

Phys.G12-subatomic physics-Qs.bank**Multiple Choice**

Identify the choice that best completes the statement or answers the question.

- _____ 1. The nucleus of an atom is made up of which of the following combinations of particles?
- electrons and protons
 - electrons and neutrons
 - protons, electrons, and neutrons
 - protons and neutrons
- _____ 2. To which of the following is the atomic number of a given element equivalent?
- the number of protons in the nucleus
 - the number of neutrons in the nucleus
 - the sum of the protons and neutrons in the nucleus
 - the number of electrons in the outer shells
- _____ 3. Rutherford's experiments involving the use of alpha particle beams directed onto thin metal foils demonstrated the existence of which of the following?
- neutron
 - proton
 - nucleus
 - positron
- _____ 4. What does the mass number of a nucleus indicate?
- the number of neutrons present
 - the number of protons present
 - the average atomic mass of the element
 - the number of neutrons and protons present
- _____ 5. If there are 128 neutrons in Pb-210, how many neutrons are found in the nucleus of Pb-206?
- 122
 - 124
 - 126
 - 130
- _____ 6. What is the binding energy of a nucleus?
- the energy needed to remove one of the nucleons
 - the average energy with which any nucleon is bound in the nucleus
 - the energy released when nucleons bind together to form a stable nucleus
 - the mass of the nucleus times c^2
- _____ 7. If the stable nuclei are plotted with neutron number versus proton number, the curve formed by the stable nuclei does not follow the line $N = Z$. Which of the following influences the binding energy so that this "valley of stability" forms?
- the volume of the nucleus
 - the size of the nuclear surface
 - the Coulomb repulsive force
 - the proton-neutron mass difference
- _____ 8. As the number of protons in the nucleus increases, the repulsive force
- becomes stronger.
 - becomes weaker.
 - remains unchanged.
 - drops to zero.
- _____ 9. Light nuclei are stable when the ratio of protons to neutrons is
- greater than 1.
 - less than 1.
 - equal to 1.
 - equal to 2.
- _____ 10. When are heavy nuclei most stable?
- when they contain more protons than neutrons
 - when they contain more neutrons than protons
 - when they contain equal numbers of protons and neutrons
 - when the Coulomb force is stronger than the nuclear force

- _____ 11. How does a radioactive isotope that emits an alpha particle change?
- Atomic number decreases by four.
 - Mass number decreases by four.
 - Atomic number decreases by one.
 - Mass number decreases by one.
- _____ 12. What are the components of natural radiation, in order from least to most penetrating?
- alpha, beta, and gamma
 - gamma, beta, and alpha
 - beta, gamma, and alpha
 - alpha, gamma, and beta
- _____ 13. The alpha emission process results in the daughter nucleus differing in what manner from the parent?
- Atomic mass increases by one.
 - Atomic number decreases by two.
 - Atomic number increases by one.
 - Atomic mass decreases by two.
- _____ 14. In the radioactive formula, ${}_{86}^{220}\text{Rn} \rightarrow {}_{84}^{216}\text{Po} + \text{X}$, what does X represent?
- ${}_{-1}^0e$
 - ${}_{1}^0e$
 - λ
 - ${}_{2}^4\text{He}$
- _____ 15. What particle is emitted when Pu-240 decays to U-236?
- alpha
 - beta
 - positron
 - gamma
- _____ 16. What particle is emitted when P-32 decays to S-32?
- alpha
 - beta
 - positron
 - gamma
- _____ 17. When bismuth-214 emits a beta particle, the remaining daughter nucleus is
- lead-213.
 - actinium-215.
 - polonium-214.
 - bismuth-215.
- _____ 18. Radium-226 decays to radon-222 by emitting
- beta particles.
 - alpha particles.
 - gamma particles.
 - positrons.
- _____ 19. Samples of two different isotopes, X and Y, both contain the same number of radioactive atoms. The half-life of Sample X is twice that of Sample Y. How do their rates of radiation compare?
- Sample X has a greater rate than Sample Y.
 - Sample X has a smaller rate than Sample Y.
 - The rates of Sample X and Sample Y are equal.
 - This cannot be determined from the information given.
- _____ 20. The natural logarithm of 2 (0.693) divided by the half-life of a radioactive substance is equal to the
- activity.
 - decay rate.
 - decay constant.
 - decay lifetime.
- _____ 21. How many half-lives does it take for a radioactive substance to decay to 12.5 percent of its original amount?
- 1
 - 2
 - 3
 - 4
- _____ 22. In fission reactions, how must the binding energy per nucleon vary?
- The binding energy per nucleon remains constant as atomic number increases.
 - The binding energy per nucleon increases as atomic number increases.
 - The binding energy per nucleon decreases as atomic number increases.
 - none of the above

