***Physics: Principle and Applications*, 7e (Giancoli)**
Chapter 30 Nuclear Physics and Radioactivity

30.1 Conceptual Questions

1) Write the standard nuclear notation for the following nuclei: hydrogen-2, sulfur-33, and lead-207.
Answer: ${}^{2}_{1}H$, ${}^{33}_{16}S$, ${}^{207}_{82}Pb$

Var: 1

2) Name the first three isotopes of hydrogen, write their symbols in standard notation, and indicate which one is the most common and which one is the most unstable.
Answer: ${}^{1}_{1}H$ is ordinary hydrogen, ${}^{2}_{1}H$ is deuterium, and ${}^{3}_{1}H$ is tritium. ${}^{1}_{1}H$ is the most common and ${}^{3}_{1}H$ is the most unstable.

Var: 1

3) The primary reason that very large nuclei are unstable is due to
A) the cumulative repulsive force of the protons.
B) the cumulative attractive force between the protons and the orbiting electrons.
C) the repulsive force between the neutrons and the protons.
D) the extreme weakness of the gravitational attraction of the protons.
Answer: A
Var: 1

4) Atomic nuclei that are all isotopes of an element all have the same
A) number of nucleons.
B) mass.
C) number of protons.
D) number of neutrons.
Answer: C
Var: 1

5) All nuclei of a given element have the same number of
A) neutrons.
B) protons.
C) nucleons.
D) protons + neutrons.
Answer: B
Var: 1

6) An yttrium isotope has 39 protons and 50 neutrons in its nucleus. Which one of the following symbols accurately represents this isotope?

A) $^{39}_{89}Y$

B) $^{89}_{50}Y$

C) $^{89}_{39}Y$

D) $^{50}_{39}Y$

E) $^{39}_{50}Y$

Answer: C
Var: 1

7) The atomic number of an atom is equal to the number of what particles in the nucleus?
A) protons
B) neutrons
C) nucleons
D) electrons
E) positrons.
Answer: A
Var: 1

8) The mass number of an atom is equal to the number of what particles in the nucleus?
A) protons
B) neutrons
C) nucleons
D) electrons
E) positrons.
Answer: C
Var: 1

9) The atomic number and mass number for calcium-39 are 20 and 39, respectively. How many neutrons are in one atom?
A) 1
B) 19
C) 20
D) 39
E) 59
Answer: B
Var: 1

10) In a $^{93}_{41}$Nb *nucleus*, how many protons, neutrons, and electrons are found there?

A) 41, 52, 93.
B) 41, 52, 41.
C) 52, 41, 41.
D) 41, 52, 0.
E) 93, 41, 93.
Answer: D
Var: 1

11) The symbol for a certain isotope of polonium is $^{214}_{84}$Po. How many neutrons are there in the nucleus of this isotope?
A) 84
B) 130
C) 214
D) 298
E) 314
Answer: B
Var: 1

12) The symbol for a certain isotope of radium is $^{226}_{88}$Ra. How many nucleons are there in the nucleus of this isotope?
A) 88
B) 138
C) 214
D) 226
E) 314
Answer: D
Var: 1

13) The symbol for a certain isotope of strontium is $^{90}_{38}$Sr. What is the mass number of this isotope?
A) 38
B) 52
C) 88
D) 90
E) 128
Answer: D
Var: 1

14) What is true of an element of atomic number 15 that has an isotope of mass number 32? (There could be more than one correct choice.)
A) the number of protons in the nucleus is 15.
B) the number of neutrons in the nucleus is 15.
C) the number of protons in the nucleus is 32.
D) the number of nucleons in the nucleus is 47.
E) the number of neutrons in the nucleus is 17.
Answer: A, E
Var: 1

15) The atomic mass unit is defined as
A) the mass of a proton.
B) the mass of an electron.
C) the mass of a hydrogen-1 atom.
D) one twelfth the mass of a carbon-12 atom.
E) the mass of a carbon-12 nucleus.
Answer: D
Var: 1

16) To a reasonable approximation, the density of a nucleus
A) is independent of the mass number.
B) is greater for large-Z nuclei.
C) is smaller for large-Z nuclei.
D) varies unpredictably for different values of Z.
Answer: A
Var: 1

17) If an atomic nucleus containing 64 nucleons has a radius R, what will be the expected radius of a nucleus containing 512 nucleons?
A) R
B) $2R$
C) $4R$
D) $8R$
E) $16R$
Answer: B
Var: 1

18) If an atomic nucleus containing 64 nucleons has a mass density ρ, what will be the expected mass density of a nucleus containing 512 nucleons?
A) ρ
B) 2ρ
C) 4ρ
D) 8ρ
E) 16ρ
Answer: A
Var: 1

19) A stable nucleus contains many protons very close to each other, all positively charged. Why do the protons not fly apart due to mutual Coulomb repulsion?
A) An attractive nuclear force in the nucleus counteracts the effect of the Coulomb forces.
B) There are an equal number of electrons in the nucleus which neutralize the protons.
C) The neutrons in the nucleus shield the protons from each other.
D) The Coulomb force does not operate within nuclei.
E) The gravity of the protons and neutrons overcomes their repulsion at such close distances.
Answer: A
Var: 1

20) Which of the following statements is *not* true of the strong nuclear force?
A) The nuclear force has a short range, of the order of nuclear dimensions.
B) For two protons that are very close together, the nuclear force and the electric force have about the same magnitudes.
C) The nuclear force does not depend on charge.
D) A nucleon in a large nucleus interacts via the nuclear force only with nearby nucleons, not with ones far away in the nucleus.
E) The nuclear force affects both neutrons and protons.
Answer: B
Var: 1

21) The two strongest forces that act between protons in a nucleus are
A) the weak nuclear and electromagnetic forces.
B) the weak nuclear and the gravitational forces.
C) the electrostatic and the gravitational forces.
D) the strong nuclear and the electrostatic forces.
Answer: D
Var: 1

22) The main reason that there is a limit to the size of a stable nucleus is
A) the limited range of the gravitational force.
B) the short range nature of the strong nuclear force.
C) the weakness of the gravitational force.
D) the weakness of the electrostatic force.
Answer: B
Var: 1

