

Nuclear Physics & Nuclear Reactions

Practice Problems

PSI AP Physics B

Name _____

Multiple Choice Questions

1. The atomic nucleus consists of:
(A) Electrons
(B) Protons
(C) Protons and electrons
(D) Protons and neutrons
(E) Neutrons and electrons
2. The atomic mass number represents the following:
(A) The total number of electrons in the atom
(B) The total number of protons in the atom
(C) The total number of protons and neutrons in the atom
(D) The total number of neutrons in the atom
(E) The total number of electrons and protons in the atom
3. The atomic number represents the following:
(A) The number of protons in the atom
(B) The number of neutrons in the atom
(C) The total number of protons and neutrons in the atom
(D) The total number of electrons and neutrons in the atom
(E) The total number of protons and electrons in the atom
4. The isotope of carbon $^{14}_6\text{C}$ consists of:

| | Protons | Neutrons |
|-----|---------|----------|
| (A) | 6 | 6 |
| (B) | 6 | 7 |
| (C) | 6 | 8 |
| (D) | 6 | 14 |
| (E) | 6 | 12 |
5. The isotope of uranium $^{238}_{92}\text{U}$ consists of:

| | Protons | Neutrons |
|-----|---------|----------|
| (A) | 92 | 143 |
| (B) | 92 | 146 |
| (C) | 92 | 144 |
| (D) | 92 | 145 |
| (E) | 92 | 238 |

6. When an electron is emitted by an unstable nucleus the atomic mass number is:
- (A) Increased by 1
 - (B) Increased by 2
 - (C) Decreased by 1
 - (D) Decreased by 2
 - (E) Doesn't change
7. When a positron is emitted by an unstable nucleus the atomic mass number is:
- (A) Increased by 1
 - (B) Increased by 2
 - (C) Decreased by 1
 - (D) Decreased by 2
 - (E) Doesn't change
8. When an α -particle is emitted by an unstable nucleus the atomic mass number is:
- (A) Increased by 1
 - (B) Increased by 2
 - (C) Decreased by 1
 - (D) Decreased by 2
 - (E) Doesn't change
9. When free protons and neutrons join to form a nucleus the energy is:
- (A) Absorb (B) Destroyed (C) Created (D) Stays the same (E) Released
10. Which of the following statements about the mass of separated nucleons and the mass of the nucleus they form is correct:
- (A) The mass of separated nucleons is greater than the nucleus mass
 - (B) The mass of separated nucleons is less than the nucleus mass
 - (C) The mass of separated nucleons is equal to the nucleus mass
 - (D) The mass of separated nucleons is greater than the nucleus mass only for light nuclei
 - (E) The mass of separated nucleons is greater than the nucleus mass only for heavy nuclei
11. Which of the following is the defect mass of a nucleus? (M – nucleus's mass, m_p – proton's mass, m_n – neutron's mass)
- (A) $\Delta m = Nm_n + Zm_p + M$
 - (B) $\Delta m = Nm_n - Zm_p - M$
 - (C) $\Delta m = Nm_n - Zm_p - M$
 - (D) $\Delta m = Nm_n + Zm_p - M$
 - (E) $\Delta m = M - Nm_n + Zm_p$

12. Which of the following is the binding energy?
- (A) $E = hf$
 - (B) $E = mgh$
 - (C) $E = 1/2mv^2$
 - (D) $E = qV$
 - (E) $E = \Delta mc^2$
13. Which of the following is the correct product of the α – decay: ${}^{226}_{88}\text{Ra} \rightarrow ? + {}^4_2\text{He}$?
- (A) ${}^{232}_{90}\text{Th}$
 - (B) ${}^{231}_{91}\text{Pa}$
 - (C) ${}^{222}_{86}\text{Rn}$
 - (D) ${}^{223}_{87}\text{Fr}$
 - (E) ${}^{210}_{85}\text{At}$
14. Which of the following is the correct product of the β^- –decay: ${}^{14}_6\text{C} \rightarrow ? + {}^0_{-1}\text{e}$?
- (A) ${}^{12}_7\text{N}$
 - (B) ${}^{13}_7\text{N}$
 - (C) ${}^{17}_8\text{O}$
 - (D) ${}^{16}_8\text{O}$
 - (E) ${}^{14}_7\text{N}$
15. Which of the following is the correct product of the β^+ –decay: ${}^{19}_{10}\text{Ne} \rightarrow ? + {}^0_{+1}\text{e}$?
- (A) ${}^{19}_9\text{F}$
 - (B) ${}^{18}_8\text{O}$
 - (C) ${}^{17}_8\text{O}$
 - (D) ${}^{16}_8\text{O}$
 - (E) ${}^{23}_{11}\text{Na}$
16. Which of the following statements is not TRUE about α - radiation?
- (A) It is produced by unstable nuclei
 - (B) It can penetrate a piece of paper
 - (C) It can ionize gasses
 - (D) It can be deflected by a magnetic field
 - (E) It is a short wavelength electromagnetic photon
17. Which of the following statements is not TRUE about γ -radiation
- (A) It is produced by unstable nuclei
 - (B) It can penetrate several centimeters of lead
 - (C) It can ionize gasses
 - (D) It can be deflected by a magnetic field
 - (E) It is a short wavelength electromagnetic photon

