Key Concepts

Chapter 12

Atomic number, Z

Mass number, A

Isotopes

Radioactive decay: ${}^{1}_{0}n$, ${}^{4}_{2}\alpha$, ${}^{-1}_{0}\beta$, ${}^{+1}_{0}\beta$, γ

Nuclear Reactions

A neutral U-238 atom absorbs a neutron and then immediately undergoes two alpha decays, three beta decays, one positron decay, and two gamma decays. Describe the resulting nucleus using isotopic notation. The resulting atom is an isotope of what element?

1) Find the mass number and atomic number of the parent nucleus.

Z = atomic number, A = mass number $\rightarrow {}^{A}_{Z}X$

$Z = 92$, $A = 238 \rightarrow {}^{238}_{92}U$

The notation U-238 indicates a uranium atom with a mass of 238. The letter is always the element symbol, as listed on the periodic table. From the periodic table, the atomic number of uranium is 92. All uranium atoms, by definition, have 92 protons. We call this the Z-number.

The mass number, A, is the sum of the number of protons and neutrons. The mass number is given in the question because a given element may have many different isotopes, which all have the same number of protons but vary in the number of neutrons they contain.

The shorthand notion, called isotopic notation, is ${}^{A}_{Z}X$, where X is the element name, A is the mass number, and Z is the atomic number.

MCAT Pitfall: *A is the mass number, not the atomic number. This is counterintuitive.*

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2) Find the result of the neutron absorption.

${}^{A}_{Z}X + {}^{1}_{0}n \rightarrow {}^{A+1}_{Z}X'$

${}^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{92}U$

A neutron has a mass number of 1 and an atomic number of 0 because it has no protons. In these problems, write the isotopic notations as a mathematical formula. The rule is that the Z numbers must add up to be the same on each side, as well as the A numbers.

The result of the absorption is the formation of a different isotope of uranium.

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3) Find the result of the alpha decays.

${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}He$

$A' = A - 2(4) = 239 - 8 = 231$

$Z' = Z - 2(2) = 92 - 4 = 88$

An alpha particle is a helium nucleus: two protons and two neutrons. Thus, for a single alpha decay, ***A*** decreases by 4 and ***Z*** decreases by 2. Because there are two alpha decays, multiply these numbers by 2 to find the change in the ***Z*** and ***A*** numbers.

Remember: *An alpha particle can be written as* ${}^{4}_{2}\alpha$ *or* ${}^{4}_{2}He$.

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4) Find the result of the beta decays.

${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}X' + {}^{0}_{-1}\beta$

$A' = A = 231$

$Z' = Z + 3(1) = 91$

A β^--particle is also called a β-particle and is just an electron. In a beta decay, a β-particle is ejected from the nucleus, whereas a neutron is transformed into a proton. Thus, the mass number A stays the same, while the Z number of the daughter nucleus increases by 1. Because there are three beta decays, multiply by 3 to find the result.

Remember: *A β-particle actually increases the atomic number of the daughter nucleus. You can remember this by noting that it is really an electron and is the only type of decay to feature a negative number on the particle.*

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5) Find the result of the positron decay.

${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}X' + {}^{0}_{+1}\beta$

$A' = A = 231$

$Z' = Z - 1 = 90$

A positron decay is the exact opposite of a beta decay and is often called β^+ decay. A positron (an anti-electron) is ejected from the nucleus, and a proton turns into a neutron. Thus, the mass number stays the same, and the Z number decreases by 1.

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6) Find the result of the gamma decays.

${}^{A}_{Z}X \rightarrow {}^{A}_{Z}X' + \gamma$

$A' = A = 231$

$Z' = Z = 90$

In gamma decay, a gamma ray (an electromagnetic wave) is ejected from the nucleus. There is no change in atomic number or mass number.

Takeaways

It is important to know the decay types and the decay particles themselves. Once you have these down, the problems are relatively simple.

Things to Watch Out For

Fission occurs when a nucleus splits into smaller nuclei. Fusion is the combination of smaller nuclei to form a larger particle. Transmutation, or radioactive decay resulting in a change of atomic number, is a specific type of fission reaction. Beta particles (electrons) and positrons are very easy to confuse; make sure that you understand the difference.

Similar Questions:

1. Is it possible for neptunium to transmute to an isotope of lead through a series of alpha decays?
2. How many beta particles are ejected when polonium-214 decays to radon-214?
3. Uranium-226 decays radioactively into radon-218 through two positron decays and an unknown number of alpha decays. How many alpha particles must be emitted in this reaction?

7) Write in isotopic notation.

$^{231}_{90}\text{Th}$

The resulting nucleus has an atomic number of 90 and a mass number of 231. Thus, it is an isotope of thorium with 231 – 90 = 141 neutrons.

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8) Here is an alternate (faster) solution.

$A' = 238 + 1 - 2(4) = 231$

$Z' = 92 - 2(2) + 3(1) - 1 = 90$

If you are comfortable with the decay types, write one equation for *A* and one for *Z* and solve directly, based on the changes to *A* and *Z* for each event. Solving the problem this way is your goal for Test Day.
