**Thermodynamics**
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**Lecture 39**
**Tutorial Problem – Part 2**

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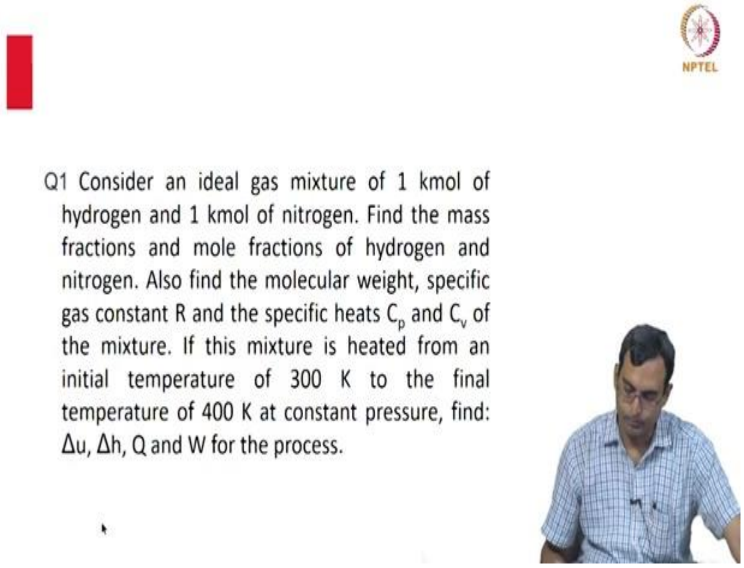


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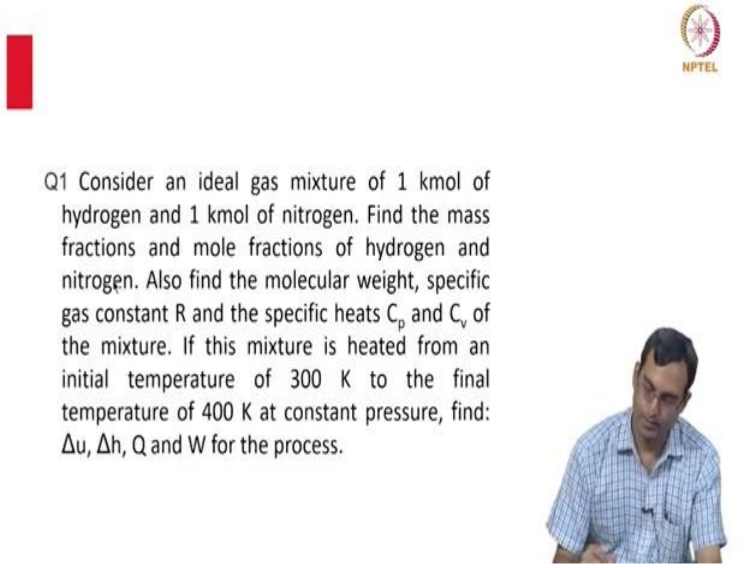


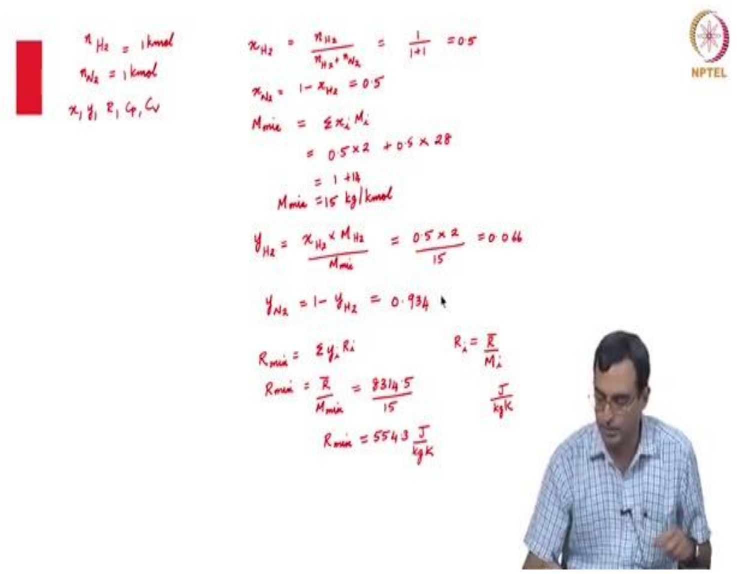

Figure 1.

