tenets of creating products that are efficient for the environment, made of inexpensive materials, and provide a valuable use to the consumer.

To do this activity, you will form into groups of 3-4 individuals. Each of you should choose one of the following job roles and then you will read the 12 Principles provided below and research any words you are unfamiliar with.

**Job Roles**

* 1. **Facilitator** - Makes sure the team starts quickly and remains focused; manages time; makes sure all voices are heard during discussion.
  2. **Reader** - Reads the article out-loud to their group mates. Makes brief checks for understanding with the assistance of the Strategy Analyst.
  3. **Strategy Analyst** - Assists with check-ins for understanding of the text read. Engages in research of words requested by the group.
  4. **Recorder** - records names and roles of group members; records group’s thoughts on the post-reading questions.

**The 12 Principles of Green Chemistry**

(taken and edited from Beyond Benign)

1. ***Pollution Prevention***: It is better to prevent waste than clean it up after-the-fact, so the goal is to create less waste from an experiment.

2. ***Atom Economy***: This principle gets more into the actual chemistry of how products are made. As chemists, atoms are assembled to make molecules which are then used to make materials. This principle says that it is best to use all the atoms in a process to prevent atomic waste.

3. ***Less Hazardous Chemical Synthesis***: This principle is aimed at reducing the hazards in a chemical process, so that it is safer to make a product. This also often makes a chemical process more efficient too!

4. ***Designing Safer Chemicals***: Whereas principle 3 focuses on the process of chemical manufacture, this one focuses on the chemical itself. The goal is to design chemicals that are less toxic or not toxic at all.

5. ***Safer Solvents and Auxiliaries***: Many chemical reactions are done in a solvent. Traditionally, organic solvents have been used that pose hazards and/or are highly toxic (such as nail polish remover). A specific type, called volatile organic compounds (VOC’s), add to pollution and can be highly hazardous to humans. This principle focuses on creating products that use less hazardous solvents (such as water).

6. ***Design for Energy Efficiency***: Today, there is a focus on renewable energy and energy conservation. This principle focuses on creating energy efficient reactions to make a product.

7. ***Use of Renewable Feedstocks***: 90-95% of the products we use in our everyday lives are made from petroleum. Our society not only depends on petroleum for transportation and energy, but also for making products. This principle seeks to shift our dependence on petroleum and to make products from renewable materials that can be gathered or harvested locally, such as biofuels.

8. ***Reduce Derivatives***: In chemistry, we regularly engage in the manipulation of molecules in order to shape the molecules into what we want them to look like. This often produces unwanted extra products (derivatives). This principle looks at these processes and aims to reduce the manufacture of those derivatives.

9. ***Catalysis***: In a chemical process catalysts are used in order to reduce energy requirements and to make reactions happen more efficiently (and many times quicker). Very little of a catalyst is required to have an effect and sometimes, a can be truly “green” and will have little to no toxicity, perhaps even being able to be used over-and-over again.

10. ***Design for Degradation***: Not only do we want our materials to come from renewable resources, but we would also like them to decompose quickly. This principle seeks to design products to perform their intended function and then, when appropriate, degrade into safe, innocuous by-products.

11. ***Real-time Analysis for Pollution Prevention***: Chemists, like bakers, need to be able to answer the following questions: How long do I allow the reaction/baking to run? When do I know it will be “done”? Knowing exactly when it would be “done”, would reduce waste in the manufacturing process and ensure that your product is the one that you intended to make.

12. ***Inherently Safer Chemistry for Accident Prevention***: This principle focuses on safety for the worker. It is better to use materials and chemicals that will not explode, catch fire, ignite in air, etc. when making a product. So, these kinds of chemicals should be avoided whenever possible.

**Post-Reading Questions**

1. What were 3 words that you needed to look up as a group to understand the reading better? What did they mean in the context of the reading?

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| **Word** | **Meaning in Context of the Reading** |
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1. What would you like to **A**sk the author about within the text?

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| Your answer: |

1. What **A**spect would you want to engage in further research about? Why?

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| Your answer: |

1. What parts of the text do you want to **A**spire to?

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| --- |
| Your answer: |

1. How do you see the 12 principles applying to some aspect of your everyday life? Try to answer this question by specifically identifying at least 3 of them. For example, many coffee houses have switched from using plastic stirrers to wooden stirrers, which follows principle 10 (design for degradation).

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| Your answer: |