Algebra Based Physics **Radioactivity & Half-life Lab**

I. Radioactive Decay Analogy

The purpose of this activity is to provide a model for the process of radioactive decay using objects that can be seen easily. Here RED beans will be used to represent radioactive nuclei that decay, that change into a different nucleus by some process. The nuclei that are produced after the decay will be represented by White Beans.

The Half-Life is the TIME required for one-half of the members of a sample to go through their decay process and change. The number of steps required here is the equivalent of this time in a real decay process.

Procedure:

1. COUNT 100 Red beans and place them in a container. Also obtain roughly the same amount of White beans and put them in another container.

2. From the Red Bean container, draw out 10 red beans. Replace them with 10 White beans.

3. Now stir the beans in the Read Bean container. Then randomly draw 10 beans out. Examine the set of removed beans, and record the number of RED beans that were removed. Record your results in a table like the one started below:

Sample Number	No. of Red Beans Removed from Sample	No. of Red Beans Remaining in Sample	Theoretical No. of Red Beans Remaining in Sample
0	none	100	
1	10	90	
2			
3			
4			
5			
6			
7			
8			
9			
10			

4. For each RED bean that was removed, put a white bean back. If your removed sample included any white beans, simply return them. After each exchange you will again have 100 beans in the Red Bean Container, but not all are red.

5. Repeat steps 2 and 3 until there are no more than 20 red beans remaining in your container.

6. Now complete the “Theoretical” number of Red Beans Remaining column in the table. You do this on the basis of what is likely to happen: For sample 2, when there were 90 red beans and 10 white beans, a random sample of 10 can be expected to have 9 red and 1 white, so after 2 samples there theoretically should

be 81 red beans remaining. For sample 3, drawn from a theoretical population of 81 red and 19 white beans we could expect 8.1 reds and 1.9 whites (or 8 reds and 2 whites in a single draw,) leaving 73 red beans. Continue this for as many steps required to get down to 20 red beans or less.

7. Plot a line on a graph of Number of Red Beans Remaining versus Sample Number for your Theoretical Decay process.

   Then just plot the Actual No. of Red Beans remaining at each sample as points (which should lie around this line).

8. What is the HALF-LIFE of this process?

9. How closely do the actual points fit the Theoretical Line?

II. Determination of Half-Life

In this lab the rate of decay of a radioactive sample will be measured at regular intervals. From these values, the rate of decay will be determined and an estimate made of the sample's half-life.

Theory:

B. Radioactive Decay:

A basic concept of radioactive decay is that the probability of decay for each type of radioactive nuclide is constant. In other words, there are a predictable number of decays per second even if it is not possible to predict which nuclei in the sample will decay. A quantity called the decay constant a characterizes this concept. It is the probability of decay per unit time for one radioactive nucleus. The fundamental concept is that because a is constant, it is possible to predict the rate of radioactive decay of unstable isotopes.

Consider a sample of N radioactive nuclei with a decay constant a. The rate of decay of these nuclei $\Delta N/ t$ depends on how many nuclei remain since each decay is a random event:

The symbol N/ t stands for the rate of change of N with time t.

1. What is the physical meaning of the negative value of N/ t ? ___________________

The initial number of radioactive nuclei is designated as N_i. If this occurs at time $t = 0$, the initial value, N_i, is often labeled N_0. The question of interest is how many radioactive nuclei N are left at some time t. The answer to that question is found by solving the above equation by using a method from calculus called integration. The solution is

$$N = N_i e^{-at}$$

where e is the base of natural logarithms (e = 2.718…). The equation states that the number of nuclei N at some later time t decreases exponentially from the original number N_i that are present.

For laboratory measurements the counting rate, R, the number of decay particles that pass through a detector per unit time is directly proportional to the number of remaining radioactive nuclei N, and the initial rate R_i, is directly proportional to initial number of nuclei N_i.

