Chapter 42: NUCLEAR PHYSICS

1. The smallest particle of any chemical element that can exist by itself and yet retain the qualities that distinguish it as that element is:
   A. an electron
   B. a proton
   C. a neutron
   D. an atom
   E. a molecule

   ans: D

2. Of the following, which has the smallest rest energy?
   A. A neutron
   B. An electron
   C. An ion
   D. A proton
   E. An atom

   ans: B

3. The mass of an electron:
   A. is almost the same as that of a neutron
   B. is negative
   C. equals that of a proton
   D. is zero if the electron is at rest
   E. is much less than that of a proton

   ans: E

4. The mass of a neutron:
   A. equals that of an electron
   B. equals that of a proton
   C. is a little more than that of a proton
   D. is exactly that of a proton plus an electron
   E. is as yet unmeasured

   ans: C

5. The mass of a hydrogen atom, in kilograms, is approximately:
   A. 10^{-27}
   B. 10^{-31}
   C. 10^{-24}
   D. 10^{-13}
   E. 10^{-8}

   ans: A

6. 1 atomic mass unit is about:
   A. 1.66×10^{-31} kg
   B. 9.11×10^{-31} kg
   C. 1.66×10^{-27} kg
   D. 9.11×10^{-27} kg
   E. 1.66×10^{-25} kg

   ans: C

7. The atomic number of an element is:
   A. the whole number nearest to its mass
   B. the number of protons in its nucleus
   C. the nearest whole number of hydrogen atoms having the same mass as a single atom of the given element
   D. the number of neutrons in its nucleus
   E. its order of discovery

   ans: B

8. Iron has atomic number 26. Naturally mined iron contains isotopes of mass numbers 54, 56, 57, and 58. Which of the following statements is FALSE?
   A. Every atom of iron has 26 protons
   B. Some iron atoms have 30 neutrons
   C. Some iron atoms have 54 neutrons
   D. The isotopes may be separated in a mass spectrometer
   E. There are four kinds of naturally occurring iron atoms with the same chemical properties

   ans: C

9. Let Z denote the atomic number and A denote the mass number of a nucleus. The number of neutrons in this nucleus is:
   A. Z
   B. $A - Z$
   C. $A - 2Z$
   D. A
   E. $2A - Z$

   ans: B

10. The isotopes of an element:
   A. cannot be separated at all
   B. occur well separated in nature
   C. have similar chemical behavior
   D. cannot be separated by physical methods
   E. have equal masses

   ans: C

11. Bromine, with atomic mass 79.942 u, is composed of nearly equal amounts of two isotopes, one of which contains 79 nucleons per atom. The mass number of the other isotope is:
    A. 78
    B. 79
    C. 80
    D. 81
    E. 82

    ans: D

12. The mass density of an atomic nucleus is:
    A. about $10^{15}\,\mathrm{kg/m^3}$
    B. about $10^{12}\,\mathrm{kg/m^3}$
    C. increases with increasing nuclear mass
    D. increases with decreasing nuclear radius
    E. about the same as that of all other nuclei

    ans: E

13. Volumes of atomic nuclei are proportional to:
    A. the mass number
    B. the atomic number
    C. the total nuclear spin
    D. the number of neutrons
    E. none of these

    ans: A

14. A femtometer is:
    A. larger than $10^{-9}\,\mathrm{m}$
    B. $10^{-9}\,\mathrm{m}$
    C. $10^{-12}\,\mathrm{m}$
    D. $10^{-15}\,\mathrm{m}$
    E. $10^{-18}\,\mathrm{m}$

    ans: D

15. A nucleus with a mass number of 64 has a mean radius of about:
    A. 4.8 fm
    B. 19 fm
    C. 77 fm
    D. 260 fm
    E. 2.6×10^5 fm

    ans: A

16. A proton in a large nucleus:
    A. attracts all other protons
    B. repels all other protons
    C. repels all neutrons
    D. attracts some protons and repels others
    E. attracts some neutrons and repels others