- _____ 23. In fusion reactions, how does the binding energy per nucleon vary?
- The binding energy per nucleon remains constant as atomic number increases.
 - The binding energy per nucleon remains constant as atomic number decreases.
 - The binding energy per nucleon increases as atomic number increases.
 - The binding energy per nucleon decreases as atomic number increases.
- _____ 24. At around what mass number is the binding energy per nucleon greatest?
- 26
 - 58
 - 111
 - 235
- _____ 25. In order to adequately control a chain reaction, it is necessary to have within the fissionable material a nonfissionable material. How does this material interact with neutrons?
- The material absorbs neutrons.
 - The material emits neutrons.
 - The material scatters neutrons.
 - The material converts neutrons.
- _____ 26. What daughter isotopes are produced when a neutron combines with a nucleus of $^{235}_{92}\text{U}$? Assume that three neutrons are also produced in the reaction.
- $^{140}_{56}\text{Ba}$, $^{95}_{36}\text{Kr}$
 - $^{142}_{56}\text{Ba}$, $^{93}_{36}\text{Kr}$
 - $^{140}_{56}\text{Ba}$, $^{93}_{36}\text{Kr}$
 - $^{141}_{56}\text{Ba}$, $^{94}_{36}\text{Kr}$
- _____ 27. At this time, all nuclear reactors operate through
- fission only.
 - fusion only.
 - both fission and fusion.
 - neither fission nor fusion.
- _____ 28. How is a fission reactor different from a fusion reactor?
- The fuel is cheaper.
 - The fuel must be processed.
 - There is less radioactive waste.
 - The transportation of fuel is safer.
- _____ 29. Why is it *not* possible for a thermonuclear fusion reaction to be maintained in the ocean?
- The temperature is not high enough.
 - The density is not high enough.
 - There is insufficient deuterium in the ocean.
 - The deuterium in the ocean is not radioactive.
- _____ 30. Which interaction of nature binds neutrons and protons into nuclei?
- strong
 - weak
 - electromagnetic
 - gravitational
- _____ 31. Which interaction of nature depends on the distance through which it acts and is involved in beta decay?
- strong
 - weak
 - electromagnetic
 - gravitational
- _____ 32. Which interaction of nature holds the planets, stars, and galaxies together, even though its effect on elementary particles is negligible?
- strong
 - weak
 - electromagnetic
 - gravitational
- _____ 33. Which interaction of nature binds atoms and molecules by attracting unlike charges and repulsing like charges?
- strong
 - weak
 - electromagnetic
 - gravitational
- _____ 34. Which of the following do physicists believe are fundamental particles?
- three quarks and three leptons
 - six quarks and three leptons
 - three quarks and six leptons
 - six quarks and six leptons

- _____ 35. Which statement about quarks is *not* correct?
- Only two quarks are needed to construct a hadron.
 - An isolated quark has been observed by physicists.
 - Every quark has an antiquark of opposite charge.
 - There are six quarks that fit together in pairs.
- _____ 36. Which of the following is an example of a baryon?
- meson
 - electron
 - lepton
 - proton
- _____ 37. Which of these particles are classified as hadrons?
- leptons
 - electrons
 - mesons
 - neutrinos
- _____ 38. As the early universe cooled and expanded, which interaction separated first from the four unified interactions?
- the strong interaction
 - the electromagnetic interaction
 - the weak interaction
 - the gravitational interaction
- _____ 39. During the expansion of the early universe, which two interactions were the last to separate?
- the strong and weak interactions
 - the gravitational and strong interactions
 - the electromagnetic and weak interactions
 - the electromagnetic and gravitational interactions
- _____ 40. Which of the following is *not* one of the current questions regarding the standard model?
- Why do quarks carry fractional charge and electrons carry whole charge?
 - What determines particle mass?
 - How many quarks make up a proton?
 - Can quarks exist in isolation?

Short Answer

- What are atoms that have the same atomic number but different neutron numbers?
- Why do elements containing more than 83 protons have unstable nuclei?
- What does the value of λ indicate for any isotope?
- Complete the following nuclear reaction.
$${}_{10}^{22}\text{Ne} + {}_2^4\text{He} \rightarrow \text{_____} + 2 {}_0^1\text{n}$$
- What is nuclear fission?
- What is nuclear fusion?
- In the nuclear chain reaction of uranium-235, what particle reacts with the uranium nucleus to make it unstable?
- What can trigger a chain reaction in a nuclear reactor?
- Why are fusion reactors a desirable source of energy?
- In a fission reactor, what must be done to overcome the tendency of uranium-238 to absorb neutrons instead of undergoing fission?