23) In massive stars, three helium nuclei fuse together, forming a carbon nucleus, and this reaction heats the core of the star. The net mass of the three helium nuclei must therefore be
A) higher than that of the carbon nucleus.
B) less than that of the carbon nucleus.
C) the same as that of the carbon nucleus because mass is always conserved.
D) the same as that of the carbon nucleus because energy is always conserved.
Answer: A
Var: 1

24) A fusion reaction releases energy because the binding energy of the resulting nucleus
A) is greater than the binding energy of the original nuclei.
B) is equal to the binding energy of the original nuclei.
C) is less than the binding energy of the original nuclei.
D) is released in the process.
E) is absorbed in the process.
Answer: A
Var: 1

25) The binding energy per nucleon of a nucleus
A) increases steadily as we go to heavier elements.
B) decreases steadily as we go to heavier elements.
C) is approximately constant throughout the periodic table, except for very light nuclei.
D) has a maximum near iron in the periodic table and decreases after that for heavier elements.
E) has a minimum near iron in the periodic table and increases after that for heavier elements.
Answer: D
Var: 1

26) An α particle is also known as
A) an electron.
B) a positron.
C) a helium nucleus.
D) a high-energy photon.
Answer: C
Var: 1

27) A β^- particle is also known as
A) an electron.
B) a positron.
C) a helium nucleus.
D) a high-energy photon.
Answer: A
Var: 1

28) A β^+ particle is also known as
A) an electron.
B) a positron.
C) a helium nucleus.
D) a high-energy photon.
Answer: B
Var: 1

29) A gamma ray is also known as
A) an electron.
B) a positron.
C) a helium nucleus.
D) a high-energy photon.
Answer: D
Var: 1

30) What is the mass number of alpha particles?
A) 1
B) 2
C) 3
D) 4
E) 6
Answer: D
Var: 1

31) What are the mass number, the atomic number, and neutron number for each of the following particles?
(a) proton
(b) neutron
(c) alpha particle
Answer: (a) 1, 1, 0 (b) 1, 0, 1 (c) 4, 2, 2
Var: 1

32) What are the mass number *A* and the charge (in units of *e*) for each of the following particles or rays?
(a) beta-plus
(b) beta-minus
(c) gamma ray
Answer: (a) 0, 1 (b) 0, -1 (c) 0, 0
Var: 1

33) The nuclei of ${}^{4}_{2}He$ are also known as

A) α particles.
B) β particles.
C) γ rays.
D) x-rays.
E) positrons.
Answer: A
Var: 1

34) In beta-minus decay
A) a proton is emitted.
B) a neutron is emitted.
C) an electron is emitted.
D) an electron decays into another particle.
E) a proton is transformed into a neutron.
Answer: C
Var: 1

35) During β^+ decay
A) a neutron is transformed to a proton.
B) a proton is transformed to a neutron.
C) a neutron is ejected from the nucleus.
D) a proton is ejected from the nucleus.
E) the number of nucleons decreases.
Answer: B
Var: 1

36) During β^- decay
A) a neutron is transformed to a proton.
B) a proton is transformed to a neutron.
C) a neutron is ejected from the nucleus.
D) a proton is ejected from the nucleus.
E) the number of nucleons increases.
Answer: A
Var: 1

37) When a β^+ particle is emitted from an unstable nucleus, the atomic number of the nucleus
A) increases by 1.
B) decreases by 1.
C) increases by 2.
D) decreases by 2.
E) does not change.
Answer: B
Var: 1

38) When a β^- particle is emitted from an unstable nucleus, the atomic number of the nucleus
A) increases by 1.
B) decreases by 1.
C) increases by 2.
D) decreases by 2.
E) does not change.
Answer: A
Var: 1

39) When a β^- particle is emitted from an unstable nucleus, the atomic mass number of the nucleus
A) increases by 1.
B) decreases by 1.
C) increases by 2.
D) decreases by 2.
E) does not change.
Answer: E
Var: 1

40) In β^- decay, the number of neutrons in the nucleus is
A) decreased by 1.
B) decreased by 2.
C) increased by 1.
D) increased by 2.
E) remains unchanged.
Answer: A
Var: 1

41) In β^- decay, the number of protons in the nucleus is
A) decreased by 1.
B) decreased by 2.
C) increased by 1.
D) increased by 2.
E) remains unchanged.
Answer: C
Var: 1

42) In positron decay, the number of protons in the nucleus is
A) decreased by 1.
B) decreased by 2.
C) increased by 1.
D) increased by 2.
E) remains unchanged.
Answer: A
Var: 1

43) A radioactive isotope of atomic number Z emits an alpha particle, and the daughter nucleus then emits a beta-minus particle. What is the atomic number of the resulting nucleus?
A) Z -1
B) $Z + 1$
C) $Z - 2$
D) $Z - 3$
Answer: A
Var: 1

44) A radioactive isotope of atomic number Z emits a beta-minus particle, and then the daughter nucleus emits a gamma ray. What is the atomic number of the resulting nucleus after both processes?
A) Z - 1
B) Z + 1
C) Z - 2
D) Z - 3
Answer: B
Var: 1

45) Polonium-216 decays to lead-212 by emitting what kind of nuclear radiation?
A) alpha
B) beta-minus
C) beta-plus
D) gamma
E) x-rays.
Answer: A
Var: 1

46) The atom ${}^{223}_{87}$Fr decays to ${}^{223}_{88}$Ra by emitting what kind of nuclear radiation?

