Radioactive Dating Activity Discussion Writeup

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Note: Students are to read the Radioactive Dating handout prior to class.

A. What is my targeted level and is the level of the activity appropriate for my students?

This is geared toward intro level astronomy students at the college level. The M&M portion could be used with lower levels. This class is typically a mix of students ranging from freshmen through seniors. However, they are non-science majors on the whole, including (often) education majors in the summer class. I have them for a 2.5 hour combined lecture/lab class, where I can walk around and help the groups of students (3 to 4 students in a group). This will stretch my students, particularly on the abstract reasoning parts, especially part 2. However I really want to get students to build these skills. I think this could be modified for a 1.5 hour lab; or possibly be modified to a demo (part 1) along with lecture tutorials (especially part 3).

B. What teaching frameworks does the activity match?

We don't really have standards in our college classroom, but I believe these will match the following NGSS standards, which may apply for high school students:

Science and Engineering Practices

<u>Developing and Using Models</u>

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-6)

Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4)

<u>Engaging in Argument from Evidence</u>

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7)

<u>ESS2.D: Weather and Climate</u>

Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4)

C. What misconceptions will the activity have to address?

Students have a hard time understanding how the random process of decay can lead to an accurate dating of an object.

D. Within the activity, where are likely places that students may become confused, and what am I going to do to prepare for that?

Also, the idea that sometimes adding or subtracting parent or daughter isotopes can actually be helpful may be challenging. I will lead the class in discussion after this section so we can understand why this is.

Students may need additional scaffolding mathematically, which can be incorporated in the pre-activity lecture/discussion or on-the-spot as required. I believe with my students an on-the-spot class discussion around part 2 would be most helpful.

E. Where will this activity fit within my curriculum?

This will fit in my “How Do We Know?” section of my Climate Change unit, where we start with Earth (later we compare to other bodies in the solar system that have atmospheres). I will discuss the general atmosphere properties, and the greenhouse effect. I would then discuss what we know about historical climate variations (e.g. solar irradiance, obliquity, etc.) and follow with this exercise. After this I would discuss more in detail about atmospheric forcing and current rapid changes.

Resources:

This activity is largely adapted from:
http://www.ucmp.berkeley.edu/fosrec/McKinney.html

Additional resources:

https://www.uky.edu/KGS/education/agedating.htm (particularly the Isochron Dating one if you want substantially more detail)

www.nsta.org/images/news/legacy/scope/0604/jordanradiometrics.pdf

http://www.indiana.edu/~ensiweb/lessons/date.les.html (I didn’t use this one but maybe it would be useful to someone)

http://www.aip.org/history/climate/Radioc.htm

http://ltrr.arizona.edu/about/treerings

http://www.realclimate.org/index.php?p=87

Radioactive Dating

Introduction

Radioactive dating (also called radiometric dating) is one of the techniques that scientists use to determine how old something is. The type that most people have heard of is radiocarbon dating. In this exercise we will use M&Ms [1]to simulate radioactivity to gain a better understanding of how radioactive dating works. We will then apply this lesson to climate change by using tree rings, though other methods (such as ice cores) also can be used.

You may refer to the *Radioactive Dating* handout to answer the following questions.

With your group define the following:

Radioactive:

Isotope:

Parent-isotope:

Daughter-isotope:

Half-life:

Radioactive Dating:

How do we determine the half-life of a radioactive isotope?

What elements could we use for radioactive dating?

[1] Could also use Skittles. You need something that has a mark on one side and not the other (so Reese's Pieces won't work).

Part 1: M&Ms

To simulate radioactive dating, we will use M&Ms to stand in for Carbon-14, which has a half-life of 5730 years. Be sure to wash your hands before this exercise since you will get to eat the M&Ms afterward.

Material:

2 paper plates

M&Ms

Container

Procedure

Place all M&Ms with radioactive isotope up (M-side up) on the plate. Be sure you have 100 M&Ms. This is your starting value at t = 0.

Pour all M-side up (radioactive) M&Ms into the container.

Shake, and then pour out onto the plate. This is the first half-life. Set aside the decayed M&Ms (M-side down) on the other plate. Count the remaining radioactive M&Ms and record this number and the time elapsed (1 half-life).

Replace ONLY the radioactive M&Ms into the container; repeat step 3. Do this 8 times in total (8 half-lifes) being sure to record the "actual" time it took (+1 half-life in years) and the number of remaining radioactive M&Ms each time.