11. How is particle physics related to the model of the universe?
12. According to the big bang theory, what occurred in the brief instant after the big bang?
13. How does the activity of a radioactive substance relate to the amount of the substance and its half-life?
14. Complete the following nuclear reaction.

$${}_{70}^{170}\text{Yb} + {}_2^4\text{He} \rightarrow \underline{\hspace{2cm}}$$
15. Complete the following nuclear reaction.

$${}_{76}^{186}\text{Os} \rightarrow \underline{\hspace{2cm}} + {}_2^4\text{He}$$
16. Complete the following nuclear reaction.

$${}_{19}^{40}\text{K} \rightarrow {}_{20}^{40}\text{Ca} + \underline{\hspace{2cm}} + \bar{\nu}$$
17. Complete the following nuclear reaction.

$$\underline{\hspace{2cm}} \rightarrow {}_{53}^{129}\text{I} + {}_{-1}^0\text{e} + \bar{\nu}$$
18. Complete the following nuclear reaction.

$$\underline{\hspace{2cm}} \rightarrow {}_{68}^{164}\text{Er} + {}_{-1}^0\text{e} + \bar{\nu}$$
19. How are gluons, photons, gravitons, and W and Z bosons similar?
20. Show how the charge of a proton results from the combination of two u quarks and one d quark.

Problem

1. Calculate the binding energy of the iron-56 nucleus. ($c^2 = 931.49$ MeV/u; atomic mass of ${}_{26}^{56}\text{Fe} = 55.934\,940$ u; atomic mass of ${}^1_1\text{H} = 1.007\,825$ u; $m_n = 1.008\,665$ u)
2. Calculate the binding energy of the chlorine-35 nucleus. ($c^2 = 931.49$ MeV/u; atomic mass of ${}_{17}^{35}\text{Cl} = 34.968\,853$ u; atomic mass of ${}^1_1\text{H} = 1.007\,825$ u; $m_n = 1.008\,665$ u)
3. Calculate the binding energy of the phosphorus-31 nucleus. ($c^2 = 931.49$ MeV/u; atomic mass of ${}_{15}^{31}\text{P} = 30.973\,762$ u; atomic mass of ${}^1_1\text{H} = 1.007\,825$ u; $m_n = 1.008\,665$ u)
4. Calculate the binding energy of the copper-63 nucleus. ($c^2 = 931.49$ MeV/u; atomic mass of ${}_{29}^{63}\text{Cu} = 62.929\,599$ u; atomic mass of ${}^1_1\text{H} = 1.007\,825$ u; $m_n = 1.008\,665$ u)
5. Calculate the binding energy per nucleon of the cobalt-59 nucleus. ($c^2 = 931.49$ MeV/u; atomic mass of ${}_{27}^{59}\text{Co} = 58.933\,198$ u; atomic mass of ${}^1_1\text{H} = 1.007\,825$ u; $m_n = 1.008\,665$ u)
6. Calculate the binding energy per nucleon of the gold-197 nucleus. ($c^2 = 931.49$ MeV/u; atomic mass of ${}_{79}^{197}\text{Au} = 196.966\,543$ u; atomic mass of ${}^1_1\text{H} = 1.007\,825$ u; $m_n = 1.008\,665$ u)

Name: _____

ID: A

7. If a fossil bone is found to contain a fourth as much carbon-14 as the bone of a living animal, what is the approximate age of the fossil? (Half-life of carbon-14 = 5734 years.)
8. Tritium (hydrogen-3) has a half-life of 12.37 years. How many years will have elapsed when the radioactivity of a tritium sample has decreased to 12.5 percent of its original value?
9. A pure sample of radium-226 contains 5.6×10^{14} atoms of the isotope. If the half-life of radium-226 is 1.6×10^3 years, what is the activity of this sample?
10. A sample of fluorine-18 decays to 3.125 percent of its original amount in 9.15 h. If the activity of the sample is $22 \mu\text{Ci}$, how many fluorine-18 nuclei undergo decay in the sample?

