6. The Mean Range Of 210Po A-particles (E = 5.3 MeV) In Air At S.T.P. Is 0.03842 N. Find Its Range In

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Understanding the behavior of alpha particles, especially those emitted by radioactive isotopes like Polonium-210 (210Po), is crucial in fields such as nuclear physics, radiation safety, and medical physics. This article aims to analyze and determine the range of 210Po alpha particles in air under standard temperature and pressure (S.T.P.), given their mean range expressed as 0.03842 N (where N is the density correction factor). We will explore the fundamental concepts, relevant formulas, and calculation procedures necessary for accurate determination.

Introduction to Alpha Particles and Their Ranges

Alpha particles are helium nuclei consisting of two protons and two neutrons. They are emitted during alpha decay, and their energies vary depending on the specific isotope. For 210Po, the alpha particles have an energy of approximately 5.3 MeV.

The range of an alpha particle is the maximum distance it can travel in a medium before losing all its energy and coming to a stop. Factors influencing this range include:

- The energy of the alpha particles
- The density and composition of the medium (air, in this case)
- The temperature and pressure conditions
- The interaction cross-sections with the medium

The mean range, especially as expressed by the standard range in terms of N (the density correction factor), provides a way to compare the ranges under different conditions.

Understanding the Given Data

The given data states:

- The mean range of 210Po alpha particles in air at S.T.P. = 0.03842 N

Here:

- **N** is the density correction factor, which accounts for deviations from standard conditions.
- At S.T.P., N is typically equal to 1, making the mean range numerically equal to 0.03842

cm for standard conditions.

The goal is to find the physical range (in centimeters) of 210Po alpha particles in air at S.T.P., based on this data.

Standard Conditions and Density Correction Factor (N)

Definition of S.T.P.

Standard Temperature and Pressure (S.T.P.) usually refers to:
- Temperature: 0°C (273.15 K)
- Pressure: 1 atm (101.3 kPa)

Under these conditions, the density of air is approximately 1.293 g/cm^3.

Role of the Density Correction Factor (N)

The density correction factor N adjusts the range to account for variations in density from the standard conditions. When the medium's density differs from standard, the range scales proportionally.

The relation is:
$$ R = R_0 \times N $$
where:
- R = actual range in the medium
- R_0 = range at S.T.P.
- N = ratio of the actual density to the standard density

Since in this context, the data is given at S.T.P., $N = 1$.

Calculating the Range of 210Po Alpha Particles in Air at S.T.P.

Given that the mean range is expressed as 0.03842 N, and N = 1 at S.T.P., the physical range R can be computed directly:

$$
R = 0.03842 \times N
$$

At S.T.P.:

$$
R = 0.03842 \times 1 = 0.03842\, \text{cm}
$$

This indicates that the alpha particles from 210Po can travel approximately 0.03842 centimeters in air under standard conditions.

Alternative Approach: Using Empirical and Theoretical Data

While the direct interpretation gives a straightforward answer, it's valuable to understand the underlying principles and how such data connects with theoretical models and empirical formulas for alpha particle range.

Bragg's Law and Range-Energy Relations

Alpha particle ranges are often estimated using empirical formulas derived from experimental data. One such relation is the Bethe formula for stopping power, which describes how charged particles lose energy in a medium.

A commonly used empirical relation for alpha particle range in air is:

$$
R = k \times E^{n}
$$

where:
- R = range in cm
- E = energy in MeV
- k and n are empirical constants

For alpha particles in air:

$$
R \approx 0.32 \times E^{3/2}
$$

Given $E = 5.3\, \text{MeV}$:

$$
R \approx 0.32 \times (5.3)^{3/2}
$$

Calculating:

$$
(5.3)^{3/2} = (5.3)^{1} \times (5.3)^{1/2} \approx 5.3 \times 2.3 \approx 12.19
$$

\]

Therefore:

\[
R \approx 0.32 \times 12.19 \approx 3.90\, \text{cm}
\]

This estimation suggests that the alpha particles could travel up to approximately 3.9 cm in air at S.T.P. This is consistent with typical alpha particle ranges for energies around 5 MeV.

Note: The discrepancy between this estimate and the initial data (0.03842 N) indicates that the given mean range is expressed in different units or with a specific correction factor.

Understanding the Discrepancy and Final Calculation

The key lies in understanding what the value 0.03842 N represents. Usually, the notation indicates:

- The range in units of mg/cm^2, often used in radiation physics.
- The "N" here likely refers to the density correction factor, with the range expressed as a mass per unit area rather than a linear distance.

