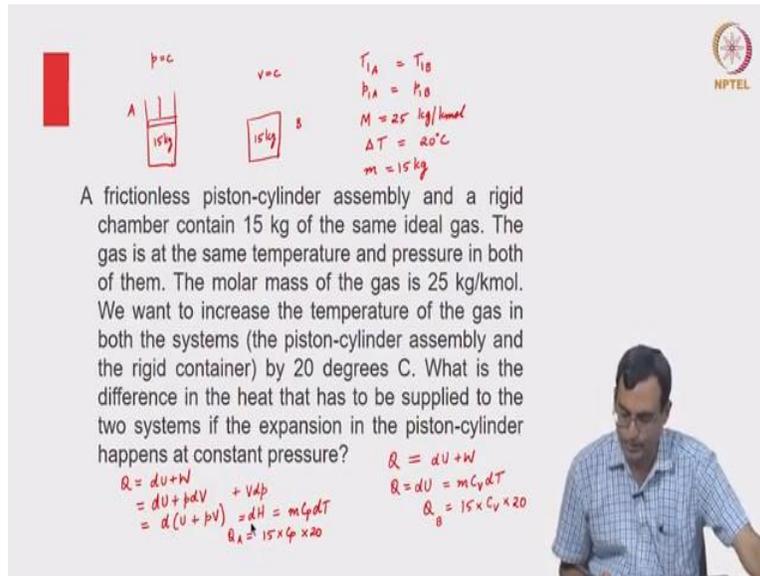


Thermodynamics
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Lecture - 33
Tutorial Problem - Part 6

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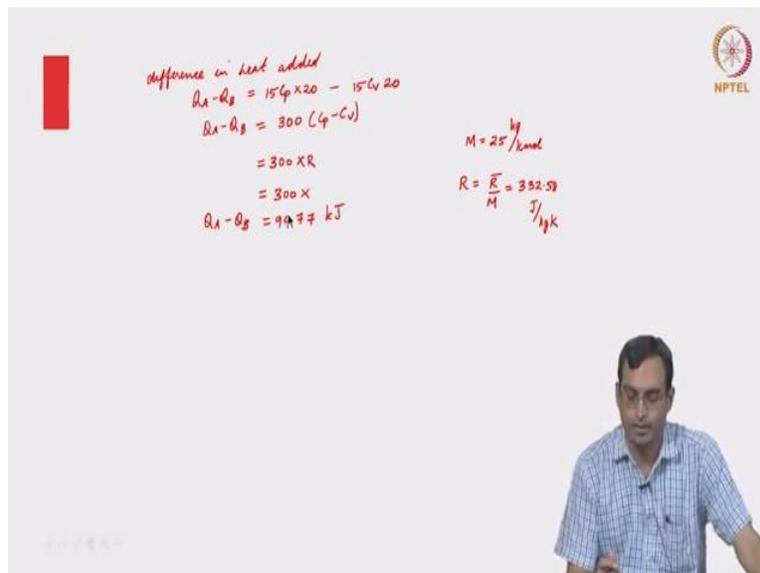
$p=c$
 $v=c$
 $T_{1A} = T_{1B}$
 $P_{1A} = P_{1B}$
 $M = 25 \text{ kg/kmol}$
 $\Delta T = 20^\circ\text{C}$
 $m = 15 \text{ kg}$

A frictionless piston-cylinder assembly and a rigid chamber contain 15 kg of the same ideal gas. The gas is at the same temperature and pressure in both of them. The molar mass of the gas is 25 kg/kmol. We want to increase the temperature of the gas in both the systems (the piston-cylinder assembly and the rigid container) by 20 degrees C. What is the difference in the heat that has to be supplied to the two systems if the expansion in the piston-cylinder happens at constant pressure?

$Q = dU + W$
 $Q = dU + PdV + VdP$
 $= d(U + PV) = dH = mC_p dT$
 $Q_A = 15 \times C_p \times 20$

$Q = dU + W$
 $Q = dU = mC_v dT$
 $Q_B = 15 \times C_v \times 20$

Figure 1.



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difference in heat added
 $Q_A - Q_B = 15C_p \times 20 - 15C_v \times 20$
 $Q_A - Q_B = 300(C_p - C_v)$
 $= 300 \times R$
 $= 300 \times \frac{R}{M}$
 $Q_A - Q_B = 997.7 \text{ kJ}$

$M = 25 \text{ kg/kmol}$
 $R = \frac{R}{M} = 332.58 \text{ J/kgK}$

Solution of the problem in Fig. 1:

The piston-cylinder assembly and the rigid chamber contain the same ideal gas.

Expansion in the piston-cylinder assembly happens at constant pressure.

The first law for the piston-cylinder arrangement,

$$\delta Q_A = dU + \delta W = dU + pdV \text{ (there are no changes in kinetic and potential energy)}$$

Now, $\delta Q_A = dU + pdV + Vdp = dU + d(pV) = d(U + pV) = dH$ (adding Vdp does not change anything as $dp=0$)

Integrating,

$$Q_A = \Delta H = mC_p\Delta T = 15 \text{ kg} \times C_p \times 20^\circ\text{C} \dots\dots(1)$$

Heat is transferred to the rigid chamber. This is a constant volume process. The first law for the rigid chamber,

$$\delta Q_B = dU \text{ (there is no shaft work, electrical work, magnetic work, surface tension work, etc.)}$$

Integrating,

$$Q_B = \Delta U = mC_v\Delta T = 15 \times C_v \times 20^\circ\text{C} \dots\dots(2)$$

We are asked to find the difference between the heat supplied to the two systems. Hence,

$$Q_A - Q_B = 15 \times 20 \times (C_p - C_v) = 300 \times R = 300 \times 332.58 = 99.77 \text{ kJ} \quad (R = \frac{\bar{R}}{M} = \frac{8314.5 \text{ J/kmol}\cdot\text{K}}{25 \text{ kg/kmol}} = 332.58, \text{ where } 25 \text{ kg/kmol is the molar mass of the gas})$$

We see that for the same temperature rise, the amount of heat supplied to the piston-cylinder assembly is more than the rigid chamber. It is because the heat supplied to the

rigid chamber goes into heating the gas alone, whereas in the case of the piston-cylinder assembly, the supplied heat is used to do work in addition to raise the temperature of the gas.