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Class 12
Physics

Chapter 22

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CLASS XII — PHYSICS

Chapter: Particle Physics & Radioactivity

Important MCQs & Short Questions (SLO-Based)

Syllabus Learning Outcomes: P-12-F-22 to P-12-F-42

SECTION A: MULTIPLE CHOICE QUESTIONS (MCQs)

Each question carries 1 mark. Choose the BEST answer.

1. The mass-energy equivalence equation $E = \Delta mc^2$ was proposed by:

(A) Niels Bohr
(B) Albert Einstein
(C) Ernest Rutherford
(D) James Chadwick
Ans: (B) Albert Einstein

2. If the mass defect of a nucleus is 0.03 u, the binding energy is approximately:

(A) 2.8 MeV
(B) 14 MeV
(C) 27.9 MeV
(D) 931 MeV
Ans: (C) 27.9 MeV [1 u = 931.5 MeV]

3. Mass defect of a nucleus is defined as:

(A) Mass of nucleus minus mass of electrons
(B) Difference between mass of constituent nucleons and actual nuclear mass
(C) Mass of protons minus mass of neutrons
(D) Total mass of the atom
Ans: (B) Difference between mass of constituent nucleons and actual nuclear mass

4. Binding energy per nucleon is highest for:

(A) Hydrogen
(B) Uranium-235
(C) Iron-56
(D) Carbon-12
Ans: (C) Iron-56

5. The graph of binding energy per nucleon vs. mass number shows a peak at around mass number:

(A) 4
(B) 12
(C) 56
(D) 235
Ans: (C) 56

6. Which of the following has the LOWEST binding energy per nucleon?

(A) Iron-56
(B) Helium-4

(C) Hydrogen-1
(D) Carbon-12
Ans: (C) Hydrogen-1

7. In nuclear fission, a heavy nucleus splits into:

(A) Two protons and a neutron
(B) Two lighter nuclei and neutrons, releasing energy
(C) Two electrons and a photon
(D) An alpha particle and a beta particle
Ans: (B) Two lighter nuclei and neutrons, releasing energy

8. Nuclear fusion releases energy because the products have:

(A) Greater mass than reactants
(B) Lower binding energy per nucleon
(C) Higher binding energy per nucleon
(D) More nucleons
Ans: (C) Higher binding energy per nucleon

9. In a nuclear reactor, a chain reaction is sustained by:

(A) Alpha particles
(B) Beta particles
(C) Neutrons
(D) Gamma rays
Ans: (C) Neutrons

10. The role of a moderator in a nuclear reactor is to:

(A) Absorb all neutrons
(B) Slow down fast neutrons
(C) Increase the speed of neutrons
(D) Generate electricity
Ans: (B) Slow down fast neutrons

11. In a nuclear reaction, 0.5 g of mass is converted to energy. The energy released is:

(A) 4.5×10^{13} J
(B) 9×10^{13} J
(C) 1.5×10^{1}■ J
(D) 3×10^{1}■ J
Ans: (A) 4.5×10^{13} J [$E = mc^2 = 0.5 \times 10$■$^3 \times (3 \times 10$■$)^2$]

12. Fluctuations in the count rate of a Geiger counter provide evidence that radioactive decay is:

(A) Predictable
(B) Controlled by temperature
(C) Random
(D) Triggered by pressure
Ans: (C) Random

13. Radioactive decay is described as spontaneous because:

(A) It can be controlled chemically
(B) It occurs without any external trigger
(C) It depends on temperature
(D) It happens only in heavy elements

Ans: (B) It occurs without any external trigger

14. The activity A of a radioactive sample is related to decay constant λ and number of atoms N by:

(A) $A = N/\lambda$
(B) $A = \lambda + N$
(C) $A = \lambda N$
(D) $A = \lambda/N$
Ans: (C) $A = \lambda N$

15. The SI unit of radioactive activity is:

(A) Gray
(B) Becquerel
(C) Sievert
(D) Roentgen
Ans: (B) Becquerel

16. Half-life of a radioactive element is defined as the time taken for:

(A) All atoms to decay
(B) The activity to double
(C) Half the atoms in a sample to decay
(D) The count rate to reach zero
Ans: (C) Half the atoms in a sample to decay

17. After 3 half-lives, the fraction of a radioactive sample remaining is:

(A) 1/2
(B) 1/4
(C) 1/8
(D) 1/16
Ans: (C) 1/8

18. The relationship between decay constant λ and half-life $T_{½}$ is:

(A) $\lambda = T_{½} / 0.693$
(B) $\lambda = 0.693 \times T_{½}$
(C) $\lambda = 0.693 / T_{½}$
(D) $\lambda = 1 / T_{½}$
Ans: (C) $\lambda = 0.693 / T_{½}$

19. A radioactive isotope has a half-life of 5 years. Its decay constant is approximately:

(A) 0.0693 yr■¹
(B) 0.139 yr■¹
(C) 0.693 yr■¹
(D) 5 yr■¹
Ans: (B) 0.139 yr■¹ [$\lambda = 0.693/5$]

20. Radioactive decay follows which type of relationship with time?

(A) Linear
(B) Quadratic
(C) Exponential
(D) Sinusoidal
Ans: (C) Exponential

21. The equation x = x■e^(–λt) represents the:

(A) Growth of a radioactive sample
(B) Exponential decay of a radioactive quantity
(C) Energy released in fission
(D) Chain reaction rate
Ans: (B) Exponential decay of a radioactive quantity

22. In the decay equation x = x■e^(–λt), the variable x could represent:

(A) Temperature of the sample
(B) Number of undecayed nuclei or activity
(C) Pressure of the container
(D) Atomic number
Ans: (B) Number of undecayed nuclei or activity

23. In a water-moderated nuclear reactor, water acts as:

(A) Fuel
(B) A moderator to slow neutrons
(C) A control rod
(D) Shielding
Ans: (B) A moderator to slow neutrons

24. Control rods in a nuclear reactor are made of materials that:

(A) Produce neutrons
(B) Speed up neutrons
(C) Absorb neutrons
(D) Reflect gamma rays
Ans: (C) Absorb neutrons

25. Uranium fuel needs to be enriched before use in a reactor because natural uranium has only about ___% of fissile U-235:

(A) 0.7%
(B) 3%
(C) 10%
(D) 50%
Ans: (A) 0.7%

26. Compared to a chemical reaction, a nuclear fission reaction releases approximately _____ times more energy per unit mass:

(A) 10 times
(B) 100 times
(C) 1,000 times
(D) Several million times
Ans: (D) Several million times

27. A medical tracer is a substance containing a radioactive nucleus that is:

(A) Injected to destroy tumours directly
(B) Introduced into the body and absorbed by the tissue being studied
(C) Used to sterilise surgical instruments
(D) Applied externally to measure bone density
Ans: (B) Introduced into the body and absorbed by the tissue being studied

28. Which property of a medical tracer makes it suitable for diagnostic purposes?

(A) Very long half-life
(B) Alpha emission only
(C) Short half-life and gamma emission
(D) It is chemically inert
Ans: (C) Short half-life and gamma emission

29. In an annihilation reaction between an electron and a positron, the products are:

(A) Two protons
(B) Two gamma-ray photons
(C) One neutron and one proton
(D) Two alpha particles
Ans: (B) Two gamma-ray photons

30. Annihilation reactions conserve which of the following?

(A) Mass only
(B) Energy only
(C) Both mass–energy and momentum
(D) Charge only
Ans: (C) Both mass–energy and momentum

31. In PET scanning, the positrons emitted by the tracer annihilate with electrons in the tissue, producing:

(A) X-rays travelling in the same direction
(B) Two gamma-ray photons travelling in opposite directions
(C) Ultrasound waves
(D) Beta particles
Ans: (B) Two gamma-ray photons travelling in opposite directions

32. PET stands for:

(A) Proton Emission Tomography
(B) Positron Emission Tomography
(C) Photon Emission Technique
(D) Pulse Echo Tomography
Ans: (B) Positron Emission Tomography

33. The minimum energy of each gamma-ray photon produced in electron-positron annihilation is:

(A) 0.51 keV
(B) 0.51 MeV
(C) 1.02 MeV
(D) 1.02 GeV
Ans: (B) 0.51 MeV [rest mass energy of electron = 0.511 MeV]

34. The total energy released when an electron and positron annihilate (both at rest) is:

(A) 0.51 MeV
(B) 1.02 MeV
(C) 2.04 MeV
(D) 0.255 MeV
Ans: (B) 1.02 MeV

35. In PET imaging, the position of a tracer in the body is determined by:

(A) Measuring X-ray absorption

(B) Processing arrival times of the two gamma-ray photons
(C) Counting alpha particles emitted
(D) Measuring body temperature changes
Ans: (B) Processing arrival times of the two gamma-ray photons

