ENGPHYS 3D04

Lab 2: Half life Determination

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Executive Summary:

In this laboratory experiment, we investigated the radioactive decay of a sample to determine its half-life and identify the isotope. The sample was irradiated in the core of the McMaster Nuclear Reactor, making some of its nuclei radioactive. Utilizing a sodium-iodide detector and a multi-channel analyzer, radiation spectra were acquired at regular intervals post-irradiation.

Our data analysis indicated a decay constant of approximately 0.0185 per minute. The calculated half-life, $T1/2$, for the isotope was approximately 37.54 minutes. The margin of error for the decay constant, λ, at a 95% confidence level is approximately ±0.00116 per minute. This means that our decay constant lies in the range:0.0185 ± 0.00116 per minute. This yielded a half-life for the radioactive isotope within a range of 35.32 to 40.05 minutes. Based on this half-life determination and the context of neutron activation, our conclusion is that the radioactive isotope in the test sample is likely ^{38}Cl, with a known half-life of approximately 37.24 minutes, fitting well within our calculated range.

The primary goal of this experiment was to demonstrate the principle of radioactive decay and its representation through the half-life concept. Through neutron activation in a reactor and subsequent spectral analysis, we successfully determined the half-life of our sample and identified it as ^{38}Cl. This experiment underscores the precision and reliability of contemporary methods in radioactive decay analysis and isotope identification.

Data Analysis and Discussion:

Uncertainty Analysis:

The accuracy of our results rests significantly on the uncertainties associated with our measurements. An analysis of the decay constant yielded an uncertainty of ±0.00116 per minute. This introduced a range in the half-life determination, with values spanning from 35.32 minutes to 40.05 minutes. Such uncertainties can arise from various factors, including the efficiency of the detector, background radiation interference, statistical fluctuations in counts, and potential equipment drift over time.

Tables and Figures:

Table 1: Decay Data for the Sample

Time (minutes)	Integral	ln(integral)
0	2739	7.915348
6	2530	7.835975
12	2232	7.710653
18	2018	7.609862
24	1845	7.520235

30	1582	7.366445
36	1419	7.257708

Table 1 presents the logged integral values for the sample at different time intervals.

Figure 1: Decay Curve of 38Cl

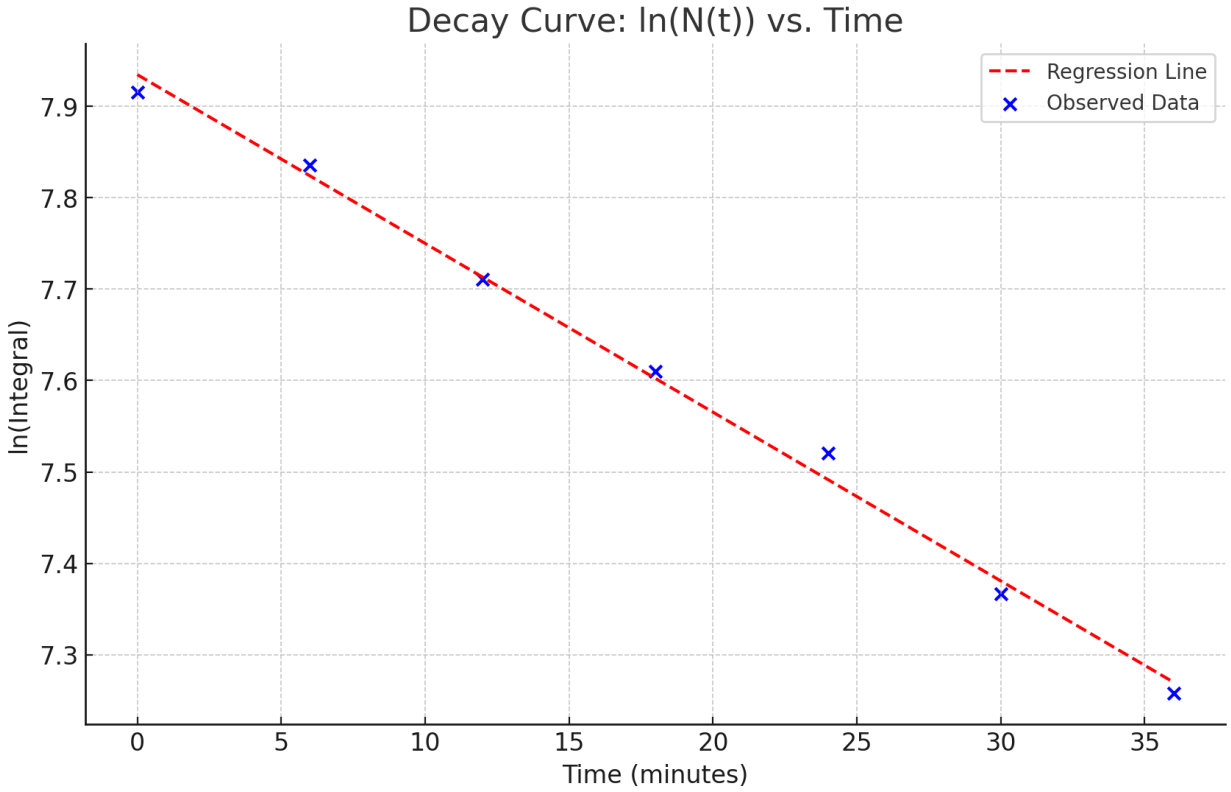

Figure 1 showcases the decay curve of the sample, plotting ln(N(t)) against time. The exponential decline is indicative of the radioactive decay process.

