

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

Section: 42-2; Difficulty: E

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

Section: 42-2; Difficulty: E

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

Section: 42-2; Difficulty: 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

Section: 42-2; Difficulty: E

5. 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

Section: 42-3; Difficulty: E

6. 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
Section: 42–3; Difficulty: E
7. 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
Section: 42–3; Difficulty: E
8. 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
Section: 42–3; Difficulty: E
9. 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
Section: 42–3; Difficulty: E

10. 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

Section: 42–3; Difficulty: E

11. The mass density of an atomic nucleus is:
- A. about 10^{15} kg/m^3
 - B. about 10^{12} 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

Section: 42–3; Difficulty: E

12. 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

Section: 42–3; Difficulty: E

13. A femtometer is:
- A. larger than 10^{-9} m
 - B. 10^{-9} m
 - C. 10^{-12} m
 - D. 10^{-15} m
 - E. 10^{-18} m

ans: D

Section: 42–3; Difficulty: E

14. 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. $2.6 \times 10^5 \text{ fm}$

ans: A

Section: 42–3; Difficulty: M

15. 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
Section: 42–3; Difficulty: E
16. 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
Section: 42–3; Difficulty: E
17. 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
Section: 42–3; Difficulty: E
18. 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
Section: 42–3; Difficulty: E
19. 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
Section: 42–3; Difficulty: E

20. 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

Section: 42–3; Difficulty: E

21. 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

Section: 42–3; Difficulty: E

22. 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

Section: 42–3; Difficulty: E

23. 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

Section: 42–3; Difficulty: M

24. 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

Section: 42–4; Difficulty: E

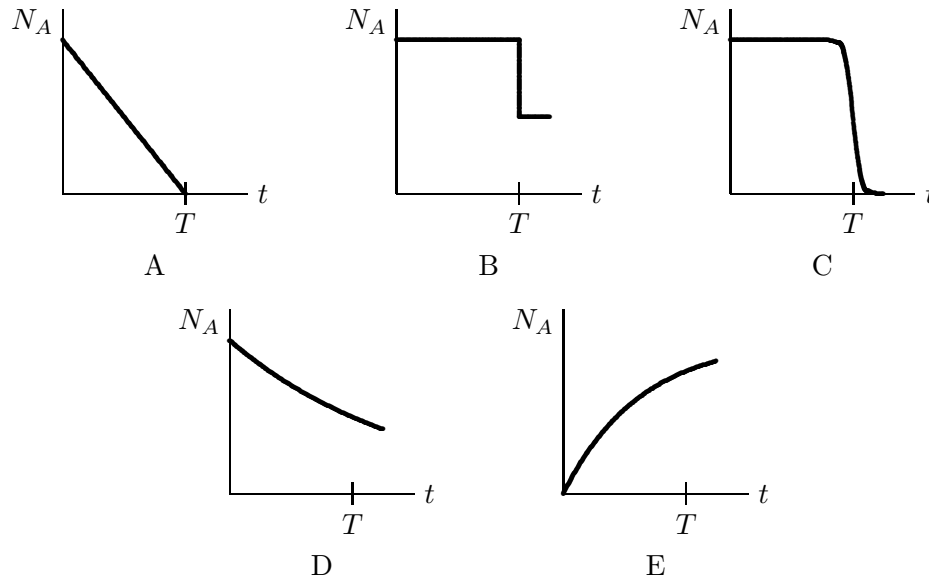
25. Which expression correctly describes the radioactive decay of a substance whose half-life is T ?

- 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

Section: 42-4; Difficulty: E

26. 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

Section: 42-4; Difficulty: E

27. 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

Section: 42-4; Difficulty: E

28. 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

Section: 42-4; Difficulty: E

29. Possible units for the disintegration constant λ are:

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

ans: D

Section: 42-4; Difficulty: E

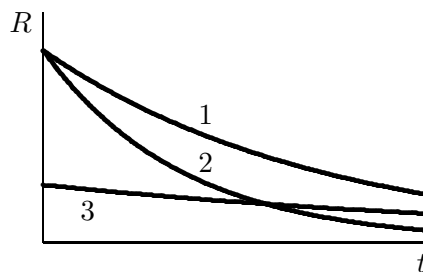
30. The half-life of a given nuclear disintegration $A \rightarrow B$:

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

Section: 42-4; Difficulty: E

31. 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

Section: 42-4; Difficulty: E

32. 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
Section: 42–4; Difficulty: M
33. 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
Section: 42–4; Difficulty: M
34. ^{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
Section: 42–4; Difficulty: M
35. 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
Section: 42–4; Difficulty: M

36. 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

Section: 42–4; Difficulty: M

37. 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

Section: 42–4; Difficulty: M

38. 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

Section: 42–4; Difficulty: M

39. 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

Section: 42–5; Difficulty: E

40. 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

Section: 42–5; Difficulty: E

41. 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

Section: 42–5; Difficulty: M

42. 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

Section: 42–5; Difficulty: M

43. 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

Section: 42–5; Difficulty: E

44. 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

Section: 42–5; Difficulty: E

45. 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

Section: 42–5; Difficulty: E

46. 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

Section: 42–5; Difficulty: M

47. 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

Section: 42–5; Difficulty: M

48. 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

Section: 42–5; Difficulty: M

49. 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
Section: 42–6; Difficulty: E
50. 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
Section: 42–6; Difficulty: E
51. 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
Section: 42–6; Difficulty: E
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. $A, Z - 1$
B. $A - 1, Z$
C. $A + 1, Z - 1$
D. $A, Z + 1$
E. $A, Z - 1$
ans: D
Section: 42–6; Difficulty: E
53. 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
Section: 42–6; Difficulty: E

54. 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

Section: 42-6; Difficulty: E

55. 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

Section: 42-6; Difficulty: E

56. 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

Section: 42-6; Difficulty: M

57. 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

Section: 42-6; Difficulty: M

58. 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

Section: 42-6; Difficulty: M

59. ^{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
Section: 42–6; Difficulty: M
60. 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
Section: 42–6; Difficulty: M
61. 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
Section: 42–5, 6; Difficulty: E
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
Section: 42–5, 6; Difficulty: M

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

Section: 42–5, 6; Difficulty: M

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

Section: 42–5, 6; Difficulty: M

65. 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

Section: 42–8; Difficulty: E

66. 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

Section: 42–8; Difficulty: E

67. 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

Section: 42–8; Difficulty: E