# INTRODUCTION TO RADIOACTIVITY

**EQUIPMENT**

| | |
|---|---|
| *1 Radioactivity decay* | *Radioactive source* |
| *model consisting of:* | *Alcohol* |
| *Set of plastic markers* | |
| *Shaker* | |
| *Ice water cooled cloud* | |
| *chamber* | |

## INTRODUCTION

The isotopes of some elements are radioactive and spontaneously emit radiation. Often, the original, or parent atom disintegrates into another, different atom called its daughter. The probability for the disintegration of radioactive atoms in a given time period depends on the isotope but does not depend on the past history of the atom. The time for one half of a group of atoms to decay is called the half-life of the isotope. When radioactive elements decay, they emit 3 types of radiation: alpha particles (the nucleus of the helium atom, which consists of 2 neutrons and 2 protons), beta particles (an electron or positron), and gamma rays (a high frequency photon).
Since the probability of decay is statistical, or depends on chance, we must observe a sample of many radioactive atoms to fully understand the characteristics of radioactive decay.

## THE CLOUD CHAMBER

The cloud chamber used in this experiment is a small closed container with absorbent paper or felt in the interior. The paper/felt is soaked with methyl alcohol, and cooled with ice water so that a *supersaturated vapor* forms.

A supersaturated vapor is a gas that is cooled below its condensation point. Any impurity in the vapor will cause it to condense at the site of the impurity and become a liquid.

When a radioactive source is placed in the chamber, the emitted radiation ionizes the vapor, leaving behind a trail of ions. These ions are sites on which neighboring gas molecules can condense. You will see this condensation as a small white cloud forming behind the particle as it streaks from the source. The process is very similar to the contrail left behind a jet plane when it reaches a certain height in the atmosphere.

## A. An Examination of Alpha Particles

This activity (is taken from the "Physics in Motion" unit from the Georgia Public Broadcasting website (gpb.org/physics-motion). The title of the unit is

**Radioactive Decay/Radioactive Decay Virtual Lab.**

In this activity, you will examine alpha decay using the the PhET Alpha Decay simulation. The URL is

(https://phet.colorado.edu/en/simulation/legacy/alpha-decay).

When the simulation opens, click on the 'Single Atom' tab The nucleus that will be investigated is Polonium-211.
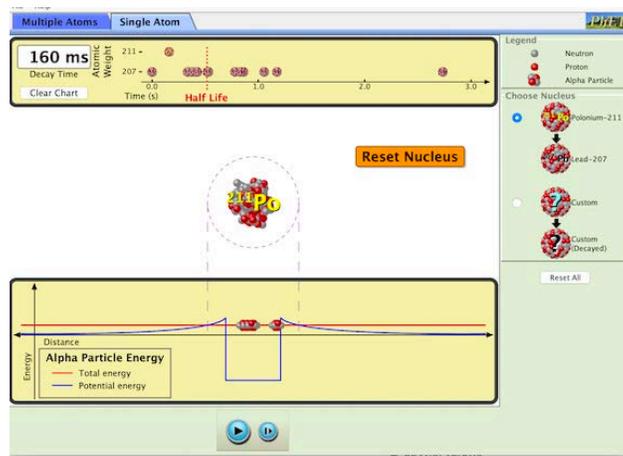


Use the 'Play/Pause' and 'Step' buttons at the bottom to control the running of the simulation. The Decay Time given in the upper left corner is in units of ms (1000 ms = 1 s).

Please answer the following questions.

**Alpha Decay PhET simulation Questions.**

1. How many protons & neutrons does Polonium-211 have?

2. After Polonium-211 decays, what stable nucleus is formed?

3. Does the atomic number change when Polonium-211 decays into the stable nucleus? Explain.

**If necessary, click on 'Reset Nucleus' to see simulation again.**

4. Pause the simulation immediately after the decay occurs.

What does the particle that is emitted from the nucleus consist of? What is this particle called?

5. What is the half-life of Polonium-211?

6. Repeat the simulation for a total of 10 times. How many times does Polonium-211 decay before the half-life time of those 10 times?

**Next, click on the 'Multiple Atoms' tab in the simulation. Add all 100 Polonium-211 atoms nuclei to the simulation by adding 10 nuclei at a time under the 'Bucket o' Polonium'. Once you have 100 added, click on 'Reset All Nuclei.'**

7. After you click on 'Reset All Nuclei', the simulation starts over again. By when do/did you expect most of the Polonium-211 nuclei to decay?

8. Pause the simulation at the half-life marker. In the upper left-hand corner, there is a pie chart and a data table. How many Polonium-211 nuclei remain after one half-life has elapsed? How many Lead-207 have been created?

