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 $22.4\times10^{-3}\ \text{m}^3$. There are 6.02×10^{23} molecules in this volume and so the volume per molecule is $\dfrac{22.4\times10^{-3}}{6.02\times10^{23}} = 3.7\times10^{-26}\ \text{m}^3$. (b) One mole of lead has mass 207 g and so a volume given by

$\rho = \dfrac{M}{V} \Rightarrow V = \dfrac{M}{\rho} = \dfrac{207\ \text{g}}{11.3\times10^{3}\ \text{kg m}^3} = \dfrac{207\times10^{-3}\ \text{kg}}{11.3\times10^{3}\ \text{kg m}^3} = 1.8\times10^{-5}\ \text{m}^3$. So the volume per molecule is $\dfrac{1.8\times10^{-5}}{6.02\times10^{23}}\ \text{m}^3 = 3.0\times10^{-29}\ \text{m}^3$. (c) The ratio is $\dfrac{3.7\times10^{-26}}{3.0\times10^{-29}} \approx 1200$. (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 aluminum contains 6.02×10^{23} molecules and has a mass of 27 g. Thus one molecules has mass $\dfrac{27}{6.02\times10^{23}}\ \text{g} = \dfrac{27}{6.02\times10^{23}}\times10^{-3}\ \text{kg} = 4.5\times10^{-26}\ \text{kg}$. (b) One cubic meter of aluminum has a mass given by

$\rho = \dfrac{M}{V} \Rightarrow M = \rho V = 2.7\ \dfrac{\text{g}}{\text{cm}^3}\times1\ \text{m}^3 = 2.7\times\dfrac{10^{-3}\ \text{kg}}{(10^{-2})^3\ \text{m}^3}\times1\ \text{m}^3 = 2.7\times10^{3}\ \text{kg}$. This corresponds to $\dfrac{2.7\times10^{3}}{4.5\times10^{-26}} = 6.0\times10^{28}$ molecules per cubic meter.

6 (a) One mole of copper contains 6.02×10^{23} molecules and has a mass of 64 g. Thus one molecules has mass $\dfrac{64}{6.02\times10^{23}}\ \text{g} = \dfrac{64}{6.02\times10^{23}}\times10^{-3}\ \text{kg} = 1.1\times10^{-25}\ \text{kg}$. (b) One cubic meter 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 $\frac{2.7 \times 10^3}{1.1 \times 10^{-25}} = 2.4 \times 10^{28}$ molecules per cubic meter.