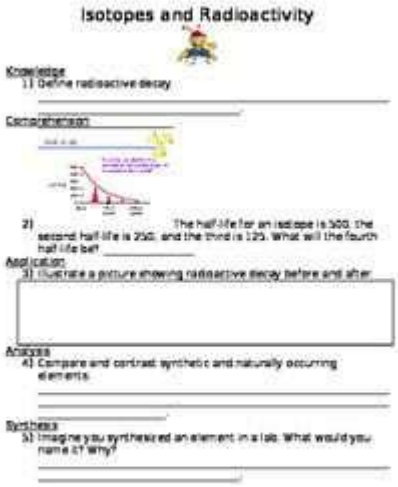
Half Life Of Radioactive Isotopes Answer Key


Isotopes and Radioactivity

Knowledge
1) Define radioactive decay

Comprehension

2) The half-life for an isotope is 300, the second half-life is 250, and the third is 125. What will the fourth half-life be?

Application
3) Illustrate a picture showing radioactive decay before and after

Analysis
4) Compare and contrast synthetic and naturally occurring elements.

Synthesis
5) Imagine you synthesized an element in a lab. What would you name it? Why?

Half life of radioactive isotopes is a fundamental concept in nuclear physics, chemistry, and various applications such as medicine, archaeology, and energy production. Understanding the half-life helps scientists and researchers comprehend how long a radioactive substance will emit radiation and how quickly it will decay into stable isotopes. This article delves into the significance of half-life, how it is calculated, its applications, and examples of various radioactive isotopes.

What is Half-Life?

Half-life, denoted as $t_{1/2}$, is the time required for half of the radioactive atoms in a sample to decay. This decay process is a random event at the level of individual atoms, but when considering a large number of atoms, it follows a predictable statistical pattern.

The half-life is a characteristic property of each radioactive isotope and can range from fractions of a second to billions of years. The concept is crucial for understanding not only how long a substance remains radioactive but also for determining the age of materials, evaluating the safety of radioactive waste, and planning medical treatments involving radioactive isotopes.

Understanding Radioactive Decay

Radioactive decay can occur in several forms, including:

- **Alpha decay:** The emission of an alpha particle (two protons and two neutrons) from the nucleus.
- **Beta decay:** The conversion of a neutron into a proton (or vice versa), resulting in the emission of a beta particle (an electron or positron).
- **Gamma decay:** The release of gamma radiation, which is high-energy electromagnetic radiation, often accompanying alpha or beta decay.

Each type of decay affects the half-life and the resulting isotopes produced, leading to a variety of decay chains and end products.

Calculating Half-Life

The half-life of a radioactive isotope can be calculated using the formula:

$$
N(t) = N_0 \left(\frac{1}{2} \right)^{\frac{t}{t_{1/2}}}
$$

Where:
- $N(t)$ = the quantity of the substance remaining at time t
- N_0 = the initial quantity of the substance
- t = the elapsed time
- $t_{1/2}$ = the half-life of the substance

This formula illustrates that after one half-life, half of the original quantity remains; after two half-lives, a quarter remains, and so forth.

Example Calculation

Suppose you have a sample of Carbon-14 (^{14}C) with an initial quantity of 100 grams and a half-life of 5,730 years. To find out how much of the isotope remains after 17,190 years (which is three half-lives), you can plug the values into the formula:

$$
N(17190) = 100 \left(\frac{1}{2} \right)^{\frac{17190}{5730}} = 100 \left(\frac{1}{2} \right)^{3} = 100 \cdot \frac{1}{8} = 12.5 \text{ grams}
$$

Thus, after 17,190 years, 12.5 grams of Carbon-14 would remain.

Applications of Half-Life

The concept of half-life has several practical applications across various fields:

1. Radiometric Dating

Radiometric dating is a method used to determine the age of an object through the decay of radioactive isotopes. Common isotopes used in this process include:

- **Carbon-14:** Used for dating organic materials up to about 50,000 years old.
- **Uranium-238:** Used for dating rocks and the Earth itself, with a half-life of about 4.5 billion years.
- **Potassium-40:** Useful for dating geological formations, with a half-life of 1.25 billion years.

These isotopes allow scientists to piece together the history of life on Earth and understand geological processes.

2. Medical Applications

Radioactive isotopes are widely used in medicine for diagnosis and treatment. Some key examples include:

- **Iodine-131:** Used in the treatment of thyroid disorders, particularly hyperthyroidism and thyroid cancer.
- **Technetium-99m:** A widely used radioisotope in imaging and diagnostic procedures due to its ideal half-life of 6 hours, minimizing patient exposure to radiation.
- **Cobalt-60:** Utilized in radiation therapy for cancer treatment.

The ability to understand and calculate half-lives allows healthcare professionals to use these isotopes safely and effectively.

3. Nuclear Power and Waste Management

In nuclear power generation, the half-life of isotopes is crucial for understanding fuel

behavior and managing nuclear waste. For instance:

- **Uranium-235:** Used as fuel in nuclear reactors, with a half-life of about 703.8 million years.
- **Plutonium-239:** A byproduct of nuclear reactors with a half-life of 24,100 years, requiring careful long-term storage solutions.

The long half-lives of some isotopes necessitate stringent regulations and innovative technologies to ensure safe disposal and management of radioactive waste.

Conclusion

The half-life of radioactive isotopes is a critical concept that intersects with various scientific fields and practical applications. From dating ancient artifacts to advancing medical procedures and managing nuclear energy, understanding half-lives enables scientists and professionals to make informed decisions regarding the use and safety of radioactive materials.

As research continues to evolve, so too will our understanding of half-lives, leading to potential new applications and deeper insights into the nature of matter itself. Whether in the lab, the clinic, or the context of the environment, the principles surrounding half-life remain pivotal in shaping our approach to the challenges and opportunities presented by radioactive isotopes.

Frequently Asked Questions

What is the definition of the half-life of a radioactive isotope?

The half-life of a radioactive isotope is the time required for half of the radioactive atoms in a sample to decay into a more stable form.

How is the half-life of a radioactive isotope used in carbon dating?

In carbon dating, the half-life of carbon-14 (about 5,730 years) is used to determine the age of organic materials by measuring the remaining amount of carbon-14 in a sample.

Why do different radioactive isotopes have different

half-lives?

Different radioactive isotopes have varying half-lives due to differences in their nuclear structure and the forces acting on their protons and neutrons, which influence the stability and decay process.

Can the half-life of a radioactive isotope change over time?

No, the half-life of a radioactive isotope is a constant property that does not change over time or due to external conditions.

How do you calculate the remaining quantity of a radioactive isotope after a certain number of half-lives?

To calculate the remaining quantity, use the formula: Remaining quantity = Initial quantity (1/2)^(number of half-lives).

What are some examples of radioactive isotopes and their half-lives?

Examples include Uranium-238 (half-life of about 4.5 billion years), Radon-222 (half-life of about 3.8 days), and Iodine-131 (half-life of about 8 days).

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