    ans: D

17. Two protons are separated by 10^{-16} m. The nuclear (N), electrostatic (E), and gravitational (G) forces between these protons, in order of increasing strength, are:
    A. E, N, G
    B. N, G, E
    C. G, E, N
    D. G, N, E
    E. E, G, N

    ans: C

18. Two protons are about 10^{-10} m apart. Their relative motion is chiefly determined by:
    A. gravitational forces
    B. electrical forces
    C. nuclear forces
    D. magnetic forces
    E. torque due to electric dipole moments

    ans: B

19. The binding energy of a nucleus is the energy that must be supplied to:
    A. remove a nucleon
    B. remove an alpha particle
    C. remove a beta particle
    D. separate the nucleus into its constituent nucleons
    E. separate the nucleus into a collection of alpha particles

    ans: D

20. If a nucleus has mass M, Z protons (mass m_p), and N neutrons (mass m_n), its binding energy is equal to:
    A. Mc^2
    B. $(M - Zm_p - Nm_n)c^2$
    C. $(Zm_p + Nm_n - M)c^2$
    D. $(Zm_p + Nm_n)c^2$
    E. $(Zm_p - M)c^2$

    ans: C

21. Stable nuclei generally:
    A. have a greater number of protons than neutrons
    B. have low mass numbers
    C. have high mass numbers
    D. are beta emitters
    E. none of the above

    ans: E

22. Let A be the mass number and Z be the atomic number of a nucleus. Which of the following is approximately correct for light nuclei?
    A. $Z = 2A$
    B. $Z = A$
    C. $Z = A/2$
    D. $Z = \sqrt{A}$
    E. $Z = A^2$

    ans: C

23. The greatest binding energy per nucleon occurs for nuclides with masses near that of:
    A. helium
    B. sodium
    C. iron
    D. mercury
    E. uranium

    ans: C

24. Which of the following nuclides is least likely to be detected?
    A. ^{52}Fe ($Z = 26$)
    B. ^{115}Nd ($Z = 60$)
    C. ^{175}Lu ($Z = 71$)
    D. ^{208}Pb ($Z = 82$)
    E. ^{238}U ($Z = 92$)

    ans: B

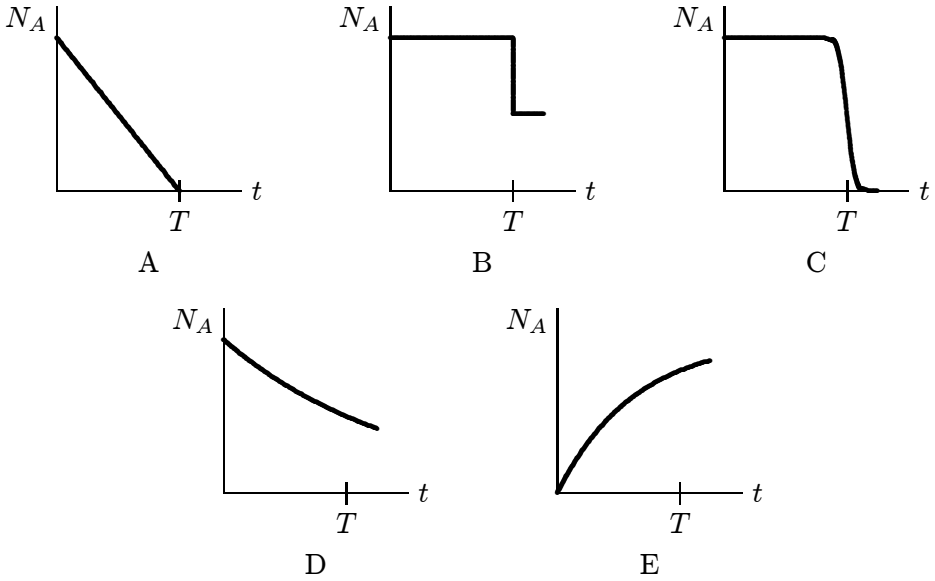
25. The half-life of a radioactive substance is:
    A. half the time it takes for the entire substance to decay
    B. usually about 50 years
    C. the time for radium to change into lead
    D. calculated from $E = mc^2$
    E. the time for half the substance to decay

    ans: E

26. Which expression correctly describes the radioactive decay of a substance whose half-life is T?
A. $N(t) = N_0 e^{-(t \ln 2)/T}$
B. $N(t) = N_0 e^{-t/T}$
C. $N(t) = N_0 e^{-tT}$
D. $N(t) = N_0 e^{-tT \ln 2}$
E. $N(t) = N_0 e^{-t/T \ln 2}$

ans: A

27. Radioactive element A decays to the stable element B with a half-life T. Starting with a sample of pure A and no B, which graph below correctly shows the number of A atoms, N_A, as a function of time t?



