1. Which nuclear emission has the greatest mass and the least penetrating power?
   A) an alpha particle  B) a beta particle
   C) a neutron  D) a positron

2. Which equation represents alpha decay?
   A) $^{116}\text{In} \rightarrow ^{116}\text{Sn} + X$
   B) $^{234}\text{Th} \rightarrow ^{234}\text{Pa} + X$
   C) $^{38}\text{K} \rightarrow ^{38}\text{Ar} + X$
   D) $^{222}\text{Rn} \rightarrow ^{218}\text{Po} + X$

3. An unstable nucleus loses the most mass if the nucleus emits
   A) an alpha particle  B) a beta particle
   C) a positron  D) a gamma ray

4. Which list of nuclear emissions is arranged in order from the least penetrating power to the greatest penetrating power?
   A) alpha particle, beta particle, gamma ray
   B) alpha particle, gamma ray, beta particle
   C) gamma ray, beta particle, alpha particle
   D) beta particle, alpha particle, gamma ray

5. An alpha particle has the same composition as a
   A) hydrogen nucleus  B) deuterium nucleus
   C) beryllium nucleus  D) helium nucleus

6. Given the reaction:
   $^{226}\text{Ra} \rightarrow ^{222}\text{Rn} + X$
   Which type of emanation is represented by $X$?
   A) alpha particle  B) beta particle
   C) proton  D) positron

7. Which particle has the greatest mass?
   A) an alpha particle  B) a beta particle
   C) a neutron  D) a positron

8. Given the nuclear equation:
   $^1\text{H} + X \rightarrow ^6\text{Li} + ^4\text{He}$
   The particle represented by $X$ is
   A) $^9\text{Li}$  B) $^9\text{Be}$  C) $^{10}\text{Be}$  D) $^{10}\text{C}$

9. An electron has a charge identical to that of
   A) a neutron  B) a proton
   C) an alpha particle  D) a beta particle

10. What is the decay mode of $^{37}\text{K}$?
    A) $\beta^-$  B) $\beta^+$  C) $\gamma$  D) $a$

11. Compared to the mass and the penetrating power of an alpha particle, a beta particle has
    A) less mass and greater penetrating power
    B) less mass and less penetrating power
    C) more mass and greater penetrating power
    D) more mass and less penetrating power

12. Which particle has a negative charge?
    A) a lithium ion  B) an alpha particle
    C) an aluminum ion  D) a beta particle

13. Which two radioisotopes have the same decay mode?
    A) $^{37}\text{Ca}$ and $^{53}\text{Fe}$
    B) $^{220}\text{Fr}$ and $^{60}\text{Co}$
    C) $^{37}\text{K}$ and $^{42}\text{K}$
    D) $^{99}\text{Tc}$ and $^{19}\text{Ne}$

14. Given the equation:
    $^{14}_6\text{C} \rightarrow ^{14}_7\text{N} + X$
    Which particle is represented by the letter $X$?
    A) an alpha particle  B) a beta particle
    C) a neutron  D) a proton

15. When cobalt-60 undergoes nuclear decay, it emits
    A) a positron  B) a neutron
    C) a beta particle  D) an alpha particle

16. Which type of radiation has neither mass nor charge?
    A) gamma  B) neutron
    C) alpha  D) beta

17. Which statement best describes gamma radiation?
    A) It has a mass of 1 and a charge of 1.
    B) It has a mass of 0 and a charge of –1.
    C) It has a mass of 0 and a charge of 0.
    D) It has a mass of 4 and a charge of +2.
18. A mixture of emanations from radioactive atoms is passed through electrically charged plates, as shown in the diagram below.

