INVESTIGATION 5

HOW IS NATURAL RADIOACTIVE DECAY RELATED TO RADIATION MEASUREMENT?

INTRODUCTION

Radiation chemistry or physics emphasizes half-life, types of radiation, and the principles of radioactive decay. These are important topics to consider, and are critical to developing an understanding of radioactivity. Let's put all three of these concepts together to see how we can measure radiation from a radioactive decay series. Radon-222 does not wait until all of the radium-226 has decayed away before it starts its own decay process. Many of the isotopes involved in a decay series will be decaying simultaneously. This makes the overall picture more complicated. In this exercise, you will examine radioactivity measurements derived from a portion of the uranium-238 decay series. You will determine how the half-lives of the individual isotopes relate to the half-life of the total amount of gamma radiation emitted simultaneously by more than one isotope.

Isotopes - Two or more forms of the same element which have the same number of protons, but a different number of neutrons in their nucleii.

OBJECTIVES

To apply the concepts of half-life, radioactive decay processes, and radiation measurement methodologies to assess the radioactivity given off by a series of isotopes that makes up part of a natural decay series.

PROCEDURE

1. A chemistry and physics instructor conducted the following experiment, and the results she obtained are reported in Table 1. Examine the data and construct a graph of radioactivity versus time. Answer the questions that follow, based upon your interpretation of the experimental results.

CASE STUDY

A bottle topped with a septum (a rubber-like barrier through which a syringe can be inserted) is half filled with a solution containing radium-226 (Figure 1). The air above the solution contains radon-222 that was derived from the radioactive decay of radium (radon is a gas). A hypodermic needle is used to draw a sample of radon contaminated air and pull it through a filter (to keep out solid particulates, i.e. radon decay products) onto a bed of activated charcoal (Figure 2). The syringe is then sealed and placed on the detector of a gamma spectroscopy system to measure the activity of lead-214 and bismuth-214 gamma emissions. The radioactive decay series proceeds as follows (half-life in parentheses):

radium-226
alpha, gamma (1600 years)
radon-222
alpha (3.8 days)
polonium-218
alpha (3 minutes)
lead-214
beta, gamma (27 minutes)
bismuth-214
beta, gamma (20 minutes)
polonium-214
alpha (164 microseconds)

Since the detector being used is specific for gamma radiation, it will not pick up the alpha radiation emitted by the polonium-218, but will pick up the gamma rays emitted by lead-214 and bismuth-214. Alpha and beta radiation would not be able to penetrate through the walls of the syringe to reach the detector. The results of gamma measurements during the course of 16 days are given in Table 1.

DATA

Table 1. Results from the experiment described above.

Time (days)	Radioactivity (µCi)[1]
0	0
0.050	10.1
0.075	24.0
0.100	38.0
0.125	50.2
0.150	48.1
0.500	43.5
1	40.1
2	32.2
4	22.5
6	15.7
8	10.4
10	7.0
14	5.0
16	4.7

[1]µCi - micro curie is a unit of radioactivity equal to one millionth of a curie

