alpha and beta decay practice problems with answers

Alpha and beta decay practice problems with answers are essential for students and enthusiasts of nuclear physics who wish to deepen their understanding of radioactive decay. Radioactive decay is a natural process by which unstable atomic nuclei lose energy by emitting radiation. The two most common types of decay are alpha (α) decay and beta (β) decay. Both processes involve the transformation of one element into another and are governed by specific rules regarding particle emission and nuclear reactions. This article will provide a comprehensive overview of alpha and beta decay, followed by practice problems with detailed solutions to aid in mastering these concepts.

Understanding Alpha Decay

Alpha decay occurs when an atomic nucleus emits an alpha particle, which consists of two protons and two neutrons (essentially a helium nucleus). This process reduces the atomic number of the original element by two and the mass number by four.

Key Characteristics of Alpha Decay:

1. Emission of Alpha Particles: Helium nuclei (α particles) are released.
2. Decrease in Atomic Number: The atomic number decreases by 2.
3. Decrease in Mass Number: The mass number decreases by 4.
4. Common in Heavy Elements: Typically observed in heavy elements like uranium and radium.

Example of Alpha Decay:
When Uranium-238 undergoes alpha decay, it transforms into Thorium-234:

$$
^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He
$$

Understanding Beta Decay

Beta decay involves the transformation of a neutron into a proton (or vice versa) within an atomic nucleus, leading to the emission of a beta particle (an electron or a positron). There are two types of beta decay: beta-minus (β-) and beta-plus (β+).

Key Characteristics of Beta Decay:

1. Beta-minus Decay (β-): A neutron is converted into a proton, emitting an electron and an antineutrino.
- Atomic number increases by 1.
- Mass number remains unchanged.

2. Beta-plus Decay (β+): A proton is converted into a neutron, emitting a positron and a neutrino.
- Atomic number decreases by 1.
- Mass number remains unchanged.

Example of Beta Decay:
- Beta-minus decay: Carbon-14 decays into Nitrogen-14:

$$
^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e + \bar{\nu}
$$

- Beta-plus decay: Fluorine-18 decays into Oxygen-18:

$$
^{18}_{9}F \rightarrow ^{18}_{8}O + ^{0}_{+1}e + \nu
$$

Practice Problems on Alpha and Beta Decay

To reinforce understanding, here are some practice problems related to both alpha and beta decay, along with detailed solutions.

Problem 1: Alpha Decay

Problem:
Radium-226 undergoes alpha decay. Write the equation for this decay and identify the daughter nuclide.

Solution:
1. Starting nuclide: $^{226}_{88}Ra$
2. Alpha particle emitted: $^{4}_{2}He$
3. Daughter nuclide calculation:
- Atomic number: $88 - 2 = 86$
- Mass number: $226 - 4 = 222$
4. Equation:

$$
^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He
$$

- The daughter nuclide is Radon-222 ($^{222}_{86}Rn$).

Problem 2: Beta-minus Decay

Problem:
A sample of Strontium-90 undergoes beta-minus decay. Write the decay equation and identify the resulting nuclide.

Solution:
1. Starting nuclide: $^{90}_{38}Sr$
2. Beta particle emitted: $^{0}_{-1}e$ and an antineutrino ($\bar{\nu}$)
3. Daughter nuclide calculation:
- Atomic number: $38 + 1 = 39$
- Mass number: 90 (remains unchanged)
4. Equation:
$$
^{90}_{38}Sr \rightarrow ^{90}_{39}Y + ^{0}_{-1}e + \bar{\nu}
$$
- The resulting nuclide is Yttrium-90 ($^{90}_{39}Y$).

Problem 3: Beta-plus Decay

Problem:
What happens to a sample of Sodium-22 when it undergoes beta-plus decay? Write the decay equation.

Solution:
1. Starting nuclide: $^{22}_{11}Na$
2. Beta-plus particle emitted: $^{0}_{+1}e$ and a neutrino (ν)
3. Daughter nuclide calculation:
- Atomic number: $11 - 1 = 10$
- Mass number: 22 (remains unchanged)
4. Equation:
$$
^{22}_{11}Na \rightarrow ^{22}_{10}Ne + ^{0}_{+1}e + \nu
$$
- The resulting nuclide is Neon-22 ($^{22}_{10}Ne$).

Problem 4: Mixed Decay Problem

Problem:
If Plutonium-239 undergoes two alpha decays followed by one beta-minus decay, what is the final nuclide produced?

Solution:
1. Starting nuclide: $^{239}_{94}Pu$
2. First alpha decay:
- New nuclide: $^{235}_{92}U$ (after one alpha decay)

3. Second alpha decay:
- New nuclide: $^{231}_{90}Th$ (after second alpha decay)
4. Beta-minus decay:
- New nuclide: $^{231}_{91}Pa$ (after beta decay)

Final equation:

$$
^{239}_{94}Pu \rightarrow ^{235}_{92}U \rightarrow ^{231}_{90}Th \rightarrow ^{231}_{91}Pa
$$

- The final nuclide is Protactinium-231 ($^{231}_{91}Pa$).

Conclusion

Understanding alpha and beta decay is crucial for grasping the fundamental principles of nuclear physics. By practicing problems like those presented in this article, students can solidify their knowledge and enhance their problem-solving skills in the realm of radioactive decay. Mastery of these concepts not only aids in academic pursuits but also lays the foundation for further exploration in nuclear chemistry, medicine, and energy. With continued practice and application, anyone can become proficient in recognizing and solving decay problems effectively.

Frequently Asked Questions

What is the primary difference between alpha decay and beta decay?

Alpha decay involves the emission of an alpha particle (2 protons and 2 neutrons), resulting in a decrease of the atomic number by 2 and the mass number by 4. Beta decay involves the conversion of a neutron into a proton with the emission of a beta particle (an electron), increasing the atomic number by 1 while the mass number remains unchanged.

How can you determine the new element formed after an alpha decay process?

To determine the new element formed after alpha decay, subtract 2 from the atomic number of the original element and 4 from the mass number. The new atomic number corresponds to a different element on the periodic table.

In a beta decay problem, if a carbon-14 nucleus

undergoes beta decay, what is the resulting nucleus?

When carbon-14 (atomic number 6) undergoes beta decay, it transforms into nitrogen-14 (atomic number 7), as a neutron is converted into a proton. The mass number remains 14.

What type of decay is represented by the equation 238U → 234Th + 4He?

This equation represents alpha decay, where uranium-238 emits an alpha particle (which is helium-4) and transforms into thorium-234.

How do you balance a beta decay equation, such as 32P → 32S + β-?

To balance a beta decay equation, ensure that the total atomic number and mass number are equal on both sides. In the case of 32P → 32S + β-, the atomic number changes from 15 (phosphorus) to 16 (sulfur), while the mass number remains 32, maintaining balance.

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