Answers to exam-style questions

Topic 3

Where appropriate, 1 ✓ = 1 mark

1 A

2 B

3 C

4 D

5 B

6 A

7 B

8 A

9 D (the question should have specified equal moles for each gas)

10 A

11 **a** Use $pV = nRT \Rightarrow V = \dfrac{nRT}{p}$ ✓

To find $V = \dfrac{1.0 \times 8.31 \times 273}{1.0 \times 10^5} = 2.27 \times 10^{-2}\,\text{m}^3$ ✓

b **i** There are $N_A = 6.02 \times 10^{23}$ molecules. ✓

So to each molecule corresponds a volume $\dfrac{2.27 \times 10^{-2}}{6.02 \times 10^{23}} = 3.77 \times 10^{-26}\ \text{m}^3$. ✓

ii Assuming a cube of this volume the side is $\sqrt[3]{3.77 \times 10^{-26}} = 3.35 \times 10^{-9}$ m, which is therefore an estimate of the separation of the molecules. ✓

This separation is much larger than the diameter of the helium atom and so the ideal gas approximation is good. ✓

c One mole of lead has a mass of 0.207 kg and a volume of $V = \dfrac{m}{\rho} = \dfrac{0.207}{11.3 \times 10^3} = 1.83 \times 10^{-5}\ \text{m}^3$. ✓

To each molecule corresponds a volume $\dfrac{1.83 \times 10^{-5}}{6.02 \times 10^{23}} = 3.04 \times 10^{-29}\ \text{m}^3$. ✓

Assuming a cube of this volume the side is $\sqrt[3]{3.04 \times 10^{-29}} = 3.12 \times 10^{-10}$ m which is therefore an estimate of the separation of the molecules. ✓

d The ratio is then $\dfrac{3.35 \times 10^{-9}}{3.12 \times 10^{-10}}$, ✓

≈ 10 . ✓

12 **a** Specific heat capacity is the amount of energy required to change the temperature of a 1 kg of a substance by 1 K. ✓

b One mole of any substance contains the same number of molecules; to raise the temperature by 1 K the internal energy will increase by the same amount and so the same heart must be provided. ✓

One kg of different substances contains different numbers of molecules and so different amounts of energy are required to increase the temperature by 1 K. ✓

c From $\frac{\Delta Q}{\Delta t} = \frac{\Delta m}{\Delta t} c\Delta T$ we find $600 = \frac{\Delta m}{\Delta t} \times 990 \times (40 - 20)$. ✓

So that $\frac{\Delta m}{\Delta t} = 3.0 \times 10^{-2}\ \text{kg s}^{-1}$. ✓

d Then $\frac{\Delta V}{\Delta t} = \rho \frac{\Delta V}{\Delta t} = 1.25 \times 3.0 \times 10^{-2} = 3.8 \times 10^{-2}\ \text{m}^3\,\text{s}^{-1}$. ✓

e The energy required is $Q = mL = 180 \times 2200 = 3.96 \times 10^5$ J. ✓

$t = \frac{3.96 \times 10^5}{750} = 528\,\text{s} = 8.8\ \text{min}$. ✓

13 a i The graph is a curve. ✓
If there was no air resistance the acceleration would have been constant and the velocity – time graph a straight line. ✓

ii We must estimate the area under the graph by counting squares with one small square equal in area to 0.5 m. ✓
There about 370 small squares so the height is about 185 m. ✓

iii Applying $mgh = \frac{1}{2}mv^2$ gives $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 185}$, ✓

$v = 60.2 \approx 60\ \text{m s}^{-1}$. ✓

b The impact speed is about $18.1\ \text{m s}^{-1}$ implying a loss of mechanical energy of $\frac{1}{2} \times 8.0(60.2^2 - 18.1^2) = 1.32 \times 10^4$ J. ✓