9. Pause the simulation after every 0.5 seconds and note the number of Polonium-211 nuclei present. Fill in the data table below and create a graph of the number of Polonium-211 nuclei vs. time.

| Time (seconds) | # of Polonium-211 nuclei |
|---|---|
| 0 | |
| 0.5 | |
| 1.0 | |
| 1.5 | |
| 2.0 | |
| 2.5 | |
| 3.0 | |

**Number of Polonium-211 nuclei vs. time**
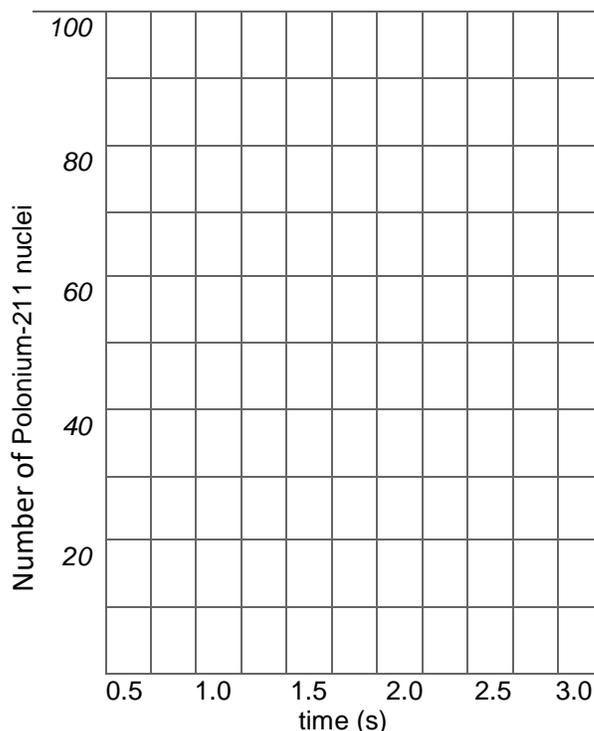
**Part B. Radiometric dating using Carbon-14**

In this part of the lab, you will use the PhET simulation "Radioactive Dating Game." The URL is

https://phet.colorado.edu/en/simulation/legacy/radioactive-dating-game

**Once you have opened the simulation, click on the 'Decay Rate' tab**

1. In the far right-hand column of the data table below, record what percentage of an original amount of C-14 you would expect to remain after 1 Half-Life, 2 Half-Lives, and 3 Half-Lives have elapsed.

2. In the simulation, move the slider on the bucket almost all the way to the left so that there are not many nuclei out of the bucket. The simulation will start automatically, but click the 'Pause' button at the bottom.

3. Click the 'Reset All Nuclei' button above the bucket. Then click the 'Step' button near the bottom one time.

4. Find the total number of original C-14 nuclei by adding the numbers of C-14 and N-14 atoms on the pie chart to the left. See figure below for an example. In this figure, total # of nuclei is 19+2 = 21.
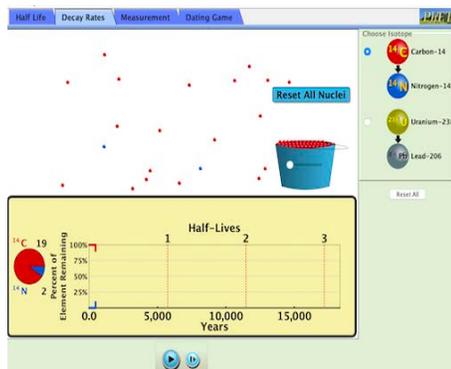


If this number is less than 100, enter it in the **chart (table) below on page 4** under "Small Sample". If it is greater than 100, move the slider farther to the left and go back to Step 1.

5. Advance the simulation using the 'Play/Pause' and/or 'Step' buttons, and pause the simulation exactly when it

reaches 1 Half-Life. Record the number of C-14 nuclei remaining, then calculate and record the percentage of the original C-14 remaining.

6. Continue the simulation with the 'Play/Pause' and/or 'Step' buttons, pausing at 2 Half-Lives and 3 Half-Lives to find the number and percentage of remaining C-14 at those points.

7. Move the slider all the way to the right of the bucket, and repeat Steps 2. through 6. for a large sample of nuclei.

**Once you have completed the first table on page 4 click the 'Dating game' tab.**

In this part of the lab of the lab you will use a probe to measure the age of various items (objects). The age and composition of the item tested (e.g., a rock) determines which type of probe is to be used.

For objects that are relatively (geologically) young and that were once alive, you would use the Carbon-14 probe. For objects that are much older, use the Uranium-238 probe. For some objects you may need to use a custom probe.

For Item #9, use the C-14 probe, even though the % of C-14 remaining will be off the scale of the graph. You can still use what you know about the half-life of C-14, and the relationship between half-life and % remaining to estimate the age using the C-14 probe.

For Items #11, 13, 15, neither C-14 nor U-238 will give usable measurements. Without using a probe, use the ages of other items in the same rock layer to estimate the ages of these fossils. After getting a Rock Layer estimate, select a Custom probe for each fossil that will enable you to get a good measurement for estimating that object's age.

