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Course: Chemistry
Instructor: Brandon Rodriguez

Lesson: Implementation & Reflection
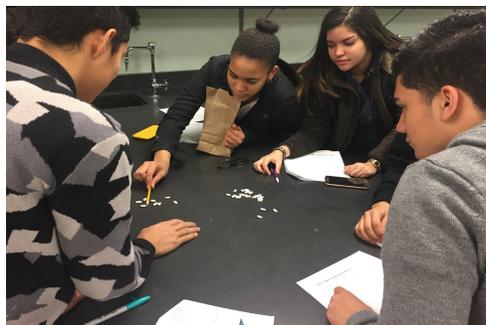
Lesson: Half-life with beans or M&Ms
1. **Description of the Resource**

My 12th grade AP Environmental Science students have become environmental activists this year. Through a partnership with Hibakusha stories (https://hibakushastories.org/), my students were able to board the sloop Clearwater and sail the Hudson River towards Indian Point, a three-unit nuclear power plant located just 50 miles from New York City, to raise awareness of the hazard this nuclear plant represents for the city, and to demand the dismantlement of this decommissioned nuclear plant.
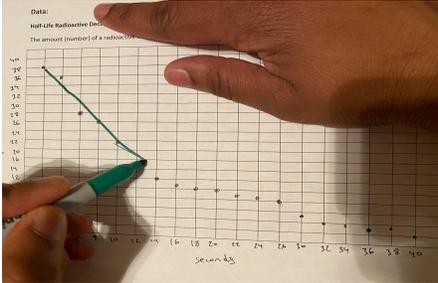
Prior to the sailing, the students did intensive research on nuclear plants, worked on two case studies (Chernobyl and Fukushima), and learned the chemistry behind nuclear energy.

One of the experiments we carried out in the classroom was the half-life experiment, for students to understand half-lives, and radioactive dating. Because we did not have emanems in school, I used beans that we previously marked, and served the same purpose. The activity I followed corresponds to one of the resources of this course and can be found here: http://nuclearconnect.org/in-the-classroom/for-teachers/half-life-of-paper-mms-pennies-or-puzzle-pieces.

2. **Student artifacts**

	A group of students is separating the "radioactive" beans from the ones that are not radioactive. Students dump the beans onto the table and record how many are still radioactive. The radioactive beans have the "m" label facing up.

	A student is drawing the line of best fit. After drawing the line of best fit, students were asked to calculate the half-life for the beans. Most of them got a number between 12 and 18 seconds.
	Students partnered with Clearwaters to sail to the Nuclear Plant (Indian Point) and to demand the closure of the facility. These environmental advocates measured the temperature of the water and salinity near the plant to compare it with the same variables far away from the plant. They also got to catch and release some of the Hudson river fish, to learn a little more about the biodiversity in the river.
	We visited :"The Hiroshima Panels", and met Toshi Maruki, a Nagasaki survivor and the artist who created the Hiroshima panels that represent the suffering of people caused by the nuclear bombs of Hiroshima and Nagasaki. The students had a chance to visit the exhibit and chat with Toshi about his own experience.

3. Reflection

The lab " Half-life of M&M's" came in a perfect moment, as we were involved in the Hibakusha project, and students were learning about nuclear energy and nuclear disarmament. The lab was very visual and engaging enough for students to capture what the "half-life" of an element meant. When we finished the lab, we compared the half-life of our beans with the half-life of Uranium-235, the most common element used in nuclear plants (main component of "Little boy"), and with Plutonium-239, the main component of "Fat Man", detonated over the city of Nagasaki on 9 August 1945.

Students also discovered from the lab that radioactive decay is also used to date fossils, rocks and even the age of the Earth itself; they were blown away by the fact that scientists estimate the age of Earth based on the half-life of Uranium.

As I said before, this lab was not particularly academically challenging for my AP Environmental Students; however, it provided a great opportunity to investigate radioactive decay, and to talk

about the importance of the "half-life" of an element to estimate how long a certain chemical element could become a human health hazard; this brought up interesting ideas such as why people are becoming tourists in the Exclusion Zone in Chernobyl, and how countries are planning to dispose radioactive materials, based on their half-life.

