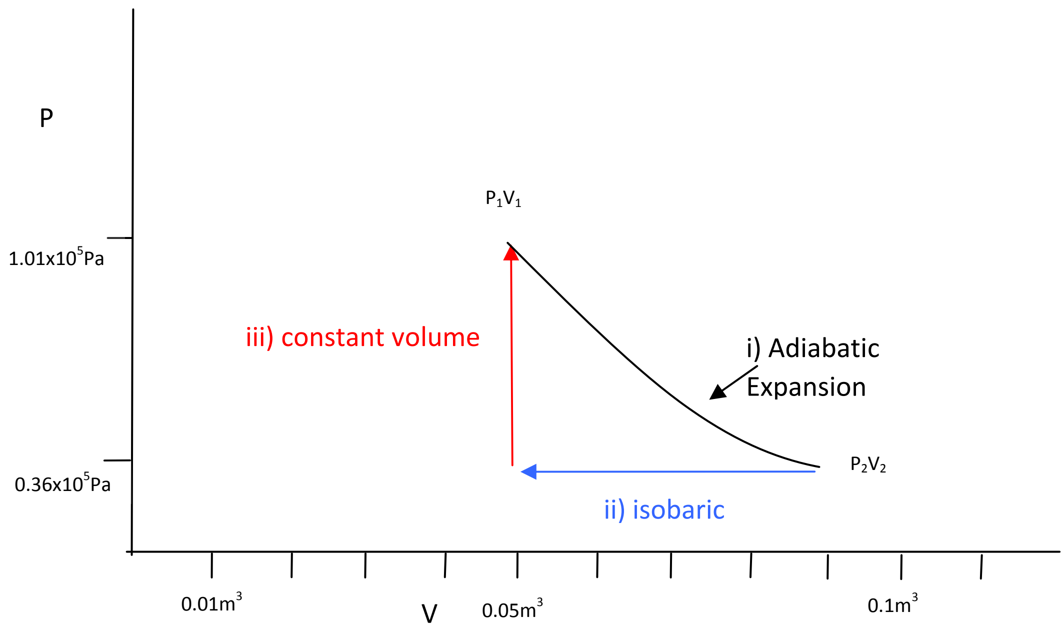
2. 1.0 mol sample of an ideal monatomic gas originally at a pressure of 1 atm undergoes a 3-step process as follows:

(i) It expands adiabatically from T1 = 588 K to T2 = 389 K
(ii) It is compressed at constant pressure until its temperature reaches T3 K
(iii) It then returns to its original pressure and temperature by a constant volume process.

a. Plot these processes on a PV diagram
b. Determine the temperature T3
c. Calculate the change in internal energy, work done by the gas and heat added to the gas for each of these three processes
d. Calculate the change in internal energy, work done by the gas and heat added to the gas for the complete cycle.




Figures in bold are given data points.

| | | | |
|---|---|---|---|
| $V_1 = 0.0484m^3$ | **$T_1$ = 588K** | **$P_1 = 1.01x10^5$ Pa** | **1 mole, ideal gas, monoatomic** |
| $V_2 = 0.0899m^3$ | **$T_2$ = 389K** | $P_2 = 3.59x10^4$Pa | **γ = 1.66** |

Solve for $V_1$ using universal gas law:

$$V_1 = \frac{nRT_1}{P_1} \rightarrow V_1 = \frac{1M \cdot 8.314JM^{-1}K^{-1} \cdot 588K}{1.01x10^5\,Pa} \rightarrow V_1 = 0.0484m^3$$

Solve for $V_2$ using proportionality of temperature and volume during adiabatic process:

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} \rightarrow \frac{588K}{389K} = \left(\frac{V_2}{0.0484m^3}\right)^{0.66} \rightarrow \left(\frac{588K}{389K}\right)^{\frac{1}{0.66}} = \frac{V_2}{0.0484m^3} \rightarrow 1.5116^{\frac{1}{0.66}} = \frac{V_2}{0.0484m^3}$$

$$\rightarrow 1.859 = \frac{V_2}{0.0484m^3} \rightarrow V_2 = 0.0899\text{m}^3$$

To solve for $P_2$ we will use proportionality of volume and pressure:

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \rightarrow \frac{P_2}{1.01x10^5\,Pa} = \left(\frac{0.0484m^3}{0.0899m^3}\right)^{1.66} \rightarrow \frac{P_2}{1.01x10^5\,Pa} = 0.35629 \rightarrow P_2 = 3.59\text{x}10^4\text{Pa}$$

(ii)It is compressed at constant pressure until its temperature reaches T3 K

P = $3.59\text{x}10^4$Pa

Using Charles' Law:

$$\frac{V_1}{T_3} = \frac{V_2}{T_2} \rightarrow \frac{0.0484\text{m}^3}{T_3} = \frac{0.0899\text{m}^3}{389\text{K}} \rightarrow T_3 = 209.4\text{K}$$

**$T_3$ = 209.4K**

**<u>Process 1: Adiabatic</u>**

**dQ = 0** No heat added in an Adiabatic expansion, the gas expands using internal energy.

**dU = dW** = $C_v$·dT = 12.471 $JK^{-1}$ · (588K-389K) → **2,482 J**

**<u>Process 2: Isobaric</u>**

**W** = $P(V_2-V_1)$ → $3.59\text{x}10^4$Pa ($0.0484m^3$- $0.0899m^3$) → **-1,490 J** work done <u>on</u> the gas - final volume is less.

**dU** = $C_v$·dT → 12.471 $JK^{-1}$ · (209.4K-389K) = **-2,239 J**

**dQ** = -2,239 J + -1,490 J = **-3,729 J**

**<u>Process 3: Constant Volume</u>**

Initial Data: T = 209.4K P = $3.59\text{x}10^4$Pa V = $0.0484m^3$

Final Data: T = 588 K P = $1.01\text{x}10^5$ Pa

**dW = 0** – no change in volume, no work done.

**dQ = dU** = $C_v$·dT → 12.471 $JK^{-1}$ · (588K - 209.4K) = **4,722 J**

**For the entire process :**

dQ =

dU =

dW = no net change in volume, no work.