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Answer Section

MULTIPLE CHOICE

- | | | | |
|-----------|--------|--------|-------------|
| 1. ANS: D | PTS: 1 | DIF: I | OBJ: 22-1.1 |
| 2. ANS: A | PTS: 1 | DIF: I | OBJ: 22-1.1 |
| 3. ANS: C | PTS: 1 | DIF: I | OBJ: 22-1.1 |
| 4. ANS: D | PTS: 1 | DIF: I | OBJ: 22-1.1 |
| 5. ANS: B | | | |

Given

A of lead-210 = 210

A of lead-206 = 206

Solution

number of protons in Pb = number of protons in Pb-210 = $210 - 128 = 82$

number of neutrons in Pb-206 = $206 - 82 = 124$

- | | | | |
|------------|--------|---------|-------------|
| | PTS: 1 | DIF: II | OBJ: 22-1.1 |
| 6. ANS: C | PTS: 1 | DIF: II | OBJ: 22-1.2 |
| 7. ANS: C | PTS: 1 | DIF: II | OBJ: 22-1.2 |
| 8. ANS: A | PTS: 1 | DIF: I | OBJ: 22-1.2 |
| 9. ANS: C | PTS: 1 | DIF: I | OBJ: 22-1.2 |
| 10. ANS: B | PTS: 1 | DIF: I | OBJ: 22-1.2 |
| 11. ANS: B | PTS: 1 | DIF: I | OBJ: 22-2.1 |
| 12. ANS: A | PTS: 1 | DIF: I | OBJ: 22-2.1 |
| 13. ANS: B | PTS: 1 | DIF: I | OBJ: 22-2.1 |
| 14. ANS: D | | | |

Given

A of radon-220 = 220

Z of radon-220 = 86

A of polonium-216 = 216

Z of polonium-216 = 84

Solution

Mass number of X = $200 - 216 = 4$

Atomic number of X = $86 - 84 = 2$

From the periodic table, the nucleus with an atomic number of 2 is He, so a helium-4 nucleus (an alpha particle) is the unknown reaction product.

- | | | |
|--------|---------|-------------|
| PTS: 1 | DIF: II | OBJ: 22-2.2 |
|--------|---------|-------------|

15. ANS: A

Given A of plutonium-240 = 240 Z of plutonium-240 = 94 A of uranium-236 = 236 Z of uranium-236 = 92*Solution*Mass number of X = $240 - 236 = 4$ Atomic number of X = $94 - 92 = 2$

The emitted particle is a helium-4 nucleus, or an alpha particle.

PTS: 1

DIF: I

OBJ: 22-2.2

16. ANS: B

Given A of phosphorus-32 = 32 Z of phosphorus-32 = 15 A of sulfur-32 = 32 Z of sulfur-32 = 16*Solution*Mass number of X = $32 - 32 = 0$ Atomic number of X = $15 - 16 = -1$

The emitted particle is an electron, or a beta particle.

PTS: 1

DIF: I

OBJ: 22-2.2

17. ANS: C

Given A of bismuth-214 = 214 Z of bismuth-214 = 83 A of an electron (beta particle) = 0 Z of an electron (beta particle) = -1 *Solution*

Bismuth has an atomic number of 83.

Mass number of X = $214 - 0 = 214$ Atomic number of X = $83 - (-1) = 84$

From the periodic table, the nucleus with an atomic number of 84 is Po, so a polonium-214 nucleus is the unknown reaction product.

PTS: 1

DIF: II

OBJ: 22-2.2

18. ANS: B

Given A of radium-226 = 226 Z of radium-226 = 88 A of radon-222 = 222 Z of radon-220 = 86*Solution*Mass number of X = $226 - 222 = 4$ Atomic number of X = $88 - 86 = 2$

From the periodic table, the nucleus with an atomic number of 2 is He, so helium-4 nuclei (alpha particles) form the unknown reaction products.

PTS: 1 DIF: I OBJ: 22-2.2

19. ANS: B PTS: 1 DIF: II OBJ: 22-2.3

20. ANS: C PTS: 1 DIF: I OBJ: 22-2.3

21. ANS: C

Given

percentage of sample remaining after decay = 12.5

Solution

$$12.5 \text{ percent} = 0.125 = \frac{1}{8} = \frac{1}{2^3}$$

The substance undergoes 3 half-lives.