You should note that there are a range of correct answers for the estimated age of an object. *Too many answers that are exactly the same as someone else will be suspicious.*

Table for Decay Rates

| | Small Sample Original number of C-14:_____ | | Large Sample Original number of C-14:_____ | | Expected % of C-14 remaining |
|---|---|---|---|---|---|
| | # of C-14 remaining | % of C-14 remaining | # of C-14 remaining | % of C-14 remaining | |
| 1 Half Life | | | | | |
| 2 Half Lives | | | | | |
| 3 Half Lives | | | | | |

Table for Dating Game

| Item | Item Location | Probe Used (C-14, U-238, Custom, or Rock Layer) | Probe Half-Life (years) | % of Isotope Remaining | Estimated Age (years) |
|---|---|---|---|---|---|
| 1. Animal Skull | Surface | | | | |
| 2. Living Tree | Surface | | | | |
| 3. Distant Living Tree | Surface | | | | |
| 4. House | Surface | | | | |
| 5. Dead Tree | Surface | | | | |
| 6. Bone | 1st Layer | | | | |
| 7. Wooden Cup | 1st Layer | | | | |
| 8. Human Skull | 1st Layer | | | | |
| 9. Human Skull | 2nd Layer | C-14 | | | |
| 10. Fish Bones | 2nd Layer | | | | |
| 11. Fish Fossil | 3rd Layer | Rock Layer | | | |
| 12. Rock 1 | 3rd Layer | | | | |
| 13. Dinosaur Skull | 3rd Layer | Rock Layer | | | |
| 14. Rock 2 | 4th Layer | | | | |
| 15. Trilobyte | 4th Layer | Rock Layer | | | |
| 16. Rock 3 | 5th Layer | | | | |
| 17. Rock 4 | 5th Layer | | | | |
| 18. Rock 5 | 5th Layer | | | | |

**Part C – Cloud Chamber**

For this part of the experiment you will view two (2) videos which were taken using the cloud chamber that is normally used in the lab experiment.

In the first video (which is around 2 ½ minutes long) you will look at a cloud chamber with no source. This will allow you to view the effects of naturally occurring radiation.

In the second video there were two sources used. One source was Lead-210 which is **primarily a beta emitter** and the second source is a welding rod containing thorium and it is **primarily an alpha emitter.**

The behavior of the sources (and consequently what to look for) can be summarized as follows.

1) "The dense straight tracks are produced by $\alpha$ (alpha) particles and other massive charged particles, while $\beta$(beta) particles produce faint and often crooked tracks."

2) "Thorium is primarily an alpha emitter. Daughters in the decay chain emit alpha, beta, and **gamma radiation.** "

3) "In addition, $\gamma$ *(gamma)* rays *(radiation)* interact with the gas molecules to produce energetic photo electrons, Compton electrons, and positive and negative electron pairs".

1) & 3) are taken from the **Diffusion Cloud Chamber** manual by AU Physics Enterprises and 2) is from Teledyne Tungsten Products (a manufacturer of thoriated welding rods) from their MSDS Sheets.

**The statements above imply that from one source you will see mostly faint (thinner) straight tracks while the other source will produce mostly alpha particles while also producing a variety of other particles (and consequently a variety in the types of tracks).**

The YouTube video for the no source cloud chamber can be found at https://youtu.be/dZTsllK6fok

The YouTube video for the cloud chamber with two sources can be found at:

**Tuesday labs** https://youtu.be/A9DMlfU_pBs

**Wednesday labs**-https://youtu.be/m--WKjpCSww

**Thursday labs**- https://youtu.be/A9DMlfU_pBs

To help with the identification of the types of particles observed see link on lab webpage (underneath the procedure). Link is named What to look for in the cloud chamber

Use your observations form the cloud chamber to answer questions. You are advised to look at the questions before you look at the video.

**Questions**

1) Define the half-life of an isotope.

2) Radioactive elements emit 3 distinct types of radioactive particles.  Name and describe each particle.

3) Precambrian time is older than 600,000,000 years.  Can carbon 14 be used in dating organic material from that era?  Explain. Based upon what you observed in the "Radioactive Dating Game" what type of probe would you use?.

4) In the "Dating Game" activity, about how many C-14 half-lives old was Item #9 (lower Human Skull)?

5) Based on the "Dating Game" activity, at what age do you think C-14 would no longer be useful for estimating the age of a dead object? How many half-lives of C-14 is that age? Why do you think C-14 is no longer useful after this point?

6) As the age of an object gets older, should the half-life of the probe needed to accurately estimate its age get relatively shorter or longer?

7) What did you see when you looked in the cloud chamber with no source?  Be quantitative (for instance say I saw two or three…) and qualitative in your description. Be sure and mention how the tracks in this video might have been different from the ones with the sources.

8) In the video with the sources, which source was in the cloud chamber when it started and which source was it replaced with. Remember, you had only two (an alpha and a beta source). Explain. Again, you should be quantitative and qualitative in your description. Be sure and look at the link on the website for help in identifying the types of tracks observed.