The nuclear emanations 1, 2, and 3 are called, respectively,
A) alpha, beta, and gamma
B) beta, gamma, and alpha
C) gamma, alpha, and beta
D) gamma, beta, and alpha

19. How many days are required for 200. grams of radon-222 to decay to 50.0 grams?
A) 1.91 days   B) 3.82 days   C) 7.64 days   D) 11.5 days

20. If 8.0 grams of a sample of $^{60}$Co existed in 1990, in which year will the remaining amount of $^{60}$Co in the sample be 0.50 gram?
A) 1995   B) 2000   C) 2006   D) 2011

21. An original sample of a radioisotope had a mass of 10 grams. After 2 days, 5 grams of the radioisotope remains unchanged. What is the half-life of this radioisotope?
A) 1 day   B) 2 days   C) 5 days   D) 4 days

22. What is the total number of grams of a 32-gram sample of $^{32}$P remaining after 71.5 days of decay?
A) 1.0 g   B) 2.0 g   C) 8.0 g   D) 4.0 g

23. Approximately how many grams of a 40-gram sample of $^{131}$I will remain unchanged after 24 days?
A) 5   B) 10   C) 13   D) 20

24. What is the half-life of a radioisotope if 25.0 grams of an original 200.-gram sample of the isotope remains unchanged after 11.46 days?
A) 2.87 d   B) 3.82 d   C) 11.46 d   D) 34.38 d

25. Based on Reference Table $N$, what fraction of a sample of gold-198 remains radioactive after 2.69 days?
A) $\frac{1}{4}$   B) $\frac{1}{2}$   C) $\frac{3}{4}$   D) $\frac{7}{8}$

26. As the temperature of a sample of a radioactive element decreases, the half-life of the element
A) decreases   B) increases   C) remains the same

27. Which term identifies a type of nuclear reaction?
A) transmutation   B) neutralization   C) deposition   D) reduction

28. In which type of reaction is an atom of one element converted to an atom of a different element?
A) decomposition   B) neutralization   C) saponification   D) transmutation

29. Given the balanced equation representing a reaction:

$$\frac{27}{13}Al + \frac{4}{2}He \rightarrow \frac{30}{15}P + \frac{1}{0}n$$

Which type of reaction is represented by this equation?
A) combustion   B) decomposition   C) saponification   D) transmutation

30. Which equation is an example of artificial transmutation?
A) $^{9}Be + \frac{4}{2}He \rightarrow ^{12}C + \frac{1}{0}n$
B) $U + 3F_{2} \rightarrow UF_{6}$
C) $Mg(OH)_{2} + 2HCl \rightarrow 2H_{2}O + MgCl_{2}$
D) $Ca + 2H_{2}O \rightarrow Ca(OH)_{2} + H_{2}$

31. The primary use of a particle accelerator is to
A) detect a radioactive particle   B) isolate a radioactive particle   C) increase the kinetic energy of a charged particle   D) increase the potential energy of a charged particle

32. A particle accelerator is used to provide charged particles with sufficient
A) kinetic energy to penetrate a nucleus   B) kinetic energy to penetrate an electron cloud   C) potential energy to penetrate a nucleus   D) potential energy to penetrate an electron cloud

33. When a uranium nucleus breaks up into fragments, which type of nuclear reaction occurs?
A) fusion   B) fission   C) replacement   D) redox
34. When a nucleus with a high mass undergoes fission, the resulting nuclei are more stable than the original nucleus because they have a
A) higher binding energy per nucleon
B) lower binding energy per nucleon
C) higher number of electrons
D) lower number of electrons

35. What is the primary result of a fission reaction?
A) conversion of mass to energy
B) conversion of energy to mass
C) binding together of two heavy nuclei
D) binding together of two light nuclei

36. In which reaction is mass converted to energy by the process of fission?
A) \( ^{14}\text{N} + ^{1}\text{n} \rightarrow ^{14}\text{C} + ^{1}\text{H} \)
B) \( ^{235}\text{U} + ^{1}\text{n} \rightarrow ^{85}\text{Br} + ^{146}\text{La} + 3 ^{1}\text{n} \)
C) \( ^{226}\text{Ra} \rightarrow ^{222}\text{Ra} + ^{4}\text{He} \)
D) \( ^{1}\text{H} + ^{1}\text{H} \rightarrow ^{4}\text{He} \)

