Solutions

Each answer shows the steps, then the **result**.

2.1

- $E = mc^2$

2.2

- the difference between the **total mass of the separate nucleons** and the **mass of the nucleus**

2.3

- the energy needed to **separate a nucleus** into its individual nucleons (equivalent to the mass defect)

2.4

- $14 + 4 = A + 1 \Rightarrow A = \mathbf{17}$

3.1 B

- the most stable nuclei have the **highest binding energy per nucleon**

3.2

- $E = \Delta m \times 931\ \text{MeV u}^{-1}$

$$E = (0.030\ \text{u})(931\ \text{MeV u}^{-1}) = \mathbf{28}\ \text{MeV}$$

3.3

- both light nuclei (fusing) and heavy nuclei (splitting) move **towards the peak** of the curve
- this **increases** the binding energy per nucleon
- the products are more tightly bound, so energy is **released**

3.4

- $E = mc^2$

$$E = (1.0 \times 10^{-29}\ \text{kg})(3.0 \times 10^{8}\ \text{m s}^{-1})^2 = \mathbf{9.0} \times \mathbf{10^{-13}}\ \text{J}$$

3.5

- mass lost $\Delta m = 209.98286\ \text{u} - (205.97444\ \text{u} + 4.00260\ \text{u}) = 0.00582\ \text{u}$

$$Q = (0.00582\ \text{u})(931\ \text{MeV u}^{-1}) = \mathbf{5.4}\ \text{MeV}$$

3.6

(a) the **difference** between the total mass of the separate nucleons and the mass of the assembled nucleus

(b) left: $2 \times 2.01410\ \text{u} = 4.02820\ \text{u}$; right: $3.01603\ \text{u} + 1.00867\ \text{u} = 4.02470\ \text{u}$

- difference = **0.00350** u

(c) $\Delta m = (0.00350\ \text{u})(1.66 \times 10^{-27}\ \text{kg u}^{-1}) = 5.81 \times 10^{-30}\ \text{kg}$

$$E = \Delta mc^2 = (5.81 \times 10^{-30}\ \text{kg})(3.00 \times 10^{8}\ \text{m s}^{-1})^2 = 5.2 \times 10^{-13}\ \text{J}$$

$$\frac{5.2 \times 10^{-13}\ \text{J}}{1.60 \times 10^{-13}\ \text{J MeV}^{-1}} = \mathbf{3.3}\ \text{MeV}$$

(d) 1.0 g of deuterium contains

$$N = \frac{1.0 \times 10^{-3}\ \text{kg}}{(2.01410\ \text{u})(1.66 \times 10^{-27}\ \text{kg u}^{-1})} = 3.0 \times 10^{23}$$

nuclei

- the reaction consumes **two** nuclei per event, so there are 1.5×10^{23} events

$$\text{total} = (1.5 \times 10^{23})(3.3\ \text{MeV}) = \mathbf{4.9} \times \mathbf{10^{23}}\ \text{MeV}$$

(e) binding energy per nucleon rises steeply from hydrogen to a maximum near iron, then falls slowly for heavier nuclei

- energy is released whenever the products have a **greater** binding energy per nucleon than the reactants
- so joining light nuclei moves up the curve and releases energy, while splitting a heavy nucleus moves up it from the other side and does the same