**Solution of the problem in Fig. 1:**

$n_{H_2} = 1\ kmol, n_{N_2} = 1\ kmol, M_{H_2} = 2\frac{kg}{kmol}, M_{N_2} = 28\frac{kg}{kmol}, \gamma = 1.4$ for a diatomic gas.

Now, $x_{H_2} = \frac{n_{H_2}}{n_{H_2}+n_{N_2}} = \frac{1}{2} = 0.5$ and $x_{N_2} = \frac{n_{N_2}}{n_{H_2}+n_{N_2}} = 0.5$

Molecular weight of the mixture, $M_{mix} = \sum x_i M_i = 0.5 \times 2 + 0.5 \times 28 = 15 \frac{kg}{kmol}$




Mass fractions, $y_{H_2} = \frac{x_{H_2} M_{H_2}}{M_{mix}} = 0.066$ and $y_{N_2} = 1 - 0.066 = 0.934$

We can find $R_{mix}$ using different ways, $R_{mix} = \sum y_i R_i$ or $R_{mix} = \frac{\bar{R}}{M_{mix}}$

We use the second option, $R_{mix} = \frac{\bar{R}}{M_{mix}} = \frac{8314.5 \frac{kJ}{kmol \cdot K}}{15 \frac{kg}{kmol}} = 554.3 \frac{J}{kg \cdot K}$

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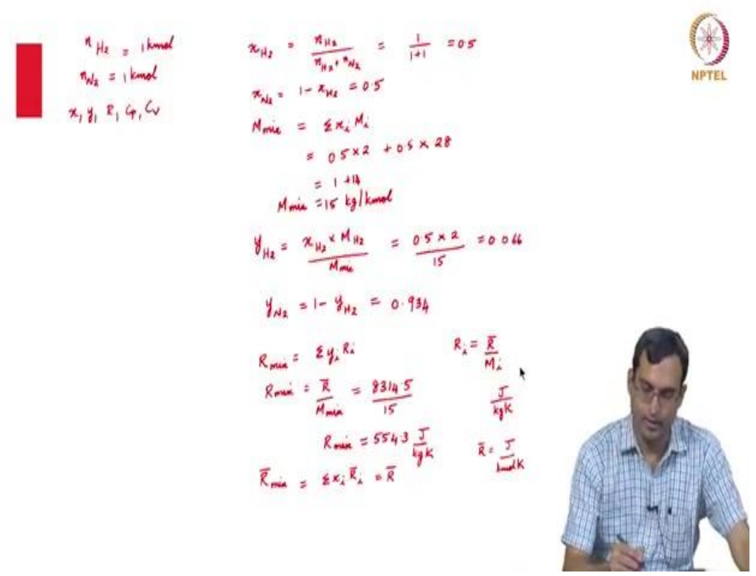