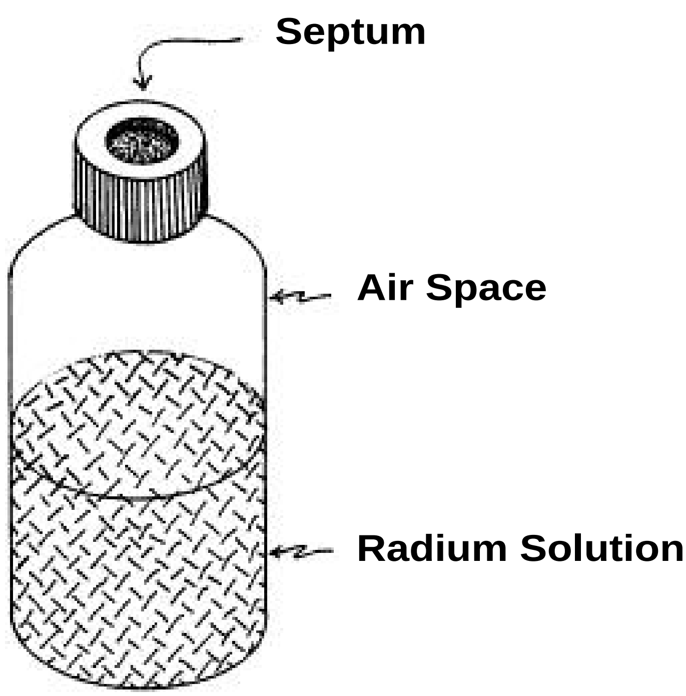

Figure 1. Bottle containing radium-226 in solution. As the radium decays to form radon, a gas, the radon accumulates in the air space above the solution. A sample of radon gas can be withdrawn from the bottle by inserting the needle of a syringe (shown below) through the septum on top.

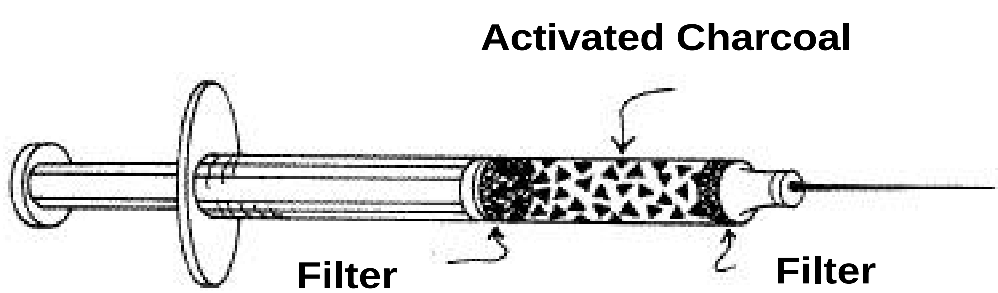

Figure 2. Syringe containing activated charcoal for the collection of radon gas. Radon is drawn through the filter to prevent the entry of radon decay products (which are solids). After drawing radon into the syringe, the whole system is sealed and can be placed directly on a gamma counter.

ANALYSIS

2. Graph the data in Table 1. You may use LabQuest or graph the data by hand. Make sure to label your axes.

3. Examine your graph of the data obtained in this experiment. You should note a rapid increase in radioactivity, followed by a more gradual decline. Explain why this occurred. How do you explain the rapid early rise in gamma rays?

4. The peak (high point) of the graph represents equilibrium between radon and its decay products. Explain what this means.

5. Use the data displayed in your graph to calculate the half-life of the radiation sources being measured in this exercise. What is your estimate?
Hint: Remember that half-life is the time that it takes to reduce the amount of radioactive material, and consequently the amount of radioactivity, in half.

Look at the decay series on page 42. When would decay products begin contributing to the gamma count? What effect would these daughters have on the half-life estimate?

6. Your estimate of half-life for the overall experiment should be very close to the half-life for one of the isotopes in the decay series. Which isotope is it? Explain why this is the case.

7. Experimentation has shown that the ratio of isotopes present in a sample is proportional to the ratio of their half-lives.

Radium half-life = 1600 years x 365 = 584,000 days
Radon half-life =3.8 days

$$\frac{584{,}000}{3.8} = \text{Ratio of } \frac{\text{radium}}{\text{radon}} \quad \frac{154{,}000}{1}$$

Using a similar calculation, what is the ratio of polonium-214 to radon-222? Explain in your own words why you think this relationship exists.

CONCLUSIONS

8. Given only the data provided to you in this exercise, can you predict how long the experimental syringe will remain radioactive? If not, what additional information would you need to have in order to make a reasonable prediction?

9. How do the concepts presented in this exercise relate to measurement of household radon?

NOTES