Pedagogical approach
The pedagogical approach that I follow in the AP environmental science class is always a holistic and integrated approach that has the goal of showing students of the interconnectivity of the different disciplines, including the different sciences, and math but also literature, politics and economy. In the AP environmental science class, my students work in short and long-term projects that have the ultimate goal to develop critical thinking and to make the learning experience meaningful and real for the students.

As I monitored thermal pollution in a nuclear plant a number of years ago myself, I was able to bring to my students my first-hand experience with nuclear plants, and I was able to ignite my students' curiosity about nuclear plants, advantages, disadvantages and unfortunate accidents that occured around the world. Creating partnerships with external organizations is one of the pedagogical approaches I use in my classroom; in this way, I foster my students' curiosity on a topic in which they get academically and personally involved, turning them into scientists, researchers and environmental activists. The complete sequencing of this project was a success; and until today, my students still talk about how much this experience impacted them.

AP Environmental Science Ms. Antunez 12th grade	Lab #_____ Half-life of M&M's (or beans) Name:_____Date:_____ Lab modified from http://nuclearconnect.org/in-the-classroom/for-teachers/half-life-of-paper-mms-pennies-or-puzzle-pieces

Purpose

- To define the terms half-life and radioactive decay

- To model the rate of radioactive decay

- To create line graphs from collected data

- To compare data

- To understand how radioactive decay is used to date archaeological artifacts

Background: Pretend that the 40 M&Ms in the sample you are given is a radioactive isotope of the regular M&Ms most people love to eat. The y-axis of your graph represents the amount of M&M "atoms" that are radioactive. The x-axis of the graph represents the time elapsed. By definition, the half-life is the amount of time it takes for a radioactive isotope's atoms to decay so that the sample reaches half of its previous radioactivity. This means that only half of the original amount of radioactive substance is still radioactive. If this amount of elapsed time is repeated, only half of that remaining radioactive amount will still be radioactive.

Procedure: Set up your graph labels and numbers. Every y-axis line represents 2 M&Ms, up to 40. Every x-axis line represents 2 seconds, up to 40 s. Consider your pure M&M isotope to have all of its atoms radioactive before time elapses. This means the first data point on your graph is at (0 s, 40 radioactive M&Ms). Gently shake the M&Ms in the Ziplock bag for 10 seconds. Then dump the M&Ms onto your paper plate and record how many M&Ms are still radioactive. The radioactive M&Ms will still have the "m" label. (You may eat the M&Ms that do not have the "m" label, as they have already decayed and are no longer "radioactive".) Plot this new reduced amount (number of radioactive M&Ms) on your graph at 2 seconds of elapsed time. Then put these remaining "radioactive" M&Ms back into the Ziplock bag. Repeat this process every 2 seconds until there isn't enough radioactive sample left to work with. If the points on your graph indicate a straight line, draw a best-fit straight line through your data points. If the data points

suggest a curve, draw a best-fit gentle curve going through the data points. (No Ziggy-zaggy short lines!)

Materials:

- Bag of: M&M's ®, pennies or, puzzle pieces
- Paper – 8.5˝ x 11˝
- Graph Paper
- Zip-Lock Bags
- Pen, Marker, or Pencil
- Student graphing paper

Data Table

Time (seconds)	Decayed M&M's	Remaining M&M's
2		
4		
6		
8		
10		
12		
14		
16		
18		
20		
22		
24		
16		
28		

30		
32		
34		

Graphing paper

Data:

Half-Life Radioactive Decay Plot of a Radioactive Isotope of M&M Atoms.

