Thermodynamics
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Lecture 40
Tutorial Problem - Part 3

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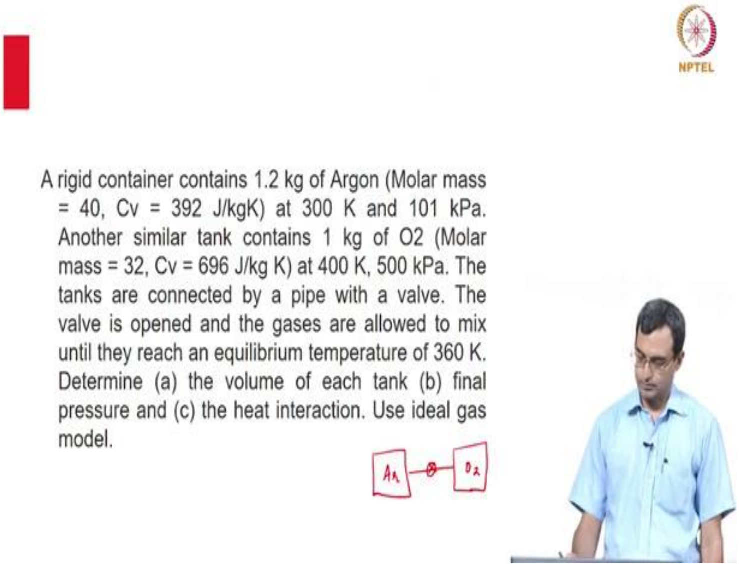
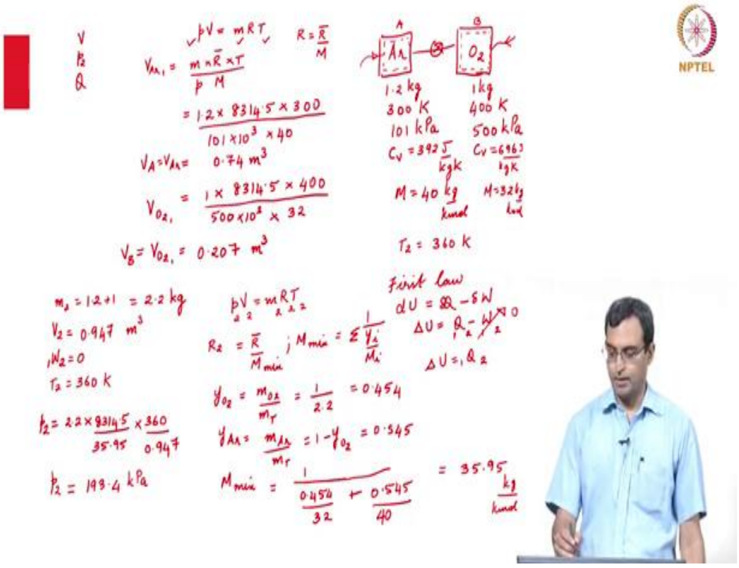
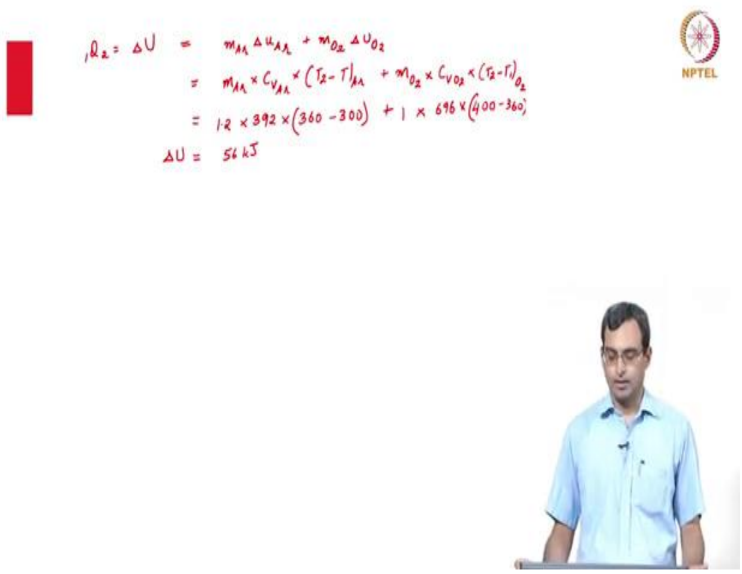


Figure 1.





Solution of the problem in Fig. 1:

$m_{Ar} = 1.2\ kg, m_{O_2} = 1\ kg, T_{1_{Ar}} = 300\ K, T_{1_{O_2}} = 400\ K, p_{1_{Ar}} = 101\ kPa, p_{1_{O_2}} = 500\ kPa, C_{v_{Ar}} = 392\frac{J}{kg \cdot K}, C_{v_{O_2}} = 696\ \frac{J}{kg \cdot K}, M_{Ar} = 40\frac{kg}{kmol}, M_{O_2} = 32\frac{kg}{kmol}, T_f = T_2 = 360\ K.$

Both the gases can be treated as ideal gases. Hence, they follow ideal gas relationship. We are asked to calculate volume of each tank.

So, $V_{Ar} = \frac{m_{Ar}RT_{1_{Ar}}}{p_{1_{Ar}}} = \frac{m_{Ar}\left(\bar{R}/M_{Ar}\right)T_{1_{Ar}}}{p_{1_{Ar}}} = 0.74\ m^3$ = volume of the tank containing Argon

Similarly, $V_{O_2} = 0.207\ m^3$ = volume of the tank containing Oxygen

After mixing, $m_{mix} = m_{Ar} + m_{O_2} = 2.2\ kg, V_{mix} = V_{Ar} + V_{O_2} = 0.947\ m^3, T_2 = T_{mix} = 360\ K$

The mixture is also an ideal gas. Hence, $p_{mix}V_{mix} = m_{mix}R_{mix}T_{mix}$.

Now, $R_{mix} = \frac{\bar{R}}{M_{mix}} = \frac{\bar{R}}{\sum\frac{y_i}{M_i}} = \frac{\bar{R}}{\frac{m_{Ar}}{m_{mix}}+\frac{m_{O_2}}{m_{mix}}} = \frac{8314.5\frac{kJ}{kmol \cdot K}}{35.95\frac{kg}{kmol}} = 231.3\ \frac{kJ}{kg \cdot K}$ [Mmix = 1/summation(yi/Mi)]

Therefore, $p_{mix} = \frac{m_{mix}R_{mix}T_{mix}}{V_{mix}} = 193.4\ kPa$

The work interaction for this process of mixing is 0, i.e., W=0 (there is no shaft work, electrical work, magnetic work, surface tension work, etc.).

The first law in the integrated form, $\Delta U = Q - W$ (there are no changes in kinetic and potential energy).

Since W=0, $Q = \Delta U = m_{Ar}\Delta u_{Ar} + m_{O_2}\Delta u_{O_2} = m_{Ar}C_{v_{Ar}}\left(T_2 - T_{1_{Ar}}\right) + m_{O_2}C_{v_{O_2}}\left(T_2 - T_{1_{O_2}}\right) = 1.2 \times 392 \times (360 - 300) + 1 \times 696 \times (360 - 400) = 384\,J$

Q is positive. Hence, there is a flow of heat into the system (both the tanks considered together) during the process of mixing and the internal energy increases.