Tritium, Or 3 H, Has A Half-life Of 12.32 Years. Imagine A Sample Of Tritium Is Prepared. (a) What Fraction

Tritium, Or 3 H, Has A Half-life Of 12.32 Years. Imagine A Sample Of Tritium Is Prepared. (a) What Fraction of the original sample remains after a certain period? Understanding the decay of Tritium is essential in various fields, including nuclear physics, radiometric dating, and environmental science. This article explores the properties of Tritium, its half-life, how to calculate the remaining fraction after specific periods, and the practical implications of its radioactive decay.

Introduction to Tritium (3 H)

Tritium, also known as hydrogen-3 or 3 H, is a radioactive isotope of hydrogen. It contains one proton and two neutrons in its nucleus, making it heavier than the most common isotope of hydrogen, protium (1 H). Tritium is naturally occurring in trace amounts but is primarily produced artificially in nuclear reactors and particle accelerators. Its applications are widespread, from self-powered luminous devices to nuclear fusion research.

Properties of Tritium

Tritium features unique physical and radioactive properties:

- **Atomic Number:** 1
- **Mass Number:** 3
- **Radioactive Decay Mode:** Beta decay
- **Decay Product:** Helium-3 (3 He)
- **Half-life:** 12.32 years
- **Emission Type:** Beta particles with low energy (~18.6 keV)
- **Uses:** Radioluminescence, tracing, nuclear fusion experiments

Understanding Half-life

The concept of half-life is fundamental in radioactivity. It defines the time required for half of the radioactive atoms in a sample to decay. For Tritium, this is 12.32 years, meaning:
- After 12.32 years, 50% of the original Tritium atoms remain.
- After another 12.32 years (total 24.64 years), 25% remains.
- The decay continues exponentially, halving with each interval of 12.32 years.

Mathematically, the remaining fraction f of the original sample after time t is expressed as:
$$
f = \left(\frac{1}{2} \right)^{\frac{t}{T_{1/2}}}
$$
where $T_{1/2}$ is the half-life.

Calculating the Remaining Fraction of Tritium

Basic Formula

Given the half-life $T_{1/2} = 12.32$ years, the fraction of Tritium remaining after t years is:
$$
f = \left(\frac{1}{2} \right)^{\frac{t}{12.32}}
$$

Examples of Decay Calculations

Suppose a sample of Tritium is prepared, and we want to determine how much remains after specific periods:

1. **After 12.32 years (one half-life):**
   $$
   f = \left(\frac{1}{2} \right)^{\frac{12.32}{12.32}} = \left(\frac{1}{2} \right)^1 = 0.5
   $$
   So, 50% of the original Tritium remains.

2. **After 24.64 years (two half-lives):**
   $$
   f = \left(\frac{1}{2} \right)^{\frac{24.64}{12.32}} = \left(\frac{1}{2} \right)^2 = 0.25
   $$

Only 25% remains.

3. **After 36.96 years (three half-lives):**
   $$
   f = \left(\frac{1}{2} \right)^{\frac{36.96}{12.32}} = \left(\frac{1}{2} \right)^3 = 0.125
   $$
   Approximately 12.5% remains.

Implications of Tritium Decay

Understanding the decay of Tritium has critical implications:

Radioactive Dating and Environmental Impact

- Tritium's half-life makes it useful for dating recent geological and environmental samples.
- It can be used to trace water movement and study hydrological cycles.
- Because Tritium decays relatively quickly, it is less useful for dating ancient artifacts but effective for recent events.

Safety and Handling

- Tritium emits low-energy beta particles, making it relatively safe when contained.
- However, its radioactive nature requires careful handling, especially in nuclear facilities.
- Decay over time reduces radioactivity, but proper disposal remains essential.

Nuclear Fusion Research

- Tritium is a key fuel component in nuclear fusion experiments.
- Its decay properties are critical for understanding its behavior in fusion reactors.

Practical Calculation: How Much Tritium Remains After 50 Years?

Let's consider a practical example: if a sample starts with 100 grams of Tritium, how much remains after 50 years?

Applying the formula:

$$
f = \left(\frac{1}{2} \right)^{\frac{t}{T_{1/2}}}
$$

$$
f = \left(\frac{1}{2} \right)^{\frac{50}{12.32}} \approx \left(\frac{1}{2} \right)^{4.06} \approx 0.057
$$

Thus, approximately 5.7 grams of Tritium would remain after 50 years.