18. If the half-life time of a radioactive material is 2 days, how much of the material will be left after 6 days?
- (A) $1/2$
(B) $1/4$
(C) $1/6$
(D) $1/8$
(E) $1/16$
19. In an experiment with a radioactive material a physics student conducted two measurements. Initially, it was measured 120 g of the material and after a certain time the amount of the radioactive material was reduced to 7.5 g. If the half-life time of the material is 20 min, what is the elapsed time between the two measurements?
- (A) 20 min (B) 40 min (C) 60 min (D) 80 min (E) 100 min
20. The nuclear reaction $X \rightarrow Y + Z$ occurs spontaneously. If M_x , M_y , and M_z are the masses of the three particles, which of the following relationships is true?
- (A) $M_x < M_y - M_z$
(B) $M_x < M_y + M_z$
(C) $M_x > M_y + M_z$
(D) $M_x - M_y < M_z$
(E) $M_x - M_z < M_y$
21. The half-life of $^{234}_{90}\text{Th}$ is 24 days. If 8 kilogram of this isotope is present initially, what amount remains after 72 days?
- (A) 2 kg (B) 1 kg (C) 5 kg (D) 4 kg (E) 0.5 kg
22. Cobalt 60 is a radioactive source with a half-life of about 5 years. After how many years will the activity of a new sample of cobalt 60 be decreased to $1/8$ its original value?
- (A) 2.5 years (B) 5 years (C) 10 years (D) 15 years (E) 25 years
23. A free proton ($m_p = 1.007825 \text{ U}$) captures a neutron ($m_n = 1.008665 \text{ U}$) and forms a deuterium ($m_d = 2.014102 \text{ U}$). Which of the following is true about the mass of deuterium?
- (A) Less than $1.007825 \text{ U} + 1.008662 \text{ U}$
(B) Greater than $1.007825 \text{ U} + 1.008662 \text{ U}$
(C) Less than $1.007825 \text{ U} - 1.008662 \text{ U}$
(D) Less than $1.007825 \text{ U} + 1.008662 \text{ U} - 2.014102 \text{ U}$
(E) It is equal to $1.007825 \text{ U} + 1.008662 \text{ U}$

24. When the nuclear reaction takes place, which of the following is true about the reaction?

- I. The energy is conserved
- II. The electric charge is conserved
- III. The mass is conserved
- IV. The number of nucleons is conserved

(A) I and II only (B) I, II and III only (C) III only (D) I, II and IV only (E) IV only

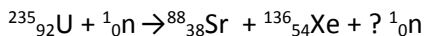
25. The name of the following reaction ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n}$ is:

(A) Fission (B) Fusion (C) α -Decay (D) β -Decay (E) γ -Decay

26. The name of the following reaction ${}^{235}_{92}\text{U} + {}^1_0\text{n} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3 {}^1_0\text{n}$ is:

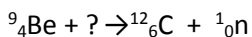
(A) Fission (B) Fusion (C) α -Decay (D) β -Decay (E) γ -Decay

27. How many neutrons are released during the following fission reaction?



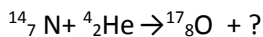
(A) 2 (B) 3 (C) 4 (D) 6 (E) 12

28. What is the missing element from the following reaction?



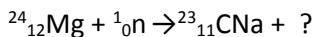
(A) ${}^0_{-1}\text{e}$ (B) ${}^0_{+1}\text{e}$ (C) ${}^1_1\text{H}$ (D) ${}^2_1\text{H}$ (E) ${}^4_2\text{He}$

29. What is the missing element from the following reaction?



(A) ${}^0_{-1}\text{e}$ (B) ${}^0_{+1}\text{e}$ (C) ${}^1_1\text{H}$ (D) ${}^2_1\text{H}$ (E) ${}^4_2\text{He}$

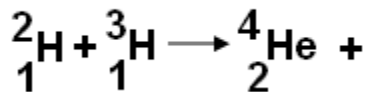
30. What is the missing element from the following reaction?



