A Sample Of Polonium-210 Has An Initial Mass Of 390 Milligrams (mg). If The Half-life Of Polonium-210

A Sample Of Polonium-210 Has An Initial Mass Of 390 Milligrams (mg). If The Half-life Of Polonium-210, understanding its decay process, properties, and applications is essential for scientists, researchers, and health professionals. This article explores the characteristics of Polonium-210, its radioactive decay, and its significance in various fields.

Introduction to Polonium-210

Polonium-210 (Po-210) is a highly radioactive element discovered by Marie Curie in 1898. It is part of the chalcogen group and has the atomic number 84. Due to its intense radioactivity, Po-210 emits alpha particles during decay, making it both useful in specific applications and dangerous if misused.

Properties of Polonium-210

Physical and Chemical Characteristics

- **Appearance**: Silvery-gray metal that is brittle at room temperature.
- **Density**: Approximately 9.4 g/cm^3.
- **Melting Point**: About 254°C (489°F).
- **Boiling Point**: Approximately 962°C (1764°F).
- **Chemical Reactivity**: Reacts with acids, especially nitric acid, forming polonium salts.

Radioactive Nature

Po-210 is an alpha emitter with a half-life of approximately 138 days, meaning it decays quite rapidly compared to many other radioactive isotopes. Its decay process releases alpha particles, which are helium nuclei consisting of two protons and two neutrons.

Understanding Half-life and Radioactive Decay

What Is Half-life?

Half-life is the time required for half of the radioactive atoms in a sample to decay. For Po-210, this is about 138 days, meaning that after this period, only half of the initial amount remains.

Radioactive Decay Equation

The decay process can be modeled mathematically as:

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

where:
- $N(t)$ = remaining quantity after time t
- N_0 = initial quantity
- $T_{1/2}$ = half-life (138 days for Po-210)

Using this, we can determine how much of the original sample remains after a specific period.

Decay of a 390 mg Sample of Polonium-210

Given an initial mass $N_0 = 390\, \text{mg}$ of Polonium-210, we can analyze how the mass decreases over time.

Calculating Remaining Mass Over Time

Suppose we want to determine how much Po-210 remains after a certain period, say, 300 days.

Using the decay formula:

$$ N(t) = 390\, \text{mg} \times \left(\frac{1}{2}\right)^{\frac{t}{138\, \text{days}}} $$

For $t = 300$ days:

$$ N(300) = 390 \times \left(\frac{1}{2}\right)^{\frac{300}{138}} \approx 390 \times \left(\frac{1}{2}\right)^{2.17} $$

Calculating:

$$ \left(\frac{1}{2}\right)^{2.17} \approx 0.219 $$

So,

$$ N(300) \approx 390 \times 0.219 \approx 85.41\, \text{mg} $$

This indicates that after approximately 300 days, about 85.41 mg of Po-210 remains.

Half-life Timeline

- After 138 days (1 half-life), the remaining mass is:

$$390 \times \frac{1}{2} = 195\, \text{mg}$$

- After 276 days (2 half-lives), the remaining mass is:

$$390 \times \left(\frac{1}{2}\right)^2 = 97.5\, \text{mg}$$

- After 414 days (3 half-lives), the remaining mass is:

$$390 \times \left(\frac{1}{2}\right)^3 = 48.75\, \text{mg}$$

This exponential decay pattern illustrates the rapid decrease in radioactive material over time.

Applications of Polonium-210

Despite its dangerous nature, Po-210 has several important applications, primarily due to its alpha-emission properties.

Industrial Uses

- **Static Eliminators**: Po-210 is used in devices to neutralize static electricity in manufacturing environments, particularly in the production of textiles and photographic films.

- **Heat Source**: In certain spacecraft and satellites, Po-210 provides a reliable heat source due to its steady alpha particle emission.

Scientific and Medical Research

- Used as a neutron initiator in nuclear physics experiments.
- Employed in studies related to radiation effects and nuclear decay.

Historical and Controversial Uses

- In the past, Po-210 was infamously used in assassination attempts, most notably in the poisoning of Alexander Litvinenko in 2006. This highlights the element's toxicity and potential for misuse.

Safety and Handling Precautions

Handling Polonium-210 requires strict safety protocols due to its intense radioactivity.

Protection Measures

- **Shielding**: Use of gloves and protective clothing to prevent alpha particle exposure.
- **Containment**: Working within glove boxes and sealed environments.
- **Monitoring**: Using radiation detectors to monitor exposure levels.

Health Risks

- Alpha particles are harmful if ingested or inhaled, as they can damage internal tissues.
- Even external alpha radiation is mostly harmless due to its low penetration depth, but contamination poses serious health risks.

Environmental Impact and Disposal

Proper disposal of Polonium-210 is crucial to prevent environmental contamination.

Disposal Methods

- Sealed containment in specialized radioactive waste repositories.
- Long-term storage until decay reduces radioactivity to safer levels.

