

Measuring the Radioactivity of a Smoke Detector Spring 2009

Introduction

In this experiment you will estimate the amount of Americium (“Am-uh-RISH-ee-um”; Symbol: *Am*) inside a smoke detector. You will also learn something about the penetrating power of alpha (α) particles. Information on how a smoke detector operates can be found on page 2 of these instructions.

Safety Warning:

Treat all radioactive sources with respect. You should never eat or drink in the lab when working with radioactive sources, and always wash your hands after handling sources, even relatively low-level ones such as smoke detectors. Be sure to replace the cover on the smoke detector when you are finished measuring the radiation emitted.

Experiment

1. Locate the Americium isotopes on a chart of the nuclides ($Z = 95$). Identify which isotope is likely to be inside the smoke detector (think about what the active life span of a working smoke detector has to be). Find the half-life and the decay product(s) of this isotope from the table. List the possible isotope candidates, and explain your choice and why the other isotopes were rejected.
2. Next, open up the smoke detector and locate the source. Follow the directions at the end of these instructions to operate the radiation monitor software. Adjust the monitor detector so that it is resting *directly on* the source, and verify that it is radioactive by starting the program. The number of counts is displayed every 10 seconds; collect data for two or three minutes, and record in a table in your report. Calculate the count rate in *decays/sec*, and compare it to the published value. Why is there a large discrepancy?
3. With the radiation monitor detector held a fixed distance from the source (resting on top of the source well), measure *and compare* the count rate with 0, 1, 2, and 3 sheets of paper between the source and monitor (one minute worth of counts is sufficient). Three sheets of paper should block all α particles. Do you still register counts? Why *isn't* it zero (you may need to refer to the nuclide chart again)?
4. There are assorted pieces of metal (copper, steel, tin, lead) and glass available. Place one between the detector and source, and again measure the counts for one minute. Try a few of these materials; are they more or less effective than paper? Also try an air gap of 1 or 2 *cm*. What happens to the counts?
5. The radiation consists mostly of wimpy alpha particles, most of which don't make it out of the source container and through the window of the monitor detector. A more reliable estimate of the activity of the source is printed on the cover that surrounds the source (units: Becquerel {Bq} or Curie {Ci}; 1 Bq = 1 count/sec, and 1 Ci = 3.7×10^{10} Bq). Use *this manufacturer's value* and the half-life to calculate the approximate number of Americium nuclei in the smoke detector. Recall that

$$N = N_0 e^{-\lambda t}$$

and

$$A = -\frac{dN}{dt}$$

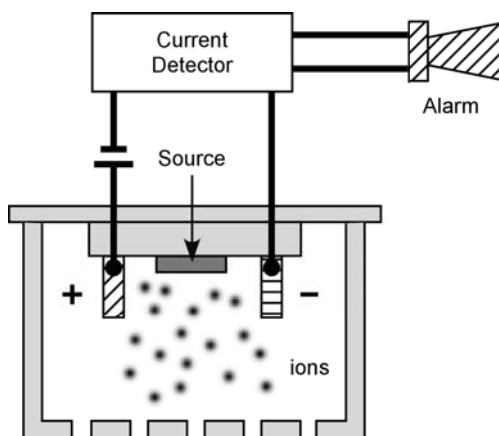
The decay constant, λ , is given by:

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

6. Use your result from step 5, Avogadro's number ($N_A = 6.02 \times 10^{23}$ atoms per mole), and the atomic mass to calculate the number of grams of Americium in the smoke detector.

How a Smoke Detector Works¹

There are two types of smoke detectors available to consumers. One kind indicates the presence of smoke when it interferes with a photoelectric beam of light in the detector. The smoke detectors we will examine in this experiment are ionization-type detectors. The detector consists of an ionization chamber, a sensitive current detector, and an alarm. A weak radioactive source ionizes the air in the chamber of the detector, creating a region of charged particles. A voltage is maintained between the plates inside the chamber, setting up a very small current in the external circuit. As long as the current is maintained, the alarm is deactivated. However, if smoke drifts into the chamber of the detector, the ions become attached to the smoke particles. These heavier particles do not drift as readily as do the lighter ions, which results in a decrease in the detector current. The external circuit senses this decrease in current and sets off the alarm.



Using the Software for the RM-60 Micro Roentgen Radiation Monitor

- I. Position the window on the bottom of the radiation monitor directly on top of the radiation source.
- II. Double-click the **AW-RADW** icon on the desktop. Click on the *Rad Collection* menu, then select *Express Start Collection of Rad Data*. Hit the **Cancel** button twice (you don't need to save data files).
- III. A separate window appears which will contain a series of bar graphs, and the counting process begins. The computer will emit a *click* each time the monitor sees a radiation event. The number of counts of radiation events in a 10 second interval appears in the last column of the main window of the program, along with the date and time, the radioactive absorption rate (in $\mu\text{Röntgen/hr}$), and an average of this absorption rate (which appears in the bar graph).
- IV. Allow the program to collect two or three minutes of data. The program is stopped by clicking the *Rad Collection* menu and selecting *Stop Collection of Rad Data*.

¹ From *College Physics*, 3rd Ed. Serway & Faughn, p. 1025