1. A radioactive isotope of vanadium, $^{51}_{23}V$, decays by producing $\beta$ particles and gamma rays. The nuclide formed has the atomic number
   A) 22.
   B) 21.
   C) 23.
   D) 24.
   E) none of these

2. The most likely decay mode (or modes) of the unstable nuclide $^{11}_{6}C$ would be
   A) positron production.
   B) $\alpha$-particle production.
   C) electron capture.
   D) $\beta$ emission
   E) either positron production or electron capture or both.

3. The nuclide Bi-213 is the daughter nuclide resulting from the $\alpha$ decay of what parent nuclide?
   A) Tl-209
   B) Fr-215
   C) Hg-297
   D) At-217
   E) $^4_2$He

4. Which reaction will produce an isotope of the parent nuclide?
   A) $^{210}_{84}$Po $\rightarrow$ He + ?
   B) $^{88}_{35}$Br $\rightarrow$ n + ?
   C) $^{227}_{89}$Ac $\rightarrow$ $\beta$ + ?
   D) $^{13}_{7}$N $\rightarrow$ $\beta$ + ?
   E) $^{73}_{33}$As + e $\rightarrow$ ?

5. Which types of processes are likely when the neutron-to-proton ratio in a nucleus is too large?
   I. $\alpha$ decay
   II. $\beta$ decay
   III. positron production
   IV. electron capture

   A) I, II
   B) II, III
   C) III, IV
   D) II only
   E) IV only
6. The nuclide $^{232}_{90}$Th is radioactive. When one of these atoms decays, a series of $\alpha$- and $\beta^-$-particle emissions occurs, taking the atom through many transformations to end up as an atom of $^{208}_{82}$Pb. How many $\alpha$ particles are emitted in converting $^{232}_{90}$Th into $^{208}_{82}$Pb?

A) 6  
B) 8  
C) 2  
D) 214  
E) 4

7. Electron capture transforms $^{40}_{19}$K into what nuclide?

A) $^{40}_{20}$Ca  
B) $^{40}_{18}$Ar  
C) $^4_2$He  
D) $^{40}_{19}$K  
E) $^{39}_{20}$Ca

8. The stable nuclide $^{206}_{82}$Pb is formed from $^{238}_{92}$U by a long series of $\alpha$ and $\beta$ decays. Which of the following nuclides could not be involved in this decay series?

A) Pa-234  
B) U-239  
C) Po-218  
D) Tl-210  
E) Rn-222

9. What is the most likely decay for the Fe-59 nucleus?

A) $\beta$ decay  
B) positron emission  
C) $\alpha$ decay  
D) $\gamma$-ray emission  
E) proton emission

10. Which of the following balanced equations is labeled incorrectly?

A) alpha emission: $^{209}_{83}$Bi + $^4_2$He $\rightarrow$ $^{211}_{85}$At + $^2_0$n  
B) fusion: $^1_1$H + $^1_1$H $\rightarrow$ $^1_1$H + $^1_1$H  
C) bombardment: $^{239}_{94}$Pu + $^1_0$n $\rightarrow$ $^{240}_{95}$Am + $^0_{-1}$e  
D) beta production: $^{239}_{92}$U $\rightarrow$ $^{239}_{93}$Np + $^0_{-1}$e  
E) alpha production: $^{230}_{90}$Th $\rightarrow$ $^{226}_{88}$Ra + $^4_2$He

11. When the U-235 nucleus is struck with a neutron, the Zn-72 and Sm-160 nuclei are produced, along with some neutrons. How many neutrons are emitted?

A) 2  
B) 3  
C) 4  
D) 5  
E) 6
12. The rate constant for the beta decay of a particular radioactive element is $2.78 \times 10^{-2}$/day. What is the half-life of this nuclide?
   A) $4.01 \times 10^{-4}$ days
   B) $1.80 \times 10^{-1}$ days
   C) $3.60 \times 10^{1}$ days
   D) $2.49 \times 10^{1}$ days
   E) $7.19 \times 10^{2}$ days

13. What is the number of half-lives needed for a radioactive element to decay to one-eighth of its original activity?
   A) 1
   B) 2
   C) 3
   D) 0
   E) 4

14. A 0.20-mL sample of a solution containing $^3$H that produces $3.7 \times 10^{3}$ cps is injected into the bloodstream of an animal. After circulatory equilibrium has been established, a 0.20-mL sample of blood is found to have an activity of 20 cps. Calculate the blood volume of the animal.
   A) 18 mL
   B) 37 mL
   C) 11 mL
   D) 180 mL
   E) none of these