(A) ${}^0_{-1}\text{e}$ (B) ${}^0_{+1}\text{e}$ (C) ${}^1_1\text{H}$ (D) ${}^2_1\text{H}$ (E) ${}^4_2\text{He}$

Free Response Problems

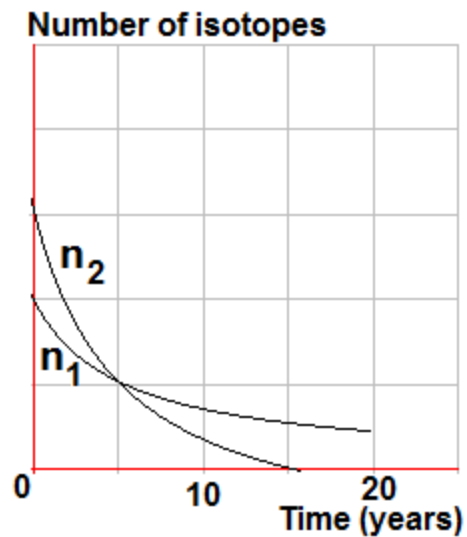
1. Consider the following nuclear fusion reaction that uses deuterium and tritium as fuel.



- a. Complete the reaction equation. What is the name of the new particle released during the reaction?
- b. Determine the mass defect of a single reaction, given the following information.

$${}^2_1\text{H} = 2.014\text{ u} \quad {}^4_2\text{He} = 4.0026\text{ u} \quad {}^3_1\text{H} = 3.016049\text{ u} \quad {}^1_0\text{n} = 1.0087\text{ u}$$

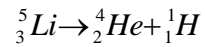
- c. Determine the energy in joules released during a single fusion reaction.
- d. The United States requires about 10^{20} J per year to meet its energy needs. How many single reactions would be necessary to provide this magnitude of energy?



2. Two radioactive isotopes are placed in a metal container, which is then sealed. The graph represents the number of remaining radioactive nuclei n_1 and n_2 as a function of time.

- From the graph, determine the half-life of isotope 1 and the half-life of isotope 2.
- At time $t = 5$ years, which isotope is decaying at the greater rate? Explain your reasoning.
- What type of radiation (alpha, beta, or gamma) would be most likely to escape through the container walls?
- What characteristics of the type of radiation named in part (c) distinguish it from the other two?
- After many years, when the container is removed, it is found to contain helium gas, and the total mass of the contents is found to have decreased. Explain each of these two observations.

3. A lithium nucleus, while at rest, decays into a helium nucleus of rest mass 6.6483×10^{-27} kg and a proton of rest mass 1.6726×10^{-27} kg, as shown by the following reaction.



In this reaction, momentum and total energy are conserved. After the decay, the proton moves with a non-relativistic speed of 2.12×10^7 m/s.

- a. Determine the kinetic energy of the proton.
- b. Determine the speed of the helium nucleus.
- c. Determine the kinetic energy of the helium nucleus.
- d. Determine the mass that is transformed into kinetic energy in this decay.
- e. Determine the rest mass of the lithium nucleus.

4. A polonium nucleus of atomic number 84 and mass number 210 decays to a nucleus of lead by the emission of an alpha particle of mass 4.0026 atomic mass units and kinetic energy 5.5 MeV. (1 atomic mass unit = $931.5 \text{ MeV}/c^2 = 1.66 \times 10^{-27} \text{ kg}$.)

- a. Determine each of the following.
 - i. The atomic number of the lead nucleus
 - ii. The mass number of the lead nucleus
- b. Determine the mass difference between the polonium nucleus and the lead nucleus, taking into account the kinetic energy of the alpha particle but ignoring the recoil energy of the lead nucleus.
- c. Determine the speed of the alpha particle. A classical (non-relativistic) approximation is adequate.
- d. Determine the De Broglie wavelength of the alpha particle.

The alpha particle is scattered from a gold nucleus (atomic number 79) in a "head-on" collision.

- e. Write an equation that could be used to determine the distance of closest approach of the alpha particle to the gold nucleus. It is not necessary to actually solve this equation.

Answers:

Multiple Choice

1. D
2. C
3. A
4. C
5. B
6. E
7. E
8. D
9. E
10. A
11. D
12. E
13. C
14. E
15. A
16. E
17. D
18. D
19. D
20. C
21. B
22. D
23. A
24. D
25. B
26. A
27. E
28. E

29. C

30. D

Free Response

1. a) n, neutron
b) $0.0188u$ or $3.12 \times 10^{-29} \text{ kg}$
c) $2.809 \times 10^{-12} \text{ J}$
d) 3.56×10^{31} reactions
2. a) Isotope 1 – 5 yrs; Isotope 2 – 2.5 yrs
b) Isotope 2; it has a greater slope at t
c) Gamma
d) It is the only type of radiation that can pass through metal.
e) Helium gas means that there was alpha decay. Less mass means that energy was released.
3. a) $3.76 \times 10^{-13} \text{ J}$
b) $5.33 \times 10^6 \text{ m/s}$
c) $9.44 \times 10^{-14} \text{ J}$
d) $1.05 \times 10^{-30} \text{ kg}$
4. a) i. 82
ii. 206
b) $9.8 \times 10^{-30} \text{ kg}$
c) $1.63 \times 10^7 \text{ m/s}$
d) $6.13 \times 10^{-15} \text{ m}$
e) $\frac{1}{2}mv^2 = kq_1q_2/r$