Conclusion

Tritium's half-life of 12.32 years makes it a fascinating isotope with several scientific and industrial applications. Its exponential decay allows scientists to predict the remaining amount of Tritium after any period accurately. Whether used in dating, energy research, or safety protocols, understanding how to calculate the fraction of remaining Tritium is vital. As time progresses, the radioactive decay diminishes the sample's activity, emphasizing the importance of precise calculations in handling and utilizing this radioactive isotope.

Key Takeaways

- **Half-life:** Tritium decays by half every 12.32 years.
- **Decay formula:** The remaining fraction is $(1/2)^{t/12.32}$.
- **Practical applications:** Dating recent samples, nuclear fusion, and radioluminescent devices.
- **Safety note:** Despite low-energy emissions, Tritium requires careful handling.

Understanding the decay process of Tritium not only provides insights into nuclear physics but also informs safety practices and technological innovations. Its predictable half-life ensures scientists can accurately gauge the remaining activity of samples over time, facilitating advancements across multiple scientific disciplines.

Frequently Asked Questions

What is Tritium (3H) and why is it significant?

Tritium (3H) is a radioactive isotope of hydrogen with a nucleus containing one proton and two neutrons. It is significant for its applications in nuclear fusion, radioluminescent devices, and scientific research due to its radioactive properties.

What does it mean that Tritium has a half-life of 12.32 years?

It means that after 12.32 years, half of a given sample of Tritium will have decayed into other elements, reducing the original amount by 50%.

If a sample of Tritium is prepared, what fraction remains after 12.32 years?

The fraction remaining after one half-life is 1/2 or 0.5.

How can we calculate the remaining fraction of Tritium after a certain period?

You can use the formula: remaining fraction = (1/2)^(time / half-life).

What is the decay process of Tritium?

Tritium decays via beta decay, transforming into Helium-3 by emitting a beta particle and an antineutrino.

Why is understanding the half-life of Tritium important in practical applications?

Knowing the half-life helps in estimating the longevity, safety, and handling of Tritium in scientific and industrial uses.

How long would it take for a Tritium sample to decay to 25% of its original amount?

It would take approximately 24.64 years, which is two half-lives, since after each half-life, half of the remaining sample decays.

Can Tritium be used as a dating method? If so, how?

Yes, Tritium can be used in hydrology and environmental studies to date water and other samples based on its radioactive decay over time.

Are there safety concerns associated with handling Tritium?

Yes, since Tritium is radioactive, proper safety protocols are necessary to prevent radiation exposure, especially during handling, storage, and disposal.

What is the significance of the exponential decay law in relation to Tritium's half-life?

The exponential decay law describes how the quantity of Tritium decreases over time, with the half-life being the time it takes for the quantity to reduce by half, following an exponential pattern.

Additional Resources

Tritium, Or 3 H, Has A Half-life Of 12.32 Years. Imagine A Sample Of Tritium Is Prepared. (a) What Fraction

Understanding the fascinating world of radioactive isotopes requires a grasp of their fundamental properties, especially their half-lives. Among these isotopes, tritium stands out due to its unique characteristics and applications. In this article, we will explore the concept of half-life through the lens of tritium, examining what happens to a sample over time, how much remains after certain periods, and what this means for scientific and practical purposes.

Introduction to Tritium and Radioactive Decay

Tritium, also known as hydrogen-3, is a radioactive isotope of hydrogen. Unlike its more stable counterparts—protium (^{1}H) and deuterium (^{2}H)—tritium contains one proton and two neutrons in its nucleus, rendering it inherently unstable. This instability causes tritium to undergo radioactive decay, transforming into helium-3 over time. Due to its radioactive nature, tritium has a half-life of approximately 12.32 years, which means that half of any given sample will decay into helium-3 within this period.

Radioactive decay is a stochastic process, meaning it is unpredictable for any single atom but statistically predictable for large numbers of atoms. The decay process follows an exponential law, which allows scientists to estimate how much of a radioactive substance remains after a certain period.

The Concept of Half-life: What Does 12.32 Years Mean?

The half-life of a radioactive isotope is the time required for half of the original number of radioactive atoms to decay. For tritium, this is 12.32 years, a period that offers insight into its longevity and stability.

