LAB 11 Half-life of a radioactive substance by R.E. Tremblay

Purpose: To determine the half-life of a radioactive substance known as Ba-137*.

Caution: No eating or drinking in the lab.

Materials: a watch with a second hand-bring this from home, nuclear counter, radioactive source(will be supplied by the instructor after you are set up), ruler, 35 mm plastic film container, graph paper, semi-log graph paper , download here.

Discussion: A substance is said to be radioactive if the nuclei of its atoms emit pieces of themselves and changes into a different atoms , or if the nuclei of the atoms rearrange into a less energetic state and emit a photon of light in the process. A radioactive element has a characteristic half-life, which is the time that it takes for 1/2 of its remaining atoms to decay. As the atoms of a radioactive element decay, the substance emits fewer particles/sec and is therefore less radioactive as time goes by. As each half-life passes, the substance is 1/2 as radioactive as it previously was.

In this lab, a sample of Cs-137 is in a lead container that shields us from the beta radiation that it emits. Although the Cs-137 has a relatively long half-life, it decays into ${}^{137}_{56}Ba^*$ which has a half-life of 2.55 minutes. The reaction is written as follows:

$${}^{137}_{55}Cs \rightarrow {}^{0}_{-1}\beta + {}^{137}_{56}Ba^*$$

Beta decay example

${}^{137}_{56}Ba^*$ is a gamma ray emitter and dissolves in hydrochloric acid. Your instructor will drip a dilute hydrochloric acid into the lead container and 'milk out' a small sample of ${}^{137}_{56}Ba^*$ for you to analyze.

In this lab the daughter, Barium-137m, decays by gamma emission to Barium-137. This is an example of an isomeric transmission as nucleons go from a higher to a lower energy state. Each of the gamma ray photons, has an energy of 662 keV. This is an example an isotope that undergoes gamma decay.

$${}^{137}_{56}Ba^* \rightarrow {}^{0}_{0}\gamma + {}^{137}_{56}Ba$$

Gamma decay example

LAB 11 Half-life of a radioactive substance **by R.E. Tremblay**

Name:________________________

Lab preparation: Please complete the following exercise before coming to lab. Hand this page in, before the beginning of the lab.

1. Define radioactivity:

2. Define half-life:

3. What is the half-life of ${}^{137}_{56}Ba^{*}$?

4. Write the decay equation for ${}^{137}_{56}Ba^{*}$.

4. Will drinking or eating be allowed during this lab?

LAB 11 Half-life of a radioactive substance **by R.E. Tremblay**

Procedure:

1) Make sure that the high voltage knobs on the left of the counter are both at zero and then plug in the counter. Press the power switch on.

2) Press reset. The display should be all zeros.

3) Adjust the count interval knob to 0.5 minute, press the **test** switch and then press the count switch and watch the counter count. After 1/2 minute the instrument will stop counting and should display the number 1800. If it does not, try this test again.

4) **Press the test switch off** and reset to zero. Plug the Geiger-Mueller tube into the back of the nuclear timer.

5) Adjust the high voltage to 400 Volts, press count and wait 1/2 min. for the counter to stop on its own. Record the display and press reset. Do step five 3 times and determine the average count. Record this average as the **'background cosmic ray count'**.

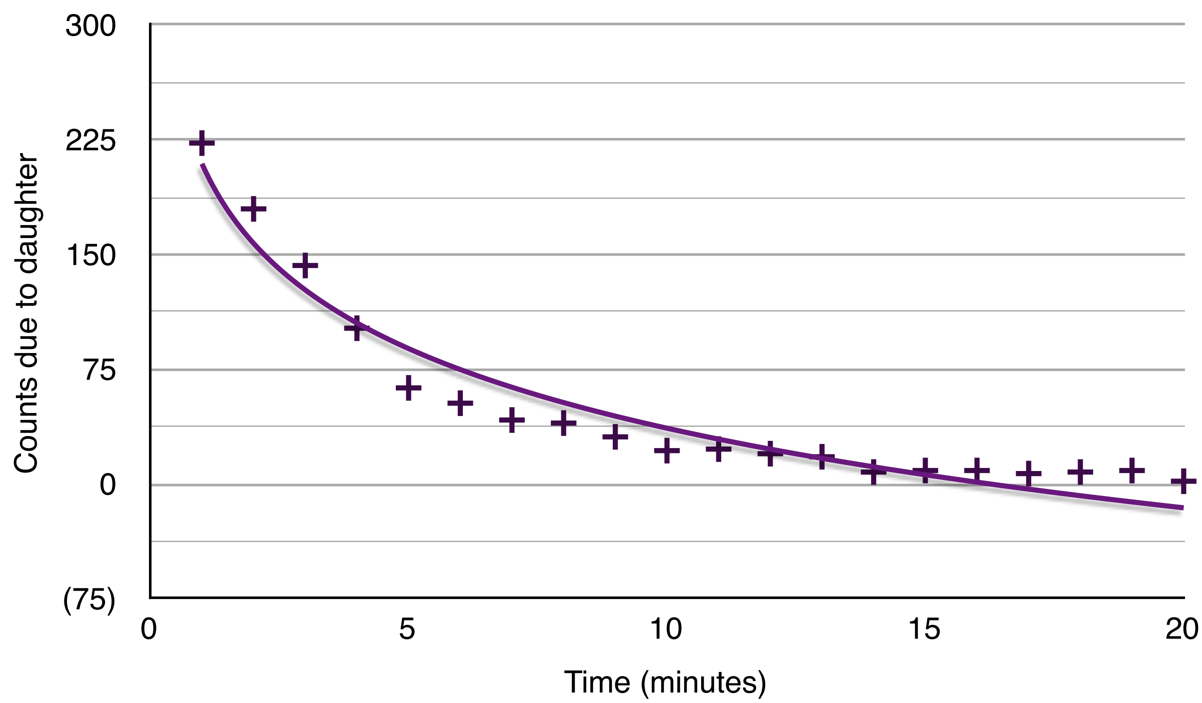
6) Reset to zero. Leave the voltage set to 400V and notify your instructor that you are ready for the radioactive sample. **Be patient**. It will take about 5 minutes per station to regenerate enough of the daughter isotope to be "milked" from the parent.

