 E-Factor

**HIGH SCHOOL**

**Green Chemistry & Sustainable Science**

**Teacher Background Information:** The Environmental Impact Factor (E-Factor) relates to the 2nd Principle of Green Chemistry, Atom Economy. Frequently applied in an industrial sense, the E-Factor compares the amount of useful product to the amount of waste produced in a chemical process.

**Safety Information:** Do not allow students to eat potato chips that come in contact with any lab equipment or contaminated surfaces.

**Educational Goals:** To understand the Environmental Impact Factor (E-Factor) and how it is used in chemical processes and how it can be applied to everyday life.

**Student Objectives:** Students will…

* Use models to practice calculating E-Factors
* Relate E-Factor to chemical processes

**Materials:**

* Digital scale
* Clear waste container (1-2 L size)
* Fun size M&M’S (one per student)
* Bulk bag of M&M’S
* 2 single serve bags of potato chips

**Time Required:** One 45-minute class period

**NGSS Standards Met:**

* **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
* **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
* **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

**Key Terms**: Atom economy, percent yield, green chemistry principles

**Teacher Prep:** Use the bulk bag of M&M’S to prepare five baggies of M&M’S as shown in the table below. (Baggies of M&M’s do not need to be precise ratios, but should range in the ratio of green M&M’s to other colored M&M’s. Ex: One bag should look similarly to the exemplar in the table next to petrochemicals with a composition being mostly green M&M’s, while another bag modeling pharmaceuticals should only have approximately one green M&M in it.) Fill your chosen waste container half full with water.

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| **E-Factor** | **M&M’S Model** | **Industry Segment** |
| 0.1 | ef0 | **Petrochemicals**  A chemical derived from Petroleum or natural gas  Example: Solvents detergents, adhesives |
| 1 | ef1 | **Bulk Chemicals**  Plastics and polymers  Example: plastic bottles, grocery bags |
| 10 | ef10 |
| 100 | ef100 | **Fine Chemicals**  Chemicals used to make specific items  Example: coating on laptop screens, electronics parts |
| 250 | ef250 | **Pharmaceuticals**  Example: antibiotics, blood thinners |

**Keys for Success:**

This activity may be completed in its entirety as described below, or you could use only one of the included activities.

Other household items could be substituted for the M&M’S, for example you could use different types of dried beans (kidney, pinto, navy, etc.).

You may wish to provide a second bag of M&M’S per student to pass out after student pour their “waste” M&M’S into the waste container.

Large glassware works well as a waste container.

**Procedure:**

* Give students the E-Factor equation below:

E-Factor ≡ mass of waste ÷ mass of product

* Ask the students for 4 volunteers who are ready for a snack.
* Ask the volunteers to come to the front of the class.
* Tell students that the goal of this experiment is to satisfy your need for a quick snack and to test out our equation using these individually packaged potato chips.
* Ask the students to unpack the potato chips and make a pile of chips and a pile of waste. You may want to have students use gloves at this stage so that they can eat the chips after.
* Ask the students to find the mass of the chips and then the mass of the packaging and record the totals on the board.
* Explain to the students that we are not finished, as we have not yet used a key component in green chemistry, principle #4, and tested to see if this product retains its efficacy. Therefore, the volunteers will need to eat the chips and tell us if they satisfy their craving for a snack. Provide the second bag of chips to the student to eat and discard of the chips that have been weighed.
* While they eat, have another student come up and solve the E-Factor equation for the potato chips.
* Debrief with students as to how well the product performed in regards to its E-Factor. Make sure you to discuss the intent behind the packaging and why the company may have chosen it.
* Ask students how the E-Factor of this product might be improved.
* Ask students to get into groups of two or three.
* Tell the students that green chemists use E-Factor to evaluate chemical processes, so at this point you will be passing out bags of “chemicals”.
* Hand out a small bag of M&M’S to each group of students.
* Ask students to separate the green M&M’S from the other colors and make two piles. It turns out that green M&M’S have been discovered to be a key component in a new technology that makes hologram images come out of smart phones so that people can have a more realistic video chat.
* Ask students to calculate the E-Factor for the bag of M&M’S.
* The green part is actually the chemical that you need. So, unfortunately, the only ones that you can use are the green ones. Collect the “waste” in the prepared waste container.
* Ask the students to tell you how they feel about having all this waste in order for them to have hologram images of their friends come out of their smart phones.
* Tell the students that you are going to give them another equation to help them be creative.
* Put the following equation on the board:

E-Factor = (mass of inputs - mass of outputs) ÷ mass of product

* Ask students to creatively come up with ways that they could reduce the E-Factor. Discuss with students their possibilities, real or imagined. As a reward for their creativity, pass out the extra bags of M&M’S.
* Acknowledge that the hologram video chat is not real (yet!), but E-Factor is actually being used to consider real technologies.
* Show students the pre-prepared bags of M&M’S and explain how these bags represent chemical processes.