

Nuclear Stability

Answer key with explanations

A. Ideas

1. The strong force.

(a) A very **short-range attraction** between all nucleons (protons and neutrons). (b) Protons repel each other across the whole nucleus, but the strong force acts only between neighbours. Extra **neutrons add attraction without adding repulsion**, so larger nuclei need more of them. (c) Beyond $Z = 83$, the total proton repulsion is too great for any number of neutrons to hold the nucleus together permanently.

2. N/Z .

(a) $2/2 = 1.00$ (b) $8/8 = 1.00$ (c) $30/26 = 1.15$ (d) $124/82 = 1.51$. The ratio **rises** with atomic number: heavier stable nuclei need proportionally more neutrons.

B. Predicting decay

3. Decay equations.

- (a) Co-60 has one more neutron than stable Co-59: β^- . ${}^{60}_{27}\text{Co} \longrightarrow {}^{60}_{28}\text{Ni} + {}^0_{-1}\text{e}$
(b) F-18 has one fewer neutron than stable F-19: β^+ . ${}^{18}_9\text{F} \longrightarrow {}^{18}_8\text{O} + {}^0_{+1}\text{e}$
(c) Rn-222 has $Z = 86$, beyond 83: α . ${}^{222}_{86}\text{Rn} \longrightarrow {}^{218}_{84}\text{Po} + {}^4_2\text{He}$
(d) P-32 has one more neutron than stable P-31: β^- . ${}^{32}_{15}\text{P} \longrightarrow {}^{32}_{16}\text{S} + {}^0_{-1}\text{e}$

4. Doubly magic.

Both the number of protons **and** the number of neutrons are magic numbers: Ca-40 has 20 and 20; Pb-208 has 82 and 126. Like full electron shells, full nuclear shells give **extra stability**, so these nuclides are especially stable (Pb-208 is the end of the thorium decay series).

C. Decay series

5. Th-232 to Pb-208.

α : $(232 - 208) \div 4 = 6$. Six α lower Z by 12: $90 - 12 = 78$. Lead is 82, so Z rises by 4: **4 β^-** .
Check: $90 - 12 + 4 = 82$ ✓

6. U-235 to Pb-207.

α : $(235 - 207) \div 4 = 7$. Seven α lower Z by 14: $92 - 14 = 78$. Lead is 82: **4 β^-** . Check: $92 - 14 + 4 = 82$ ✓

D. Applying the ideas

7. Fluorine-18.

F-18 has $N/Z = 9/9 = 1.00$, lower than stable F-19 ($10/9 = 1.11$): it has **too few neutrons**, so it lies below the band. It converts a proton into a neutron by **emitting a positron**, which then meets an electron in the body and produces the gamma rays a PET scanner detects.

E. Challenge

8. Tritium.

Tritium has 1 proton and 2 neutrons: $N/Z = 2/1 = 2.0$, far above the stable ratios for hydrogen (0 and 1). Too many neutrons: **β^- decay**. ${}^3_1\text{H} \longrightarrow {}^3_2\text{He} + {}^0_{-1}\text{e}$