Nuclear and Particle Physics Questions – OCR A Level Physics

Praneel Physics

1. State what is meant by the term nucleon number. **(P)**

Working and Answer:

It is the total number of protons and neutrons in the nucleus of an atom.

2. Name the fundamental forces acting in a nucleus. **(P)**

Working and Answer:

Strong nuclear force, electromagnetic force, and weak nuclear force.

3. What is the approximate radius of a nucleus? **(P)**

Working and Answer:

About $1 \times 10^{-15}\,\text{m}$

4. Define the term isotope. **(P)**

Working and Answer:

Atoms of the same element with the same number of protons but different numbers of neutrons.

5. What is meant by the strong nuclear force and how does it behave with distance? **(PP)**

Working and Answer:

It is the force that holds protons and neutrons together; it is attractive at medium ranges (1–3 fm) and repulsive at very short ranges.

6. Explain the term mass defect in nuclear physics. **(PP)**

Working and Answer:

It is the difference between the mass of a nucleus and the sum of the masses of its constituent nucleons.

7. State the equation that relates mass defect to binding energy. **(PP)**

Working and Answer:

$$E = \Delta mc^2$$

8. Describe what happens in beta-minus decay. **(PP)**

Working and Answer:

A neutron decays into a proton, emitting a beta particle (electron) and an antineutrino.

9. Calculate the energy released when a mass defect of $5.0 \times 10^{-29}\,\text{kg}$ occurs. Use $c = 3.0 \times 10^{8}\,\text{m/s}$. **(PPP)**

Working and Answer:

$$E = \Delta m c^2 = 5.0 \times 10^{-29} \times (3.0 \times 10^{8})^2 = 4.5 \times 10^{-12}\,\text{J}$$

10. A nucleus has a binding energy of 8.0×10^{-13} J. Calculate the mass defect. **(PPP)**

Working and Answer:

$$\Delta m = \frac{E}{c^2} = \frac{8.0 \times 10^{-13}}{(3.0 \times 10^8)^2} = 8.89 \times 10^{-30}\,\text{kg}$$

11. The radius of a nucleus is found to be 6.0×10^{-15} m. Estimate the number of nucleons using $R = R_0 A^{1/3}$, with $R_0 = 1.2 \times 10^{-15}$ m. **(PPP)**

Working and Answer:

$$A^{1/3} = \frac{R}{R_0} = \frac{6.0 \times 10^{-15}}{1.2 \times 10^{-15}} = 5 \Rightarrow A = 125$$

12. Calculate the kinetic energy of a 5.0 MeV alpha particle in joules. **(PPP)**

Working and Answer:

$$E = 5.0 \times 10^6 \times 1.6 \times 10^{-19} = 8.0 \times 10^{-13}\,\text{J}$$

13. Explain why high temperatures are required for nuclear fusion to occur. **(PPPP)**

Working and Answer:

To overcome the electrostatic repulsion between positively charged nuclei so that the strong nuclear force can act.

14. Describe the structure of the Standard Model of particle physics. **(PPPP)**

Working and Answer:

It includes fundamental particles: quarks, leptons, gauge bosons, and the Higgs boson.

15. A particle has a rest energy of 0.511 MeV. Calculate its rest mass in kg. **(PPPP)**

Working and Answer:

$$E = mc^2 \Rightarrow m = \frac{E}{c^2} = \frac{0.511 \times 10^6 \times 1.6 \times 10^{-19}}{(3.0 \times 10^8)^2} = 9.1 \times 10^{-31}\,\text{kg}$$

16. Calculate the total binding energy of a helium-4 nucleus if the average binding energy per nucleon is 7.1 MeV. **(PPPP)**

Working and Answer:

$$E = 4 \times 7.1 = 28.4\,\text{MeV} = 28.4 \times 1.6 \times 10^{-13} = 4.54 \times 10^{-12}\,\text{J}$$

17. In a fission reaction, 0.2% of the mass of 1.0 kg of uranium is converted to energy. Calculate the energy released. **(PPPPP)**

Working and Answer:

$$\Delta m = 0.002 \times 1.0 = 0.002\,\text{kg} \Rightarrow E = \Delta mc^2 = 0.002 \times (3.0 \times 10^8)^2 = 1.8 \times 10^{14}\,\text{J}$$

18. A proton and neutron bind to form a deuteron. If the binding energy is 2.2 MeV, calculate the equivalent mass loss. **(PPPPP)**

Working and Answer:

$$\Delta m = \frac{2.2 \times 10^6 \times 1.6 \times 10^{-19}}{(3.0 \times 10^8)^2} = 3.91 \times 10^{-30}\,\text{kg}$$

19. Determine the energy equivalent of a mass of 1.0×10^{-27} kg. **(PPPPP)**

Working and Answer:

$$E = mc^2 = 1.0 \times 10^{-27} \times (3.0 \times 10^8)^2 = 9.0 \times 10^{-11}\,\text{J}$$

20. A nucleus emits an alpha particle of energy 6.5×10^{-13} J. Calculate the speed of the alpha particle. $m = 6.64 \times 10^{-27}$ kg **(PPPPP)**

Working and Answer:

$$E = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2 \times 6.5 \times 10^{-13}}{6.64 \times 10^{-27}}} = 1.4 \times 10^7 \text{ m/s}$$