A) alpha
B) beta-minus
C) beta-plus
D) gamma
E) x-rays.
Answer: B
Var: 1

47) A β^- decay occurs in an unstable nucleus when
A) a proton is converted to an electron by the strong force.
B) a proton is converted to a neutron by the strong force.
C) a neutron is converted to a proton by the weak force.
D) a neutron is converted to an alpha particle by the weak force.
E) a neutron is converted to a positron by the weak force.
Answer: C
Var: 1

48) When an unstable nucleus decays by emitting an alpha particle, the atomic number Z of the nucleus
A) increases by 4.
B) increases by 2.
C) decreases by 2.
D) decreases by 4.
E) remains unchanged.
Answer: C
Var: 1

49) When an unstable nucleus decays by emitting an alpha particle, the atomic mass number *A* of the nucleus
A) increases by 4.
B) increases by 2.
C) decreases by 2.
D) decreases by 4.
E) remains unchanged.
Answer: D
Var: 1

50) Isotope A has a decay constant of 0.723 s^{-1} and isotope B has a decay constant of 0.514 s^{-1}. Which isotope has a longer half-life?
A) isotope A
B) isotope B
Answer: B
Var: 1

51) The half-life of cobalt-60 is 5.3 years, while that of strontium-90 is about 29 years. Suppose you have samples of both isotopes, and that they initially contain equal numbers of atoms of these isotopes. How will the activities (number of decays per second) of the samples compare?
A) The activity of the cobalt-60 sample will be greater.
B) The activities cannot be compared without more information.
C) The activities will be equal.
D) The activity of the strontium-90 sample will be greater.
Answer: A
Var: 1

52) The half-life of cobalt-60 is 5.3 years, while that of strontium-90 is about 29 years. Suppose you have samples of both isotopes, and that they initially have the same activity (number of decays per second). What must be true of the numbers of cobalt-60 and strontium-90 nuclei in these samples?
A) There are more strontium-90 than cobalt-60 nuclei.
B) There are equal numbers of cobalt-60 and strontium-90 nuclei.
C) There are more cobalt-60 than strontium-90 nuclei.
D) It is not possible to compare numbers of nuclei without knowing the masses of the samples.
Answer: A
Var: 1

53) If the half-life of a material is 45 years, how much of it will be left after 100 years?
A) more than 1/2
B) less than 1/2 but more than 1/4
C) more than 1/4 but less than 1/2
D) less than 1/4 but more than 1/8
E) less than 1/8
Answer: D
Var: 1

54) What happens to the half-life of a radioactive substance as it decays?
A) It remains constant.
B) It increases.
C) It decreases at a constant rate.
D) It decreases at an exponential rate.
Answer: A
Var: 1

55) What happens to the half-life of a radioactive substance as we increase its temperature?
A) It does not change.
B) It increases.
C) It decreases at a constant rate.
D) It decreases at an exponential rate.
Answer: A
Var: 1

56) Two radioactive isotopes, X and Y, both decay to stable products. The half-life of X is about a day, while that of Y is about a week. Suppose a radioactive sample consists of a mixture of these two nuclides. If the mixture is such that the activities arising from X and Y are initially equal, then a few days later the activity of the sample will be due
A) predominantly to Y.
B) predominantly to X.
C) entirely to Y.
D) to X and Y equally.
Answer: A
Var: 1

57) Suppose the half-life of an isotope is 2 days. You purchase 10 grams of the isotope, but it was produced in a laboratory 4 days before it was delivered to you. How much of this isotope will you have 3 days after it was delivered to you?
A) more than 2.5 grams but less than 5 grams
B) 2.5 grams
C) more than 1.25 grams but less than 2.5 grams
D) 1.25 grams
E) less than 1.25 grams
Answer: E
Var: 1

58) Isotope A has a decay constant of 0.861 s^{-1} and isotope B has a decay constant of 0.627 s^{-1}. Which isotope has a longer mean life (time constant)?
A) isotope A
B) isotope B
Answer: B
Var: 1

59) How many protons, neutrons, and nucleons are there in a carbon-14 nucleus?
Answer: 6 protons, 8 neutrons, 14 nucleons
Var: 1

60) Modern in-air nuclear bomb tests have created an extra high level of ^{14}C in our atmosphere. If future archaeologists date samples from this era, without knowing of this testing, will their carbon-14 dates be too young, too old, or correct? If correct, why?
A) Too young.
B) Too old.
C) Correct, since ^{14}C from bomb tests is different from that produced naturally.
D) Correct, because modern biological materials do not gather ^{14}C from bomb tests.
Answer: A
Var: 1

61) Carbon-14 decays by β^- emission. What nucleus is left after this decay?
A) carbon-13
B) carbon-14
C) carbon-15
D) nitrogen-14
E) nitrogen-15
Answer: D
Var: 1

30.2 Problems

1) In a head-on collision, an alpha particle (Z = 2) of energy 8.20 MeV bounces straight back from a nucleus of charge 80.0 e. How close were the centers of the objects at closest approach? (1 eV = 1.60×10^{-19} J, $e = 1.60 \times 10^{-19}$ C, $1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N · m^2/C^2)
A) 2.81×10^{-14} m
B) 3.39×10^{-12} m
C) 6.56×10^{-15} m
D) 2.17×10^{-14} m
Answer: A
Var: 50+

2) In the first nuclear reaction observed, physicists saw an alpha particle (Z = 2) interact with a nitrogen nucleus in air (Z = 7) to produce a proton. The energy of the alpha particle was 55 MeV, enough to enable the nuclei to touch in spite of the Coulomb repulsion. What distance (in fm) between the centers of the alpha particle and the nitrogen was reached? This determines a limit on the radius of the nitrogen nucleus. (1 eV = 1.60×10^{-19} J, $e = 1.60 \times 10^{-19}$ C, $1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N · m^2/C^2)
A) 0 fm
B) 0 fm
C) 0 fm
D) 0 fm
Answer: A
Var: 11

3) The diameter of an atom is 1.4×10^{-10} m and the diameter of its nucleus is 1.0×10^{-14} m. What fraction of the atom's volume is occupied by its nucleus?
A) 3.6×10^{-13}
B) 7.1×10^{-5}
C) 5.1×10^{-9}
D) 2.6×10^{-17}
Answer: A
Var: 19

4) The radius R of a nucleus of mass number A is given by $R = R_0 A^{1/3}$, where $R_0 = 1.2 \times 10^{-15}$ m, calculate the density of a nucleus that has contains 57 protons and 82 neutrons. The mass of a nucleon (proton or neutron) is 1.67×10^{-27} kg.
Answer: 2.3×10^{17} kg/m^3
Var: 1

5) Estimate the radius (in fm) of a radon nucleus that contains 86 protons and 136 neutrons.
Answer: 7.3 fm
Var: 1

6) What should be the approximate diameter (in fm) of a nucleus containing 92 protons and 143 neutrons?
Answer: 15 fm
Var: 1

7) How many nucleons would you expect a nucleus to contain if its diameter is 13.4 fm?
Answer: 174
Var: 1

8) What is the approximate nuclear radius of an isotope of sodium with 11 protons and 12 neutrons?
Answer: 3.4×10^{-15} m
Var: 1

9) Calculate the estimated nuclear radius of $^{90}_{38}Sr$?

