Exp. 2 Radioactive Decay

In Chapter 2 in Wang et al., Radiotracer Methodology in the Biological, Environmental, and Physical Sciences, we considered an outline of some of the quantitative aspects of radioactive decay. Among the important concepts considered was equation 2-10 which said that

$$A = A_o e^{-\lambda t} \qquad \text{(II-1)}$$

where A is the counting rate at some time t due to a radioactive sample that gave counting rate A_o at time $t = 0$. The above equation shows the counting rate due to a radioactive sample decreases exponentially with time. At the same time, we discussed the concept of a half-life for each nuclide where the half-life, $t_{1/2}$ is the time required for the sample activity to decrease by 1/2. Formally we showed that

$$t_{1/2} = \frac{\ell n 2}{\lambda} = \frac{0.693}{\lambda} \qquad \text{(II-2)}$$

We also showed (in Figure 2-16) how the composite decay rate of a sample containing a mixture of two independently decaying activities could be "resolved" into separate decay curves for each component. In this experiment, we shall demonstrate how many of these concepts are used in the laboratory.

A. Measurement of the Half-Life of a Radionuclide*

Procedure

1. Set the high voltage plateau on the G-M counting system at the value

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*All parts of this experiment have been taken from standard laboratory experiments used at Oregon State University. Because of the availability of a nuclear reactor, we have chosen to use reactor-produced radionuclides of short $t_{1/2}$ to allow completion of all portions of the experiment within a three-hour laboratory period. The experiment, of course, can be performed with a large number of other radionuclides which may be more accessible to another university.

indicated by your instructor. Insure your counting system is responding correctly using a standard source.

2. Remove all radioactive sources in the vicinity of your counter and initiate a background count. Due to the statistical nature of radioactive decay background counts should be as long as is reasonably possible. A minimum of ten minutes is suggested. Record the data in your lab notebook. The format shown below is appropriate.

Count No.	Total Counts	Total Time	Counts/Minute

3. Prepare a sample of radioactive ^{28}Al* for counting by taping a piece of radioactive ^{28}Al foil furnished by your instructor to a sample mounting card. Be sure to use tweezers to handle the foil and wear gloves, etc. Label the sample as to activity and approximate count.

4. Place a sample on the appropriate counter shelf which gives a count rate $\leq$ 5000 cpm.** Count the sample for 10 one-minute intervals, noting the clock time when each count was initiated and the number of counts. Record this data in your lab book. The format shown below is appropriate.

5. Subtract the background rate (in cpm) from each of the above counts and record the results in Table II-1.

Table II-1

Count No.	Time of Day	No. Cts/Min.	Background (cpm)	Net Count Rate (Sample-Background

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**With most of the OSU G-M counters, the deadtime loss is negligible at count rates -$\leq$ 5000 cpm.

*∿0.1 mg pure Al-500W-pneumatic terminal-2 minutes

6. Plot the net count rate vs. elapsed time on semilog paper as shown in Figure II-1.

7. Using the methods and expressions outlined in Chapter 2, calculate the decay constant, λ; the half-life, $t_{1/2}$ and the mean life, t_m, for ^{28}Al.

$t_{1/2}$ (expt'l)____________________

λ (expt'l)____________________ $t_{1/2}$ (known)=2.2405 min.

t_m (expt'l)____________________

Discuss any discrepancies between your $t_{1/2}$ value and the known value.

B. Resolution of a Decay Curve of a Mixture of Two Independently Decaying Activities.

Introduction:

The decay of a mixture of two or more separate radionuclides involves a more complex analysis. In the case where one cannot discriminate between the radiations emitted by each nuclide, the total count rate is the sum of the count rates from the two separate nuclidic decays.

$$A_t = A_o^1 e^{-\lambda_1 t} + A_o^2 e^{-\lambda_2 t}$$

The plot of ln A_t vs. t for two decays is shown by the solid line in Fig. II-2. For long times, i.e., $t >> t_{1/2}^2$, essentially all of nuclide 2 has decayed away and the count rate is then given by

$$A_t = A_o^1 e^{-\lambda_1 t} \qquad \text{for } t >> t_{1/2}^2$$

This data at large t can be extrapolated back to time zero (dashed curve Fig. II-2) to find A_o, and the slope of this curve is $-\lambda_1$.

If this curve is then subtracted from the total curve, the resultant curve (long dash-short dash line in Fig. II-2) is

$$A_t - A_o^1 e^{-\lambda t} = A_o^2 e^{-\lambda_2 t}$$

From the resultant curve A_o^2 and λ_2 can be determined.

Although this technique can be applied, in theory, to a greater number of simultaneous decays the associated errors become quite large and the method becomes cumbersome.

Experimental

In this section of the experiment, each student will be given a mixture of ^{28}Al ($t_{1/2}$ = 2.24 min) and ^{116m}In ($t_{1/2}$ = 54.12 min) and asked to measure and resolve the composite decay curve.

