9. What must be true in order for a nuclear reaction to happen naturally?

A. The nucleus must release energy in the reaction.
B. The binding energy per nucleon must decrease in the reaction.
C. The binding energy per nucleon must increase in the reaction.
D. There must be an input of energy to cause the reaction.

10. Which is the weakest of the four fundamental interactions?

F. electromagnetic
G. gravitational
H. strong
J. weak

11. Which of the following choices does *not* correctly match a fundamental interaction with its mediating particles?

A. strong: gluons
B. electromagnetic: electrons
C. weak: *W* and *Z* bosons
D. gravitational: gravitons

12. What is the charge of a baryon containing one up quark (u) and two down quarks (d)?

F. -1
G. 0
H. $+1$
J. $+2$

SHORT RESPONSE

13. Suppose it could be shown that the ratio of carbon-14 to carbon-12 in living organisms was much greater thousands of years ago than it is today. How would this affect the ages we assign to ancient samples of once-living matter?

14. A fission reactor produces energy to drive a generator. Describe briefly how this energy is produced.

15. Balance the following nuclear reaction:
${}^{1}_{0}n + ? \longrightarrow {}^{4}_{2}\text{He} + {}^{7}_{3}\text{Li}$

16. Smoke detectors use the isotope ${}^{241}\text{Am}$ in their operation. The half-life of Am is 432 years. If the smoke detector is improperly discarded in a landfill, estimate how long its activity will take to decrease to a relatively safe level of 0.1 percent of its original activity. (Hint: The estimation process that you should use notes that the activity decreases to 50% in one half-life, to 25% in two half-lives, and so on.)

EXTENDED RESPONSE

17. Iron-56 (${}^{56}_{26}\text{Fe}$) has an atomic mass of 55.934 940 u. The atomic mass of hydrogen is 1.007 825 u, and $m_n = 1.008\ 665$ u. Show your work for the following calculations:

a. Find the mass defect in the iron-56 nucleus.
b. Calculate the binding energy in the iron-56 nucleus.
c. How much energy would be needed to dissociate all the particles in an iron-56 nucleus?

18. Use the table below to calculate the energy released in the alpha decay of ${}^{238}_{92}\text{U}$. Show your work.

Nucleus	Mass
${}^{238}_{92}\text{U}$	238.050 784 u
${}^{234}_{90}\text{Th}$	234.043 593 u
${}^{4}_{2}\text{He}$	4.002 602 u

Test TIP If you finish a test early, go back and check your work before turning in the test.