EXPERIMENT - RADIOACTIVE DECAY

In this experiment you will show that the radioactive decays follows first order kinetics, determine the half life of the decay and calculate the initial number of atoms in the sample.

Procedure:

The data will collected in class as a demonstration and the file will be stored on my homepage. First, background radiation will be measured so that the average value can be subtracted from the counts measured during the decay. Then a small sample of $^{137}$Ba will be removed from the generator and placed under the counter. The decay being observed is from an excited nuclear state of $^{137}$Ba to the ground state $^{137}$Ba with the emission of a $\gamma$ photon.

Calculations:

1. **Calculate the average rate during each time interval.** To do this create a new calculated column called “rate” whose equation takes the counts and divides by 10 giving the rate as counts/sec.

2. **Convert the average rate measured into instantaneous rate.** To do this you will correct the time value to account for the fact that the average rate of decay during the interval is the instantaneous rate at one specific time during the interval. Since the decay rate decreases in a non-linear way during the interval the average rate calculated is the instantaneous rate at a time that is about 5.2 seconds earlier than the time measured at the end of the interval. Create a new calculated column called “corrected time” whose equation takes the measured time value and subtract 5.2 seconds. At these times, the instantaneous rate of the decay would have been equal to the average rate measured.

3. Using the background radiation data, draw a graph of rate vs corrected time. Autoscale the axes. To find the average (mean) select the Statistics link under Analyze in the toolbar. Give the graph a title and copy this graph to your lab report making sure it shows the Statistics box.

4. Correct the rate of decay observed during the trial with the $^{137}$Ba, by subtracting the average background rate from the observed rates during the trial. To do this, create another calculated column called “corrected rate” and have the computer subtract your average background rate from the numbers in the “rate” column you have previous created.
5. **Find the rate constant for the decay.**

If the decay follows 1\(^{st}\) order kinetics then we can write the rate law and the integrated rate as:

\[
\text{rate} = kN
\]

\[
\ln N = -kt + \ln N_0
\]

where \(N\) is the number of radioactive atoms present in the sample and \(k\) is the rate constant. If we solve the rate law for \(N\) and then substitute that expression into the integrated rate law we get:

\[
\ln\left(\frac{\text{rate}}{k}\right) = -kt + \ln\left(\frac{\text{rate}_0}{k}\right)
\]

Using the properties of logs this would become:

\[
\ln(\text{rate}) - \ln k = -kt + \ln(\text{rate}_0) - \ln k
\]

This reduces to:

\[
\ln(\text{rate}) = -kt + \ln(\text{rate}_0)
\]

So, a plot of \(\ln(\text{corrected rate})\) vs time should be linear (just like a plot of \(\ln N\) vs time) with a slope equal to the rate constant with the opposite sign. The y-intercept will be the natural logarithm of the initial rate.

Add a new calculated column to compute \(\ln(\text{corrected rate})\). Then plot a graph of \(\ln(\text{corrected rate})\) vs the corrected time using the decay data. Copy this graph to your report making sure the slope value WITH ITS UNCERTAINTY is shown on the graph.
6. **Relating the corrected rates to numbers of atoms.** If the decay is 1st order as we suspect, the rate is related to the number of radioactive atoms present by the rate law:

\[
\text{rate} = kN
\]

\[
N = \frac{\text{rate}}{k}
\]

Actually for this to be strictly correct we would have to have counted ALL the \(\gamma\) photons emitted each second. This would require a sensor that surrounded the sample completely, but this will work for what we want to do with it. Use the initial rate to calculate the initial number of radioactive Ba atoms in the sample that are emitting photons in the direction of the sensor. Convert this number into grams of barium. You should see that radioactive decay kinetics can be studied with extremely small amounts of sample.