A) 4.0×10^{-15} m
B) 1.2×10^{-15} m
C) 1.1×10^{-13} m
D) 5.4×10^{-15} m
E) 3.3×10^{-13} m
Answer: D
Var: 1

10) Calculate the estimated density of the nucleus of $^{90}_{38}Sr$? ($m_{\text{neutron}} \approx m_{\text{proton}} = 1.67 \times 10^{-27}$ kg)
A) greater than 3.0×10^{20} kg/m^3
B) 90 kg/m^3
C) 2.1×10^{19} kg/m^3
D) 2.0×10^{15} kg/m^3
E) 2.3×10^{17} kg/m^3
Answer: E
Var: 1

11) Estimate the radius of a nucleus with mass 50 u. ($m_{\text{neutron}} \approx m_{\text{proton}} = 1.67 \times 10^{-27}$ kg)
A) about 4.4 fm
B) about 8.5 fm
C) about 3.7 fm
D) about 6.2 fm
Answer: A
Var: 1

12) Estimate the mass of a nucleus with radius 2.8×10^{-15} m. (1 u = 1.6605×10^{-27} kg)
A) about 2.1×10^{-26} kg
B) about 7.5×10^{-27} kg
C) about 2.3×10^{-26} kg
D) about 4.7×10^{-26} kg
Answer: A
Var: 1

13) A proton is projected at a stationary ${}^{226}_{88}Ra$ aluminum target. The proton momentarily comes to a halt at a distance from the center of an aluminum nucleus, equal to twice the nuclear radius. Assume that the nucleus retains its spherical shape and that the nuclear force on the proton is negligible. The initial kinetic energy of the proton, in MeV, is closest to:
A) 8.7 MeV
B) 5.8 MeV
C) 2.9 MeV
D) 13 MeV
E) 17 MeV
Answer: A
Var: 14

14) An excited ${}^{236}_{92}U^*$ nucleus undergoes fission into two fragments as follows:

${}^{236}_{92}U^* \rightarrow {}^{144}_{56}Ba + {}^{92}_{36}Kr$

If, at the instant of fission, the Ba and Kr fragments are spherical and just barely in contact, what is the electrostatic potential energy of these two fragments? (1 eV = 1.60×10^{-19} J, $e = 1.60 \times 10^{-19}$ C, $1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N · m^2/C^2)
A) 230 MeV
B) 240 MeV
C) 250 MeV
D) 260 MeV
E) 270 MeV
Answer: C
Var: 1

15) How much energy is released when 0.60 μg of ^{3}H have decayed to ^{3}He? The mass of ^{3}He is 3.0160293 u, the mass of ^{3}H is 3.0160492 u, 1 u = 931.5 MeV/c^2, 1 eV = 1.60×10^{-19} J, and $N_A = 6.022 \times 10^{23}$ molecules/mol.
Answer: 360 J
Var: 1

16) A summary of the nuclear reactions that power our sun is $4p \rightarrow {}^4He + 2e^-$, with masses of 938.272 MeV/c^2 for a proton, 3727.38 MeV/c^2 for the helium nucleus, and 0.511 MeV/c^2 for each electron. How much energy is released by each of these reactions?
A) 24.69 MeV
B) 28.3 MeV
C) 2790.13 MeV
D) 279.01 MeV
Answer: A
Var: 1

17) A beryllium-8 nucleus at rest undergoes double alpha decay as follows:
${}^8_4Be \rightarrow {}^4_2He + {}^4_2He$

The known atomic masses are:

${}^4_2He$: 4.002603 u

${}^8_4Be$: 8.005305 u

What is the kinetic energy of each departing alpha particle? (1 u = 931.5 MeV/c^2)
A) 46 keV
B) 65 keV
C) 92 keV
D) 130 keV
E) 180 keV
Answer: A
Var: 1

18) One of the fusion reactions that occurs in the sun is:
${}^3_2He + {}^3_2He \rightarrow {}^4_2He + {}^1_1H + {}^1_1H$

The following atomic masses are known:

${}^1_1H$: 1.007825 u

${}^3_2He$: 3.016029 u

${}^4_2He$: 4.002603 u

What is the reaction energy released in this fusion reaction? (1 u = 931.5 MeV/c^2)
A) 11 MeV
B) 13 MeV
C) 15 MeV
D) 17 MeV
E) 19 MeV
Answer: B
Var: 1

19) The following masses are known:

$^{1}_{0}n$ 1.008665 u

$^{1}_{1}H$ 1.007825 u

$^{226}_{88}Ra$ 226.025403 u

What is the binding energy of $^{226}_{88}Ra$? (1 u = 931.5 MeV/c^2)

A) 1700 MeV
B) 1900 MeV
C) 2100 MeV
D) 2300 MeV
E) 2500 MeV
Answer: A
Var: 12

20) The stability of $^{11}_{6}C$ with respect to alpha, beta-plus and beta-minus decay is to be determined. The following atomic masses are known:

$^{4}_{2}He$: 4.002603 u

$^{7}_{4}Be$: 7.016928 u

$^{11}_{5}B$: 11.009305 u

$^{11}_{6}C$: 11.011433 u

$^{11}_{7}N$: 11.026742 u

The $^{11}_{6}C$ nucleus is

A) not subject to alpha, beta-plus or beta-minus decay.
B) subject to alpha decay only.
C) subject to beta-plus decay only.
D) subject to beta-minus decay only.
E) subject to beta-plus or beta-minus decay, but not to alpha decay.
Answer: C
Var: 1

21) The stability of ${}^{36}_{17}Cl$ with respect to alpha, beta-plus and beta-minus decay is to be determined. The following atomic masses are known:

${}^{4}_{2}He$: 4.002603 u

${}^{32}_{15}P$: 31.973907 u

${}^{36}_{16}S$: 35.967081 u

${}^{36}_{17}Cl$: 35.968307 u

${}^{38}_{18}Ar$: 35.967546 u

The ${}^{36}_{17}Cl$ nucleus is

A) not subject to alpha, beta-plus or beta-minus decay.
B) subject to alpha decay only.
C) subject to beta-plus decay only.
D) subject to beta-minus decay only.
E) subject to beta-plus or beta-minus decay, but not to alpha decay.
Answer: E
Var: 1

