Question 3The Radioactive Nuclide (_83^215)Bi Decays Into (_84^215)Bi Po. (a) Write The Nuclear Reaction

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Understanding radioactive decay processes is fundamental in nuclear chemistry and physics. In this article, we will explore the decay of the radioactive nuclide bismuth-215, denoted as (_83^215)Bi, and examine how it transforms into polonium-215, (_84^215)Po. We will specifically focus on formulating and explaining the nuclear reaction involved in this decay process, providing a comprehensive overview suitable for students, educators, and enthusiasts interested in nuclear decay mechanisms.

Introduction to Radioactive Nuclides and Decay Processes

Radioactive nuclides are unstable atoms that spontaneously emit radiation to attain more stable configurations. These emissions often involve the release of particles such as alpha particles, beta particles, or gamma rays. Understanding the specific decay pathways of these nuclides helps in various applications, including nuclear medicine, radiometric dating, and nuclear power generation.

Overview of Bismuth-215 (_83^215)Bi

Bismuth-215 is a radioactive isotope with an atomic number of 83 and a mass number of 215. It is part of the decay chains involving heavy, unstable elements that undergo transformations to reach more stable forms.

- Atomic Number (Z): 83
- Mass Number (A): 215
- Decay Mode: Beta decay (most likely, based on the change in atomic number)
- Decay Product: Polonium-215 (_84^215)Po

Understanding the decay of bismuth-215 is crucial because it provides insights into the behavior of heavy, unstable nuclei and the mechanisms by which they achieve stability.

Formulating the Nuclear Reaction of (_83^215)Bi Decay

The core focus of this article is to write and explain the nuclear reaction equation for the decay of (_83^215)Bi into (_84^215)Po.

Step 1: Identifying the Decay Type

Given that the atomic number increases from 83 to 84, the decay involves the emission of a beta particle (beta-minus decay). In beta-minus decay, a neutron within the nucleus is transformed into a proton, emitting an electron (beta particle) and an antineutrino.

- Beta-minus decay reaction:

$$
n \rightarrow p + e^- + \bar{\nu}_e
$$

- Effect on nucleus:

- Atomic number increases by 1
- Mass number remains unchanged

Step 2: Writing the Nuclear Reaction Equation

Based on the decay process:

$$
\text{Initial Nuclide: } ^{215}_{83}\mathrm{Bi}
$$
$$
\text{Decay: } ^{215}_{83}\mathrm{Bi} \rightarrow ^{215}_{84}\mathrm{Po} + e^- + \bar{\nu}_e
$$

The neutrino is often omitted in simplified nuclear equations, but for completeness, it can be included.

Full nuclear reaction:

$$
^{215}_{83}\mathrm{Bi} \rightarrow ^{215}_{84}\mathrm{Po} + e^- + \bar{\nu}_e
$$

Simplified reaction (common in nuclear physics):

$$
^{215}_{83}\mathrm{Bi} \rightarrow ^{215}_{84}\mathrm{Po} + \beta^-
$$

where β^- represents the beta particle (electron).

Step 3: Verifying Conservation Laws

- Atomic Number (Z): 83 on the left; 84 on the right (due to the proton formed)
- Mass Number (A): 215 on both sides
- Charge: Balanced via the emission of a beta particle
- Energy: The reaction releases energy as the nucleus transforms into a more stable state

Explanation of the Nuclear Reaction

This nuclear reaction signifies a beta-minus decay process, where a neutron in the bismuth-215 nucleus transforms into a proton, increasing the atomic number by one, and emitting a beta particle and an antineutrino. The resulting nucleus, polonium-215, is more stable, although it may undergo further decay processes.

Key points:

- The decay increases the atomic number by 1, changing the element from bismuth to polonium.
- The mass number remains unchanged because a neutron is converted into a proton.

- The emitted beta particle carries away excess energy, ensuring conservation of energy and charge.
- The decay process is spontaneous and governed by nuclear forces and stability considerations.

Applications and Significance of Understanding This Decay

Knowing the nuclear reaction of (_83^215)Bi decay is valuable in multiple contexts:

- **Nuclear Medicine:** Radioisotopes like polonium-215 are used in targeted alpha therapy for cancer treatment.
- **Radioactive Dating:** Understanding decay chains helps in age determination of geological samples.
- **Nuclear Physics Research:** Studying such decay processes enhances our understanding of nuclear forces and stability.

