

Radioactivity and Half-Life Demonstration

Background

This demonstration simulates **radioactive decay**. A sample of a radioactive element consists of a vast number of radioactive nuclei that do not all decay at the same time. As unstable atoms are transformed, the radioactivity of a substance decreases. The time required for this activity to decrease by half is called **half-life**. Half-life is a characteristic of each radioactive isotope. Depending on the isotope, it may range from a few fractions of a second to several billion years, as shown in the following chart:



Isotope	Half-life
Polonium-214	0.164 second
Oxygen-15	2 minutes
Bismuth-212	60.5 minutes
Sodium-24	15 hours
Iodine-131	8 days
Phosphorus-32	14.3 days
Cobalt-60	5.3 years
Carbon-14	5,730 years
Plutonium-239	24,110 years
Uranium-238	4.5 billion years

As radioactive elements decay, they change into other elements. Decay continues until a nonradioactive nucleus is formed. This process is called the **decay series**. There are 3 types of radioactive decay

- **Alpha decay:** The nucleus releases an alpha particle. This decreases the mass number by 4 and the atomic number by 2. Uranium-238 undergoes alpha decay.
- **Beta decay:** The nucleus releases a beta particle. This does not decrease the mass number, but does decrease the atomic number by one. Carbon-14 undergoes beta decay.
- **Gamma decay:** The nucleus releases a gamma ray. Gamma decay almost always accompanies alpha and beta decay. The nucleus does not change. It makes a transition to a lower energy state.

The radioactivity of a substance is measured by the number of decays that occur during a given period of time. Here are 2 common units of measurement for radioactivity

- The **curie (Ci)**
 $1 \text{ Ci} = 3.7 \times 10^{10} \text{ decays/s}$
- The **becquerel (Bq)**, an SI unit
 $1 \text{ Bq} = 1 \text{ decay/s}$

These units *do not* accurately measure how dangerous a given amount of radiation might be for humans. For medical purposes, other units of measurement reflecting this aspect are more appropriate.

Materials needed

- Ziplock Baggie
- M&M's
- Skittles
- Microsoft Excel

Procedure

In groups of three to four.

1. Place the M&M's (supplied by your teacher) in the ziplock bag and seal it. These candy pieces represent the parent atoms.
Your group's total number of Parent atoms = _____

2. Shake the bag for several seconds and lay it on the table. Open it and remove only the candy pieces with the "M" showing. These are the Parent Atoms, which transmute (decay) to a new element, the Daughter element.

3. Count the remaining and removed Parent Atoms. Record the numbers in the data table below. Do not put the removed Parent Atoms back in the bag. (DO NOT EAT THEM YET!)

Teacher Signature: _____ (necessary to continue)

4. Replace the removed Parent Atoms with an equal number of Skittles. These new candy pieces are the Daughter Atoms. They are the product of the parent atoms' decay.

5. Record the number of Daughter Atoms added in the table below. Check your progress. The total number of M&M's and Skittles in your bag must be the same as the number of M&M's you started with.

6. Seal the bag and shake it for several seconds. Open it. Count and remove only the Parent Atoms with the "M" showing. Fill in your data table. Do not put the removed Parent Atoms back in the bag. (DO NOT EAT THEM YET!)

7. Replace the Parent Atoms you removed with the same number of Daughter Atoms.

Teacher Signature: _____ (necessary to continue)

8. Repeat the above procedure until all of the Parent Atoms have changed into Daughter atoms. This process is called transmutation.

Results

At each step record the Parent Atoms removed and the Daughter Atoms added.

Shake #	# of half-lives	Total Parent Atoms	Total daughter atoms
0	0		0
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

Graphing Data:

Prepare 2 graphs using Microsoft Excel,

1. Number of Half-lives Vs. Total Parent Atoms
2. Number of Half-lives Vs. Total Daughter atoms

Summing It Up:

1. Approximately what percent of the remaining PARENT Atoms did you remove after each shake? Why?
2. Each shake represents a "half-life" for the "M&M" PARENT Atoms. What does half-life mean? (Put this meaning in your own words. Check what your book has to say.)
3. If you started with 100 "M&M's", would the half-life change? Please explain.
4. Use a calculator to complete this question. In nature, Parent Atoms decay into Daughter Atoms in a predictable mathematical order. Half-life is defined as; "The time required for half of any given amount of a radioactive substance (Parent Atoms) to decay into another substance (Daughter Atoms)".

Try multiplying $1/2 \times 1/2$ over and over to determine if you ever get to zero.

$$1/2 \times 1/2 \times 1/2 \times 1/2 \times 1/2 \times 1/2 \times 1/2 \times 1/2 \times 1/2$$

Will a small amount of the Parent Atom always remain? Yes or No

5. Carbon-14 has a half-life of 5730 years. How old would a real fossil be after eight Carbon-14 half-lives? Show your work. (Hint: Refer to your graph for help)