2. Determine the equation relating the counting rate R to the initial rate R_i, the decay constant a, and the time t.

$$R = \_\_\_\_\_\_\_\_$$

C. Half-life:

An important concept associated with the radioactive decay process is the *half-life*. The time interval for a radioactive sample to go from N_i nuclei to one-half that value N_i /2 is defined as the half-life, $t_{1/2}$.

3. Find the half-life in terms of a. Set R/R_i equal to $^1/_2$, take the natural log, and solve for t:

$$\frac{R}{R_i} = \frac{1}{2} = e^{-at}$$

$$\ln\left(\frac{\_\_}{\_\_}\right) = \ln\left(\_\_^{\_\_}\right)$$

$$-\ln 2 = -at_{1/2}$$

$$t_{1/2} = \frac{\_\_}{\_\_}$$

4. To find a from our decay rate measurements. Transform the equation $R = R_i e^{-at}$ by taking the natural logarithm of both sides:

$$\ln(R) = \ln\left(R_i e^{-at}\right)$$

$$\ln R = \ln R_i - at$$

$$a = \_\_\_\_\_\_\_\_$$

Since R_i is a constant, this equation predicts that the ln R versus t graph will be a straight line with slope -a.

Experiment

A. Background Observation

1. Observe the video for the background measurement.

B. Radioactive Sample Observation

1. Once you have completed step IIA, ask the instructor to provide the video of the sample element and make notes about the sample, activation and decay process.

2. Data were recorded as an Excel file. ask your instructor for a copy of the data file. The data were continuously recorded at fixed intervals.

3. Data Analysis – R vs t graph.

    a. Should the background count level be subtracted from the measured values? If yes, do so now.

    b. Plot a graph of Count Rate versus (Starting) Time form your data. Draw a SMOOTH curve that fits your data as well as possible.

    c. Refer to this line on the graph and use it to estimate the half-lfe of your sample at three different places ALONG THE LINE.

    d. Use equation 30-5 and for three DIFFERENT pairs of data and the time t between them, compute decay constant and half-life values.

    e. You have six estimates of half-life. What is the average half-life and its standard deviation from your results?

4. Data Analysis – ln(R) vs t graph.

    a. Plot a graph of natural log of the Count Rate [ln(R)] versus (Starting) Time form your data. Determine a trendline that fits your data as well as possible.

    b. Use the slope information of the trendline and determine the half-life of your sample.

III. Independent Check

A. From your sample, what element is likely to be involved in decay here?

B. The sample was prepared by neutron activation: a neutron is added to a stable nucleus which then undergoes decay since the extra neutron makes the nucleus unstable.

1. Complete the following neutron activation expression for your sample. Choose the isotope that you believe is responsible for the decays that were observed.

Activation Process

$_{\_\_}\_\_\_^{\_\_} + {}_0n^1 \rightarrow {}_{\_\_}\_\_\_^{\_\_}$

2. In beta decay, a neutron in the nucleus decays into a proton, electron, and an anti-neutrino. Complete the decay expression for this type of decay with the appropriate silver isotopes from part 3. Also, indicate accepted half-life from your research.

Decay Process	Decay Mode	Half-life
$_{\_\_}\_\_\_^{\_\_} \Rightarrow {}_{\_\_}\_\_\_^{\_\_} + {}_{-1}e^0 + \bar{\nu}$	Beta	

Investigate the accepted value of the half-life for the isotope of the element you are investigating. You can use a dedicated program such as AtomicMac periodic table program, data on the NuDat table of isotopes Web site (or similar) located at

www.nndc.bnl.gov/nudat2

or a printed version such as the CRC Handbook of Chemistry and Physics to retrieve information on your element and its isotopes.

3. Compare your half-life values with Accepted value. Determine the percent error of your experimental values for the half-life to the accepted value.

IV. Conclusion.

Write a concluding statement about what you learned in this laboratory, what you discovered, which isotope produced the decay, the experimental half-life you determined, and the error.