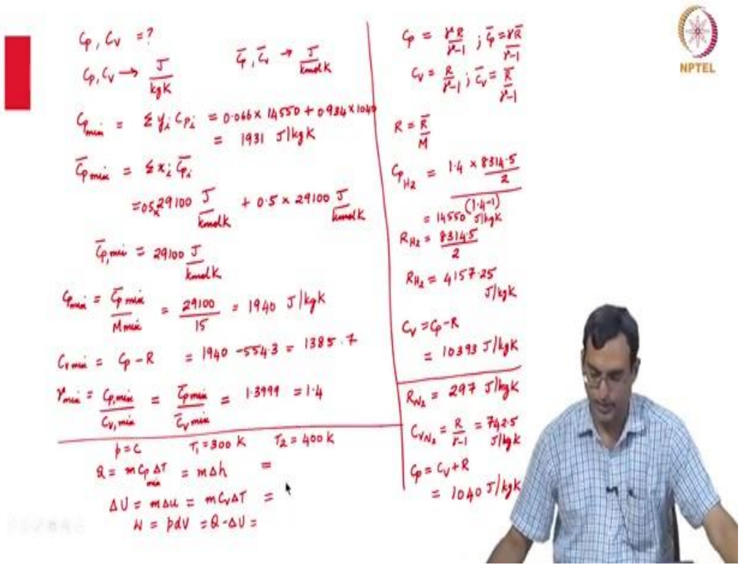

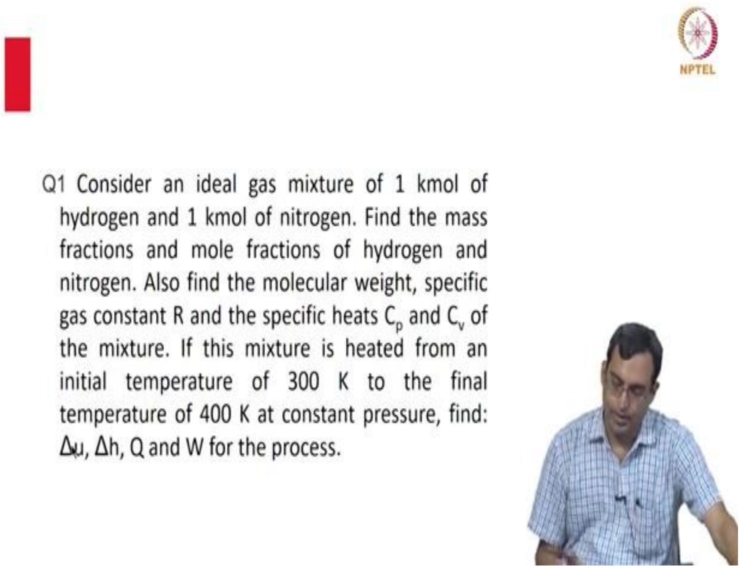


We need to find $C_p$ and $C_v$ of the mixture. Let's also find $\bar{C}_p$ and $\bar{C}_v$ of the mixture.

Now, $C_{p_{H_2}} = \frac{\gamma R}{\gamma - 1} = \frac{1.4\left(\bar{R}/M_{H_2}\right)}{1.4-1} = \frac{1.4\times 4157.25}{0.4} = 14550\,\frac{J}{kg\cdot K}$ and $\bar{C}_{p_{H_2}} = \frac{\gamma \bar{R}}{\gamma-1} = \frac{1.4\times 8314.5}{1.4-1} = 29100\,\frac{J}{kmol\cdot K}$.

Now, $C_{v_{H_2}} = C_{p_{H_2}} - R = \frac{R}{\gamma-1} = 10393\,\frac{J}{kg\cdot K}$ and $\bar{C}_{v_{H_2}} = \bar{C}_{p_{H_2}} - \bar{R} = \frac{\bar{R}}{\gamma-1} = 20786\,\frac{J}{kmol\cdot K}$

In the similar fashion, $C_{p_{N_2}} = 1040\,\frac{J}{kg\cdot K}$, $C_{v_{N_2}} = 742.5\,\frac{J}{kg\cdot K}$, $\bar{C}_{p_{N_2}} = 29100\,\frac{J}{kmol\cdot K}$, $\bar{C}_{v_{N_2}} = 20786\,\frac{J}{kmol\cdot K}$ ($\gamma = 1.4$ for both the gases)

Now, $C_{p_{mix}} = \sum y_i C_{p_i} = 0.066 \times 14550 + 0.934 \times 1040 = 1931\ \frac{J}{kg \cdot K}$.