Procedure:

1. Repeat the background measurement and record the result in Table II-2.
2. Prepare an Al-In source by taping a short piece of radioactive Al-In wire to a sample mounting card. Use the same precautions used in preparing the Al-sample. [(∿12 mg) In-Al wire - 50. W-TRIGA pneumatic terminal - 2 minutes.]
3. Position the sample on the counter shelf which gives an initial counting rate of ∿5000 cpm.
4. Make measurements of the activity of the Al-In sample as a function of time over a period of two hours. Begin with a series of one-minute counts and then as the ^{28}Al dies away, increase the count times to ten minutes. Record the results as average count rate (cpm) with the value of the time of day being the mid-point of the counting time in your lab notebook. The format shown below is appropriate. (Thus an observation of 1000 counts in a ten-minute count running from 1440 to 1450 would be reported as an average count rate of 100 cpm observed at 1445).

Table II-2

Time of Day	Count Duration	Number Counts	Avge. Ct. Rate (cpm)	Bkgrnd.	Nt. Ct. Rate

5. Plot the net corrected activity of the Al-In wire vs. time on semilog paper as shown in Figure 2-16. Using the methods outlined in Chapter 2, resolve the decay curve into its two components and determine the half-life associated with each nuclide.

$t_{1/2}$ (^{28}Al-expt'l)________________________________

$t_{1/2}$(^{116m}In-expt'l)________________________________

6. Using values of the neutron flux, foil weight and composition, counter efficiency, and length of time of irradition given to you by your instructor, use equation 17-11 to calculate the thermal neutron capture cross sections for the ^{27}Al(n,γ) ^{28}Al and ^{115}In(n,γ) ^{116m}In reactions.

σ[^{27}Al(n,γ) ^{28}Al] expt'l = ____________________barns

σ[^{115}In(n,γ) ^{116m}In) expt'l = ________________barns

The literature values of these cross sections are 0.23 barns and 157 barns. Comment on any discrepancies between your measured values and the accepted values.

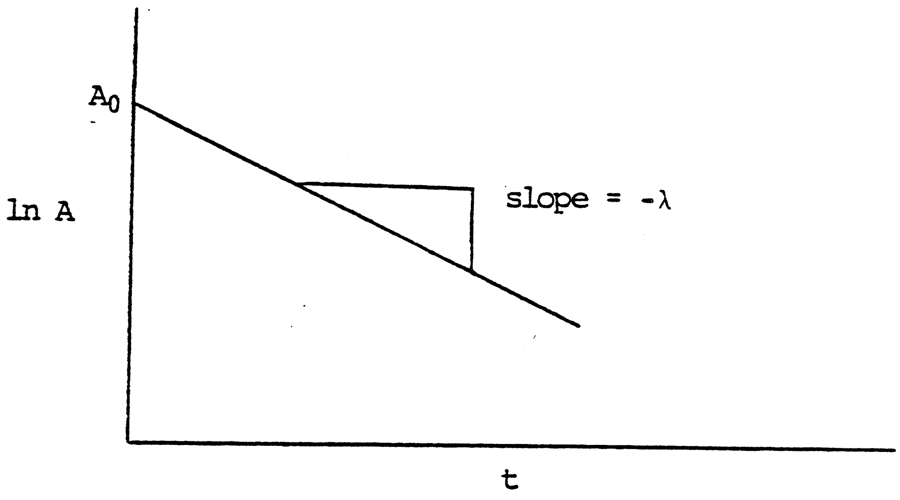

Fig. II-1 Decay Curve for Single Radionuclide

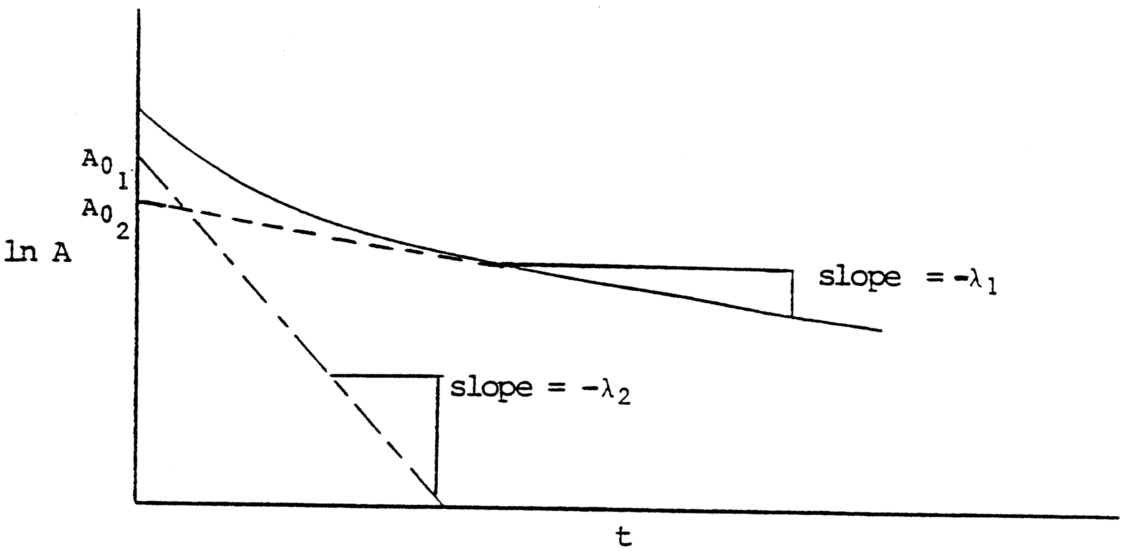

Fig. II-2 Composite Decay Curve