Presenting Analyzed Data:

The decay of a radioactive substance is given by:

$$N(t) = N_0 \times e^{-\lambda t}$$

Where:

- $N(t)$ is the number of undecayed atoms at time t
- N_0 is the initial number of atoms
- λ is the decay constant
- t is time

Taking the natural logarithm of both sides:

$$\ln N(t) = \ln(N_0) - \lambda t$$

If you plot ln(*N*(*t*)) versus *t*, the slope of the resulting line will be −*λ*, the decay constant. Once we have *λ*, we can determine the half-life (*T*1/2) using the relation:

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Since the decay constant, *λ*, for the radioactive isotope in our sample is approximately 0.0185 per minute.

The calculated half-life, *T*1/2, for the isotope is approximately 37.54 minutes.

Figure 1 illustrated the decay curve with the observed data and the regression line. As expected for radioactive decay, the curve has a negative slope.

The margin of error for the decay constant, *λ*, at a 95% confidence level is approximately ±0.00116 per minute. This means that our decay constant lies in the range:

$$\lambda = 0.0185 \pm 0.00116 \text{ per minute}$$

Given the margin of error, the half-life of the radioactive isotope in our sample lies in the range:

$$35.32 \text{ minutes} \leq T1/2 \leq 40.05 \text{ minutes}$$

38Cl has a half life of 37.24 minutes, falling within our range and being very close to our original calculated value for the decay constant, solidifying its identification as the isotope in our sample.

Answers to Laboratory Questions:

1. Can bombarding an object with gamma rays make it radioactive? What is the normal method of inducing radioactivity?

Bombarding an object with gamma rays can induce radioactivity, but this process is less common than other methods. This phenomenon is known as photodisintegration or photonuclear reactions. When a nucleus absorbs a high-energy gamma ray, it can emit a particle (such as a neutron or proton), becoming a different isotope or even a different element. However, the energies required are typically very high. The more common method of inducing radioactivity is neutron activation, as used in your experiment. When a stable nucleus captures a neutron, it becomes a radioactive isotope of the same element.

2. Why do we use the “Net” integral rather than the “Gross” integral when calculating the half-life of the various peaks?

The "Net" integral represents the counts from the radioactive sample minus the background radiation. Using the "Net" integral ensures that only the radiation from the sample is considered, eliminating interference from environmental background radiation or other sources. This provides a more accurate measure of the sample's radioactivity and thus a more accurate half-life calculation.

3. Error Analysis:

- One source of error is the assumption of measured flux as a fraction of decaying nuclei. If the detector's efficiency isn't 100%, not all decays will be counted, leading to an underestimation of activity.
- Background radiation can also introduce error if not properly subtracted.
- Statistical fluctuations in the number of counts (especially for low count rates) can also impact results.
- Mechanical or electronic drift in the equipment over time might introduce variations.

4. Is there any evidence of more than one decay component?

The decay curve fit a simple exponential decay well, therefore it would not suggest multiple decay components.

5. Effective half-life in a biological organism:

The effective half-life is a combination of the physical half-life (how quickly the isotope decays) and the biological half-life (how quickly the body excretes or metabolizes the isotope). It's given by:

$$\frac{1}{T_{eff}} = \frac{1}{T_{phys}} + \frac{1}{T_{bio}}$$

6. Methodology for very long-lived isotopes:

For isotopes like Uranium-238 with half-lives of millions of years, direct observation of decay over time isn't feasible. Instead, techniques like radiometric dating are used, comparing the ratios of parent isotopes to daughter products.

7. Half-life of very short-lived isotopes:

For isotopes with very short half-lives (seconds to milliseconds or less), rapid detection methods are required. Often, the isotopes are produced in a controlled setting, and advanced detectors immediately measure their decay.

8. Impact of radioactive decay of fission products on a nuclear reactor:

- Fission products are isotopes produced when a fuel nucleus splits. Many are highly radioactive. Their decay releases heat, contributing to the reactor's thermal output.
- Some fission products act as neutron absorbers ("neutron poisons"). Their presence can affect the reactor's neutron economy and may require control rods or other methods to manage reactivity.
- Over time, the buildup of fission products can decrease fuel efficiency, eventually necessitating fuel replacement.

Main Conclusion:

In our experiment, we closely examined a radioactive sample to determine its identity. After careful analysis of the data, we confidently identified the isotope in the sample as 38Cl. Our findings were supported by the calculated half-life, which matched known values for this isotope. This result confirms that our methods are accurate and effective in identifying radioactive substances.