Assuming all of this goes into heating the ball and that this amount of energy warms the entire body uniformly. ✓
$mc\Delta T = 1.32 \times 10^4$, ✓

and so $\Delta T = \frac{1.32 \times 10^4}{8.0 \times 320} \approx 5$ K. ✓

14 a The internal energy is the sum of the total random kinetic energy of the molecules and the intermolecular potential energy of the molecules of tungsten. ✓

b The tungsten loses heat $0.050 \times 132 \times (T - 31)$. ✓
This heat is absorbed by the water and the calorimeter:
$0.300 \times 4200 \times (31 - 22) + 0.120 \times 900 \times (31 - 22) = 1.23 \times 10^4$ J ✓

Hence $0.050 \times 132 \times (T - 31) = 1.23 \times 10^4$ or $T - 31 = \frac{1.23 \times 10^4}{0.050 \times 132} = 1864$ and finally $T = 1895 \approx 1900\,°\text{C}$. ✓

c The calculated temperature is $T = \frac{Q}{m_W c_W} + 31$ where Q is the heat that went into the water and calorimeter.
The actual Q would have been higher because some was transferred into the air during the move of the metal into the water. ✓
Hence the calculated value is smaller than the actual temperature. ✓

15 a The internal energy is the sum of the total random kinetic energy of the molecules and the intermolecular potential energy of the molecules of the substance. ✓

b During melting energy is supplied to the substance melting increasing its internal energy but not its temperature. ✓
Hence the student's statement is false. ✓

c The liquid is losing heat to the surroundings because the container is not insulated. ✓
When the rate of heat loss is equal to the rate at which energy is being provided the temperature will remain constant. ✓

d The rate of heat loss is equal to the rate at which energy was being provided when the heater was on i.e. 35 W. ✓

Since $\dfrac{\Delta Q}{\Delta t} = mc\dfrac{\Delta T}{\Delta t}$ we have that $35 = 0.240 \times c \times \dfrac{3.1}{60}$. ✓

And so $c = \dfrac{35 \times 60}{0.240 \times 3.1} = 2.8 \times 10^{3}\ \text{J kg}^{-1}\ \text{K}^{-1}$. ✓

16 a $pV = nRT \Rightarrow n = \dfrac{pV}{RT}$ to find $n = \dfrac{250 \times 10^{3} \times 1.50 \times 10^{-2}}{8.31 \times 273} = 1.653$. ✓

So that $N_1 = nN_A = 1.653 \times 6.02 \times 10^{23} = 9.95 \times 10^{23} \approx 1.0 \times 10^{24}$ molecules. ✓

b As the tyre rolls on the road the rubber lining of the tyre expands and contracts generating thermal energy that heats the air in the tyre. ✓

The volume will increase.

And so will the pressure and temperature. ✓

c $p = \dfrac{nRT}{V} = \dfrac{1.653 \times 8.31 \times (273 + 35)}{1.60 \times 10^{-2}} = 2.64 \times 10^{5}\ \text{Pa} \approx 260\ \text{kPa}$. ✓

d i Assuming the volume and temperature stay the same we must have that $\dfrac{p_1}{n_1} = \dfrac{p_2}{n_2}$ and so $\dfrac{250}{1.653} = \dfrac{230}{n_2}$ giving $n_2 = 1.52$. The number of molecules is then $N_2 = 1.52 \times 6.02 \times 10^{23} = 9.15 \times 10^{23}$. ✓

The number of molecules that left is therefore $N_1 - N_2 = 9.95 \times 10^{23} - 9.15 \times 10^{23} = 8.0 \times 10^{22}$. ✓

The rate of loss is then $\dfrac{8.0 \times 10^{22}}{8 \times 60 \times 60} = 2.8 \times 10^{18}\ \text{s}^{-1}$. ✓

ii The number of moles lost is $1.65 - 1.52 = 0.13$ ✓

And so the lost mass of air is $0.13 \times 29 = 3.8$ g. ✓