Nuclear Equations

Unit: Atomic and Nuclear Physics

NGSS Standards/MA Curriculum Frameworks (2016): HS-PS1-8

AP® Physics 2 Learning Objectives/Essential Knowledge (2024): 15.7.A, 15.7.A.2, 15.7.A.3, 15.7.A.4, 15.7.A.5

Mastery Objective(s): (Students will be able to…)

- Describe the radioactive decay of a given sample of material consisting of a finite number of nuclei.
- Determine the products of α, $\beta-$, and $\beta+$ decay and electron capture.

Success Criteria:

- Equations give the correct starting material and products.

Language Objectives:

- Describe the changes to the nucleus during radioactive decay.

Tier 2 Vocabulary: decay, capture

Notes:

nuclear equation: a chemical equation describing the process of an isotope undergoing radioactive decay. For example:

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

In a nuclear equation, the atomic number and mass number are conserved on both sides of the arrow. If you look at the bottom (atomic) numbers, and replace the arrow with an = sign, you will have the following:

92 = 90 + 2

Similarly, if you look at the top (mass) numbers, and replace the arrow with an = sign, you will have:

238 = 234 + 4

Sample problems:

Q: What are the products of beta-minus ($\beta-$) decay of $^{131}\mathrm{I}$?

A: A $\beta-$ particle is an electron, which we write as ${}^{0}_{-1}e$ in a nuclear equation. This means $^{131}\mathrm{I}$ decays into some unknown particle plus ${}^{0}_{-1}e$. The equation is:

$$^{131}_{53}\mathrm{I} \rightarrow {}^{m}_{p}X + {}^{0}_{-1}e$$

We can write the following equations for the atomic and mass numbers:

Atomic #s: $53 = p + -1 \rightarrow p = 54$; therefore, X is Xe

Mass #s: $131 = m + 0 \rightarrow m = 131$

Therefore, particle X is ${}^{131}_{54}\mathrm{Xe}$ So our final answer is:

The two products of decay in this reaction are ${}^{131}_{54}\mathrm{Xe}$ and ${}^{0}_{-1}e$.

Q: Which particle was produced in the following radioactive decay reaction:

$$^{212}_{86}\mathrm{Rn} \rightarrow {}^{208}_{84}\mathrm{Po} + {}^{m}_{p}X$$

A: The two equations are:

Atomic #s: $86 = 84 + p \rightarrow p = 2$; therefore X is He

Mass #s: $212 = 208 + m \rightarrow m = 4$

Therefore, particle X is ${}^{4}_{2}\mathrm{He}$, which means it is an α particle.

Homework Problems

For these problems, you will need to use a Figure CC. Periodic Table of the Elements (on page 512 of your Physics Reference Tables) and radioactive decay information from *Table EE. Selected Radioisotopes* on page 513 of your Physics Reference Tables.

Give the nuclear equation(s) for radioactive decay of the following:

1. **(M)** ^{222}Rn

2. **(M)** ^{85}Kr

3. **(S)** ^{220}Fr

4. **(S)** ^{37}K

5. **(S)** ^{3}H

Give the starting material for the following materials produced by radioactive decay:

6. **(M)** Alpha (α) decay resulting in $^{267}_{108}$Hs

7. **(M)** Beta-minus ($\beta-$) decay resulting in $^{185}_{75}$Re