

Answers to Coursebook questions – Chapter 3.1

- 1**
- a** Temperature is a macroscopic concept that is proportional to the average random kinetic energy of the molecules of a substance.
- b** Heat or thermal energy is the energy that is exchanged between two bodies as a result of a temperature difference between them.
- c** Internal energy is the sum of the total random kinetic energy and the total intermolecular potential energy of the molecules of a substance.
- 2** The thermal energy lost by one body must equal the thermal energy gained by the other because of energy conservation. The changes in temperature are not, however, necessarily equal.
- 3**
- a** No thermal energy has been exchanged since the temperature of the two halves is the same.
- b** Same as before, 300 K.
- c** Half of the original, 4×10^6 J.
- 4**
- a** The volume of 22.4 L is $22.4 \times 10^{-3} \text{ m}^3$. There are 6.02×10^{23} molecules in this volume and so the volume per molecule is $\frac{22.4 \times 10^{-3}}{6.02 \times 10^{23}} = 3.7 \times 10^{-26} \text{ m}^3$.
- b** One mole of lead has mass 207 g and so a volume given by
- $$\rho = \frac{M}{V} \Rightarrow V = \frac{M}{\rho} = \frac{207 \text{ g}}{11.3 \times 10^3 \text{ kg m}^{-3}} = \frac{207 \times 10^{-3} \text{ kg}}{11.3 \times 10^3 \text{ kg m}^{-3}} = 1.8 \times 10^{-5} \text{ m}^3.$$
- So the volume per molecule is $\frac{1.8 \times 10^{-5}}{6.02 \times 10^{23}} \text{ m}^3 = 3.0 \times 10^{-29} \text{ m}^3$.
- c** The ratio is $\frac{3.7 \times 10^{-26}}{3.0 \times 10^{-29}} \approx 1200$.
- d** The separation of the molecules (hydrogen to lead) is then $\sqrt[3]{1200} \approx 10$ (to 1 s.f.).

This shows a general result, namely that the ratio of the separation of gas molecules to the separation of solid molecules is of order 10.



- 5 a** One mole of aluminium contains 6.02×10^{23} molecules and has a mass of 27 g. Thus one molecules has mass

$$\frac{27}{6.02 \times 10^{23}} \text{ g} = \frac{27}{6.02 \times 10^{23}} \times 10^{-3} \text{ kg} = 4.5 \times 10^{-26} \text{ kg}.$$

- b** One cubic metre of aluminium has a mass given by

$$\rho = \frac{M}{V} \Rightarrow M = \rho V = 2.7 \frac{\text{g}}{\text{cm}^3} \times 1 \text{ m}^3 = 2.7 \times \frac{10^{-3} \text{ kg}}{(10^{-2})^3 \text{ m}^3} \times 1 \text{ m}^3 = 2.7 \times 10^3 \text{ kg}.$$
 This

corresponds to $\frac{2.7 \times 10^3}{4.5 \times 10^{-26}} = 6.0 \times 10^{28}$ molecules per cubic metre.

- 6 a** One mole of copper contains 6.02×10^{23} molecules and has a mass of 64 g. Thus one molecules has mass $\frac{64}{6.02 \times 10^{23}} \text{ g} = \frac{64}{6.02 \times 10^{23}} \times 10^{-3} \text{ kg} = 1.1 \times 10^{-25} \text{ kg}.$

- b** One cubic metre of copper has a mass given by

$$\rho = \frac{M}{V} \Rightarrow M = \rho V = 8.96 \frac{\text{g}}{\text{cm}^3} \times 1 \text{ m}^3 = 8.96 \times \frac{10^{-3} \text{ kg}}{(10^{-2})^3 \text{ m}^3} \times 1 \text{ m}^3 = 8.96 \times 10^3 \text{ kg}.$$

This corresponds to $\frac{8.96 \times 10^3}{1.1 \times 10^{-25}} = 8.1 \times 10^{28}$ molecules per cubic metre.