Vanadium Half-Life Experiment

Reed Research Reactor

Summary

This lab experimentally calculates the half-life of a vanadium isotope.
The instructor will place a radioactive disk in your *SpecTech* counter.
Do not touch the disk.

Introduction

Stable atoms turn radioactive when a neutron is added to its nucleus. This new radioactive atom then releases energy in the form of various particles. In this experiment, a vanadium sample will be turned radioactive by bombarding the sample with neutrons.

$$^{51}V_{(\text{stable})} + n \longrightarrow {}^{52}V_{(\text{radioactive})} \longrightarrow {}^{52}Cr + \beta^- + \gamma$$

The *SpecTech* counters will measure the β^- and γ particles emitted from the radioactive sample, where each particle is "1 count." By measuring how many particles are released over several trials, we can see how radiation decays as time goes on. This is modelled by the **radioactive decay** function:

$$A_t = A_0 e^{-\lambda t},$$

where: $A_t \equiv$ activity after an elapsed time, t,
$A_0 \equiv$ initial activity,
$\lambda \equiv$ decay constant, unique to each isotope,
$t \equiv$ elapsed time, t,
$e \approx 2.718 \equiv$ a constant.

This experiment will use a derivation of the radioactive decay function to experimentally determine the half-life of the radioactive vanadium (^{52}V) sample. Half-life is the amount of time a sample takes to lose half of its radioactivity. Theoretically, the **half-life equation** of a given isotope is:

$$t_{1/2} = \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda},$$

where: $t_{1/2} \equiv$ half-life,
$\lambda \equiv$ decay constant.

Experimentally (in this lab), we can measure the radioactivity of a sample over time, and see how long it takes for half of the radiation to decay. For example, suppose a sample has 1000 counts of radioactivity at $t = 0$ sec and 500 counts at $t = 100$ sec. Then, the sample's half-life is 100 seconds, as that is how long it took to halve its radioactivity (1000 → 500 counts).

There are several uses for the half-life value. If you do not know the identity of the isotope, but have the experimental half-life ($t_{1/2}$), then you can calculate the decay constant (λ) using the half-life equation. The λ can be compared to known values to identify the isotope. Half-life is also used in popular radiochemistry techniques such as carbon dating.

Procedure

A. Measuring background radiation

1. The instructor will project a stopwatch on the whiteboard. They will tell you when to press COUNT on your *SpecTech*, and they will start the stopwatch at the same time.
2. After 40 seconds, the *SpecTech* counter will automatically stop reading counts. You have 10 seconds to record your data in Table 1.
3. Repeat steps 1 and 2 until Table 1 is complete. If you make a mistake, simply skip the current trial and wait for the next trial.
4. Calculate the average background radiation count.

B. Measuring the decay of the irradiated vanadium sample

1. The reactor staff will irradiate vanadium samples in a neutron source. The instructor will then place one vanadium sample in each counter. **Do not touch the sample.**
2. The instructor will tell you when to press COUNT on your *SpecTech*, and they will start the stopwatch at the same time.
3. After 40 seconds, the *SpecTech* counter will automatically stop reading counts. You have 10 seconds to record your data in Table 2.
4. Repeat steps 1 and 2 until Table 2 is complete. If you make a mistake, simply skip the current trial and wait for the next trial.
5. In Table 2, compute the net counts for each time interval by calculating counts minus your average background count.

C. Determine half-life from the graph

1. Plot **time** versus **net counts** using the data in Table 2. Use the beginning of the interval (0, 50, 100, etc.) as your time values.
2. Draw a single best fit curve through the plotted points. This freehand curve should "average" the points. Do not connect the dots.
3. On your **curve**, find the time (t_1) where the activity is 800 counts. Find the time (t_2) where the activity is 400 counts. In Table 3, compute the difference in these two time values ($t_1 - t_2$) to determine the half-life ($t_{1/2}$).
4. Repeat the previous step, but with two other count values besides 800 and 400. Remember that to find the **half**-life, the count values must be related by a factor of 2.
5. Take the average of the 2 computed half-lives to determine the half-life of ^{52}V decay.

Table 1: Radiation, Background

Count Interval (sec)	**Counts**
0-40	
50-90	
100-140	
Average	

Table 2: Radiation, Decay

Time Interval (sec)	**(min:sec)**	**Counts**	**Net Counts**
0-40	:00-:40		
50-90	:50-1:30		
100-140	1:40-2:20		
150-190	2:30-3:10		
200-240	3:20-4:00		
250-290	4:10-4:50		
300-340	5:00-5:40		
350-390	5:50-6:30		
400-440	6:40-7:20		
450-490	7:30-8:10		
500-540	8:20-9:00		
550-590	9:10-9:50		
600-640	10:00-10:40		

Table 3: Half-Life from Graph

Counts	**Time**	**Counts**	**Time**
800	$t_1 =$		
400	$t_2 =$		
$t_{1/2} = t_1 - t_2 =$		$t_{1/2}$	

Average half-life value for ^{52}V decay: