



Attempt all questions before checking the answer key.
Use $1 \text{ u } c^2 = 931.5 \text{ MeV}$ and nuclear radius $R = 1.2 A^{(1/3)} \text{ fm}$ where needed.

A. Very short answers - 1 mark each

1. Define mass defect of a nucleus.
2. What is binding energy per nucleon?
3. State one feature showing that nuclear force differs from electrostatic force.
4. Distinguish isotopes from isobars.
5. Why is nuclear density approximately independent of mass number?

B. Short answers / practice - 2 marks each

6. Find the ratio of radii of nuclei with mass numbers 27 and 216.
7. A nucleus has mass defect 0.030 u. Find its binding energy in MeV.
8. Why do both fusion of light nuclei and fission of heavy nuclei release energy?
9. Explain the saturation property and short range of nuclear forces.
10. A nucleus has total binding energy 160 MeV and mass number 20. Find binding energy per nucleon and explain what it indicates.
11. Does larger total binding energy always imply larger binding energy per nucleon?
12. Find neutron number for $A = 56$ and $Z = 26$.
13. Find radius ratio for nuclei with mass numbers 8 and 64.
14. Find energy equivalent of 0.010 u .
15. Why are nuclear forces called short-range forces?
16. Are isotopes identical in neutron number?
17. A nucleus has 240 MeV binding energy and $A = 30$. Find binding energy per nucleon.
18. Explain why free neutrons are useful for initiating fission.
19. How does nuclear volume change when mass number doubles?
20. Explain why mass is lower for a bound nucleus than for its separated nucleons.

C. Short answers - 3 marks each

21. For deuterium use atomic masses $m_H = 1.007825 \text{ u}$ and $m_D = 2.014102 \text{ u}$, and $m_n = 1.008665 \text{ u}$. Find mass defect and binding energy; explain why atomic electron masses cancel.
22. Estimate the radius of a nucleus of mass number 125 and compare it with that of $A = 64$.
23. A fission event releases 200 MeV. Find the energy from 10^{20} events in joules using $1 \text{ MeV} = 1.60 \times 10^{-13} \text{ J}$.
24. Complete and balance $^{235}_{92}\text{U} + {}^1_0\text{n} \rightarrow ^{141}_{56}\text{Ba} + ^{92}_{36}\text{Kr} + x {}^1_0\text{n}$. Find x and identify the conserved quantities.
25. Explain why fusion requires very high temperature even though the final products are more tightly bound.

D. Long answers - 5 marks each

26. Sketch binding energy per nucleon against mass number. Explain the main features, approximate peak region, and implications for nuclear stability, fission and fusion.
27. Derive the approximate mass-number independence of nuclear density using $R = R_0 A^{(1/3)}$. Estimate density for $R_0 = 1.2 \text{ fm}$ and nucleon mass $1.67 \times 10^{-27} \text{ kg}$.
28. Distinguish nuclear fission and fusion, give one balanced example of each and explain their energy release using mass defect.
29. For ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + \text{n}$, use atomic masses 2.014102, 3.016049 and 4.002603 u, and neutron mass 1.008665 u. Find the Q-value and explain the cancellation of electron masses.
30. A nucleus of $A = 240$ and binding energy per nucleon 7.5 MeV splits into two $A = 120$ nuclei each with 8.4 MeV per nucleon. Estimate energy released and mass converted per event; state the simplifications made.

ANSWER KEY - Numerical / short answers

- 6) 1:2. 7) 27.945 MeV. 10) 8 MeV/nucleon. 11) No; nucleon number must also be compared. 12) 30. 13) 1:2. 14) 9.315 MeV. 16) No; they have the same proton number. 17) 8 MeV. 19) It approximately doubles. 21) 0.002388 u ; $\approx 2.224 \text{ MeV}$. 22) 6 fm; $A = 64$ gives 4.8 fm; ratio 1.25. 23) $3.2 \times 10^9 \text{ J}$. 24) $x = 3$; charge and nucleon number conserved. 27) $\approx 2.31 \times 10^{17} \text{ kg/m}^3$. 29) $\approx 17.59 \text{ MeV}$. 30) 216 MeV; $\approx 0.2319 \text{ u}$ ($3.85 \times 10^{-28} \text{ kg}$).