PTS: 1 DIF: II OBJ: 22-2.3

22. ANS: C PTS: 1 DIF: I OBJ: 22-3.1

23. ANS: C PTS: 1 DIF: I OBJ: 22-3.1

24. ANS: B PTS: 1 DIF: II OBJ: 22-3.1

25. ANS: A PTS: 1 DIF: I OBJ: 22-3.2

26. ANS: C PTS: 1 DIF: I OBJ: 22-3.2

27. ANS: A PTS: 1 DIF: I OBJ: 22-3.3

28. ANS: B PTS: 1 DIF: I OBJ: 22-3.3

29. ANS: A PTS: 1 DIF: II OBJ: 22-3.3

30. ANS: A PTS: 1 DIF: I OBJ: 22-4.1

31. ANS: B PTS: 1 DIF: I OBJ: 22-4.1

32. ANS: D PTS: 1 DIF: I OBJ: 22-4.1

33. ANS: C PTS: 1 DIF: I OBJ: 22-4.1

34. ANS: D PTS: 1 DIF: I OBJ: 22-4.2

35. ANS: B PTS: 1 DIF: I OBJ: 22-4.2

36. ANS: D PTS: 1 DIF: I OBJ: 22-4.2

37. ANS: C PTS: 1 DIF: I OBJ: 22-4.2

38. ANS: D PTS: 1 DIF: I OBJ: 22-4.3

39. ANS: C PTS: 1 DIF: I OBJ: 22-4.3

40. ANS: C PTS: 1 DIF: II OBJ: 22-4.3

SHORT ANSWER

1. ANS:
isotopes

PTS: 1 DIF: I OBJ: 22-1.1

2. ANS:
The repulsive forces between protons cannot be compensated by the attractive strong nuclear force resulting from the addition of more neutrons.

PTS: 1 DIF: I OBJ: 22-1.2

3. ANS:
The decay constant λ indicates the rate at which that isotope decays.

PTS: 1 DIF: I OBJ: 22-2.3

4. ANS:



Given

A of neon-22 = 22

Z of neon-22 = 10

A of helium-4 (alpha particle) = 4

Z of helium-4 (alpha particle) = 2

A of a neutron = 1

Z of a neutron = 0

Solution

Mass number of unknown = $22 + 4 - 2 = 24$

Atomic number of unknown = $10 + 2 - 0 = 12$

From the periodic table, the nucleus with an atomic number of 12 is Mg.

PTS: 1 DIF: IIIA OBJ: 22-2.2

5. ANS:
Nuclear fission is a process during which a heavy nucleus splits into two or more lighter nuclei.

PTS: 1 DIF: I OBJ: 22-3.1

6. ANS:
Nuclear fusion is a process during which two or more nuclei combine to form a heavier nucleus.

PTS: 1 DIF: I OBJ: 22-3.1

7. ANS:
neutron

PTS: 1 DIF: II OBJ: 22-3.2

8. ANS:
Released neutrons can be captured by other nuclei, making these nuclei unstable. This triggers additional fission events and, possibly, a chain reaction.

PTS: 1 DIF: I OBJ: 22-3.2

9. ANS:
They use deuterium as a fuel source, and deuterium is commonly found in seawater, which is cheap and plentiful. Also, they produce less waste compared with fission reactors.

PTS: 1 DIF: I OBJ: 22-3.3

10. ANS:
Reactor fuels must be processed or enriched to increase the proportion of uranium-235, which undergoes fission and releases energy, to a level that will sustain the reaction.

PTS: 1 DIF: II OBJ: 22-3.3

11. ANS:
Particle physics helps us understand the origin and evolution of the universe. According to the big bang theory, particles (and matter and energy) evolved along with the four interactions of physics.

PTS: 1 DIF: I OBJ: 22-4.3

12. ANS:
The four fundamental interactions of physics operated in a unified manner. The high temperatures and energy caused all particles and energy to be indistinguishable.

PTS: 1 DIF: I OBJ: 22-4.3

13. ANS:
The activity increases with the amount of the substance and decreases for substances with longer half-lives.

PTS: 1 DIF: II OBJ: 22-2.3

14. ANS:



Given

A of ytterbium-170 = 170

Z of ytterbium-170 = 70

A of helium-4 (alpha particle) = 4

Z of helium-4 (alpha particle) = 2

Solution

Mass number of unknown = $170 + 4 = 174$

Atomic number of unknown = $70 + 2 = 72$

From the periodic table, the nucleus with an atomic number of 72 is Hf, so a hafnium-174 nucleus is the unknown reaction product.

PTS: 1 DIF: IIIA OBJ: 22-2.2

15. ANS:

*Given* A of osmium-186 = 186 Z of osmium-186 = 76 A of helium-4 (alpha particle) = 4 Z of helium-4 (alpha particle) = 2*Solution*Mass number of unknown = $186 - 4 = 182$ Atomic number of unknown = $76 - 2 = 74$

From the periodic table, the nucleus with an atomic number of 74 is W, so a tungsten-182 nucleus is the unknown decay product.