ans: D

28. A large collection of nuclei are undergoing alpha decay. The rate of decay at any instant is proportional to:
A. the number of undecayed nuclei present at that instant
B. the time since the decays started
C. the time remaining before all have decayed
D. the half-life of the decay
E. the average time between decays

ans: A

29. The relation between the disintegration constant λ and the half-life T of a radioactive substance is:
A. $\lambda = 2T$
B. $\lambda = 1/T$
C. $\lambda = 2/T$
D. $\lambda T = \ln 2$
E. $\lambda T = \ln(1/2)$

ans: D

30. Possible units for the disintegration constant λ are:

A. kg/s
B. s/kg
C. hour
D. day^{-1}
E. cm^{-1}

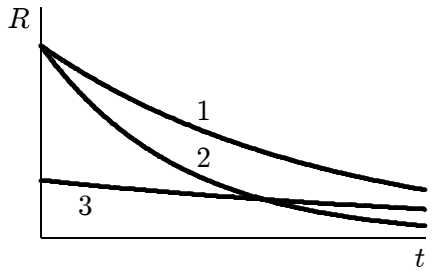
ans: D

31. The half-life of a given nuclear disintegration A $\rightarrow$ B:

A. depends on the initial number of A atoms
B. depends on the initial number of B atoms
C. is an exponentially increasing function of time
D. is an exponentially decreasing function of time
E. none of the above

ans: E

32. The graph shows the activity R as a function of time t for three radioactive samples. Rank the samples according to their half-lives, shortest to longest.



A. 1, 2, 3
B. 1, 3, 2
C. 2, 1, 3
D. 2, 3, 1
E. 3, 1, 2

ans: C

33. The half-life of radium is about 1600 years. If a rock initially contains 1 g of radium, the amount left after 6400 years will be about:

A. 938 mg
B. 62 mg
C. 31 mg
D. 16 mg
E. less than 16 mg

ans: C

34. Starting with a sample of pure ^{66}Cu, 7/8 of it decays into Zn in 15 minutes. The corresponding half-life is:

A. 15 minutes
B. 5 minutes
C. 7 minutes
D. 3.75 minutes
E. 10 minutes

ans: B

35. ^{210}Bi (an isotope of bismuth) has a half-life of 5.0 days. The time for three-quarters of a sample of ^{210}Bi to decay is:

A. 2.5 days
B. 10 days
C. 15 days
D. 20 days
E. 3.75 days

ans: B

36. Radioactive ^{90}Sr has a half-life of 30 years. What percent of a sample of ^{90}Sr will remain after 60 years?

A. 0%
B. 25%
C. 50%
D. 75%
E. 14%

ans: B

37. The half-life of a radioactive isotope is 6.5 h. If there are initially 48×10^{32} atoms of this isotope, the number of atoms of this isotope remaining after 26 h is:

A. 12×10^{32}
B. 6×10^{32}
C. 3×10^{32}
D. 6×10^{4}
E. 3×10^{2}

ans: C

38. At the end of 14 min, 1/16 of a sample of radioactive polonium remains. The corresponding half-life is:

A. (7/8) min
B. (8/7) min
C. (7/4) min
D. (7/2) min
E. (14/3) min

ans: D

39. The half-life of a radioactive isotope is 140 days. In how many days does the decay rate of a sample of this isotope decrease to one-fourth of its initial decay rate?