Furthermore, understanding beta decay reactions like this one aids in the development of nuclear models and simulations.

Conclusion

The decay of the radioactive nuclide (_83^215)Bi into (_84^215)Po involves a beta-minus decay process, which can be succinctly written as:

$$
^{215}_{83}\mathrm{Bi} \rightarrow ^{215}_{84}\mathrm{Po} + e^- + \bar{\nu}_e
$$

This reaction exemplifies the fundamental principles of nuclear decay, including conservation of mass and charge, and illustrates how unstable nuclei transform into more stable configurations. Recognizing these processes is essential for advancing nuclear science, medical applications, and our understanding of the universe's fundamental building blocks.

Frequently Asked Questions

What is the nuclear reaction when _83^215Bi decays into _84^215Bi Po?

_83^215Bi decays by beta emission to form _84^215Po: _83^215Bi → _84^215Po + β⁻

What type of decay occurs in the transformation of _83^215Bi to _84^215Po?

The decay involves beta-minus decay, where a neutron in bismuth-215 transforms into a proton, emitting an electron (beta particle).

What is the significance of the change from _83^215Bi to _84^215Po in

nuclear chemistry?

It illustrates a neutron-to-proton conversion during beta decay, increasing the atomic number by one while keeping the mass number constant.

How do you write the nuclear reaction for _83^215Bi decaying into _84^215Po?

The reaction is written as: _83^215Bi → _84^215Po + e^- (beta particle).

What is the role of beta emission in the decay of _83^215Bi?

Beta emission allows the neutron in bismuth-215 to convert into a proton, transforming the element into polonium-215.

Why does the atomic number increase by one during this decay?

Because a neutron converts into a proton during beta decay, increasing the atomic number by one, changing the element from bismuth to polonium.

What is the importance of understanding nuclear reactions like _83^215Bi decaying to _84^215Po?

Understanding such reactions helps in nuclear physics research, radioactive dating, medical applications, and nuclear energy development.

Additional Resources

Radioactive Decay of _83^215Bi to _84^215Bi: An In-Depth Analysis

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Introduction: Exploring the Intricacies of Radioactive Decay

In the fascinating realm of nuclear physics, radioactive decay serves as a fundamental process that underpins a wide array of scientific and technological applications. Among the many isotopes studied, Bismuth isotopes stand out due to their intriguing decay pathways and their significance in understanding nuclear stability, decay chains, and nuclear models. Today, we focus on the decay process of the isotope _83^215Bi (Bismuth-215) into _84^215Bi (Polonium-215), exploring the nuclear reactions involved, their mechanisms, and their implications.

Understanding the Isotopes: _83^215Bi and _84^215Bi

Before delving into the decay process, it is essential to understand the basic characteristics of the involved isotopes.

Bismuth-215 (_83^215Bi)

- Atomic Number (Z): 83
- Mass Number (A): 215
- Nuclear Composition: 83 protons, 132 neutrons
- Stability: Radioactive, with a relatively short half-life (exact half-life depends on experimental data, often in the order of seconds to minutes for such isotopes)
- Position in the Nuclear Chart: Near the tail end of the actinides, close to the region of nuclear stability but prone to decay due to excess neutrons or protons.

Polonium-215 (_84^215Po)

- Atomic Number (Z): 84
- Mass Number (A): 215
- Nuclear Composition: 84 protons, 131 neutrons
- Stability: Also radioactive, but generally more stable than its precursor; often a decay product in the uranium or thorium decay chains.

The Nuclear Reaction: Decay of _83^215Bi to _84^215Po

Type of Decay: Beta Decay (β^- decay)

The transition from _83^215Bi to _84^215Po predominantly occurs via beta-minus decay. This process involves the transformation of a neutron into a proton within the nucleus, accompanied by the emission of a beta particle (electron) and an antineutrino.

Why does this decay occur?
In _83^215Bi, the neutron-to-proton ratio exceeds the stable ratio, making the nucleus neutron-rich and unstable. To reach a more stable configuration, the nucleus undergoes beta-minus decay, increasing its atomic number by one while keeping the mass number constant.

