Mark scheme for Extension Worksheet – Topic 3, Worksheet 2

1 From $pV = nRT$ it follows that $n = \frac{pV}{RT} = \frac{3.2\times10^{6}\times6.1\times10^{-3}}{8.31\times310} = 7.577$; and so $N = nN_A = 7.577\times6.02\times10^{23} = 4.6\times10^{24}$ [2]

2 The initial state of the gas is determined by P, V and $T = 295\,\text{K}$ and the final by $\frac{P}{2}, 2V, T'$; and so $\frac{PV}{295} = \frac{\frac{P}{2}\times2V}{T'}$ giving $T' = 295\,\text{K}$ [2]

3 From $pV = nRT$ it follows that $T = \frac{pV}{Rn}$ so the highest temperature will be for the gas with the least number of moles; since the masses are equal, helium having a larger molar mass has fewer moles and so the highest temperature. [2]

4 Since the work done is the area under the *p*–*V* graph and the graph of the adiabatic is steeper; the work done for the adiabatic compression is greater. [2]

5 Since the temperature is the same the average kinetic energy is the same and so $\frac{1}{2}mv_X^2 = \frac{1}{2}(2m)v_Y^2 \Rightarrow \frac{v_X^2}{v_Y^2} = 2 \Rightarrow \frac{v_X}{v_Y} = \sqrt{2} \Rightarrow \text{C}$ [1]

6 Since the gas returns to its original state, $\Delta U = 0$ and so $Q_{\text{net}} = W_{\text{net}}$; along the isothermal expansion, $W = +180\,\text{J}$, along the compression at constant pressure, $W = -100\,\text{J}$ and along the heating back to the original state it is zero; so $Q_{\text{net}} = W_{\text{net}} = +80\,\text{J}$ [3]

7 During the adiabatic expansion, $Q = 0 = \Delta U + W = \Delta U + 120 \Rightarrow \Delta U = -120\ \text{J}$; during heating at constant volume, $Q = +80 = \Delta U + W = \Delta U + 0 \Rightarrow \Delta U = +80\ \text{J}$; the overall change in internal energy is negative ($\Delta U_{\text{net}} = -120 + 80 = -40\ \text{J}$) and so the final temperature is less than the original temperature. [3]

8 **a** The molecules collide with a piston that is moving away from them; and so will bounce off with a lower speed, hence lower average kinetic energy hence less temperature. [2]

b $Q = 0 = \Delta U + W \Rightarrow \Delta U = -W$; the work done is positive and so the change in internal energy is negative implying a decrease in temperature. [2]

9 Use $Q = \Delta U + W$. We know that in either case ΔU is the same; at constant volume $W = 0$ and so $Q_V = \Delta U$; at constant pressure, $Q_P = \Delta U + W > Q_V$, so least thermal energy for the constant volume case. [3]

10 **a** The change in internal energy does not depend on the path followed so ΔT is the same for (i) and (ii). [1]

b $Q = \Delta U + W$, ΔU is the same for (i) and (ii) and W is greater for (i) (more area); the thermal energy is greater for (i). [2]

11 C.

The work done is negative: the work is positive up to the intermediate state but then becomes negative as the gas is compressed. The negative is more than the positive and so overall the work is negative. [1]

The final state has the same volume as the initial state but greater pressure so it has greater temperature. [1]