22) Bismuth ${}^{212}_{83}Bi$ is known to be radioactive. The stability of ${}^{212}_{83}Bi$ with respect to alpha, beta-plus and beta-minus decay is to be determined. The following atomic masses are known:

${}^{4}_{2}He$: 4.002603 u

${}^{208}_{81}Tl$: 207.981998 u

${}^{212}_{82}Pb$: 211.991871 u

${}^{212}_{83}Bi$: 211.991255 u

${}^{212}_{84}Po$: 211.988842 u

The ${}^{212}_{83}Bi$ nucleus is

A) subject to alpha decay only.
B) subject to beta-plus decay only.
C) subject to beta-minus decay only.
D) subject to alpha or beta-plus decay, but not beta-minus decay.
E) subject to alpha or beta-minus decay, but not beta-plus decay.
Answer: E
Var: 1

23) Uranium-238 decays into thorium-234 plus an alpha particle. The known masses are

${}^{4}_{2}\text{He}$: 4.002603 u

${}^{224}_{90}\text{Th}$: 234.043583 u

${}^{238}_{92}\text{U}$: 238.050786 u

How much energy is released in this process? (1 u = 931.5 MeV/c^2)

A) 4.28 MeV
B) 3.76 MeV
C) 3.18 MeV
D) 2.89 MeV
E) 5.05 MeV
Answer: A
Var: 1

24) Radium-226 decays into radon-222 plus an alpha particle. The relevant masses are

${}^{4}_{2}\text{He}$: 4.002603 u

${}^{222}_{86}\text{Rn}$: 222.017570 u

${}^{226}_{88}\text{Ra}$: 226.025402 u

How much energy is released in this process? (1 u = 931.5 MeV/c^2)

A) 4.24 MeV
B) 3.76 MeV
C) 4.87 MeV
D) 5.05 MeV
E) 5.39 MeV
Answer: C
Var: 1

25) When a stationary plutonium-239, ${}^{239}_{94}\text{Pu}$, decays into uranium-235 plus an alpha particle, the energy released in the process is 5.24 MeV. The following masses are known:

${}^{4}_{2}\text{He}$: 4.002603 u

${}^{235}_{92}\text{U}$: 235.043924 u

What is the mass of the ${}^{239}_{94}\text{Pu}$ nucleus, in amu? (1 u = 931.494 MeV/c^2)

A) 239.05215 u
B) 239.02775 u
C) 239.00189 u
D) 238.99919 u
E) 238.98884 u
Answer: A
Var: 1

26) When a stationary plutonium-239 nucleus decays into a uranium-235 nucleus plus an alpha particle, the energy released in the process is 5.24 MeV. The following masses are known:

${}^{4}_{2}He$: 4.002603 u

${}^{235}_{92}U$: 235.043924 u

What is the kinetic energy of the ${}^{235}_{92}U$ nucleus? (1 u = 931.5 MeV/c^2)

A) 0.0829 MeV
B) 0.0837 MeV
C) 0.0852 MeV
D) 0.0863 MeV
E) 0.0877 MeV
Answer: E
Var: 1

27) The neutral helium atom, ${}^{4}_{2}He$, has a mass of 4.002603 u, a neutron has a mass of 1.008665 u, a proton has a mass of 1.007277 u, and a neutral hydrogen atom has a mass of 1.007825 u. What is the binding energy of the ${}^{4}_{2}He$ nucleus? (1 u = 931.5 MeV/c^2)

A) 20.5 MeV
B) 22.4 MeV
C) 27.3 MeV
D) 28.3 MeV
E) 23.4 MeV
Answer: D
Var: 1

28) A carbon-14 nucleus decays to a nitrogen-14 nucleus by beta-minus decay. How much energy (in MeV) is released if carbon-14 has a mass of 14.003242 u and nitrogen-14 has a mass of 14.003074 u? (1 u = 931.5 MeV/c^2)
A) 0.0156 MeV
B) 0.156 MeV
C) 1.56 MeV
D) 15.6 MeV
Answer: B
Var: 1

29) The neutral deuterium atom, $^{2}_{1}$H, has a mass of 2.014102 u; a neutral ordinary hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007277 u. What is the binding energy of the deuterium nucleus? (1 u = 931.5 MeV/c^2)
A) 1.1 MeV
B) 1.7 MeV
C) 2.2 MeV
D) 2.9 MeV
E) 3.4 MeV
Answer: C
Var: 1

30) The neutral $^{27}_{13}$Al atom has a mass of 26.981539 u; a neutral hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007277 u. What is the binding energy *per nucleon* for $^{27}_{13}$Al? (1 u = 931.5 MeV/c^2)

A) 8.3 MeV
B) 6.7 MeV
C) 5.4 MeV
D) 3.4 MeV
E) 2.8 MeV
Answer: A
Var: 1

31) The carbon in our bodies was formed in nuclear reactions in long-dead stars. How much energy was released when the right number of ^{4}He nuclei combined to make ^{12}C? The mass of 4He is 3728.40 MeV/*c*2 and the mass of 12C is 11,177.93 MeV/*c*2.
A) 7.27 MeV
B) 372 MeV
C) 8.42 MeV
D) 2.11 MeV
Answer: A
Var: 1

32) Suppose that starting with $^{227}_{89}$, the following sequence of decays occurs: first an alpha decay, then a beta-minus decay, and finally another alpha decay. What isotope is left after *each* one of the decays?
Answer: $^{223}_{87}$Fr, $^{223}_{88}$Ra, $^{219}_{86}$Rn

Var: 1

33) Starting with ${}^{235}_{92}$U, assume that the following three decays occur in sequence:

(1) alpha decay
(2) beta-minus decay
(3) alpha decay
Determine the correct isotope that is left after each decay.
Answer: ${}^{231}_{90}$T, ${}^{231}_{91}$Pa, ${}^{227}_{89}$Ac

Var: 1

34) A sodium-22 nucleus, ${}^{22}_{11}$Na, decays into a neon-22 nucleus, ${}^{22}_{10}$Ne, and one other particle.

