Radiation and Half Life

Objective

Materials

1. Bench-top liner
2. Box of absorbers
3. Distilled water
4. Geiger counter
5. Geiger tube with shield and source holders
6. Isogenerators (Ba/Cs sources)
7. Ludlum Model-3 survey meters
8. Petry dishes
9. Protective gloves
10. Radiation sources (button sources)
11. Stopwatch

Nuclear Radiation

Introduction

The nucleus of an atom consists of protons and neutrons. The electrical repelling force between each pair of protons tends to make the nucleus fly apart. But there is also a nuclear force between each pair of particles (proton-proton, proton-neutron, neutron-neutron) which tends to hold particles together. The net effect is that some combinations of numbers of protons and neutrons are stable and others are unstable. An unstable nucleus is said to be radioactive, that is, it is active in the emission of radiation. Most elements have both stable and unstable isotopes. Two different isotopes of an element have different numbers of neutrons.

Procedure

Randomness of Radioactive Decay

Radioactive decay is a spontaneous, random process governed only by probability. Random events also happen in a Geiger tube. Therefore, for a given set of conditions two successive counts for the same time interval will nearly always be different. The purpose of this part of the experiment is to give you some idea of how different.

The apparatus used is a model 500 L unit by "The Nucleus"; it consists of a scaler, Geiger tube, absorber set and source set. The first step in the operating procedure is to set the high voltage to an appropriate value. The following steps are recommended:

1. Turn the high voltage control to zero.
2. Connect the Geiger tube to the scaler and plug the scaler into wall power.
3. Set the count interval to manual.
4. Place a γ source in the holder of the Geiger tube mount.
5. Press POWER, RESET and then COUNT.
6. Increase the voltage (using coarse and fine adjustments) until the threshold for counting is reached. Set the high voltage to 75 volts above the threshold and leave it there for the entire experiment. The threshold varies from tube to tube, but if, for example, the threshold is 375 volts, set the high voltage on 450 volts.

The counting setup is now ready to use.

Set the count interval to 0.5 minutes, press RESET and COUNT. The scaler will now count for thirty seconds and stop. Locate the source at a holder position such that during a 30-second period something of the order of 1000 to 2000 counts are made. If your source is weak you may have to settle for counts under 1000.

Record the counts made during 30-second periods several times (say 5 times) and notice how different the measurements are. Theoretically the variation should be on the order of the square root of the number of counts. Does this prediction agree with your results?

Remove the source from the source holder and measure the counts due to background radiation. Sources not being used must be a significant distance from the Geiger tube.

Absorption of α, β, and γ Radiation by Matter

Change the count interval to 1 minute and record the number of counts from the source. Place the thinnest polyethylene absorber between the β source and the Geiger tube and record the counts. Repeat for the other polyethylene absorbers. Plot the number of counts in one minute vs the mass per unit area of the absorber, (mass per unit area is given with the absorber set.) Change to a γ source and measure the counts with no absorber and with each of the lead absorbers. Plot counts vs mass per unit area. If an α source is available, do a similar investigation of absorption of a radiation. Comment on how well matter absorbs each of these three types of radiation.

Half Life

Introduction

For any given radioactive isotope, there is a particular time interval, called a half life, in which the probability is 50% that each atom will disintegrate. Statistically we expect half of the nuclei to disintegrate during one half life. Of those which survive one half life, we expect half to disintegrate during the second half life, etc.

The number of nuclei that disintegrate per unit time is proportional to the number of nuclei present. But each disintegration reduces the number of nuclei. Therefore the number of disintegrations per unit time decreases. In this experiment we will measure the half life of a radioactive isotope by measuring the time for the disintegration rate to become half as great.

Procedure

> From this point in the lab activity onward, do not handle the Geiger tube, the petri dishes, the benchtop paper, and certainly not the solution you are about to receive.

The radioactive source used in this experiment is ^{137}Ba. Your laboratory instructor will provide for you with 3-10 drops of solution containing the radioisotope. Be careful not to get the solution on your hands[1]; in case you do, wash your hands immediately. This is a very weak source and the external danger is very small, but if you swallow some the internal danger could be significant.

Turn the count interval knob to manual ("MAN"). Place a freshly prepared sample of ^{137}Ba in the sample holder. Press COUNT, and note the time to the nearest second. Read and record the scalar display each 15 seconds. (This happens fast but record the display to as many digits as possible and round off at that point.) Record on 15-second intervals for about 8 minutes.

Now subtract each count recorded from the previous count to obtain the number of counts per 15 seconds. Subtract the background from this to get the net counts per 15 seconds. Determination of the background count is as follows: The ^{137}Ba should be almost gone after 15 minutes or more. Obtain a background count (with the liquid sample still in the counter stand) by counting for 2 minutes and then dividing by 8 to obtain the 15-second background value. A data sheet should look something like this.

[1] It should be very easy to avoid getting the solution on your hands and clothes, because you are not to be handling it!

Time (sec)	Total counts	Gross counts per 15 sec	Background per 15 sec	Net counts per 15 sec
0	0			
15	140	140	12	128
30	276	136	12	124

Analysis

Option I

Now plot the net counts per 15 seconds (count rate) vs time. Select a scale for both axes such that more than half of the sheet of graph paper is used. Draw the smooth curve that best fits the points. It is expected that many of the points will be a significant distance from the smooth curve. This is a result of randomness in the decay and counting processes. Do not expect all of the points to fall on a smooth curve (see Figure 1 for an example).

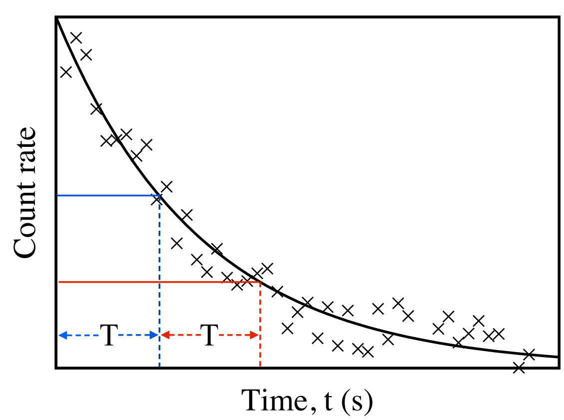

Figure 1

Now pick some point *on the smooth curve* that is near the high-count-rate end and record the count rate and time. Next, move along the smooth curve until the count rate is one half as great and record the time. The half life is the difference in these two times. Select another point on the smooth curve and repeat the procedure to get half life from that part of the curve. Find the half life a total of 4 times and take an average. Care should be taken not to use the low-count-rate part of the curve.

Option II

The decay rate of a radioactive isotope is given by the equation

$$I = I_0 e^{-0.693t/T}$$

I is the number of disintegrations per-unit-time at time t, I_0 is the initial rate, and T is the half life. This equation can be manipulated to become

$$\ln I = \frac{0.693t}{T} + \ln I_0$$

Notice now that a plot of $\ln I$ vs t is a straight line of slope $-0.693/T$ and intercept $\ln I_0$. Plot $\ln I$ (I is the net counts for 15 seconds) vs t and draw the straight line that best fits the points. Select a scale for both axes such that more than half of the sheet of graph paper is used. Select two widely separated points on the straight line and graphically take the slope. From this slope compute the half life.