PTS: 1

DIF: IIIA

OBJ: 22-2.2

16. ANS:

*Given* A of potassium-40 = 40 Z of potassium-40 = 19 A of calcium-40 = 40 Z of calcium-40 = 20*Solution*Mass number of unknown = $40 - 40 = 0$ Atomic number of unknown = $19 - 20 = -1$

The particle with a -1 charge and a mass (nucleon) number of zero is an electron (beta particle), which is the unknown decay product.

PTS: 1

DIF: IIIA

OBJ: 22-2.2

17. ANS:

*Given* A of iodine-129 = 129 Z of iodine-129 = 53 A of an electron (beta particle) = 0 Z of an electron (beta particle) = -1*Solution*Mass number of unknown = $129 + 0 = 129$ Atomic number of unknown = $53 - 1 = 52$

From the periodic table, the nucleus with an atomic number of 52 is Te, so a tellurium-129 nucleus is the unknown decaying isotope.

PTS: 1

DIF: IIIA

OBJ: 22-2.2

18. ANS:

*Given* A of erbium-164 = 164 Z of erbium-164 = 68 A of an electron (beta particle) = 0 Z of an electron (beta particle) = -1*Solution*Mass number of unknown = $164 + 0 = 164$ Atomic number of unknown = $68 - 1 = 67$

From the periodic table, the nucleus with an atomic number of 67 is Ho, so a holmium-164 nucleus is the unknown decaying isotope.

PTS: 1

DIF: IIIA

OBJ: 22-2.2

19. ANS:

Each of these field particles mediates between other particles to bring about one of the four fundamental interactions. Gravitons, which have yet to be detected, mediate the gravitational interaction. The W and Z bosons mediate the weak interaction, while gluons mediate the strong interaction. Photons are the mediating field particle for the electromagnetic interaction.

PTS: 1

DIF: II

OBJ: 22-4.1

20. ANS:

The charge for the u quark is $+\frac{2}{3}$, and the charge for the d quark is $-\frac{1}{3}$. Two u quarks contribute a charge of $+\frac{4}{3}$, and the total charge of the proton is $+\frac{4}{3} - \frac{1}{3}$, or +1.

PTS: 1

DIF: II

OBJ: 22-4.2

PROBLEM

1. ANS:
492.26 MeV

Given

$$Z \text{ of } {}_{26}^{56}\text{Fe} = 26$$

$$N \text{ of } {}_{26}^{56}\text{Fe} = 56 - 26 = 30$$

$$\text{atomic mass of } {}_1^1\text{H} = 1.007\,825 \text{ u}$$

$$m_n = 1.008\,665 \text{ u}$$

$$\text{atomic mass of } {}_{26}^{56}\text{Fe} = 55.934\,940 \text{ u}$$

$$c^2 = 931.49 \text{ MeV/u}$$

Solution

$$\Delta m = Z(\text{atomic mass of } {}_1^1\text{H}) + Nm_n - \text{atomic mass}$$

$$\Delta m = (26)(1.007\,825 \text{ u}) + (30)(1.008\,665 \text{ u}) - 55.934\,940 \text{ u}$$

$$\Delta m = 26.203\,450 \text{ u} + 30.259\,950 \text{ u} - 55.934\,940 \text{ u} = 0.528\,460 \text{ u}$$

$$E_{\text{bind}} = (0.528\,460 \text{ u})(931.49 \text{ MeV/u}) = 492.26 \text{ MeV}$$

PTS: 1 DIF: III B OBJ: 22-1.3

2. ANS:
298.21 MeV

Given

$$Z \text{ of } {}_{17}^{35}\text{Cl} = 17$$

$$N \text{ of } {}_{17}^{35}\text{Cl} = 35 - 17 = 18$$

$$\text{atomic mass of } {}_1^1\text{H} = 1.007\,825 \text{ u}$$

$$m_n = 1.008\,665 \text{ u}$$

$$\text{atomic mass of } {}_{17}^{35}\text{Cl} = 34.968\,853 \text{ u}$$

$$c^2 = 931.49 \text{ MeV/u}$$

Solution

$$\Delta m = Z(\text{atomic mass of } {}_1^1\text{H}) + Nm_n - \text{atomic mass}$$

$$\Delta m = (17)(1.007\,825 \text{ u}) + (18)(1.008\,665 \text{ u}) - 34.968\,853 \text{ u}$$

$$\Delta m = 17.133\,025 \text{ u} + 18.155\,970 \text{ u} - 34.968\,853 \text{ u} = 0.320\,142 \text{ u}$$

$$E_{\text{bind}} = (0.320\,142 \text{ u})(931.49 \text{ MeV/u}) = 298.21 \text{ MeV}$$

