# Inside a Decay

Trace particle changes through quarks and interaction vertices

**HS-PSII-10.1** "Describe the Standard Model and explain the composition and decay of subatomic particles using the Standard Model and Feynman diagrams."

NAME _____ DATE _____

## 1 READ AND MARK

Read it twice

**YOUR JOB** In paragraph 3, number the sentences beginning "First," "Next," and "Finally," in that order; underline the quark before and after its change in "First" and the two particles produced in "Next."

### What Happens When a Neutron Decays?

1. Imagine a detector recording an electron that appears after a neutron changes. The Standard Model explains such events using elementary particles and their interactions. Quarks and leptons are matter particles: a proton contains two up quarks and one down quark (uud), while a neutron contains one up quark and two down quarks (udd). An electron is a lepton, not a quark. Gluons carry the strong interaction that holds quarks together; photons carry the electromagnetic interaction. W and Z bosons carry the weak interaction, which can change quark types. The Higgs boson is also elementary, but it is not one of these force carriers.

2. Charges help track what can happen. An up quark has charge +2/3, and a down quark has charge −1/3, in units of the proton's charge. Thus uud has total charge +1, while udd has total charge 0. An electron has charge −1; its antiparticle, a positron, has charge +1. Neutrinos and antineutrinos have charge 0. A Feynman diagram represents an interaction with lines for particles and vertices where lines meet. If time runs left to right, an incoming particle line reaches a vertex, and outgoing lines show what leaves. Charge must balance at every vertex.

3. In a neutron's beta decay, a down quark changes, but the other two quarks remain. First, a down quark becomes an up quark and emits a $W^-$ boson; the neutron's quarks are now uud, a proton. Next, the virtual $W^-$ boson produces an electron and an electron antineutrino. Finally, the proton, electron, and electron antineutrino leave as the products of neutron decay. In a Feynman diagram, the quark-change vertex connects the down-quark line, up-quark line, and $W^-$ line. At a second vertex, the $W^-$ line joins the electron and antineutrino lines. Each vertex conserves charge.

## 2 ANSWER WITH EVIDENCE

Use the passage

1. Use the quark contents to explain how a neutron becomes a proton in beta decay. Which quark changes, and which two stay the same?

2. Which three particle lines meet at the quark-change vertex? Show how their charges balance.

3. Which lines meet at the second vertex? Explain how charge is conserved there.

4. In this decay, how is the W boson's role different from the electron's? Why would the Higgs boson not be labeled as the weak-interaction carrier?

## 3 YOUR TURN

Your own words

In a proton-rich nucleus, a proton can become a neutron while emitting a positron and an electron neutrino. Draw a left-to-right Feynman-style sketch showing the changing quark, the weak boson, both emitted particles, and the unchanged quarks; label charges at both vertices and write one sentence explaining why charge is conserved.

# Inside a Decay



## PART 1 · READ AND MARK

In paragraph 3, number the sentences beginning "First," "Next," and "Finally," in that order; underline the quark before and after its change in "First" and the two particles produced in "Next." Accept any marking that follows this job and points at the right text.

## PART 2 · ANSWERS

| # | QUESTION | ANSWER |
|---|---|---|
| 1 | Use the quark contents to explain how a neutron becomes a proton in beta decay. Which quark changes, and which two stay the same? | **One down quark changes to an up quark. The other up quark and down quark stay the same, changing udd into uud.** |
| 2 | Which three particle lines meet at the quark-change vertex? Show how their charges balance. | **The down-quark, up-quark, and $W^-$ lines meet. The charges balance because $-1/3 = +2/3 + (-1)$.** |
| 3 | Which lines meet at the second vertex? Explain how charge is conserved there. | **The $W^-$, electron, and electron-antineutrino lines meet. The $W^-$ charge of −1 equals the electron's −1 plus the antineutrino's 0.** |
| 4 | In this decay, how is the W boson's role different from the electron's? Why would the Higgs boson not be labeled as the weak-interaction carrier? | **The W boson carries the weak interaction between the two vertices; the electron is a lepton produced at the second vertex. The Higgs boson is elementary but is not the weak-interaction carrier.** |

## PART 3 · YOUR TURN (SAMPLE ANSWER)

Sketch: Start with uud. One $u^{+2/3}$ line reaches a vertex and branches into a $d^{-1/3}$ line and a $W^+$ line; the unchanged u and d lines continue, giving udd. At a second vertex, $W^+$ branches into an $e^+$ line and an electron-neutrino line. Charge is conserved because $+2/3 = -1/3 + 1$ at the first vertex, and $+1 = +1 + 0$ at the second.

Accept sketches with either arrangement of outgoing lines if their labels and vertex connections are correct. The emitted neutrino must be an electron neutrino, not an antineutrino.