

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

- $E = mc^2$

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

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

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

(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