If 0.03842 N is in units of mg/cm^2 (a common measurement for alpha particle range), then:

\[
\text{Range in mg/cm}^2 = 0.03842\, \text{mg/cm}^2
\]

Given that the density of air at S.T.P. is approximately 1.293 mg/cm^3, the physical range in centimeters is:

\[
R_{\text{cm}} = \frac{\text{Range in mg/cm}^2}{\text{density in mg/cm}^3}
\]

\[
R_{\text{cm}} = \frac{0.03842\, \text{mg/cm}^2}{1.293\, \text{mg/cm}^3} \approx 0.0297\, \text{cm}
\]

which rounds to approximately 0.03 cm, consistent with the initial data.

Final Answer:

The mean range of 210Po alpha particles (E = 5.3 MeV) in air at S.T.P. is approximately 0.03842 cm when expressed as a mass thickness (mg/cm^2). Converting to physical distance considering air density, the range is about 0.03 cm.

Summary and Key Takeaways

- The mean range provided (0.03842 N) is most likely a mass thickness (mg/cm^2).
- To find the physical range in centimeters, divide by the density of air at S.T.P.
- The alpha particles from 210Po with 5.3 MeV energy travel roughly 0.03 cm in air under standard conditions.
- This short range underscores the highly ionizing and limited penetration power of alpha particles.

Applications and Significance

Understanding the range of alpha particles has practical implications:

- Radiation Safety: Alpha emitters like 210Po are hazardous only if ingested or inhaled, as their short range prevents penetration through intact skin.
- Detector Design: Alpha particle ranges inform the design of detectors and shielding.
- Medical Physics: Alpha emitters are used in targeted radiotherapy, where their short range minimizes damage to surrounding healthy tissue.

Conclusion

Determining the range of alpha particles such as those emitted by 210Po involves understanding their energy, the medium's properties, and applying empirical or theoretical models. Based on the given data and standard conversion methods, the alpha particles' approximate range in air at S.T.P. is about 0.03 cm, highlighting their high ionization potential and limited penetration. This knowledge is essential in various scientific and practical applications involving radioactive materials and radiation protection.

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Frequently Asked Questions

What is the significance of the mean range of 210Po alpha particles in air at STP?

The mean range indicates how far alpha particles from 210Po can travel in air under standard conditions before losing their energy, which is important for understanding their penetration ability and safety precautions.

Given the mean range of 210Po alpha particles in air at STP is 0.03842 N, how do you calculate their actual range in centimeters?

You multiply the given range by the standard air density correction factor N to convert it into centimeters, using the relation Range = 0.03842 × N.

What is the typical energy of alpha particles emitted by 210Po?

The alpha particles emitted by 210Po have an energy of approximately 5.3 MeV.

How does the energy of 210Po alpha particles relate to their range in air?

Higher energy alpha particles generally have a longer range in air because they can penetrate further before losing all their energy, with 5.3 MeV alpha particles having a specific, measurable range.

What safety measures should be taken when handling 210Po due to its alpha emission and range?

Since 210Po emits alpha particles that can be harmful if ingested or inhaled, proper shielding, handling in controlled environments, and use of gloves and masks are essential to prevent contamination and exposure.

Can the mean range in air be used to estimate the penetration depth of alpha particles in biological tissues?

While the mean range in air provides a general idea, the actual penetration depth in biological tissues depends on density and composition; thus, tissue-specific data are needed for precise estimates.

Additional Resources

6. The Mean Range Of 210Po A-particles (E = 5.3 MeV) In Air At S.T.P. Is 0.03842 N. Find Its Range In

Understanding the behavior of alpha particles, especially their range in various media, is crucial in fields ranging from nuclear physics to radiation safety and medical applications. The problem at hand involves calculating the physical distance an alpha particle emitted by Polonium-210 (Po-210) can travel in air under standard temperature and pressure (S.T.P.). Given the mean range in terms of a standard unit, N, we're tasked with converting this into a more conventional measure—likely centimeters or meters—so that practical assessments and safety protocols can be established.

This article aims to demystify the process involved in such calculations, explaining the underlying principles, the significance of the parameters involved, and the mathematical steps to arrive at the particle's range in air at S.T.P.

Understanding the Problem: Alpha Particles and Their Range

Alpha particles are helium nuclei consisting of two protons and two neutrons. Emitted during radioactive decay, they possess considerable energy—here, 5.3 MeV for Po-210—that determines how far they can travel in a given medium before losing all their energy.

Key Data:
- Particle: Alpha particle from Po-210
- Energy: E = 5.3 MeV
- Mean range in air at S.T.P.: 0.03842 N

The notation "N" here typically denotes a standard reference unit used in radiation physics, often called the standard range unit, which correlates with the particle's energy and the medium's properties.

The Significance of the Mean Range

What is the Mean Range?

The mean range of an alpha particle is the average distance it travels before coming to rest. It's a statistical measure that accounts for the stochastic nature of energy loss as the particle interacts with atoms in the medium.

Why is it important?

- It determines shielding requirements.
- It influences detection sensitivity.
- It helps evaluate radiation dose and safety margins.

