POLONIUM LIFE LAB

MONROE

USING PENNIES

Time Frame:	Standards:
30 minutes to assemble lab, 45 minutes to complete lab and report	Idaho Standard 8-9 PS 2.4.2

Objectives:

Students will be able to create and interpret half-life graphs, and will understand how to use the graph to find mass or radioactivity by correlating with time. Students will understand the concept of half lives. Students will understand that elements decay into other elements while releasing Alpha and Beta particles

Background Information:

Radioactive decay is anytime there is a change in the nucleus of an atom that causes the element to become something else. There would be, of course, some small exceptions to this, but none that we need to worry about now.

There are three basic kinds of decay. There is Alpha, which is a particle consisting of a helium nucleus, Beta, which is a fast moving electron, and Gamma, which is high energy, electromagnetic radiation~ a photon with lots of "punch".

Alpha radiation consists of a helium nucleus. It contains two protons and two neutrons, but no electrons. It has a 2+ electrical charge and is an ion.

Beta radiation consists of a fast moving electron with a negative charge. It has ***almost*** no mass because an electron has only about 1/ 2,000th of the mass of a proton or neutron.

Gamma radiation consists of high energy electromagnetic waves. The wavelength of a gamma wave is about the same distance as the space between the sides of the nucleus of a carbon atom. It is very powerful, massless and is carried by a particle called a photon. Do not get hung up on the concept of a massless particle; save that for another day.

Recall that elements are radioactive because of an effect of the weak nuclear force. Also recall that elements are described by the components of their nucleus. Elements are named because of the number of their protons. They are also given a number based on the number of protons and neutrons combined.

An example of a radioactive element is Uranium-238. The periodic table shows that all Uranium will have 92 protons in its nucleus. The number "238" indicates that this particular isotope of Uranium has 238 protons AND neutrons in its nucleus. Subtraction tells us there MUST be 146 neutrons only. When the U-238 proceeds with Alpha decay, it will lose two protons and two neutrons, because two protons and two neutrons is an Alpha particle. It becomes Thorium-234.

Alpha Radiation Example

U	92 protons 146 neutrons 238 total		2 protons 2 neutrons 4 total	Th	90 protons 144 neutrons 234 total

A Uranium atom, that loses an Alpha particle, will become a Thorium atom. None of the protons or neutrons change charge, they just split off of the Uranium atom.

Beta Radiation Example

Th	90 protons 144 neutrons 234 total	Pa	89 protons 145 neutrons 234 total

A Thorium atom may have a proton that will spontaneously turn into a neutron. The total number of particles in the nucleus remains the same. Since there is now one less proton, the atom has fewer (less) positive charges. To make sure that the law of conservation of charge is not violated, an electron (beta particle) is created, and sent on its way.

Gamma Decay Example

Gamma decay does not change the nucleus of an atom; therefore no new elements are created. Gamma is an indicator of a high energy event or phenomenon, such as a supernova explosion, or a black hole.

Argonne National Laboratory, EVS *Human Health Fact Sheet, August 2005*

Polonium

What Is It? Polonium is a radioactive element that occurs naturally in very low concentrations in the earth's crust (at about one part in 10^{15}, or one millionth of a trillionth). Polonium was the first element discovered by Marie and Pierre Curie in 1898, while seeking the cause of radioactivity of pitchblende ore containing uranium. Polonium in its pure form is a low-melting, fairly volatile metal. Over 25 isotopes of polonium are known, with atomic masses ranging from 192 to 218 (isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) All polonium isotopes are radioactive, with only three having appreciable half-lives: polonium-208, polonium-209, and polonium-210.

Symbol: **Po**

Atomic Number: **84**
(protons in nucleus)

Atomic Weight: **210**
(naturally occurring)

Polonium-210, historically called "radium F," is the predominant naturally occurring isotope of polonium and the one most widely used. Polonium-210 is a radioactive decay product in the natural uranium-238 decay series; along with lead-210 it is one of two relatively long-lived decay products of radon-222. Polonium-210 has a half-life of 138 days, and it decays to stable lead-206 by emitting an alpha particle. One-thousandth of a gram (1 mg) of polonium-210 emits as many alpha particles as 5 g of radium-226. The energy released by its decay is so large (140 watts/g) that a capsule containing about half a gram reaches a temperature above 500°C.

Radioactive Properties of Key Polonium Isotopes

Isotope	Half-Life	Specific Activity *(Ci/g)*	Decay Mode	Radiation Energy *(MeV)*		
				Alpha *(α)*	Beta *(β)*	Gamma *(γ)*
Po-208	2.9 yr	590	α	5.1	<	<
Po-209	100 yr	17	α	4.9	<	<
Po-210	140 days	4,500	α	5.3	<	<

Ci = curie, g = gram, and MeV = million electron volts; a "<" means the radiation energy is less than 0.001 MeV. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Values are given to two significant figures. Polonium-210 is a decay product of radium-226 and is also shown on that fact sheet. The basic properties of polonium-208 and polonium-209 (which are not in the natural decay series) are also given here because they are included in the general discussion below.

