Mark scheme for Extension Worksheet – Topic 3, Worksheet 3

1 The change in internal energy is the same for paths (i) and (ii) (since ΔU is independent of path); and so since the area is greater for (i) the work is greater for (i) and so thermal energy transfer is greater for (i). [2]

2 **a** Use the point with $V = 0.2\times10^{-3}$ m^3 and $p = 5.0\times10^6$ Pa (or some other point on the curve); to get $T = \frac{pV}{Rn} = \frac{5.0\times10^6\times0.2\times10^{-3}}{8.31\times0.20} = 602$ K [2]

b Forming the trapezoid with the given volumes as base its area is $\frac{1}{2}\times(1.0+2.0)\times10^6\times0.5\times10^{-3} = 750$ J; We must now subtract the extra area. It is about 3 small rectangles. Each rectangle has an area of $0.2\times10^6\times0.1\times10^{-3} = 20$ J, hence the work done is about $750-3\times20 = 690$ J [2]

The exact area is $\int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2}\frac{RnT}{V}dV = RnT\int_{V_1}^{V_2}\frac{1}{V}dV = p_1V_1\ln\frac{V_2}{V_1}$

$$= 2.0\times10^6\times0.5\times10^{-3}\times\ln\frac{1.0\times10^{-3}}{0.5\times10^{-3}} = 693 \text{ J}$$

c $Q = \Delta U + W$ and $\Delta U = 0$; so $Q = W = 690$ J [2]

d The pressure will be greater than the original pressure by a factor of $\frac{794}{602} = 1.319$; and so the final pressure is $5.0\times10^6\times1.319 = 6.6\times10^6$ Pa [2]

3 **a** During the isothermal expansion, $\Delta U = 0$ and so $Q = W = 1020$ J; during the isobaric expansion, $\Delta U = 2990$ J and $W = (1.0-0.5)\times10^{-3}\times4.0\times10^6 = 2000$ J so that $Q = \Delta U + W = 2990+2000 = 4990$ J; so overall $Q = 1020+4990 = 6010$ J [3]

b During the compression phase, $W = -\frac{1}{2}\times(4.0+6.7)\times10^6\times0.7\times10^{-3} = -3745$ J; and since for the entire cycle $\Delta U = 0$, it follows that for the compression $\Delta U = -2990$ J; hence $Q = \Delta U + W = -2990-3745 = -6735$ J [3]

c There is more thermal energy **extracted** than put into the gas, $Q_{net} = +6010-6735 = -725$ J; this is because there is net work done on the gas equal to the area of the loop (which is -725 J as you can easily check). [2]

4 In this process thermal energy would be extracted from the water reducing its entropy; this thermal energy would be released in the room increasing its entropy; whereas this is consistent with the first law of thermodynamics, it violates the second law because the entropy decrease of the water would be greater in magnitude than the rise in the room. [3]