Key points about half-life:

- It is a statistical measure, not an exact countdown for individual atoms.
- After one half-life, 50% of the original atoms remain.
- After two half-lives (about 24.64 years), 25% remains.
- The process continues exponentially, with the remaining amount halving with each half-life.

Understanding this concept is essential for applications such as dating, nuclear medicine, and energy research, where predicting the decay over time informs safety, longevity, and utility.

Calculating the Fraction Remaining After a Given Time

Suppose a scientist prepares a sample of tritium. How much of it remains after a certain number of years? The answer involves the exponential decay law, which can be expressed mathematically as:

$N(t) = N_0 \times (1/2)^{(t / T_{1/2})}$

Where:

- $N(t)$ is the quantity remaining after time t.
- N_0 is the initial quantity.
- $T_{1/2}$ is the half-life (12.32 years for tritium).
- t is the elapsed time.

To find the fraction of the original sample remaining after a specific period, we divide $N(t)$ by N_0:

Fraction remaining $= (1/2)^{(t / T_{1/2})}$

Example Calculation:

Suppose a sample of tritium is prepared with an initial amount of 100 grams. What fraction remains after 25 years?

- t = 25 years
- $T_{1/2}$ = 12.32 years

Calculate:

$t / T_{1/2} = 25 / 12.32 \approx 2.03$

Therefore:

Fraction remaining = $(1/2)^{2.03} \approx 0.25$

This indicates that approximately 25% of the original 100 grams, or 25 grams, would remain after 25 years.

Implications of the Calculation:

- After approximately two half-lives (about 24.64 years), about 25% remains.
- The decay process is predictable and exponential, emphasizing the importance of knowing the half-life for long-term planning and safety assessments.

Applications of Tritium and Its Decay Properties

The half-life of tritium makes it a valuable isotope in multiple domains:

- Nuclear Fusion Research: Tritium is used as a fuel in experimental fusion reactors, owing to its ability to produce high-energy reactions when combined with deuterium.
- Radioluminescent Devices: Due to its radioactive decay emitting beta particles, tritium is used in luminous paints for watches, emergency signs, and aircraft instruments.
- Environmental and Biological Tracing: Tritium's presence in water cycles allows scientists to trace environmental processes and study groundwater movement.
- Dating and Age Estimation: Although less common than carbon-14, tritium can be used to date water samples and study the age of materials with relatively recent origin (up to about 100 years).

Safety Considerations:

While tritium is less hazardous than many other radioactive isotopes because its beta radiation cannot penetrate the skin, it still requires careful handling. Its radioactive decay over time reduces the activity, but proper storage and disposal are critical to prevent environmental contamination.

Extended Decay: What Happens Over Multiple Half-lives?

Understanding the decay over multiple half-lives helps in planning long-term projects involving tritium:

- After 3 half-lives (~36.96 years): 12.5% remains.
- After 4 half-lives (~49.28 years): 6.25% remains.
- After n half-lives: The remaining fraction is $(1/2)^n$.

This exponential decay pattern underscores the diminishing presence of tritium in a sample over time, which is crucial when considering its application lifespan or environmental impact.

Decay Curve Visualization:

Graphing the decay reveals a characteristic exponential curve, starting at 100% and approaching zero asymptotically. Each successive half-life flattens the curve further, illustrating the decreasing amount of tritium present.

Conclusion: The Significance of Tritium's Half-life

Tritium's 12.32-year half-life embodies a delicate balance—long enough to serve vital functions in energy and research, yet short enough to decay within human timescales. Knowing what fraction remains after a certain period enables scientists, engineers, and safety officials to manage its use responsibly.

From calculating decay over decades to understanding its role in cutting-edge fusion research, the properties of tritium demonstrate how fundamental nuclear physics principles are applied in real-world contexts. As we continue to harness radioactive isotopes like tritium for scientific advancement, their half-lives remain a cornerstone concept—guiding safe handling, environmental stewardship, and innovative applications.

In summary:

- The half-life of tritium is 12.32 years.
- After one half-life, 50% remains.
- The decay follows an exponential pattern, allowing precise calculations of remaining quantities.
- This knowledge underpins its diverse applications, from energy to environmental science.
- Responsible management hinges on understanding its decay properties and long-term behavior.

Understanding the decay of tritium not only deepens our grasp of nuclear physics but also highlights the importance of precise calculations in ensuring safe and effective utilization of radioactive materials.

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