Where Does It Come From? Because it is produced during the decay of naturally ubiquitous uranium-238, polonium-210 is widely distributed in small amounts in the earth's crust. Although it can be produced by the chemical processing of uranium ores or minerals, uranium ores contain less than 0.1 mg polonium-210 per ton. Originally, polonium-210 was obtained from the rich pitchblende ore found in Bohemia, but it can also be obtained from aged radium salts that contain about 0.2 mg per gram of radium. Although a number of other polonium isotopes are present in the natural decay series, their short half-lives preclude any appreciable concentrations.

Due to its scarcity, polonium-210 is usually produced artificially in a nuclear reactor by bombarding bismuth-209 (a stable isotope) with neutrons. This forms radioactive bismuth-210, which has a half-life of 5 days. Bismuth-210 decays to polonium-210 through beta decay. Milligram amounts of polonium-210 have been produced by this method. The longer-lived isotopes polonium-209 (half-life 103 years) and polonium-208 (half-life 2.9 years) are also produced in reactors or particle accelerators, but these are very expensive.

How Is It Used? Polonium-210 is used mainly in static eliminators, which are devices designed to eliminate static electricity in machinery where it can be caused by processes such as paper rolling, manufacturing sheet plastics, and spinning synthetic fibers. The polonium-210 is generally electroplated onto a backing foil and inserted into a brush, tube, or other holder. Alpha particles from the polonium ionize adjacent air, and the air ions then neutralize static electricity on the surfaces in contact with the air. These devices generally need to be replaced every year because of the short half-life of this radioisotope. Polonium-210 is also used in brushes to remove dust from photographic films and camera lenses. Static eliminators typically contain from tens to hundreds of mCi (thousandth of a curie) of radioactivity. Polonium-210 can also be combined with beryllium to produce neutron sources, and in fact it was used as neutron-producing initiators of at least the first generation of atomic weapons. In addition, polonium-210 has been investigated as a heat source for thermoelectric power devices for space applications.

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Radon – 214 becomes Polonium – 210, through Alpha decay
Polonium – 210 becomes stable Lead – 206, through Alpha decay

Materials:

60 Pennies per group
1 cup per group
Abundance of graph paper
Straight edges
Colored pencils

Procedure:

There is danger at the landfill. An unscrupulous industrial enterprise has dumped a load of Polonium^{210} into an area lake. It has a lethal toxicity level that is incredibly low. Right now, the lake has been tested, and the toxicity level has been found at a level of 6 parts per billion. The state government, at a total loss, has asked your science class to determine the following:

When will the lake be safe again, with a concentration of .75 parts per billion?
This number is estimated so that the graph would have some meaning. The actual toxicity level of Polonium-210 is much lower. The actual toxicity level is 0.0125 grams per billion, by mass. One millionth of a gram would most likely kill an 80-kg person. This is why safety precautions are so strict at nuclear research facilities, and nuclear power plants.
What was the concentration when the Polonium^{210} was placed in the lake 100 days ago?
Why is Polonium-210 not found naturally on Earth?

1. Use pennies as a substitute for Polonium^{210}.
2. Count out 60 pennies. These 60 pennies equal the present concentration of 6 parts per billion of Polonium^{210}. 30 pennies would equal *3 ppb*; 10 pennies would equal *1 ppb* and so on and so on. Record 60 pennies, *and 6ppb,* in your data chart at time "present".
3. Place all of the pennies face UP. This means that all of them are Polonium^{210}. Put them all in a cup, shake them up, and spill them out onto a table. The pennies that have come up "TAILS" are now stable lead. Move them aside. Record the number of pennies faces up in your data chart. These are still "Polonium^{210}".
4. Continue this process until all of the Polonium^{210} has converted into stable lead.
5. Complete two trials (steps 1 through 4) so that you can see if one of the trials was outside of a reasonable statistical range.
6. GRAPH your result using the average of the two runs.
   a. Remember, each shake of the pennies represents one half-life of Polonium^{210}. The half-life of Polonium^{210} is 138 days.
   b. Let your "x" axis extend a bit to the left of the "y" axis, because you are asked to look *back in time*. The "x" axis represents time.

Assessment:

Question One Example:
The lake will be safe again in four half-lives, or 552 days. I found this by finding the point on the "y" axis that corresponded to .75 ppb, and drawing a straight line over to the graph. I then made a line straight down to the "x" axis, and found that the time was four half-lives. Each half life is equal to 138 days, so I multiplied 4 x 138, and found time in days to be 552.

Question Two Example:
The concentration of Polonium-210 when it was placed in the lake 100 days ago was 9.1 ppb. I found this by going "back" in time 100 days on the "x" axis, and drawing a straight line up to the graph I made. I knew that the concentration one half life before 6 ppb must have been 12 ppb. I then made a line straight over to the "y" axis, and found an amount of 9.1 ppb.

Question Three Example
The half-life of Polonium-210 is so short that if any of it ever did exist on Earth, it would have long, long ago decayed into something else. In fact, if the entire Earth had started out as Polonium-210, it would now be a planet made of Lead-206, surrounded by an atmosphere of Helium. The planet would also be very, very hot.

