Radiation is not actually the danger in this lab.
Eating too much candy is the danger.

RADIOACTIVE DECAY

INTRODUCTION

All atomic nuclei with more than 82 protons are inherently unstable. The electrostatic repulsions between pairs of protons are so large, that even the addition of many more neutrons than protons cannot create sufficient nuclear attraction to stabilize the nucleus. However, you cannot predict exactly which atomic nucleus will decay or exactly when.

The idea of the radioactive half–life cannot tell you precisely which nuclei have decayed, but can tell you how much time it will take for exactly half of the atoms in your sample to decay. Half–lives vary between different elements, and from isotope to isotope of the same element. Half–lives can be very accurately calculated by measuring instantaneous rates of decay, using a radiation detector. The shorter the half–life, the faster the rate of decay.

We will not be using actual radioactive samples, but rather simulating the idea of decay using some plain M&M© candies. Which brings us to the second idea: what happens if you ingest a radioactive substance? Clearly the candy is not dangerously radioactive, but you are probably aware (and may have even experienced) that some medical tests require the patient to ingest a radioactive substance. Well, once the test is done, what about that radioactive stuff you drank (or had injected)? Does it stay in your body forever? If not forever, then for how long?

OBJECTIVES

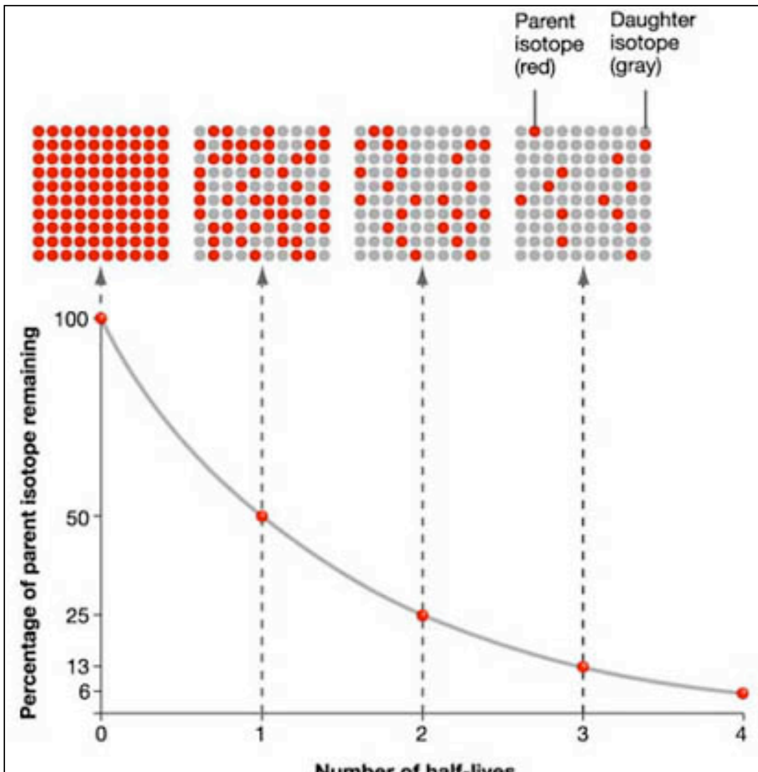
- Simulate the radioactive decay of a sample of emanemnium
- Determine the radioactive half–life of the chocolate isotope
- Construct a graph to illustrate the exponential candy decay
- Compare a biological half–life with a radioactive half–life
- Make it through the hour without eating all the experimental equipment

EQUIPMENT

- M&M© candies
- Clean plate and cups

ACTIVITY 1: RADIOACTIVE HALF–LIFE

- Examine the contents of sample cup of M&Ms. This is your experimental sample. Separate out any candies that do not have an M stamped on them. You may want to eat the unstamped pieces just to make sure they do not contaminate the remainder of your sample.
- Once the unstamped candy has been removed, count the remaining pieces and record the total number.
- Dump the candy back onto the plate in a single layer. Separate the pieces that have the M turned up. These will be counted as "decayed" isotopes.
- Count and record the number of candies remaining, then replace them in the cup.
- Repeat dumping the candy on the plate, removing the decayed pieces, and counting the remaining M&Ms until you have no candy left.



Count the the candies that land "M" up as decayed daughter isotopes.

DATA

If you have not already, record your measurements in a neat table:

	Radioactive		Biological		Combined	
Trial	Number of Decays	Number of Remaining Pieces	Number of Decays	Number of Remaining Pieces	Number of Decays	Number of Remaining Pieces
0						
1						
2						
etc.						

Questions

1. Construct a graph showing the rate of decay of the candy. On the x–axis, plot the trial number. On the y–axis, the number of undecayed M&Ms. Use the entire page, scale your axes carefully, and plot your points accurately. Draw a smooth curve (do not connect the dots) to fit the data.
2. On the y–axis of your graph, go to exactly half the total number of candies. Draw a perfectly horizontal line straight across to the curve you sketched, then draw a perfectly vertical line from the point where it intersects down to the x–axis. Where does your line intersect the x–axis?
3. What is the radioactive half-life of your sample, in units of trials? This represents the rate at which emanemnium atoms decay, regardless of where they are found.

Activity 2: Biological Half–Life

Your body is continually replacing its atoms with new ones (breathe in, breathe out…drink, sweat). This is also a random process, and there is a half-life associated with the different elements in your body.

- Use a pen or pencil to partition your plate into four equal–sized sections.
- Mark one of these sections as the "Flush" section.
- Dump all of your M&M's onto the plate and remove the one's in the "Flush" section. This represents atoms that have been replaced by the body.
- Count the number of candies left and repeat this process until there are no candies left.

Data

Record the data in the table you constructed for the first experiment.

Questions

4. You should be able to add this data to the graph you have already constructed. Use a different color to distinguish these points from the previous data, or use a different symbol (for example, if you used a ● previously, use a ▲ for this data). Label the first curve "Radioactive" and this second curve "Biological."
5. Using the same method as above, determine the biological half–life of the sample. This represents the rate at which your body replaces emanemnium atoms, regardless of whether they are radioactive or not.

Activity 3: Combined Half–Life

- Repeat the experiment one more time, using both elimination factors. Every candy that lands on "Flush" is automatically eliminated. Of the remaining candy, eliminate only those that have decayed (M side up).
- Count what remains on the plate. Continue to repeat trials until there are no pieces left.

Data

Record the data as you have been for the previous trials.

Questions

6. Add this data to your existing graph, again using a separate color or symbol to distinguish it from the previously collected data sets. Label this curve "Combined."
7. Determine the combined half–life of emanemnium from this graph. This represents the rate at which the emanemnium will leave your body due to both processes.
8. The predicted combined half–life can be calculated using:

$$t_{eff} = \frac{t_r t_b}{(t_r + t_b)}$$

   where t_{eff} is the combined half–life, t_r is the radioactive half–life, and t_b is the biological half–life. Calculate using your values, and compare this to the value obtained from your graph.
9. Explain why the effective half–life has to be shorter than either the radioactive or biological values.
10. Compare your individual values to those of the combined class. What effect does increasing the sample size have on the accuracy of the results?