Environmental Considerations

- Strict regulations govern the handling and disposal of radioactive materials.
- Potential contamination can lead to health hazards for humans and ecosystems.

Conclusion

A sample of Polonium-210 with an initial mass of 390 mg undergoes significant decay over time due to its half-life of approximately 138 days. Understanding its decay process allows scientists to predict remaining quantities, manage safety protocols, and utilize its properties effectively. While Po-210 plays vital roles in industry and research, its high toxicity necessitates caution and responsible handling. Advances in nuclear science continue to explore applications of such radioactive elements, balancing their benefits against potential risks.

References

- United States Nuclear Regulatory Commission (NRC). "Radioactive Materials." NRC.gov.
- Marie Curie and the Discovery of Radioactivity. National Museum of Nuclear Science & History.
- Knoll, Glenn F. "Radiation Detection and Measurement." Wiley, 2010.
- World Health Organization (WHO). "Radioactive Substances in Medical and Industrial Applications."

Frequently Asked Questions

What is the initial mass of Polonium-210 in the sample?

The initial mass of Polonium-210 in the sample is 390 milligrams (mg).

What is the half-life of Polonium-210?

The half-life of Polonium-210 is approximately 138.4 days.

How much Polonium-210 remains after one half-life?

After one half-life, half of the original Polonium-210 remains, so approximately 195 mg.

How can we calculate the amount of Polonium-210 remaining after a certain period?

You can use the decay formula N = N0 (1/2)^(t / T1/2), where N0 is the initial mass, t is elapsed time, and T1/2 is the half-life.

How long does it take for the Polonium-210 sample to decay to less than 10% of its original mass?

It takes approximately 4.32 half-lives, or about 599 days, for the sample to decay below 10% of its initial mass.

What is the decay constant for Polonium-210?

The decay constant λ is approximately 0.00502 per day, calculated as λ = ln(2) / T1/2.

If the sample starts at 390 mg, how much remains

after 276 days?

Approximately 97.5 mg remains after 276 days, which is two half-lives (138.4 days each).

Why is Polonium-210 considered highly radioactive?

Because it undergoes alpha decay with a relatively short half-life, releasing significant radiation energy.

What are practical applications or concerns associated with Polonium-210?

Polonium-210 is used in scientific research and as a static eliminator, but its high radioactivity poses health risks, requiring careful handling.

Can the decay of Polonium-210 be stopped or slowed?

No, radioactive decay is a spontaneous process that cannot be stopped or slowed; it proceeds at its natural half-life rate.

Additional Resources

A Sample Of Polonium-210 Has An Initial Mass Of 390 Milligrams (mg). If The Half-life Of Polonium-210

Introduction

Polonium-210 (Po-210) stands as one of the most intriguing and enigmatic elements in the realm of nuclear science and radiochemistry. Known for its intense radioactivity and historical significance, Po-210 has been at the center of numerous scientific studies, industrial applications, and, unfortunately, high-profile incidents. This article explores the decay dynamics of a given sample of Po-210, with an initial mass of 390 milligrams, focusing on its half-life, decay processes, and the implications of its radioactive behavior.

Understanding Polonium-210: An Overview

What Is Polonium-210?

Polonium-210 is a rare, highly radioactive isotope of the element polonium, which itself was discovered in 1898 by Marie and Pierre Curie. Po-210 is part of the decay chain of uranium-238, found naturally in trace amounts within uranium ores. It is distinguished by its alpha-emission capability, releasing significant energy during decay, which makes it both valuable for scientific research and potentially hazardous.

Physical and Chemical Properties

- Atomic Number: 84
- Atomic Mass: Approx. 209 u
- State: Metallic, but highly radioactive and toxic
- Appearance: Silver-gray metal
- Half-life: Approximately 138.4 days

Sources and Production

Po-210 is typically produced artificially in nuclear reactors or cyclotrons by neutron irradiation of bismuth-209. Commercially, it is obtained through complex chemical separation processes from uranium ore or nuclear waste.

Radioactive Decay and Half-life: Fundamental Concepts

Radioactive Decay Principles

Radioactive decay is a stochastic process where unstable atomic nuclei lose energy by emitting radiation. For Po-210, decay occurs primarily through alpha emission, transforming into lead-206 (Pb-206). The decay process is characterized by a specific half-life, which is the time taken for half the atoms in a sample to decay.

Decay Law

The number of remaining radioactive atoms $N(t)$ at time t can be modeled by the exponential decay law:

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

where:

- N_0 = initial number of atoms
- λ = decay constant ($\lambda = \frac{\ln 2}{T_{1/2}}$)
- $T_{1/2}$ = half-life of the isotope

The mass of the sample at any time can similarly be expressed as:

$$m(t) = m_0 \times e^{-\lambda t}$$

Analyzing the Sample of Polonium-210

Initial Parameters and Calculations

Given:

- Initial mass $m_0 = 390\, \text{mg}$
- Half-life $T_{1/2} = 138.4\, \text{days}$

Our goal is to understand how this sample decays over time, determine the remaining mass after specific periods, and explore related decay characteristics.