PTS: 1 DIF: III B OBJ: 22-1.3

3. ANS:
262.92 MeV

Given

$$Z \text{ of } {}^{31}_{15}\text{P} = 15$$

$$N \text{ of } {}^{31}_{15}\text{P} = 31 - 15 = 16$$

$$\text{atomic mass of } {}^1_1\text{H} = 1.007\,825 \text{ u}$$

$$m_n = 1.008\,665 \text{ u}$$

$$\text{atomic mass of } {}^{31}_{15}\text{P} = 30.973\,762 \text{ u}$$

$$c^2 = 931.49 \text{ MeV/u}$$

Solution

$$\Delta m = Z(\text{atomic mass of } {}^1_1\text{H}) + Nm_n - \text{atomic mass}$$

$$\Delta m = (15)(1.007\,825 \text{ u}) + (16)(1.008\,665 \text{ u}) - 30.973\,762 \text{ u}$$

$$\Delta m = 15.117\,375 \text{ u} + 16.138\,640 \text{ u} - 30.973\,762 \text{ u} = 0.282\,253 \text{ u}$$

$$E_{\text{bind}} = (0.282\,253 \text{ u})(931.49 \text{ MeV/u}) = 262.92 \text{ MeV}$$

PTS: 1 DIF: IIB OBJ: 22-1.3

4. ANS:
551.38 MeV

Given

$$Z \text{ of } {}^{63}_{29}\text{Cu} = 29$$

$$N \text{ of } {}^{63}_{29}\text{Cu} = 63 - 29 = 34$$

$$\text{atomic mass of } {}^1_1\text{H} = 1.007\,825 \text{ u}$$

$$m_n = 1.008\,665 \text{ u}$$

$$\text{atomic mass of } {}^{63}_{29}\text{Cu} = 62.929\,599 \text{ u}$$

$$c^2 = 931.49 \text{ MeV/u}$$

Solution

$$\Delta m = Z(\text{atomic mass of } {}^1_1\text{H}) + Nm_n - \text{atomic mass}$$

$$\Delta m = (29)(1.007\,825 \text{ u}) + (34)(1.008\,665 \text{ u}) - 62.929\,599 \text{ u}$$

$$\Delta m = 29.226\,925 \text{ u} + 34.294\,610 \text{ u} - 62.929\,599 \text{ u} = 0.591\,936 \text{ u}$$

$$E_{\text{bind}} = (0.591\,936 \text{ u})(931.49 \text{ MeV/u}) = 551.38 \text{ MeV}$$

PTS: 1 DIF: IIB OBJ: 22-1.3

5. ANS:
8.7680 MeV/nucleon

Given

$$Z \text{ of } {}_{27}^{59}\text{Co} = 27$$

$$N \text{ of } {}_{27}^{59}\text{Co} = 59 - 27 = 32$$

$$\text{atomic mass of } {}_1^1\text{H} = 1.007\,825 \text{ u}$$

$$m_n = 1.008\,665 \text{ u}$$

$$\text{atomic mass of } {}_{27}^{59}\text{Co} = 58.933\,198 \text{ u}$$

$$c^2 = 931.49 \text{ MeV/u}$$

Solution

$$\Delta m = Z(\text{atomic mass of } {}_1^1\text{H}) + Nm_n - \text{atomic mass}$$

$$\Delta m = (27)(1.007\,825 \text{ u}) + (32)(1.008\,665 \text{ u}) - 58.933\,198 \text{ u}$$

$$\Delta m = 27.211\,275 \text{ u} + 32.277\,280 \text{ u} - 58.933\,198 \text{ u} = 0.555\,357 \text{ u}$$

$$E_{\text{bind}} = (0.555\,357 \text{ u})(931.49 \text{ MeV/u}) = 517.31 \text{ MeV}$$

$$E_{\text{bind}} / \text{nucleon} = \frac{517.31 \text{ MeV}}{59 \text{ nucleons}} = 8.7680 \text{ MeV/nucleon}$$