37. Which substance has chemical properties similar to those of radioactive \( ^{235}\text{U} \)?
A) \( ^{235}\text{Pa} \)  B) \( ^{233}\text{Pa} \)  C) \( ^{233}\text{U} \)  D) \( ^{206}\text{Pb} \)

38. Which equation represents a fusion reaction?
A) \( ^{2}\text{H} + ^{3}\text{H} \rightarrow ^{4}\text{He} \)
B) \( ^{6}\text{C} \rightarrow ^{0}\text{He} + ^{4}\text{N} \)
C) \( ^{238}\text{U} + ^{1}\text{n} \rightarrow ^{241}\text{Pu} + ^{0}\text{H} \)
D) \( ^{1}\text{H} + ^{27}\text{Al} \rightarrow ^{24}\text{Na} + ^{4}\text{He} \)

39. For a given mass of reactants, the energy released is greatest for a reaction involving
A) slow oxidation
B) rapid oxidation
C) fission
D) fusion

40. A nuclear reaction in which two light nuclei combine to form a more massive nucleus is called
A) addition
B) fission
C) fusion
D) substitution

41. Which change takes place in a nuclear fusion reaction?
A) Matter is converted to energy.
B) Energy is converted to matter.
C) Ionic bonds are converted to covalent bonds.
D) Covalent bonds are converted to ionic bonds.

42. Given the balanced equation representing a nuclear reaction:
\[ ^{2}\text{H} + ^{3}\text{H} \rightarrow ^{4}\text{He} + ^{1}\text{n} \]
Which phrase identifies and describes this reaction?
A) fission, mass converted to energy
B) fission, energy converted to mass
C) fusion, mass converted to energy
D) fusion, energy converted to mass

43. Which conditions are required to form \( ^{4}\text{He} \) during the fusion reaction in the Sun?
A) high temperature and low pressure
B) high temperature and high pressure
C) low temperature and low pressure
D) low temperature and high pressure

44. Which nuclear equation represents a fusion reaction?
A) \( ^{235}\text{U} + ^{1}\text{n} \rightarrow ^{239}\text{Np} + ^{0}\text{He} \)
B) \( ^{235}\text{U} + ^{1}\text{n} \rightarrow ^{239}\text{Kr} + ^{141}\text{Ba} + ^{3}\text{n} \)
C) \( ^{14}\text{C} \rightarrow ^{14}\text{N} + ^{0}\text{He} \)
D) \( ^{1}\text{H} + ^{1}\text{H} \rightarrow ^{2}\text{He} \)

45. The fusion of hydrogen nuclei with the release of energy can be initiated by a fission reaction because the fission reaction provides a
A) combustion
B) reduction
C) nuclear fission
D) nuclear fusion

46. In which type of reaction do two lighter nuclei combine to form one heavier nucleus?
A) combustion
B) reduction
C) nuclear fission
D) nuclear fusion

47. Given the reaction:
\[ ^{9}\text{Be} + ^{1}\text{H} \rightarrow ^{4}\text{He} + X \]
Which species is represented by \( X \)?
A) \( ^{8}\text{Li} \)  B) \( ^{6}\text{Li} \)  C) \( ^{5}\text{B} \)  D) \( ^{10}\text{B} \)

48. Which product of nuclear decay has mass but no charge?
A) alpha particles
B) neutrons
C) gamma rays
D) beta positrons
49. Given the equation:

\[
\frac{14}{7}N + 2\text{He} \rightarrow X + \frac{17}{8}O
\]

When the equation is correctly balanced, the particle represented by the \(X\) will be

A) \(0_{-1e}\)  B) \(1_{0n}\)  C) \(1_1H\)  D) \(2_1H\)

50. In the reaction:

\[
\frac{9}{4}Be + X \rightarrow \frac{12}{6}C + \frac{1}{0n}
\]

The \(X\) represents

A) an alpha particle  B) a beta particle  C) an electron  D) a proton

51. In the equation:

\[
\frac{234}{90}Th \rightarrow \frac{234}{91}Pa + X
\]

Which particle is represented by \(X\)?