The amount (number) of a radioactive isotope of M&Ms is plotted as a function of elapsed time.
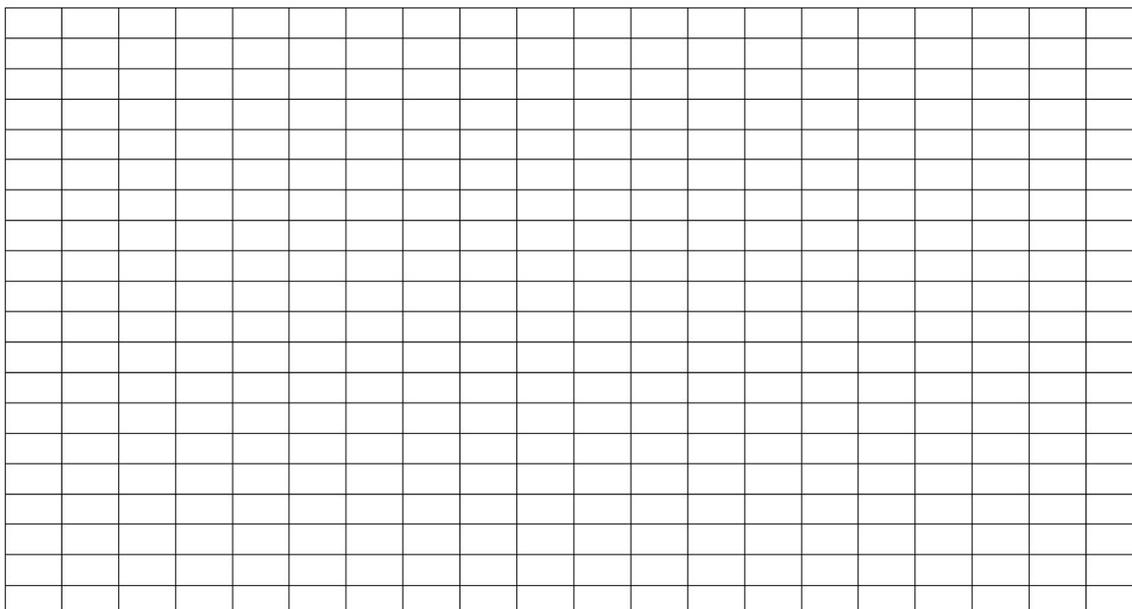
 Questions for Discussion:

1. What is the half-life of your "radioactive" isotope sample of M&Ms?

2. Define the term half-life.

3. What does it mean when we say an atom has "decayed"?

4. Do the number of atoms you start with affect the outcome? Explain.

5. If you re-did the lab with a larger-sized 500-M&M sample of the same isotope of radioactive M&Ms, how would the new curve compare with the original one? Would the half-life still be the same? Explain.

6. Did each group get the same results?

7. Did any group still have candies remaining after Trial 7?

8. Why do the totals for the 10 groups better show what happens during half-life rather than any other group's results?

9. What does the line of best-fit indicate about the nature of the decay of radionuclides?

10. How do scientists use radioactive decay to date fossils and artifacts?

11. How would you calculate the age of Earth from uranium-238? (You will need to find the half-life of U-238 and how much of it is left on Earth)

12. Now write your APES Lab Report following the guideline below:

How to Write an AP Lab Report

Prepare a written report of your experiment which includes the section titles listed below. These section titles should be used to label each section of your report.
I.   Abstract
II.   Title
III.   Introduction
IV.   Materials and Procedures
V.   Results/Data Collection/Analysis
VI.   Discussion/Conclusion
VII.   Literature Citation
VIII.   Questions

The following information should be included in each section of the lab report:

I.   **ABSTRACT**:
The abstract must be short and concise. It should be the last thing you write after all of the other sections are completed. It is a brief summary of everything that was done in the experiment. It will include a sentence pertaining to all parts of the experiment. The results and findings will be found here as well as introductory material. **(approx. 100 words)**

II.   **TITTLE**
Be as specific as possible and briefly denote primary topic dealt with during the experimentation

III.   **INTRODUCTION**:
        BACKGROUND INFORMATION:
        Do research about the topic we are studying in the lab and write in the background information
        in your own words and cite your sources. Always connect the experiment with the real world.
        Example: **(approx. 200 words)**
        PURPOSE: 1-2 sentence description of the "why" of the lab. Begin the purpose with… "The
        purpose of doing this lab exercise is…" Always write the purpose in your own words. **(It is
        helpful to look at the "Objectives" of the lab when writing the purpose.)**
        HYPOTHESIS: Write a statement making an educated guess about the results of the lab. It should
        be a predicted answer to the purpose. Always write the hypothesis in your own words.

IV.   **MATERIALS and PROCEDURES:**
A complete listing of the materials and supplies that were used to conduct the experiment should be
included in this portion of the report. Then discuss what type of data you are collecting and how you are
going to collect it. This is also where you describe your controls and variables.
        CONTROLS & VARIABLES:
        a. The controls are the lab parts that are there to keep the experiment consistent from one
        set-up to another, thereby eliminating all variables expect the one being tested.
        b. The variable that is deliberately changed is called the "independent variable."
        *Not all labs involve us manipulating something like time or light or gender etc.—you don't have
        to list this if there is no independent variable.*
        c. The variable that is observed and that changes in response to the manipulated variable is
        called the "dependent variable."