What is the other particle?
Answer: β^{+} (or a positron)
Var: 1

35) In the radioactive decay equation ${}^{238}_{92}$ $\rightarrow$ ${}^{234}_{90}$Th + X, what is X?

Answer: ${}^{4}_{2}$He (α particle)

Var: 1

36) In the radioactive decay equation ${}^{210}_{84}$Po$*$ $\rightarrow$ ${}^{210}_{84}$Po + X, what is X?

Answer: gamma ray
Var: 1

37) A nucleus ${}^{N}_{M}$X undergoes one alpha decay followed by 3 beta-minus decays.

(a) What is the resulting nucleus in terms of M and N?
(b) If there had been 3 beta-plus decays instead of the beta-minus decays, what would have been the resulting nucleus in terms of M and N?
Answer: (a) ${}^{N-4}_{M+1}$X (b) ${}^{N-4}_{M+5}$X

Var: 1

38) The isotope ${}^{235}_{92}$U is radioactive and decays in a series to ${}^{227}_{90}$Th. In this series, the particles

ejected from the nucleus are
A) one alpha particle and three beta-minus particles.
B) three alpha particles and one beta-minus particle.
C) one alpha particle and four beta-minus particles.
D) four alpha particle and one beta-minus particle.
E) two alpha particles and two beta-minus particles.
Answer: E
Var: 1

39) An oxygen-15 nucleus, ${}^{15}_{8}O$, decays to another atomic nucleus by emitting a β^+ ray. What is the other atomic nucleus?

A) ${}^{15}_{7}N$

B) ${}^{16}_{8}F$

C) ${}^{15}_{6}C$

D) ${}^{14}_{8}C$

E) ${}^{17}_{7}N$

Answer: A
Var: 1

40) Rubidium ${}^{87}_{37}Rb$ is a naturally occurring isotope that undergoes β^- decay. What isotope is the product of this decay?

A) ${}^{87}_{36}Kr$

B) ${}^{87}_{38}Kr$

C) ${}^{87}_{37}Rb$

D) ${}^{87}_{36}Sr$

E) ${}^{87}_{38}Sr$

Answer: E
Var: 1

41) Neodymium ${}^{144}_{60}Nd$ is an isotope that undergoes alpha decay. What isotope is the product of this decay?

A) ${}^{142}_{56}Ba$

B) ${}^{140}_{58}Ce$

C) ${}^{140}_{59}Pr$

D) ${}^{142}_{62}Sm$

E) ${}^{146}_{64}Gd$

Answer: B
Var: 1

42) Scandium $^{43}_{21}Sc$ decays by emitting a positron. What isotope is the product of this decay?

A) $^{43}_{21}Sc$

B) $^{45}_{21}Sc$

C) $^{44}_{20}Ca$

D) $^{43}_{21}Ca$

E) $^{44}_{22}Ti$

Answer: C
Var: 1

43) A nuclear reaction is shown: $^{10}_{5}B + ^{4}_{2}He \rightarrow ^{1}_{1}H$ + ? . Which one of the following isotopes is the missing nuclear product?

A) $^{12}_{9}F$

B) $^{21}_{7}N$

C) $^{13}_{6}C$

D) $^{13}_{7}N$

E) $^{14}_{7}N$

Answer: C
Var: 1

44) A test tube of an isotope having a decay constant of $0.765 \times 10^{-6}\ s^{-1}$ contains 3.0×10^{17} nuclei of this isotope.
(a) What is the half-life of this isotope?
(b) What is the initial activity (in Bq) of the isotope?
(c) What is the activity of the isotope after 12 days?
Answer: (a) 9.06×10^{5} s (b) 2.3×10^{11} Bq (c) 1.0×10^{11} Bq
Var: 5

45) The decay rate of a radioactive sample decreases from 175 kBq to 12.4 kBq in 18.3 s. What is the decay constant of this sample?
Answer: 0.145 s^{-1}
Var: 1

46) Rutherfordium-261 has a half-life of 1.08 min. What is the decay constant of rutherfordium-261 in terms of seconds?
A) 0.0107 s-1
B) 0.0154 s-1
C) 1.87 s-1
D) 2.91 s-1
E) 0.344 s-1
Answer: A
Var: 1

47) The decay constant of a radioactive nuclide is 4.6 × 10^{-3} s^{-1}. What is the half-life of this isotope, in minutes?
A) 2.5 min
B) 3.6 min
C) 3.1 min
D) 1.4 min
E) 2.0 min
Answer: A
Var: 50+

48) The decay constant of a radioactive nuclide is 3.1 x 10^{-3} s^{-1}. At a given instant, the activity of a specimen of the nuclide is 70 kBq. How much later has the activity declined to 10 kBq?
A) 630 s
B) 690 s
C) 750 s
D) 820 s
E) 880 s
Answer: A
Var: 50+

49) The decay constant of a radioactive isotope is 1.60 × 10^{-3} s^{-1}. At a given instant, the number of atoms of the radioactive isotope is 1.85 × 10^{12}. How many atoms of the isotope remain after a time interval of 30.0 minutes?
A) 1.04 × 10^{11}
B) 1.14 × 10^{11}
C) 1.26 × 10^{11}
D) 1.38 × 10^{11}
E) 1.52 × 10^{11}
Answer: A
Var: 1

50) The decay constant of radon-222 is 0.181 d^{-1}. If a sample of radon initially contains 6.00×10^8 radon atoms, how many of them are left after 10.0 d?
A) 9.82×10^7
B) 7.67×10^7
C) 8.34×10^8
D) 7.29×10^8
E) 8.56×10^8
Answer: A
Var: 5

51) Americium-243 has a decay constant of 9.39×10^{-5} years^{-1}. How long will it take for a sample of americium-243 to lose one-third of its nuclei?
A) 2960 s
B) 10.6×10^3 y
C) 4.32×10^3 y
D) 6.44×10^3 y
E) 7.84×10^3 y
Answer: C
Var: 5

52) The unstable isotope ^{234}Th decays by β emission with a half-life of 24.5 days. If the initial decay rate of the sample is 6.2×10^{17} Bq, what is the decay rate after 37 days?
Answer: 2.2×10^{17} Bq
Var: 50+

53) Polonium-215, $^{215}_{84}Po$, undergoes alpha decay with a half-life of 1.8 ms.