36. If the half-life of iodine-131 is 8 days, after 24 days the fraction remaining is:

(A) 1/3
(B) 1/6
(C) 1/8
(D) 1/9
Ans: (C) 1/8 [24 days = 3 half-lives, remaining = $(1/2)^3 = 1/8$]

37. The decay constant has units of:

(A) Seconds
(B) Metres per second
(C) Per second (s^{-1})
(D) Joules
Ans: (C) Per second (s^{-1})

38. Which component of a nuclear reactor prevents the spread of radiation outside?

(A) Fuel rods
(B) Moderator
(C) Shielding
(D) Coolant
Ans: (C) Shielding

39. The heat exchanger in a nuclear power station transfers energy from the:

(A) Control rods to the moderator
(B) Primary coolant (reactor core) to the secondary water/steam circuit
(C) Generator to the turbine
(D) Shielding to the atmosphere
Ans: (B) Primary coolant (reactor core) to the secondary water/steam circuit

40. A sample of a radioactive isotope has an initial activity of 800 Bq. After two half-lives its activity will be:

(A) 400 Bq
(B) 200 Bq
(C) 100 Bq
(D) 50 Bq
Ans: (B) 200 Bq

SECTION B: SHORT QUESTIONS

Each question carries 2–3 marks. Answer concisely.

Q1. [SLO P-12-F-22] State the mass-energy equivalence principle and write Einstein's equation. What does each symbol represent?

Q2. [SLO P-12-F-23] Define (a) mass defect and (b) binding energy of a nucleus. How are they related?

Q3. [SLO P-12-F-24] Sketch and describe the general shape of the binding energy per nucleon vs. mass number graph. What does the peak at Fe-56 indicate?

Q4. [SLO P-12-F-25] Differentiate between nuclear fission and nuclear fusion with one example of each.

Q5. [SLO P-12-F-26] Explain the relevance of binding energy per nucleon to nuclear fission and nuclear fusion reactions.

Q6. [SLO P-12-F-26] What is a chain reaction? How do neutrons produced in fission create and sustain it? What is the role of moderators and control rods?

Q7. [SLO P-12-F-27] A nucleus undergoes a reaction with a mass difference of 0.002 u. Calculate the energy released in MeV. (1 u = 931.5 MeV)

Q8. [SLO P-12-F-28] How do fluctuations in the count rate of a detector provide evidence for the random nature of radioactive decay?

Q9. [SLO P-12-F-29] Explain what is meant by saying that radioactive decay is (a) spontaneous and (b) random.

Q10. [SLO P-12-F-30] Define activity and decay constant. Write the equation relating them and state the SI unit of activity.

Q11. [SLO P-12-F-31] Define half-life. A sample has a half-life of 10 minutes. What fraction remains after 40 minutes?

Q12. [SLO P-12-F-32] Derive the relationship $\lambda = 0.693 / T_{1/2}$ from the exponential decay equation.

Q13. [SLO P-12-F-32] The half-life of a radioactive isotope is 20 s. Calculate its decay constant.

Q14. [SLO P-12-F-33] Explain the exponential nature of radioactive decay. Why does the activity never theoretically reach zero?

Q15. [SLO P-12-F-34] Write the decay equation x = x■e^(–λt). Using it, find the activity of a sample after t = 2T½ if initial activity is 1200 Bq.

Q16. [SLO P-12-F-35] Describe the function of each of the following components in a water-moderated nuclear reactor: (a) fuel rods, (b) moderator, (c) control rods, (d) coolant, (e) heat exchanger, (f) shielding.

Q17. [SLO P-12-F-36] Why must uranium fuel be enriched before use in a nuclear reactor? What isotope is responsible for fission?

Q18. [SLO P-12-F-37] Compare the amount of energy released per unit mass in a nuclear fission reaction with that released in a typical chemical reaction. Give a reason for the large difference.

Q19. [SLO P-12-F-38] What is a medical tracer? Briefly explain how it is used in diagnosis, including how it is introduced into the body and detected.

Q20. [SLO P-12-F-39] Describe what happens in an annihilation reaction between an electron and a positron. State the conservation laws obeyed.

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✦ *by fairy (misbah)* ✦

Best of luck for your examinations! ■