Calculating the Decay Constant

Using the half-life:

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

$$\lambda = \frac{0.6931}{138.4\, \text{days}} \approx 0.00501\, \text{day}^{-1}$$

This decay constant indicates that about 0.5% of the remaining Po-210 atoms decay each day.

Number of Atoms in the Sample

The molar mass of Po-210 is approximately 209 g/mol. The initial number of atoms N_0:

$$N_0 = \frac{m_0}{M} \times N_A$$

where:

- $m_0 = 0.39\, \text{g}$
- $M = 209\, \text{g/mol}$
- $N_A = 6.022 \times 10^{23}\, \text{atoms/mol}$

Calculating:

$$N_0 = \frac{0.39}{209} \times 6.022 \times 10^{23} \approx 1.12 \times 10^{21}\, \text{atoms}$$

Decay Dynamics Over Time

Remaining Mass After a Given Period

The decay law allows us to calculate the remaining mass after any elapsed time t:

$$m(t) = m_0 \times e^{-\lambda t}$$

For example, after 138.4 days (one half-life):

$$m(138.4) = 390\, \text{mg} \times e^{-0.00501 \times 138.4}$$

$$ m(138.4) = 390\, \text{mg} \times e^{-0.6931} $$

$$ m(138.4) = 390\, \text{mg} \times 0.5 $$

$$ m(138.4) \approx 195\, \text{mg} $$

This confirms the half-life concept—after 138.4 days, only half of the initial mass remains.

Decay After Multiple Half-lives

The remaining mass after n half-lives:

$$ m(n \times T_{1/2}) = m_0 \times \left(\frac{1}{2}\right)^n $$

Number of Half-lives	Time (days)	Remaining Mass (mg)
1	138.4	195
2	276.8	97.5
3	415.2	48.75
4	553.6	24.4

This exponential decay illustrates how rapidly the sample diminishes over successive periods.

Implications and Safety Considerations

Radioactive Hazards of Po-210

Po-210's intense alpha radiation makes it both useful in applications and dangerous to health. Alpha particles are highly ionizing but have limited penetration depth, meaning external exposure is less hazardous than internal contamination. Ingested or inhaled Po-210 can cause severe biological damage due to alpha radiation's high ionization potential.

Potential Uses of Po-210

- Static eliminators: Exploiting alpha emissions to neutralize static electricity.
- Nuclear research: As a heat source or in neutron initiation.
- Historical applications: In anti-static devices and as a neutron initiator.

Risks of Exposure

- Radiotoxicity: Po-210 is one of the most toxic substances known.
- Accidental ingestion: Can cause rapid and severe health effects.
- Security concerns: Due to its potential for misuse in malicious activities.

Decay Chain and Final Products

Po-210 decays into stable Pb-206 through alpha emission. This decay chain is relatively simple:

1. Po-210 (half-life ~138 days) → Pb-206 (stable)

The decay process emits:

- Alpha particles: High energy, ionizing radiation
- Gamma radiation: Very minimal for Po-210 decay, but some gamma emission may occur during decay

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Mathematical Modeling and Practical Applications

Modeling Radioactive Decay in Real-World Contexts

Accurate decay modeling is essential in fields such as radiometric dating, nuclear medicine, and nuclear safety. The exponential decay law enables scientists to:

- Predict remaining activity over time
- Calculate the age of geological samples
- Design safe handling and disposal protocols

Example: Estimating Remaining Radioactivity After a Year

Let's determine the remaining mass after 365 days:

$$ m(365) = 390\, \text{mg} \times e^{-0.00501 \times 365} $$

$$ m(365) = 390\, \text{mg} \times e^{-1.828} $$

$$ m(365) = 390\, \text{mg} \times 0.160 $$

$$ m(365) \approx 62.4\, \text{mg} $$

Approximately 62.4 mg of Po-210 remains after one year.

Conclusion

The decay characteristics of Polonium-210 are emblematic of the potent force of nuclear physics. Starting with an initial mass of 390 milligrams, the sample's decay over time follows a predictable exponential pattern governed by its half-life of approximately 138.4 days. Understanding these dynamics is crucial not only for scientific inquiry but also for safety, regulatory compliance, and potential industrial applications.

The rapid decay rate underscores the importance of meticulous handling, storage, and disposal procedures, considering the element’s toxicity and radiological hazards. As research advances and new applications emerge, a thorough grasp of Po-210’s decay behavior remains vital for scientists, safety professionals, and policymakers alike.

References

- Krane, K. S. (1988). Introductory Nuclear Physics. Wiley.
- Nuclear Regulatory

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