Writing the Nuclear Reaction

Basic Reaction Equation

The decay process can be summarized as:

$$
^{215}_{83}\text{Bi} \rightarrow \, ^{215}_{84}\text{Po} + \beta^- + \bar{\nu}_e
$$

In this notation:

- $^{215}_{83}\text{Bi}$: Bismuth-215 nucleus
- $^{215}_{84}\text{Po}$: Polonium-215 nucleus
- β^-: Electron emitted during decay
- $\bar{\nu}_e$: Electron antineutrino

Expanded Nuclear Reaction

The detailed nuclear reaction, considering nucleon count:

$$
^{215}_{83}\text{Bi} \rightarrow \, ^{215}_{84}\text{Po} + e^- + \bar{\nu}_e
$$

Here, the atomic number increases from 83 to 84, reflecting the conversion of a neutron into a proton, with the atomic mass remaining unchanged at 215.

Note: The emission of the beta particle and antineutrino ensures conservation of charge, lepton number, and energy.

Deciphering the Decay Mechanism

Beta Decay Process in Detail

Beta decay is a weak nuclear force-mediated process involving the transformation of a neutron into a proton within the nucleus. The steps include:

1. Neutron Conversion:
A neutron in the nucleus is transformed into a proton, emitting a W^- boson, which quickly decays into a beta particle (electron) and an electron antineutrino.

2. Energy Release:
The decay releases energy, which is shared between the emitted particles and the recoiling nucleus.

3. Atomic Number Increase:
Since a neutron becomes a proton, the atomic number increases by 1, moving the element from Bismuth to Polonium.

4. Mass Number Conservation:
The total number of nucleons (mass number) remains the same, as the mass of a neutron and proton are nearly identical.

Decay Energy (Q-value)

The energy released during decay, known as the Q-value, is critical for understanding decay rates and particle energies. It can be calculated from mass differences:

$$
Q = [m(^{215}\text{Bi}) - m(^{215}\text{Po}) - m(e^-)] \times c^2
$$

where m denotes atomic masses, and c is the speed of light.

Since the mass difference determines the maximum kinetic energy of emitted particles, precise mass measurements are vital for accurate decay modeling.

Implications of the Decay Process

Decay Chain and Nuclear Stability

The decay of $_{83}^{215}Bi$ to $_{84}^{215}Po$ is a part of the larger decay chain that contributes to the understanding of nuclear stability and transmutation processes. The transition provides insight into:

- Nuclear shell effects: How nucleons arrange themselves in shells affects decay probabilities.
- Nuclear models validation: Comparing predicted and observed decay energies and half-lives helps refine models like the shell model or liquid drop model.

Applications and Significance

Understanding such decay processes has practical relevance:

- Radioisotope production:
Producing specific isotopes for medical, industrial, or scientific purposes.

- Nuclear medicine:
Though $_{83}^{215}Bi$ and $_{84}^{215}Po$ are not commonly used directly, knowledge of decay pathways informs the safety and handling of radioactive materials.

- Nuclear astrophysics:
Studying decay chains helps elucidate nucleosynthesis pathways in stellar environments.

- Radiation safety:
Accurate decay data ensures proper shielding and handling protocols for radioactive materials.

Conclusion: The Significance of Deciphering Nuclear Reactions

The decay of $_{83}^{215}Bi$ into $_{84}^{215}Po$ exemplifies the intricate dance of particles governed by the weak nuclear force. Writing the nuclear reaction as:

$$
^{215}_{83}\text{Bi} \rightarrow \, ^{215}_{84}\text{Po} + e^- + \bar{\nu}_e
$$

captures the essence of the beta-minus decay process, highlighting the transformation within the nucleus that moves the element toward a more stable configuration.

This decay pathway not only advances our understanding of nuclear structure and stability but also plays

a pivotal role in broader scientific endeavors—from modeling stellar processes to developing medical isotopes. Such detailed analysis underscores the importance of precise nuclear data, which continues to shape our understanding of the atomic nucleus and its myriad transformations.

In essence, the decay of _83^215Bi to _84^215Po is a prime example of the subtle yet profound mechanisms at work within the atomic nucleus, offering insights that resonate across scientific disciplines and practical applications alike.

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