(a) What percent of the original polonium-215 is left after 0.010 s?
(b) How many protons and neutrons does the daughter nucleus contain?
Answer: (a) 2.1% (b) 82 protons, 129 neutrons
Var: 1

54) Given that the half-life for radium-226 is 1600 y, how long is the "quarter-life" (that is, the time for the radiation to decay to one-fourth of its initial level)?
Answer: 3200 years
Var: 1

55) Suppose that in a certain collection of nuclei there were initially 1024 billion nuclei, and 20.0 minutes later there was only 1.00 billion nuclei left, the others having decayed. On the basis of this information, how many nuclei would you estimate decayed in the first 6.00 minutes?
Answer: 896 billion
Var: 1

56) The decay rate of a radioactive sample decreases from 175 kBq to 12.4 kBq in 18.3 s. What is the half-life of this sample?
Answer: 4.79 s
Var: 1

57) A radioactive substance containing 4.0×10^{16} unstable atoms has a half-life of 2.0 days. What is its activity (in curies, Ci) after 1.0 day? (1 Ci = 3.70×10^{10} Bq)

Answer: 4.3 Ci
Var: 1

58) The activity of a sample reduces from 7.55×10^9 Bq to 5.11×10^9 Bq in 5.50 months.
(a) What is its half life?
(b) How many months from the start must one wait for the activity to decrease to 10% of its original value?
Answer: (a) 9.77 months (b) 32.4 months
Var: 5

59) A 1.0-mol sample of an isotope is decaying with a half-life of 28 y. After 61 y, how many moles of this isotope are left and what is its activity in Bq?
Answer: 0.22 mol, 1.0×10^{14} Bq
Var: 1

60) The atom ^{40}K decays radioactively to the gas ^{40}Ar. An ancient rock is found to contain enough ^{40}Ar gas to indicate that 77.0% of the ^{40}K in the rock has decayed to ^{40}Ar since the rock solidified. (Any previous argon would have boiled out of liquid rock.) How long ago did the rock solidify? The half-life of ^{40}K is 1.25 billion years.
A) 2.65 billion years
B) 0.471 billion years
C) 1.80 billion years
D) 0.324 billion years
Answer: A
Var: 1

61) The half-life of radon-222 is 3.83 d. If a sample of radon initially contains 6.00×10^8 radon atoms, how many of them are left after 10.0 d?
A) 9.82×10^7
B) 7.67×10^7
C) 8.34×10^8
D) 7.29×10^8
E) 8.56×10^8
Answer: A
Var: 1

62) The number of radioactive nuclei in a particular sample decreases to one-eighth of its original number in 9 days. What is the half-life of these nuclei?
A) 9/8 days
B) 2 days
C) 3 days
D) 8 days
E) 10 days
Answer: C
Var: 5

63) A thallium source with a half-life of 3.7 years was certified at 10 kBq ten years ago. What is its activity now?
A) 4.7 kBq
B) 3.3 kBq
C) 1.5 kBq
D) 1.0 kBq
Answer: C
Var: 1

64) A radioactive sample has a half-life of 10 min. What fraction of the sample is left after 40 min?
A) 1/2
B) 1/4
C) 1/8
D) 1/16
Answer: D
Var: 3

65) A radioactive substance with a half-life of 3.0 days has an initial activity of 2400 Bq. What is its activity after 6.0 days?
A) 1200 Bq
B) 1800 Bq
C) 600 Bq
D) 300 Bq
E) 150 Bq
Answer: C
Var: 1

66) A sample containing 4.0×10^{18} atoms of a radioactive isotope decays with a half-life of 2.3 years. How many undecayed atoms are left after 3.7 years?
A) 2.5×10^{18}
B) 1.7×10^{18}
C) 1.3×10^{18}
D) 1.1×10^{18}
Answer: C
Var: 1

67) How long would it take 4.00×10^{20} atoms to decay to 1.00×10^{19} atoms if their half-life was 14.7 years?
A) 29.4 years
B) 58.8 years
C) 78.2 years
D) 147 years
Answer: C
Var: 1

68) How long will it take a 4.50-kBq sample of material to reach an activity level of 0.140 kBq if the half-life of the sample is 435 years?
A) 14,478 years
B) 3245 years
C) 2178 years
D) 1993 years
Answer: C
Var: 1

69) Rutherfordium-261 has a half-life of 1.08 min. How long will it take for a sample of rutherfordium to lose one-third of its nuclei?
A) 1.02 min
B) 1.62 min
C) 0.632 min
D) 2.70 min
E) 3.24 min
Answer: C
Var: 5

70) Fermium-253 has a half-life of 3.00 days. If a sample of fermium originally has 7.37×10^{7} nuclei, how long will it take for there to be only 3.36×10^{6} fermium-253 nuclei left in this sample?
A) 2.75 days
B) 9.80 days
C) 13.4 days
D) 15.7 days
E) 58.6 days
Answer: C
Var: 5

71) The half-life of a radioactive material is 4.5 days. How many days are required for a sample, with an initial activity of 1.0×10^5 Bq, to decay to an activity of 100 Bq?
A) 45 days
B) 36 days
C) 54 days
D) 31 days
Answer: A
Var: 41

72) A hospital patient has been given a sample of ^{131}I , which has a half-life of 8.04 days. This sample is decaying at 5.9 times the acceptable level for exposure to the general public. How long must the patient wait for the decay rate of the sample to reach the acceptable level?
A) 21 days
B) 14 days
C) 9.9 days
D) 8.9 days
Answer: A
Var: 31

73) Plutonium has a half life of 2.4×10^4 years. How long does it take for 99.0% of the plutonium to decay?
A) 1.6×10^2 y
B) 1.6×10^3 y
C) 1.6×10^4 y
D) 1.6×10^5 y
E) 1.6×10^6 y
Answer: D
Var: 1

74) One material used in nuclear bombs is ^{239}Pu, with a half-life of 24,000 years. How long must we wait for a buried stockpile of this substance to decay to 1/1000 of its original activity?
A) 1,200,000 years
B) 240,000 years
C) 150,000 years
D) 82,000 years
E) 1,500 years
Answer: B
Var: 1