A. 35
B. 105
C. 187
D. 210
E. 280

ans: E

40. Of the three common types of radiation (alpha, beta, gamma) from radioactive sources, electric charge is carried by:

A. only beta and gamma
B. only beta
C. only alpha and gamma
D. only alpha
E. only alpha and beta

ans: E

41. An alpha particle is:

A. a helium atom with two electrons removed
B. an aggregate of two or more electrons
C. a hydrogen atom
D. the ultimate unit of positive charge
E. sometimes negatively charged

ans: A

42. A nucleus with mass number A and atomic number Z emits an alpha particle. The mass number and atomic number, respectively, of the daughter nucleus are:

A. A, $Z - 2$
B. $A - 2$, $Z - 2$
C. $A - 2$, Z
D. $A - 4$, Z
E. $A - 4$, $Z - 2$

ans: E

43. Radioactive polonium, ^{214}Po ($Z = 84$), decays by alpha emission to:

A. ^{214}Po ($Z = 84$)
B. ^{210}Pb ($Z = 82$)
C. ^{214}At ($Z = 85$)
D. ^{218}Po ($Z = 84$)
E. ^{210}Bi ($Z = 83$)

ans: B

44. A radium atom, ^{226}Ra ($Z = 86$) emits an alpha particle. The number of protons in the resulting atom is:

A. 84
B. 85
C. 86
D. 88
E. some other number

ans: A

45. Some alpha emitters have longer half-lives than others because:

A. their alpha particles have greater mass
B. their alpha particles have less mass
C. their barriers to decay are higher and wider
D. their barriers to decay are lower and narrower
E. their decays include the emission of a photon

ans: C

46. In an alpha decay the disintegration energy appears chiefly as:

A. photon energies
B. the kinetic energies of the alpha and the daughter nucleus
C. the excitation energy of the daughter nucleus
D. the excitation energy of the alpha particle
E. heat

ans: B

47. Rank the following collections of particles according to the total binding energy of all the particles in each collection, least to greatest.

collection 1: ^{244}Pu ($Z = 94$) nucleus alone
collection 2: ^{240}U ($Z = 92$) nucleus, α particle
collection 3: ^{240}U ($Z = 92$) nucleus, two separated protons, two separated neutrons

A. 1, 2, 3
B. 3, 2, 1
C. 2, 1, 3
D. 1, 3, 2
E. 2, 3, 1

ans: D

48. A beta particle is:

A. a helium nucleus
B. an electron or a positron
C. a radioactive element
D. any negative particle
E. a hydrogen atom

ans: B

49. Beta particles from various radioactive sources all have:

A. the same mass
D. the same speed
B. the same charge
E. the same deflection
C. the same energy in a magnetic field

ans: A

50. A radioactive atom X emits a β^- particle. The resulting atom:

A. must be very reactive chemically
B. has an atomic number that is one more than that of X
C. has a mass number that is one less than that of X
D. must be radioactive
E. is the same chemical element as X

ans: B

51. A nucleus with mass number A and atomic number Z undergoes β^- decay. The mass number and atomic number, respectively, of the daughter nucleus are:

A. A, $Z-1$
B. $A-1$, Z
C. $A+1$, $Z-1$
D. A, $Z+1$
E. A, $Z-1$

ans: D

52. A nucleus with mass number A and atomic number Z undergoes β^+ decay. The mass number and atomic number, respectively, of the daughter nucleus are:

A. $A-1$, $Z-1$
B. $A-1$, $Z+1$
C. $A+1$, $Z-1$
D. A, $Z+1$
E. A, $Z-1$

ans: E

53. In addition to the daughter nucleus and an electron or positron, the products of a beta decay include:

A. a neutron
B. a neutrino
C. a proton
D. an alpha particle
E. no other particle

ans: B

54. The energies of electrons emitted in β^- decays have a continuous spectrum because:

A. the original neutron has a continuous spectrum
B. a neutrino can carry off energy
C. the emitted electron is free
D. energy is not conserved
E. the daughter nucleus may have any energy

ans: B

55. If ^{204}Tl ($Z = 81$) emits a β^- particle from its nucleus:

A. stable Tl is formed
B. ^{202}Hg ($Z = 80$) is formed
C. ^{204}Pb ($Z = 82$) is formed
D. radioactive Tl is formed
E. ^{197}Au ($Z = 79$) is formed

ans: C

56. An atom of ^{235}U ($Z = 92$) disintegrates to ^{207}Pb ($Z = 82$) with a half-life of about a billion years by emitting seven alpha particles and _____ β^- particles:

A. 3
B. 4
C. 5
D. 6
E. 7

ans: B

57. When ordinary sodium (^{23}Na, $Z = 11$) is bombarded with deuterons, the products are a neutron and:

A. ^{27}Al, $Z = 13$
B. ^{24}Na, $Z = 11$
C. ^{24}Mg, $Z = 12$
D. ^{25}Mg, $Z = 12$
E. ^{20}Ne, $Z = 10$

ans: D

58. ^{65}Cu can be turned into ^{66}Cu, with no accompanying product except a gamma, if bombarded with:

A. protons
B. neutrons
C. deuterons
D. electrons
E. alpha particles

ans: B

59. Magnesium has atomic number 12, hydrogen has atomic number 1, and helium has atomic number 2. In the nuclear reaction $^{24}\text{Mg} + {}^{2}\text{H} \rightarrow (\ ) + {}^{4}\text{He}$ the missing quantity is:

A. ^{23}Na $(Z = 11)$
B. ^{22}Ne $(Z = 10)$
C. ^{21}Na $(Z = 11)$
D. ^{21}Ne $(Z = 10)$
E. ^{22}Na $(Z = 11)$

ans: E

60. Aluminum has atomic number 13, helium has atomic number 2, and silicon has atomic number 14. In the nuclear reaction $^{27}\text{Al} + {}^{4}\text{He} \rightarrow {}^{30}\text{Si} + (\ )$ the missing particle is:

A. an α particle
B. a positron
C. an electron
D. a proton
E. a neutron

ans: D

61. The ^{66}Cu $(Z = 29)$ produced in a nuclear bombardment is unstable, changing to ^{66}Zn $(Z = 30)$ by the emission of:

A. a proton
B. a gamma ray photon
C. a positron
D. an electron
E. an alpha particle

ans: D

62. When ordinary sulfur, ^{32}S $(Z = 16)$, is bombarded with neutrons, the products are ^{32}P $(Z = 15)$ and:

A. alpha particles
B. protons
C. deuterons
D. gamma ray particles
E. electrons

ans: B

63. A certain nucleus, after absorbing a neutron, emits a β^- and then splits into two alpha particles. The (A, Z) of the original nucleus must have been:

A. 6, 2
B. 6, 3
C. 7, 2
D. 7, 3
E. 8, 4

ans: D

64. When ^{23}Na ($Z = 11$) is bombarded with protons, the products are ^{20}Ne ($Z = 10$) and:
    A. a neutron
    B. an alpha particle
    C. a deuteron
    D. a gamma ray particle
    E. two beta particles

    ans: B

65. Bombardment of ^{28}Si ($Z = 14$) with alpha particles may produce:
    A. a proton and ^{31}P ($Z = 15$)
    B. hydrogen and ^{32}S ($Z = 16$)
    C. a deuteron and ^{27}Al ($Z = 13$)
    D. helium and ^{31}P ($Z = 15$)
    E. ^{35}Cl ($Z = 17$)

    ans: A

66. The becquerel is the correct unit to use in reporting the measurement of:
    A. the rate of decay of a radioactive source
    B. the ability of a beam of gamma ray photons to produce ions in a target
    C. the energy delivered by radiation to a target
    D. the biological effect of radiation
    E. none of the above

    ans: A

67. The gray is the correct unit to use in reporting the measurement of:
    A. the rate of decay of a radioactive source
    B. the ability of a beam of gamma ray photons to produce ions in a target
    C. the energy per unit mass of target delivered by radiation to a target
    D. the biological effect of radiation
    E. none of the above

    ans: C

68. The sievert is the correct unit to use in reporting the measurement of:
    A. the rate of decay of a radioactive source
    B. the ability of a beam of gamma ray photons to produce ions in a target
    C. the energy delivered by radiation to a target
    D. the biological effect of radiation
    E. none of the above

    ans: D