7) Take a 30 sec radiation count every minute for 30 min. That is, with the timer on 0.5 min., note the position of the second hand on your watch, then press count. The counter will stop on its own after .5 minutes. You now have 30 sec. to record the display as **'gross counts'** on your data sheet and to press reset so that you are ready for your next reading. Watching the second hand on your watch, press count every minute, on the minute. Continue until you have 30 values.

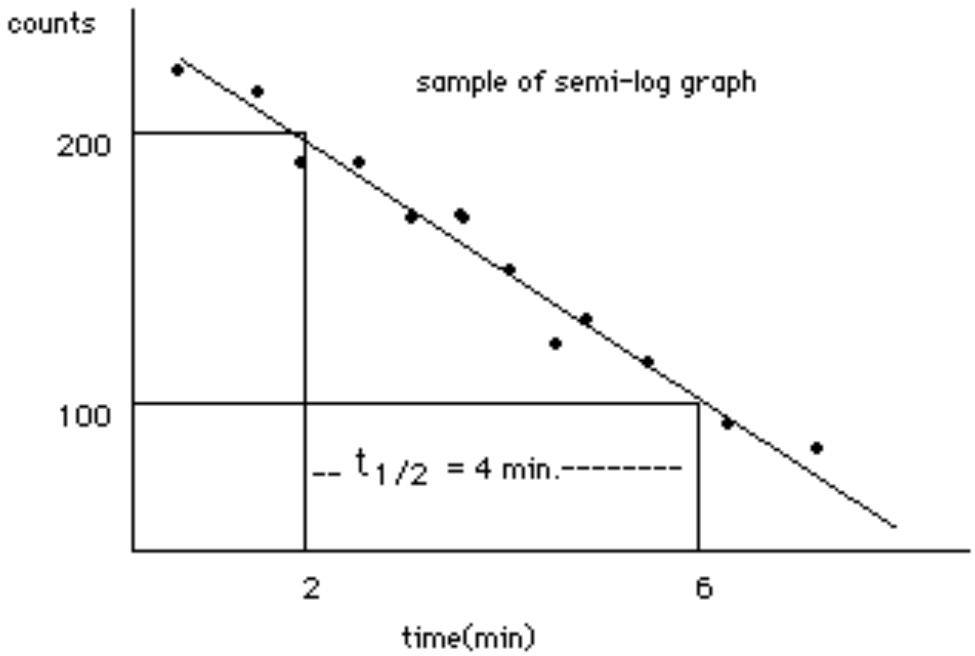
8) Notice on your data sheet that the last few values stopped decreasing. That means that there wasn't enough activity from the daughter left for us to distinguish its activity from that of the parent and background. Take an average of the last 5 counts and place it on the data sheet as **'total background count'**. Subtract the total background count from 'gross count' and enter as **'counts due to daughter'** on your data sheet.

Analysis of Results:

1) On normal graph paper, make a graph of counts due to daughter versus the elapse time for the first 20 minutes. Draw a smooth line through the data points- you should not connect the dots. No one point is more accurate than another. Notice that you do not get a straight line. This suggests an exponential relationship between radioactivity and time.



2) Make a second graph on semi-log paper. [Follow this link to learn how to use semi log graph paper.]



Download semi log graph paper. A semi log graph allows us to plot a large range of numbers.

3) We can determine the half-life of the daughter from the semi-log graph by selecting any number of counts (I used 200) and drawing a horizontal line until it intersects your slope. At the intersection, draw a vertical line down to the time. Next divide the selected number of counts in half (in my example it is 200/2 = 100) and then draw a second horizontal line from the result(100), to your curve.

At the intersection with your curve, draw another vertical line down to the time.

4) **<u>The difference in the two times is the half-life of the daughter.</u>** It represents the time for the radioactive substance to become 1/2 as radioactive as it was.

(*A method that we won't use to determine the half-life is to graph the natural log of the activity vs time and take the slope of the line. Set the slope equal to -0.693/half-life and solve for half-life).*

LAB 11 Half-life of a radioactive substance by R.E. Tremblay

Data sheet Name________________ sect.___

Background cosmic ray count________

Total background count____________

Time (minutes)	Gross count	Count due to daughter	Time (minutes)	Gross count	Count due to daughter
1			16		
2			17		
3			18		
4			19		
5			20		
6			21		
7			22		
8			23		
9			24		
10			25		
11			26		
12			27		
13			28		
14			29		
15			30		

Half-life determined from semi-log paper________________

Percent error _________________

This page contains data from a sample lab and will be used if a radioactive substance is not available.

Sample data Data sheet

Background cosmic ray count__4__

Total background count____________

Time (min.)	Gross count	Counts due to daughter
1	223	
2	180	
3	143	
4	102	
5	63	
6	53	
7	42	
8	40	
9	31	
10	22	
11	23	
12	20	
13	18	
14	8	
15	9	
16	9	
17	7	
18	8	
19	9	
20	2	
21	8	
22	9	
23	7	
24	8	
25	5	
26	3	

Half-life determined from semi-log paper________________

Percent error _________________