Solutions

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

2.1

- a **fundamental particle** (with no smaller parts)
- any two flavours of: up, down, charm, strange, top, bottom

2.2

- up $= +\frac{2}{3}e$
- down $= -\frac{1}{3}e$

2.3

- proton = **u u d**
- neutron = **u d d**

2.4

- charge $= +e$
- it is a **lepton**

3.1 B

- a baryon is **three quarks** (a proton is uud, a neutron udd)
- **C** is a **meson** (quark + antiquark); **A** and **D** are not observed as free particles

3.2

- charges: up $= +\frac{2}{3}e$, down $= -\frac{1}{3}e$

$$+\tfrac{2}{3}e + \tfrac{2}{3}e - \tfrac{1}{3}e = \tfrac{4}{3}e - \tfrac{1}{3}e = +\mathbf{e}$$

3.3

(a) $\bar{\text{u}}\,\bar{\text{u}}\,\bar{\text{d}}$ (the antiquarks of u u d)

(b) $\bar{\text{u}} = -\frac{2}{3}e$ and $\bar{\text{d}} = +\frac{1}{3}e$

$$-\tfrac{2}{3}e - \tfrac{2}{3}e + \tfrac{1}{3}e = -e$$

3.4

- a **down** quark changes into an **up** quark
- so u d d (neutron) becomes u u d (proton)
- an **electron** (the β^- particle), together with an antineutrino, is emitted

3.5

(a) a particle that **cannot be subdivided** into anything smaller

(b) a meson is a **quark and an antiquark**

- any pair such as $\text{u}\bar{\text{u}}$ ($+\frac{2}{3}e - \frac{2}{3}e = 0$) or $\text{d}\bar{\text{d}}$ ($-\frac{1}{3}e + \frac{1}{3}e = 0$) gives zero charge, because the antiquark carries the opposite charge to the quark

(c) $m = (0.67\ \text{u})(1.66 \times 10^{-27}\ \text{kg u}^{-1}) = 1.11 \times 10^{-27}\ \text{kg}$

- $E_\text{K} = \frac{1}{2}mv^2$, so $v = \sqrt{2E_\text{K}/m}$

$$v = \sqrt{\frac{2 \times 2.1 \times 10^{-16}\ \text{J}}{1.11 \times 10^{-27}\ \text{kg}}} = \mathbf{6.1 \times 10^5}\ \text{m s}^{-1}$$

(d) **88** — a neutral atom has as many electrons as protons

(e) each α removes 2 protons and 2 neutrons; each β^- turns a neutron into a proton (adds a proton, removes a neutron)

- protons: $88 - (5 \times 2) + 4 = \mathbf{82}$
- nucleons: $228 - (5 \times 4) = 208$, so neutrons $= 208 - 82 = \mathbf{126}$