Unit 24 · Nuclear Physics

HARDER PRACTICE QUESTIONS

Full marks 28

Write your answers on separate paper. Show your working. Take 1 u = 1.66×10^{-27} kg = 931.5 MeV, c = 3.0×10^{8} m/s, 1 MeV = 1.6×10^{-13} J, $r_0 = 1.2 \times 10^{-15}$ m, proton mass 1.007 276 u, neutron mass 1.008 665 u and electron mass 0.000 549 u.

1 Spot the error [3]

Find the mistake in the working and correct it.

Nitrogen-14 ($^{14}_{7}$N) has an atomic mass of 14.003 074 u. Anisha found its binding energy: "Nucleons: $7 \times 1.007\,276 + 7 \times 1.008\,665 = 14.111\,587$ u. Mass defect = $14.111\,587 - 14.003\,074 = 0.108\,513$ u, so the binding energy is $0.108\,513 \times 931.5 =$ **101.1 MeV**."

2 Work backwards [2]

A nucleus is measured to have a radius of 6.0×10^{-15} m. What is its mass number?

3 Check the readings [3]

A table of measured nuclear radii reads:

A	8	27	64	125	216
R (fm)	2.4	3.6	5.8	6.0	7.2

Show which reading doesn't fit $R = r_0 A^{(1/3)}$, and give the value it should have.

4 Show that [3]

The unit says that 1 kg of uranium-235, split in a reactor, could keep a 1 kW heater going for over two thousand years. Show this, taking 200 MeV for each fission.

5 Estimate it [2]

If the whole Earth (mass 6.0×10^{24} kg) were squeezed to nuclear density, 2.3×10^{17} kg/m^3, how large would it be?

6 A real setting [3]

The Sun gives out about 4×10^{26} W.

i. How much mass does it lose each second as radiated energy?

ii. Over its 4.6 billion years so far, about what fraction of its 1.99×10^{30} kg has it lost this way?

7 Predict, then explain [3]

Write your prediction first, then explain it.

A scientist proposes getting energy from iron-56, either by fusing two iron nuclei or by splitting one into two smaller nuclei. Predict whether either would give out energy, then explain using the binding energy curve.

8 Which explanation? [2]

In a PET scanner, the two photons from an electron–positron annihilation fly off in opposite directions. Asmita says this is because the two photons repel each other. Bishal says it is because momentum is conserved. Who is right? Explain.

9 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

> Saugat wrote: “A nucleus with a large binding energy has a lot of energy stored inside it, ready to come out. In fission, some protons are destroyed and turned into energy. A heavier nucleus is always more tightly bound than a lighter one.”

10 Think [2]

Most nuclei, small and large, have a binding energy per nucleon between 7 and 9 MeV. Why doesn't it keep growing as more nucleons are added, if every nucleon attracts every other?

11 Make your own [2]

Write a nuclear reaction of your own in which a neutron strikes a nucleus of your choice and two products come out. Show that it conserves charge and nucleon number.