PTS: 1

DIF: IIC

OBJ: 22-1.3

6. ANS:
7.9157 MeV/nucleon

Given

$$Z \text{ of } {}^{197}_{79}\text{Au} = 79$$

$$N \text{ of } {}^{197}_{79}\text{Au} = 197 - 79 = 118$$

$$\text{atomic mass of } {}^1_1\text{H} = 1.007\,825 \text{ u}$$

$$m_n = 1.008\,665 \text{ u}$$

$$\text{atomic mass of } {}^{197}_{79}\text{Au} = 196.966\,543 \text{ u}$$

$$c^2 = 931.49 \text{ MeV/u}$$

Solution

$$\Delta m = Z(\text{atomic mass of } {}^1_1\text{H}) + Nm_n - \text{atomic mass}$$

$$\Delta m = (79)(1.007\,825 \text{ u}) + (118)(1.008\,665 \text{ u}) - 196.966\,543 \text{ u}$$

$$\Delta m = 79.618\,175 \text{ u} + 119.022\,470 \text{ u} - 196.966\,543 \text{ u} = 1.674\,102 \text{ u}$$

$$E_{\text{bind}} = (1.674\,102 \text{ u})(931.49 \text{ MeV/u}) = 1559.4 \text{ MeV}$$

$$E_{\text{bind}} / \text{nucleon} = \frac{1559.4 \text{ MeV}}{197 \text{ nucleons}} = 7.9157 \text{ MeV/nucleon}$$

PTS: 1 DIF: IIC OBJ: 22-1.3

7. ANS:
 1.147×10^4 years

Given

$$\text{fraction of carbon-14 remaining after decay} = \frac{1}{4}$$

$$T_{1/2} = 5734 \text{ years}$$

Solution

It takes 5715 years for $\frac{1}{2}$ the sample to decay. Therefore, the sample decays to $\frac{1}{4} = \left(\frac{1}{2}\right)^2$ of its original strength in $2(5734 \text{ years}) = 1.147 \times 10^4$ years.

PTS: 1 DIF: IIIA OBJ: 22-2.3

8. ANS:
37.11 years

Given

$$T_{1/2} = 12.37 \text{ years}$$

percentage of hydrogen-3 remaining after decay = 12.5

Solution

$$0.125 = \frac{1}{8.00} = \left(\frac{1}{2.00}\right)^3$$

It takes 12.37 years for $\frac{1}{2}$ the sample to decay. Therefore, the sample decays to $\frac{1}{8.00} = \left(\frac{1}{2.00}\right)^3$ of its original strength in $3(12.37 \text{ years}) = 37.11 \text{ years}$.

PTS: 1 DIF: IIIA OBJ: 22-2.3

9. ANS:
 $7.7 \times 10^3 \text{ Bq}$

Given

$$N = \text{number of radium-226 nuclei} = 5.6 \times 10^{14}$$

$$T_{1/2} = 1.6 \times 10^3 \text{ years}$$

Solution

$$T_{1/2} = \frac{0.693}{\lambda}$$

$$\text{activity} = \lambda N = \left(\frac{0.693}{T_{1/2}}\right) N$$

$$\text{activity} = \left(\frac{0.693}{(1.6 \times 10^3 \text{ years})(365.25 \text{ days/year})(24 \text{ h/day})(3600 \text{ s/h})}\right) (5.6 \times 10^{14} \text{ decays})$$

$$\text{activity} = 7.7 \times 10^3 \text{ decays/s} = 7.7 \times 10^3 \text{ Bq}$$

PTS: 1 DIF: IIIB OBJ: 22-2.3

10. ANS:

$$7.7 \times 10^9 \text{ nuclei}$$

Given

percentage of fluorine-18 remaining after decay = 3.125

 $t = 9.15 \text{ h}$

$$\text{activity} = 22 \mu\text{Ci} = 2.2 \times 10^{-5} \text{ Ci}$$

Solution

$$0.03125 = \frac{1}{32.00} = \left(\frac{1}{2.000} \right)^5$$

The sample decays to $\frac{1}{32} = \left(\frac{1}{2} \right)^5$ of its original strength in $9.15 \text{ h} = 5T_{1/2}$.

$$T_{1/2} = \frac{9.15 \text{ h}}{5} = 1.83 \text{ h}$$

$$T_{1/2} = \frac{0.693}{\lambda}$$

$$\text{activity} = \lambda N = \left(\frac{0.693}{T_{1/2}} \right) N$$

$$N = \left(\frac{\text{activity}}{0.693} \right) (T_{1/2}) = \frac{(2.2 \times 10^{-5} \text{ Ci})(3.7 \times 10^{10} \text{ Bq/Ci})}{0.693} ((1.83 \text{ h})(3600 \text{ s/h}))$$

$$N = 7.7 \times 10^9 \text{ decay events} = 7.7 \times 10^9 \text{ nuclei}$$

PTS: 1

DIF: IIC

OBJ: 22-2.3