In radiation physics, the mean range is often expressed in units proportional to the particle's initial energy and the medium's density.

The Concept of the Standard Range Unit (N)

The notation "N" indicates a standard unit of range, often defined in terms of the particle energy and the medium's density, according to empirical or theoretical models.

In many textbooks, the mean range R (in cm) of alpha particles in air at S.T.P. can be approximated by the relation:

$$ R = k \times E^{n} $$

where:
- R is the range in centimeters,
- E is the energy in MeV,
- k and n are empirically determined constants.

However, in this context, the mean range is given as a multiple of N, which is a standard unit specific to the problem's framework. The key is to relate this to actual physical units.

The Empirical Relationship for Alpha Particle Range in Air

Research and experimental data suggest that the range of alpha particles in air follows an approximate proportionality with their energy, often expressed as:

$$ R \approx 0.56 \times E^{3/2} $$

where:
- R is in centimeters,
- E is in MeV.

For alpha particles with energy around 5 MeV, this formula yields ranges approximately in the order of a few centimeters.

Note: The proportionality constants and exponents can vary depending on the source, but this relation provides a good approximation.

Step-by-Step Calculation of the Range

Given Data:

- Mean range in air at S.T.P.: $R_{mean} = 0.03842 N$

- Particle energy: $E = 5.3\, \text{MeV}$

Objective:

Find the actual range R in centimeters.

Step 1: Relate the Given Mean Range to Standard Units

The problem provides the mean range in terms of N, which represents a standard unit. To find the physical range, we need to determine the value of N in centimeters.

Suppose, based on empirical data or prior studies, that:

$$R = N \times \text{(conversion factor)}$$

Alternatively, in classical physics, the standard range R_{0} for alpha particles of a given energy is often tabulated or expressed through empirical formulas.

Step 2: Use Empirical Range-Energy Relationship

Applying the approximate formula:

$$R = 0.56 \times E^{3/2}$$

Calculate R:

$$
R = 0.56 \times (5.3)^{3/2}
$$

Calculate $5.3^{3/2}$:

$$
5.3^{3/2} = 5.3^{1} \times 5.3^{1/2} = 5.3 \times \sqrt{5.3}
$$

$$
\sqrt{5.3} \approx 2.301
$$

$$
5.3 \times 2.301 \approx 12.186
$$

Now, multiply by 0.56:

$$
R \approx 0.56 \times 12.186 \approx 6.823\, \text{cm}
$$

This suggests the alpha particle travels approximately 6.82 centimeters in air at S.T.P.

Step 3: Relate to the Given Mean Range in N

Given that:

$$
R_{mean} = 0.03842 N
$$

and the calculated physical range is approximately 6.82 cm, we can find the value of N:

$$
N = \frac{R_{physical}}{0.03842} = \frac{6.82}{0.03842} \approx 177.4
$$

Thus, $N \approx 177.4$.

Final Answer:

The alpha particles emitted by Po-210 with an energy of 5.3 MeV have an approximate range of 6.82 centimeters in air at S.T.P.

Implications of the Range Calculation

Understanding the physical range of alpha particles like those from Po-210 is vital for multiple reasons:

- Radiation Safety: Alpha particles are highly ionizing but have low penetration depth. Knowing their range helps in designing effective shielding—typically a few centimeters of air or a sheet of paper can block alpha radiation.

- Detection and Measurement: Detectors are often calibrated based on the expected range of alpha particles. Accurate range calculations improve measurement precision.

- Medical and Industrial Applications: In targeted radiotherapy or industrial radiography, understanding how far alpha particles travel impacts safety and effectiveness.

Factors Affecting Alpha Particle Range

While the above calculations provide a good approximation, several factors influence the actual range:

- Medium Density: Changes in temperature and pressure alter air density, affecting the range.

- Impurities and Humidity: Variations in air composition can slightly modify the stopping power.

- Particle Energy Variations: Slight differences in emitted energy can lead to variations in range.

- Altitude: At higher altitudes, lower air density results in longer ranges.

Conclusion: Bridging Theory and Practice

Calculating the range of alpha particles like those from Po-210 involves a combination of empirical formulas, understanding of particle physics, and practical considerations regarding the medium. The approximate 6.82 centimeters range in air highlights the limited penetration ability of alpha radiation, emphasizing its safety implications and detection strategies.

This calculation not only aids in radiation safety protocols but also exemplifies how theoretical physics directly informs practical applications. By understanding the energy-dependent behavior of alpha particles, scientists and safety professionals can better manage radiation sources, design effective shielding, and develop accurate detection systems.

References and Further Reading:

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In summary, by applying empirical relationships and understanding the units involved, we've determined that Po-210 alpha particles with an energy of 5.3 MeV travel approximately 6.82 centimeters in air at standard conditions. This insight underscores the importance of precise calculations in ensuring safety and advancing technological applications involving nuclear radiation.

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