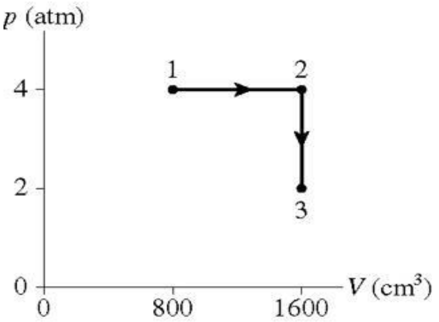
Q- 0.110 mol of a monatomic gas follows the process shown in the figure.
(a) How much heat energy is transferred to or from the gas during process 1 to 2?
(b) How much heat energy is transferred to or from the gas during process 2 to 3?
(c) What is the total change in thermal energy of the gas?



Solution:

(a) How much heat energy is transferred to or from the gas during process 1 to 2?
(1 atm = $1.013*10^5$ N/m^2 and 1cm^3 = 10^{-6} m^3)

The process 1 to 2 is parallel to volume axis thus it is an isobaric process means the pressure is constant and the volume is increasing. Hence according to gas equation PV =nRT the temperature is increasing.

As the volume is increasing the gas is doing work, or the work is done by the gas and hence positive, given by

$$W = P\,\Delta V = P\,(V_2 - V_1)$$
$$= (4*1.013*10^5\ \text{N/m}^2)\ [(1600 - 800)*10^{-6}\ \text{m}^3] = 324.16\ \text{J}.$$

The increase in the internal energy

$$\Delta U = (3/2)n\,R\,\Delta T = (3/2)\,(P_2V_2 - P_1V_1)$$
$$= 1.5\,P\,\Delta V = 1.5*324.16 = 486.24\ \text{J}$$ {P is constant

The heat supplied is utilized in two ways

One to compensate the work done by the gas and the second to increase the internal energy, hence the total heat energy transferred to the gas is

$$\Delta Q = \Delta U + W = 324.16 + 486.24 = 810.4\ \text{J}$$

(b) How much heat energy is transferred to or from the gas during process 2 to 3?

This process is the isochoric process (volume is constant) hence the work done is zero. The heat is supplied only to increase internal energy hence

$\Delta Q = U_3 - U_2 = (3/2)\, nR(T_3 - T_2) = (3/2)\,(P_3V_3 - P_2V_2)$
$= 1.5\,(P_3 - P_2)*V_2.$ {because $V_3 = V_2$}

or $\Delta Q = 1.5[(2 - 4)*1.013*10^5]*1600*10^{-6} = -\,486.24$ J

Negative means heat is released

(c)

What is the total change in thermal energy of the gas?

The total change in thermal energy of the gas is given by

ΔU = final energy – initial energy
$= (3/2)\, n\, R\, T_f - (3/2)\, n\, R\, Ti$
$= (3/2)\,(P_3V_3 - P_1V_1)$
$= 1.5*(\,2*1600 - 4*800)\, 1.013*10^5*10^{-6} = 0$