Enter your data into the class spreadsheet, and record on your sheet the class average for each time.

On the printed graph[2], draw the *calculated theoretical line* for the amount of remaining radioactive M&Ms. (Hint: remember what the definition of half-life is!)

1. Why didn't each group get the same results?

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[2] You can provide a graph and have students graph all of the data instead of using Excel. I recommend using a separate symbol for the averages vs. the class data points.

2. Which results are probably a more accurate depiction of what really happens in nature, an individual group's results or the class average? Why?

3. The graph uses **half-lives** on the horizontal axis. Suppose I have two samples, one containing ^{14}C, which has a half-life of 5730 years, and the other containing ^{235}U, which has a half-life of 704 million years. Can you use the graph to determine the age for *both* of these elements? Why/why not?

4. After how many half-lives (runs) did the class have about ¼ of its original parent isotope (m-side up)? Explain.

5. What would the age of the sample in question 4 be if you were using ^{14}C?

6. What would the age of the sample in question 4 be if you were using ^{235}U?

7. How much of the sample do you think needs to be decayed in order to use radioactive dating? Do you need half the sample to be gone?

8. Why might we need to use ^{14}C when dating things for recent events?

9. Another way of dating rocks is through relative ages. Using this relies on two principles: layers on top of other layers are younger, and things that slice through layers are younger than the layer being cut through. Why do scientists go through the complex process of radioactive dating rather than just sticking with the relative age of rocks?

Part 2: Challenges & Resetting the Date

1. A parent isotope has a half-life of 704 million years. If a sample contains 75% parent and 25% daughter, what is the age of the sample?

2. Suppose at t = 0, our sample started with an additional amount of daughter product instead of zero. Let’s say that the extra is equal to the decayed 25%.
    a. What is the new percentage of parent?

    b. What is the new percentage of daughter?

    c. What is the new would the calculated age? How does this compare to the actual age calculated in #1? *(hint: think of our assumptions so far!)*

3. Suppose instead we start with zero daughter product but some other process that we don’t know about adds some at a later date. How would this affect the result? Would it increase or decrease the calculated age compared to the actual age? *(Hint: how does the ratio of parent:daughter change?)*

4. In the last question, you found that the calculated age was different from the actual age. In reality there are sometimes processes which add or remove either the parent or daughter partway through the decay process. Fill in the table with **greater than**, **less than**, or **equal to** for Calculated Age ____ Actual Age (e.g. if the calculated age would be too old then you would write “>”). You’ve already done “adding daughter” in question 2 above.

	Added	**Removed**
Parent		
Daughter		

Part 3: Bringing it together: How do we use this to determine climate change

Adding new parent isotopes is not necessarily a bad thing. With ^{14}C, there is a process that does just that: Cosmic rays (high energy particles) collide with ^{14}N in the atmosphere to produce ^{14}C. Though plants prefer lighter isotopes of carbon[3], all isotopes are so are incorporated into living things at the same ratio throughout time. As soon as the living thing dies, however, it stops incorporating any new material and the ratios change as the radioactive isotope ^{14}C decays. In this manner, addition of new material (during life) is important: it is only at death that the decay process takes over, so carbon dating tells us when it died. Note that it is extremely important that the rate of production of ^{14}C is constant throughout time. While this is generally true, there are occasionally spikes in ^{14}C production due to high energy solar events or other events. However, most variations in the production of ^{14}C are well understood.

Note: Most atmospheric carbon is in CO_2. You will need his information to answer the next questions.

1. Explain how we can use ^{14}C to date rings of a tree:

Carbon has other isotopes as well. In particular, it has two stable isotopes: ^{13}C and ^{12}C.

2. Since plants prefer lighter isotopes, would you expect the ratio of ^{13}C /^{12}C in plants (e.g. tree rings) to be larger or smaller than the atmosphere?

3. If we burn fossil fuels, how would you expect the *atmospheric* ratio of ^{13}C /^{12}C change? Recall that fossil fuels are made from fossilized plants!

[3] http://www.realclimate.org/index.php?p=87

4. Based on your answer to #3, how will new plant isotope ratios change as the atmospheric ratio changes? How will it compare to earlier (pre-fossil fuel) ratios?

5. Outline a process to use carbon dating (using ^{14}C) and the ^{13}C /^{12}C ratio to determine if the current atmospheric CO_2 increase is due to the burning of fossil fuels.