15. Radioactive elements decay via first-order kinetics. Consider a certain type of nucleus that has a rate constant of $2.3 \times 10^{-2}$ h$^{-1}$. A sample contains $6.8 \times 10^{8}$ radioactive nuclides. Calculate the time required to reduce that number to $2.0 \times 10^{9}$.
   A) $2.3 \times 10^{1}$ h
   B) $2.1 \times 10^{10}$ h
   C) $5.3 \times 10^{1}$ h
   D) $6.8 \times 10^{1}$ h
   E) 7.8 h

16. The number of a certain radioactive nuclide present in a sample decays from $2.9 \times 10^{2}$ to $6.2 \times 10^{1}$ in 25 minutes. What is the half-life of this radioactive species?
   A) 2.6 minutes
   B) $6.2 \times 10^{-2}$ minutes
   C) $1.1 \times 10^{1}$ minutes
   D) $1.6 \times 10^{1}$ minutes
   E) $8.1 \times 10^{1}$ minutes

17. The Cs-131 nuclide has a half-life of 30 years. After 120 years, about 3 g remain. The original mass of the Cs-131 sample is closest to
   A) 30 g
   B) 40 g
   C) 50 g
   D) 60 g
   E) 70 g

18. The half-life of $^{90}$Sr is 28 years. How long will it take for a given sample of $^{90}$Sr to be 79% decomposed?
   A) $2.7 \times 10^{1}$ years
   B) 9.5 years
   C) $6.3 \times 10^{1}$ years
   D) $3.5 \times 10^{2}$ years
   E) 4.1 years
19. The half-life for electron capture for $^{19}\text{K}$ is 1.3 billion years. What will be the $^{40}\text{K} / ^{40}\text{Ar}$ ratio in a rock that is 4.5 billion years old?
A) 0.091
B) 11.
C) 10
D) 0.10
E) 0.36

20. The Br-82 nucleus has a half-life of about $1.0 \times 10^3$ minutes. If you needed at least 1.7 g of Br-82 and had ordered 33 g of NaBr (assuming all of the Br in the NaBr was Br-82), how many days could you wait for delivery?
A) 1.2 days
B) 3.0 days
C) 3.9 days
D) 2.7 days
E) 3.2 days

21. A sample of wood from an Egyptian mummy case gives a $^{14}\text{C}$ count of 9.0 cpm/gC (counts per minute per gram of carbon). How old is the wood? (The initial decay rate of $^{14}\text{C}$ is 15.3 cpm/gC, and its half-life is 5730 years.)
A) $1.9 \times 10^3$ years
B) $3.0 \times 10^3$ years
C) $4.4 \times 10^3$ years
D) $4.9 \times 10^3$ years
E) $3.4 \times 10^3$ years

22. Which statement is true about the following reaction?
A) Energy is absorbed in the reaction.
B) Energy is released in the reaction.
C) No energy change is associated with the reaction.
D) Not enough information is given for us to determine the energy change.

23. Calculate $\Delta E$ in kilojoules per mole for the reaction

$$^{230}\text{Th} \rightarrow ^{4}\text{He} + ^{1}\text{Ra}$$

Atomic masses: $^{230}\text{Th} = 230.0332$, $^{4}\text{He} = 4.00260$, $^{1}\text{Ra} = 226.02544$.

A) $-4.6 \times 10^8$ kJ/mol
B) $-2.4 \times 10^6$ kJ/mol
C) 0
D) $+2.4 \times 10^6$ kJ/mol
E) $+4.6 \times 10^8$ kJ/mol
Iron-56, \(^{56}_{26}\)Fe, has a binding energy per nucleon of 8.79 MeV. (1 MeV = \(1.60 \times 10^{-13}\) J)

24. Determine the amount of energy needed to "decompose" 1 mol of iron-56 nuclei.
   A) \(3.47 \times 10^{11}\) J
   B) \(4.74 \times 10^{11}\) J
   C) \(8.90 \times 10^{11}\) J
   D) \(1.13 \times 10^{14}\) J
   E) \(7.75 \times 10^{13}\) J

25. Determine the difference in mass between 1 mol of iron-56 nuclei and the component nucleons of which it is made.
   A) \(9.41 \times 10^{-6}\) kg
   B) \(2.43 \times 10^{-5}\) kg
   C) \(6.65 \times 10^{-5}\) kg
   D) \(5.27 \times 10^{-4}\) kg
   E) \(7.21 \times 10^{-4}\) kg

26. Which of the following statements is true of the fission of uranium-235?
   A) The electron is captured by the nucleus, which becomes unstable.
   B) The products include neutrons.
   C) The nuclides produced are individually heavier than the uranium nuclide.
   D) The ultimate nuclides produced are more stable than the uranium nuclide.
   E) two of these

**ANSWERS:**

   26. E