A) \(0_{-1e}\)  B) \(4_{2He}\)  C) \(1_1H\)  D) \(0_{+1e}\)

52. In the reaction:

\[
\frac{6}{3}Li + \frac{1}{0n} \rightarrow \frac{4}{2He} + X
\]

The species represented by \(X\) is

A) \(^2_1H\)  B) \(^3_1H\)  C) \(^3_2He\)  D) \(^4_2He\)

53. Given the nuclear reaction:

\[
\frac{14}{7}N + 2\text{He} \rightarrow \frac{1}{1}H + X
\]

Which isotope is represented by the \(X\) when the equation is correctly balanced?

A) \(^{17}_8O\)  B) \(^{18}_8O\)  C) \(^{17}_9F\)  D) \(^{18}_9F\)

54. Given the nuclear reaction:

\[
\frac{9}{4}Be + X \rightarrow \frac{6}{3}Li + \frac{4}{2He}
\]

Which particle is represented by \(X\)?

A) \(^1_1H\)  B) \(^2_1H\)  C) \(^4_2H\)  D) \(^1_0n\)

55. Energy is released during the fission of Pu-239 atoms as a result of the

A) formation of covalent bonds  B) formation of ionic bonds
C) conversion of matter to energy  D) conversion of energy to matter

56. Given the equation representing a reaction where the masses are expressed in atomic mass units:

\[
\begin{align*}
\text{hydrogen-2} + \text{hydrogen-1} & \rightarrow \text{helium-3} + 8.814 \times 10^{-16} \\
2.014 \ 102 \ u & \ 1.007 \ 825 \ u \ \ 3.016 \ 029 \ u
\end{align*}
\]

Which phrase describes this reaction?

A) a chemical reaction and mass being converted to energy
B) a chemical reaction and energy being converted to mass
C) a nuclear reaction and mass being converted to energy
D) a nuclear reaction and energy being converted to mass

57. The energy released by a nuclear reaction results primarily from the

A) form heavy nuclides from light nuclides
B) form light nuclides from heavy nuclides
C) release a large amount of energy
D) absorb a large amount of energy

58. A nuclear fission reaction and a nuclear fusion reaction are similar because both reactions

A) Rn-222  B) I-131  C) Co-60  D) C-14

59. The decay of which radioisotope can be used to estimate the age of the fossilized remains of an insect?

A) \(^{14}_6C\)  B) \(^{16}_8N\)  C) \(^{32}_1P\)  D) \(^{37}_1K\)

60. Which isotope is most commonly used in the radioactive dating of the remains of organic materials?

A) \(^{14}_6C\)  B) \(^{16}_8N\)  C) \(^{32}_1P\)  D) \(^{37}_1K\)
61. A radioactive isotope used in the study of many organic reaction mechanisms is
A) carbon-12  B) carbon-14  C) oxygen-16  D) oxygen-18

62. Which radioisotope is used to treat thyroid disorders?
A) Co-60  B) I-131  C) C-14  D) U-238

63. What is a problem commonly associated with nuclear power facilities?
A) A small quantity of energy is produced.  B) Reaction products contribute to acid rain.  C) It is impossible to control nuclear fission.  D) It is difficult to dispose of wastes.

64. Which risk is associated with using nuclear fission to produce energy in a power plant?
A) depletion of hydrocarbons  B) depletion of atmospheric oxygen  C) exposure of workers to radiation  D) exposure of workers to sulfur dioxide

65. A serious risk factor associated with the operation of a nuclear power plant is the production of
A) acid rain  B) helium gas  C) greenhouse gases, such as CO₂  D) radioisotopes with long half-lives

66. Which statement explains why nuclear waste materials may pose a problem?
A) They frequently have short half-lives and remain radioactive for brief periods of time.  B) They frequently have short half-lives and remain radioactive for extended periods of time.  C) They frequently have long half-lives and remain radioactive for brief periods of time.  D) They frequently have long half-lives and remain radioactive for extended periods of time.

67. One benefit of nuclear fission reactions is
A) nuclear reactor meltdowns  B) storage of waste materials  C) biological exposure  D) production of energy