ENGINEERING PHYSICS

2-2 Thermodynamics of ideal gases

1. P_1 = 100 kPa = 100 x 10^3 Pa, V_1 = 0.0045 m^3, T_1 = 300 K

P_2 = 100 kPa = 100 x 10^3 Pa, V_2 = 0.0060 m^3, T_2 = 300 K

R = 8.31 $Jmol^{-1}K^{-1}$

(a) (i) PV = nRT therefore $n = \frac{PV}{RT} = \frac{100 \times 10^3 \times 0.0045}{8.31 \times 300}$ = 0.1805....

= 0.18 moles

(ii) $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ so $\frac{0.0045}{300} = \frac{0.0060}{T_2}$

$T_2 = \frac{0.0060 \times 300}{0.0045}$

= 400 K

(iii) Total k.e. of n moles of an ideal gas = 3/2 nRT

k.e. gained = change in internal energy = 3/2 nRΔT = 3/2 x 0.18 x 8.31 x 100 = 224 J

(b) work done = PΔV = 100 x 10^3 x (0.0060 – 0.0045)

= 100 x 10^3 x 0.0015

= 150 J

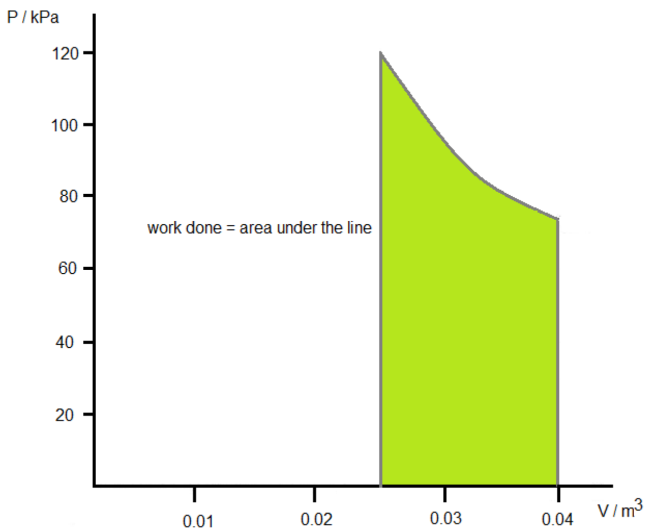
ΔU = Q – W therefore Q = ΔU + W = +224 + 150 = 374 J

2. n = 1.2 moles, T is constant, . P_1 = 120 kPa = 120 x 10^3 Pa, V_1 = 0.025 m^3, V_2 = 0.040 m^3

(a) (i) PV = nRT therefore $T = \frac{PV}{nR} = \frac{120 \times 10^3 \times 0.025}{0.040}$

= 7.5 x 10^4 Pa (or 75 kPa)

(b)



An overestimate would be $\frac{120+75}{2}$ x 10^3 x (0.040 – 0.025) = 1462.5 ≈ 1.4 kJ

3. (a) P_1 = 150 kPa = 150 x 10^3 Pa, V_1 = 0.0036 m^3, T_1 = 300 K

V_2 = 0.0052 m^3, γ = 1.40

For an adiabatic expansion, PV^{γ} = constant

$150 \times 10^3 \times 0.0036^{1.40} = P_2 \times 0.0052^{1.40}$

$$P_2 = 150 \times 10^3 \times \left(\frac{0.036}{0.052}\right)^{1.40}$$

$$= 150 \times 10^3 \times 0.5976....$$

$$= 89641$$

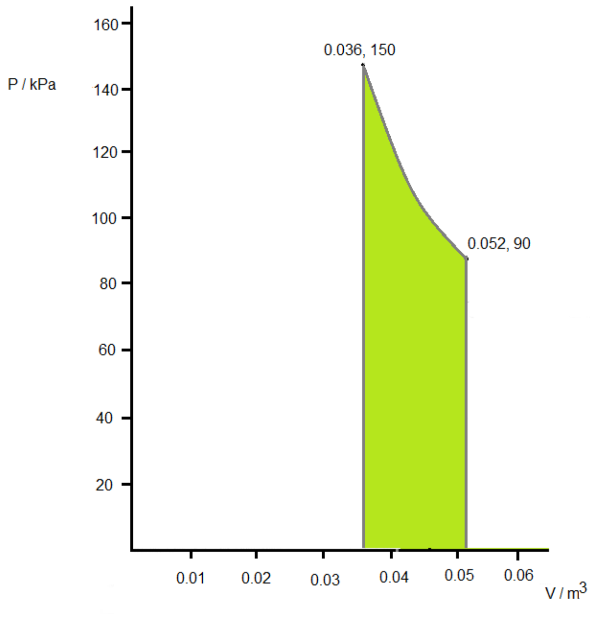
$$= 9.0 \times 10^4 \text{ Pa or } 90 \text{ kPa}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{so} \quad T_2 = \frac{P_2V_2T_1}{P_1V_1}$$

$$= \frac{90 \times 10^3 \times 0.052 \times 300}{150 \times 10^3 \times 0.036}$$

$$= 260 \text{ K}$$

(b)



An overestimate would be $\frac{150 + 75}{2}$ x (0.040 – 0.025) = 1920 ≈ 1.9 kJ

4. P_1 = 190 kPa = 190 x 10^3 Pa, V_1 = 8.0 x 10^{-5} m^3, 5.0% escapes

(a) The expansion can be considered to be adiabatic because it occurs so quickly that heat does not enter/leave the gas.

(b) 5.0% escapes therefore volume escaping = $\frac{5}{100}$ x 8.0 x 10^{-5} = 4.0 x 10^{-6} m^3

$P_1 = 100$ kPa = 100×10^3 Pa

As the expansion is adiabatic PV^γ = constant

$$190 \times 10^3 \times (4.0 \times 10^{-6})^{1.40} = 190 \times 10^3 \times V^{1.40}$$

$$V^{1.40} = \frac{190}{100} \times (4.0 \times 10^{-6})^{1.40}$$

$$= 5.267 \times 10^{-8}$$

$$V = (5.267 \times 10^{-8})^{(1/1.40)}$$

$$= 6.3 \times 10^{-6} \text{ m}^3$$