Decay Detectives

Use conserved quantities to predict what leaves and what remains.

HS-PSII-10.4 "Apply the conservation of mass, conservation of charge, and conservation of linear momentum principles to describe the results of a radioactive particle undergoing either alpha or beta decay."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline each starting nucleus's mass and atomic numbers, circle the mass-number and charge information for emitted particles, and number the momentum measurements. Use your marks to track what is conserved in each decay.

Clues from a Particle Detector

1. Inside a sealed laboratory detector, a stationary polonium nucleus releases an alpha particle. The polonium nucleus has mass number 210 and atomic number 84. An alpha particle contains two protons and two neutrons, so its mass number is 4 and its charge is 2^+, in units of the proton's charge. The remaining nucleus is an isotope of lead, whose atomic number is 82. To predict its mass number, account for the nucleons carried away. These whole-number counts track nucleons, not exact rest mass: a small amount of rest mass can become kinetic energy.

2. A second stationary source contains carbon nuclei with mass number 14 and atomic number 6. During beta-minus decay, a neutron in one nucleus changes into a proton; an electron and an antineutrino leave the nucleus. An electron has charge 1^-, and an antineutrino has charge 0, in proton-charge units. Neither emitted particle contains nucleons, so the daughter nucleus retains the original mass number. The daughter is nitrogen, which has atomic number 7. Check charge by adding the daughter's charge and both emitted charges, rather than looking only at the electron. Released energy can also become particle motion.

3. For each initially stationary nucleus, total momentum is zero, so the momenta of all outgoing particles must add to zero. In the alpha event, suppose the alpha particle moves east with 5 momentum units. In the beta event, suppose the electron carries 3 momentum units east and the antineutrino carries 4 units north. Each daughter nucleus recoils to balance the particles that leave. Momentum has both a size and a direction, so adding momentum requires more than adding the numbers alone. A detector can track the outgoing particles even when the recoiling nucleus is difficult to observe.

2 ANSWER WITH EVIDENCE

Use the passage

1. For the polonium decay, calculate the daughter's mass number. Use atomic numbers to check whether lead is the correct element.

2. For the carbon decay, calculate the daughter's mass number and atomic number. Show how the total charge still equals the starting charge.

3. In the alpha event, what momentum must the lead nucleus have? Explain using the starting momentum.

4. In the beta event, what are the size and direction of the nitrogen nucleus's momentum? Explain how both emitted particles affect it.

3 YOUR TURN

Your own words

A stationary nucleus with mass number 32 and atomic number 15 undergoes beta-minus decay. Its electron carries 6 momentum units east, and its antineutrino carries 2 units west. In three or four sentences, predict the daughter's mass number, atomic number, and recoil momentum, and check the total charge.

Decay Detectives

PART 1 · READ AND MARK

Underline each starting nucleus's mass and atomic numbers, circle the mass-number and charge information for emitted particles, and number the momentum measurements. Use your marks to track what is conserved in each decay. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	For the polonium decay, calculate the daughter's mass number. Use atomic numbers to check whether lead is the correct element.	**The mass number is 210 − 4 = 206. The atomic number is 84 − 2 = 82, which matches lead.**
2	For the carbon decay, calculate the daughter's mass number and atomic number. Show how the total charge still equals the starting charge.	**The daughter has mass number 14 and atomic number 7. Its charge of 7^+ plus the electron's 1^- and the antineutrino's 0 equals the starting charge of 6^+.**
3	In the alpha event, what momentum must the lead nucleus have? Explain using the starting momentum.	**The lead nucleus has 5 momentum units west. Its momentum must cancel the alpha particle's 5 units east because the starting nucleus was stationary.**
4	In the beta event, what are the size and direction of the nitrogen nucleus's momentum? Explain how both emitted particles affect it.	**The nitrogen nucleus has 5 momentum units southwest: 3 units west and 4 units south. These components cancel the electron's eastward momentum and the antineutrino's northward momentum.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

The daughter has mass number 32 because beta-minus decay does not eject nucleons. Its atomic number is 16 because a neutron becomes a proton; the charge balances because 16^+ plus 1^- equals 15^+. The emitted particles carry a net 4 momentum units east, so the daughter recoils with 4 units west.

Accept equivalent descriptions of opposite momentum directions. For question 4, a southwest direction alone is incomplete; the response must account for both the 3-unit and 4-unit components.