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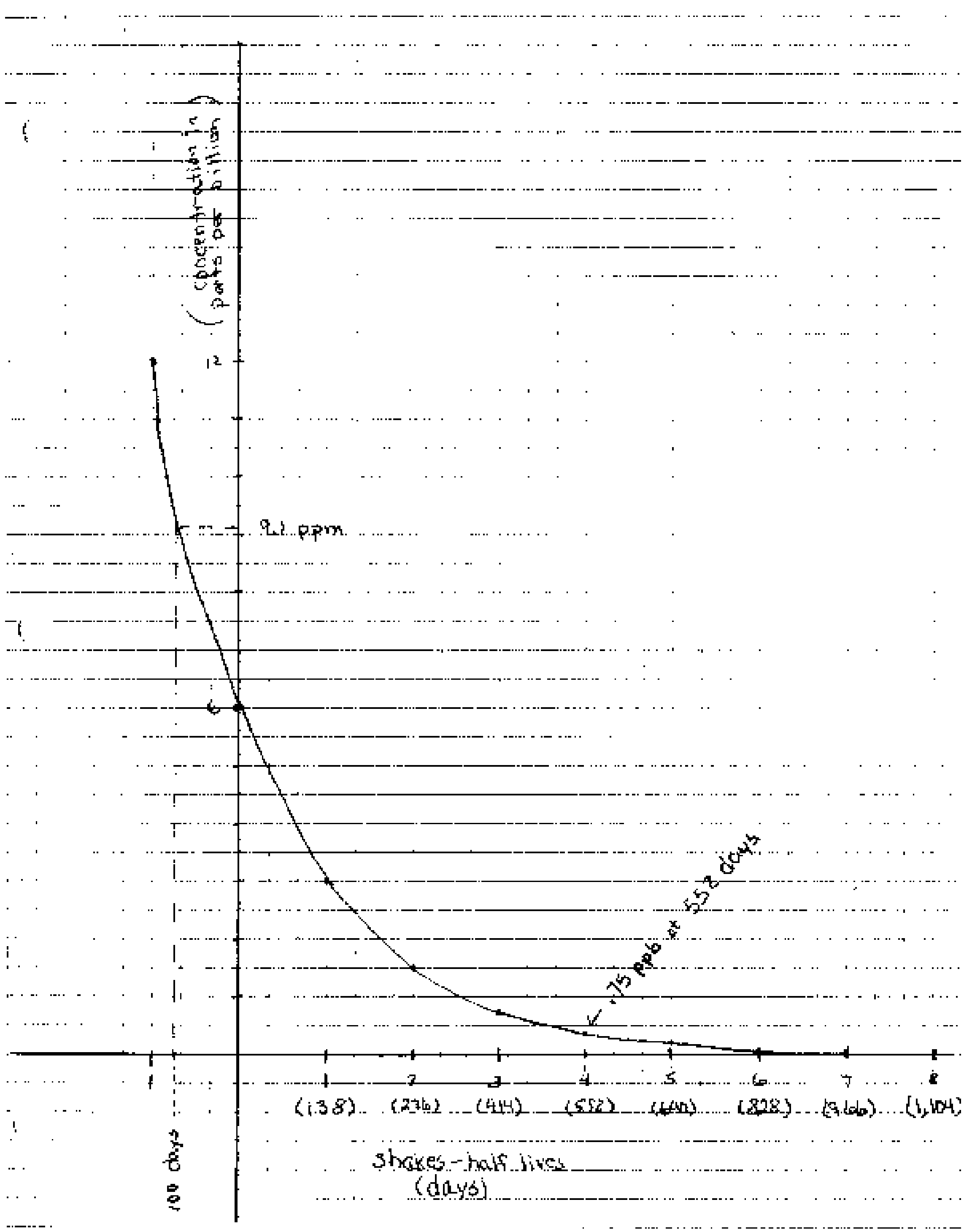
Trial #1

Shake (Time)	Polonium^{210} ppb	Changed to lead ppb	Total
0	60	0	60
1			60
2			60
3			60
4			60
5			60
6			60
7			60
8			60
9			60
10			60

Trial #2

Shake (Time)	Polonium^{210} ppb	Changed to lead ppb	Total
0	60	0	60
1			60
2			60
3			60
4			60
5			60
6			60
7			60
8			60
9			60
10			60


concentration in (parts per billion)
12
9.2 ppm
6
100 days
1
2
3
4
5
6
7
8
(138)
(276)
(414)
(552)
(690)
(828)
(966)
(1,104)
shakes - half lives (days)
.75 ppb at 552 days

Additional Content:

When you turn in your lab report, you will be giving your instructor four (4) sheets of paper in the following order.

a. The graph, using the average of the two experimental runs.
b. A separate sheet of paper answering questions one, two and three, in complete sentences.
c. A separate sheet of paper, containing your data chart.
d. This sheet of paper, containing your instructions.

References:

Given in document