        PROCEDURE:
List any precautions or warnings. Also give a brief overview of what you are doing in the lab. Think of
how you would describe the lab to your partner if they missed the lab. I should be able to repeat your
exact experiment based of this section.

V.   **RESULTS/DATA COLLECTION/ANALYSIS**
Data is the information gathered in the lab during the experiment. Data may take the form of DATA
TABLES, DIAGRAMS, or WRITTEN OBSERVATIONS and MODELS. Each lab report will have specific
instructions as to how to collect and record data. Data tables must have a title. All drawings of
specimens must be done in pencil. If drawing specimens from a microscope slide you must draw the
specimen within a circle and label with **total magnification** and the **name** of the specimen under the
circle. When graphing always place the independent variable on the X-axis.
 Charts, graphs, tables must have a title which informs the reader as to what the graph, table, etc.
entails. Tables are numbered consecutively as Table 1, Table 2, etc. Graphs are designated as Figures
and are also recorded consecutively as Fig. 1, Fig. 2, etc. Sample calculations should be included and
give the correct formula for all sample calculations. Please BOX your answers.

VI.   **DISCUSSION/ CONCLUSION**:
The Discussion is the answers to questions on the laboratory experiment. All questions are to be
answered in FULL SENTENCES in your own words or no credit will be given for your discussion.
        1. Interpretation of results: drawing valid conclusions (i.e. support or reject your hypothesis)
        based on your data, with an explanation. Where appropriate, results are compared with

given/known values.

      2. <u>Evaluate procedure</u>: The procedure (i.e. materials and methods) including limitations, precision, accuracy, weaknesses or errors in manipulation are evaluated (discussion of the limitations of data analysis may be included.), Error calculations are mandatory if applies.

      3. <u>Modifying the Procedure</u>: Suggest ways to improve the lab or suggest an area for further study. This should be based on the identification of weaknesses or limitations. This is not the time to slam the instructor on how useless the lab was in your eyes.

VII.   LITERATURE CITATION:

Given that some of the information included in your lab write up will have been taken from a published lab activity or other sources, you should include a citation of the source. The source(s) used should be cited within your lab write-up (especially in the introduction section) using scientific citation. Example: (College Board, 2013) or (Campbell & Reese, 2005)

VIII.   QUESTIONS:

Any assigned discussion questions found throughout the laboratory should be written and answered in this section.

You also need to know:

Accuracy and Precision:

Accuracy refers to the closeness of a measured value to a standard or known value. For example, if in lab you obtain a weight measurement of 3.2 kg for a given substance, but the actual or known weight is 10 kg, then your measurement is not accurate. In this case, your measurement is not close to the known value.

Precision refers to the closeness of two or more measurements to each other. Using the example above, if you weigh a given substance five times, and get 3.2 kg each time, then your measurement is very precise. Precision is independent of accuracy. You can be very precise but inaccurate, as described above. You can also be accurate but imprecise.

For example, if on average, your measurements for a given substance are close to the known value, but the measurements are far from each other, then you have accuracy without precision.

A good analogy for understanding accuracy and precision is to imagine a basketball player shooting baskets. If the player shoots with accuracy, his aim will always take the ball close to or into the basket. If the player shoots with precision, his aim will always take the ball to the same location which may or may not be close to the basket. A good player will be both accurate and precise by shooting the ball the same way each time and each time making it in the basket.

Percent Error Definition

Percent error, sometimes referred to as percentage error, is an expression of the difference between a measured value and the known or accepted value. It is often used in science to report the difference between experimental values and expected values.

The formula for calculating percent error is:

$$percent\ error = \frac{|experimental\ value\ -\ accepted\ value|}{accepted\ value} \times 100\%$$

Grading Rubric

Report Item	Possible Points	Points Earned/Comments
Abstract	10	
Title	5	
Introduction	20	
Materials and Procedures	10	
Results/Data Collection/Analysis	20	
Discussion/Conclusion	20	
Literature Citation	5	
Questions	10	