75)

Time (days)	0	2	6	11	19	30
Counts per Minute	1000	899	726	556	356	200

In a laboratory accident, a work area is contaminated with radioactive material. Health physicists monitor the area during a 30-day period and obtain the data shown in the table. The accident occurred at time $t = 0$ days. They determine that it will not be safe for workers to enter the area until the radioactivity level has dropped to 16 counts per minute. Of the choices listed, which one is the earliest time after the accident that workers could safely return?
A) 77 days
B) 90 days
C) 102 days
D) 65 days
E) 48 days
Answer: A
Var: 50+

76) Today, uranium contains 0.72% ^{235}U (half-life = 0.70 billion years) and 99.28% ^{238}U (half-life = 4.5 billion years). At a time 1.9 billion years ago, what was the fraction of ^{235}U in uranium?
A) 3.53%
B) 4.72%
C) 4.90%
D) 6.76%
Answer: A
Var: 17

77) An air sample is contaminated with ^{15}O, which has a half-life of 2.03 minutes. You can pass it through a long pipe to allow it to decay until it can be safely released into the atmosphere. If the speed of the gas in the pipe is 1.1 m/s, how long must the pipeline be for the sample to decay to 3.0% of its original activity?
A) 680 m
B) 8.0 m
C) 72 m
D) 250 m
Answer: A
Var: 1

78) The mean life (time constant) of rubidium-86 is 26.8 d. What is its half-life?
Answer: 18.6 d
Var: 1

79) The half-life of tritium is 12.3 y. What is its mean life (time constant)?
Answer: 17.7 y
Var: 1

80) The mean life (time constant) of radon-222 is 5.526 d. If a sample of radon initially contains 6.00×10^8 radon atoms, how many of them are left after 10.0 d?
A) 9.82×10^7
B) 7.67×10^7
C) 8.34×10^8
D) 7.29×10^8
E) 8.56×10^8
Answer: A
Var: 1

81) The decay rate of a radioactive sample decreases from 175 kBq to 12.4 kBq in 18.3 s. What is the mean life (time constant) of this sample?
Answer: 6.91 s
Var: 1

82) The half-life of arsenic-76 is 26.7 h. What are its (a) decay constant and (b) mean life?
Answer: (a) 0.0260 h^{-1} (b) 38.5 h
Var: 1

83) The decay constant of neptunium-239 is 0.2975 d^{-1}. What are its (a) half-life and (b) mean life?
Answer: (a) 2.330 d (b) 3.361 d
Var: 1

84) A radioactive source emits 2.4-MeV neutrons at the rate of 7100 neutrons per second. The number of atoms in the source is 2.6×10^9. What is the activity of the source, in curies (Ci)? (1.00 Ci = 3.70×10^{10} Bq)
A) 190 nCi
B) 1900 nCi
C) 19 nCi
D) 71 nCi
E) 710 nCi
Answer: A
Var: 50+

85) A certain substance has a half-life of 5.0 hours. How many nuclei of the substance are required to give an initial activity of 6.0 μCi? (1 Ci = 3.7×10^{10} Bq)
A) 5.8×10^9 nuclei
B) 8.5×10^8 nuclei
C) 6.3×10^8 nuclei
D) 3.2×10^9 nuclei
E) 2.4×10^9 nuclei
Answer: A
Var: 5

86) Fermium-253 has a half-life of 3.00 days. A sample of fermium has 3.88×10^6 nuclei. What is the initial activity of this sample?
A) 10.4 Bq
B) 10.4 kBq
C) 12.9 Bq
D) 12.9 kBq
Answer: A
Var: 1

87) The half-life of radioactive iodine-137 is 8.0 days. How many iodine nuclei are necessary to produce an activity of 1.0 μCi? (1 Ci = 3.70×10^{10} Bq)
A) 2.9×10^9
B) 4.6×10^9
C) 3.7×10^{10}
D) 7.6×10^{12}
Answer: C
Var: 1

88) What mass of ^{14}C, with a half-life of 5730 y, do you need to provide a decay rate of 280.0 Bq? The mass of ^{14}C is 14.00 u, and 1 u = 1.6605×10^{-27} kg.
A) 1.70×10^{-12} kg
B) 5.38×10^{-19} kg
C) 3.84×10^{-20} kg
D) 8.68×10^{-13} kg
Answer: A
Var: 50+

89) An old bone sample contains 321 g of carbon and has an activity of 947 decays/min due to the carbon-14 in it. The half-life of carbon-14 is 5730 y. Assume that the activity of the atmospheric carbon is, and has remained, 0.255 Bq per gram of carbon.
(a) How old is the sample?
(b) What will be the activity of the sample 2000 y from now, in decays per minute?
Answer: (a) 13,600 y (b) 743 decays/min
Var: 1

90) An archaeologist finds the ^{14}C in a sample of 2.10 g of material to be decaying at 107 Bq. A modern 1.00-g sample of the same material decays at 151 Bq,and assume this rate has also held in the past. The half-life of ^{14}C is 5730 years. How old is the sample?
A) 8980 years
B) 6230 years
C) 17,000 years
D) 8530 years
Answer: A
Var: 17

91) A sample of wood has been recovered by an archaeologist. The sample is sent to a laboratory, where it is determined that the activity of the sample is 0.144 Bq/g. By comparing this activity with the activity of living organic matter, which is 0.230 Bq/g, the scientist determines how old the wood sample is, or more precisely, when the tree that the sample came from died. Carbon-14 has a half-life of 5730 years. If the activity of living matter has been constant over time, how old is the sample of wood?
A) 3870 years
B) 4250 years
C) 4590 years
D) 2630 years
E) 2940 years
Answer: A
Var: 1

92) The radioactivity due to carbon-14 measured in a piece of a wooden casket from an ancient burial site is found to produce 20 counts per minute from a given sample, whereas the same amount of carbon from a piece of living wood produces 160 counts per minute. The half-life of carbon-14, a beta-minus emitter, is 5730 years. What would we calculate for the age of the artifact, assuming that the activity for living wood has remained constant over time?
A) 5,700 years
B) 11,500 years
C) 14,800 years
D) 17,200 years
E) 23,000 years
Answer: D
Var: 1