$\bar{C}_{p_{mix}} = \sum x_i \bar{C}_{p_i} = 0.5 \times 29100 + 0.5 \times 29100 = 29100\ \frac{J}{kmol \cdot K}$ ($C_{p_{mix}}$ can also be calculated as $C_{p_{mix}} = \frac{\bar{C}_{p_{mix}}}{M_{mix}}$)

Now, $C_{v_{mix}} = C_{p_{mix}} - R_{mix} = 1385.7\ \frac{J}{kg \cdot K}$

$$\bar{C}_{v_{mix}} = \bar{C}_{p_{mix}} - \bar{R} = 29100 - 8314.5 = 20786\ \frac{J}{kmol \cdot K}$$

$$\gamma = \frac{C_{p_{mix}}}{C_{v_{mix}}} = \frac{\bar{C}_{p_{mix}}}{\bar{C}_{v_{mix}}} = 1.4$$

There are various ways to calculate $C_{p_{mix}}$ and $C_{v_{mix}}$. You get the same values through all the ways if you consider sufficient digits after decimal point.

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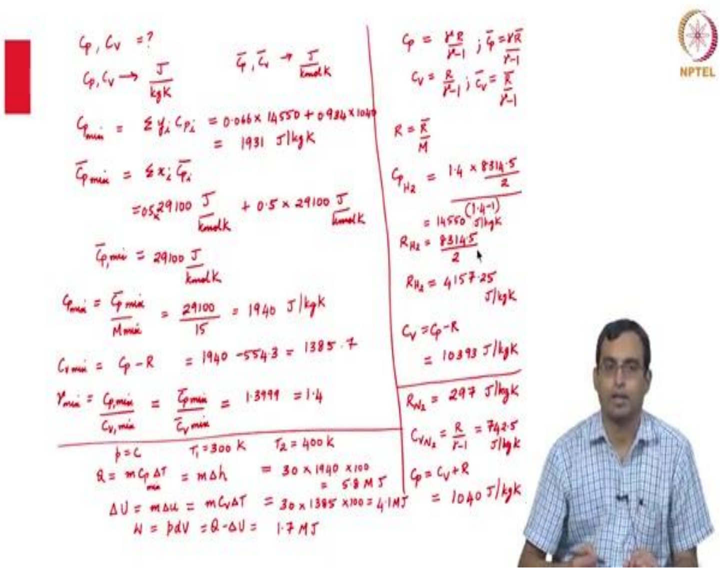

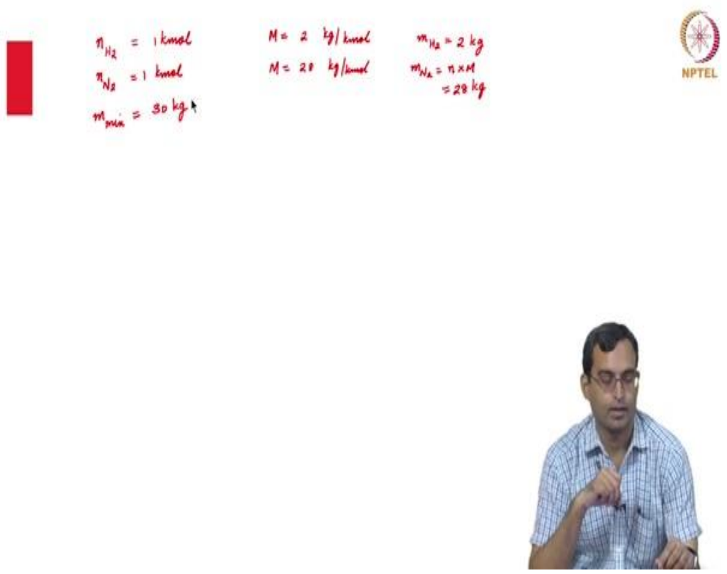


We are also asked to calculate $\Delta u, \Delta h, Q$ and W.

It is a constant pressure process. $T_1 = 300\ K, T_2 = 400\ K$.

$Q = m\Delta h = mC_p\Delta T = 30 \times 1940 \times (T_2 - T_1) = 5.8\ MJ$ $\quad (m = n_{H_2}M_{H_2} + n_{N_2}M_{N_2} = 2 + 28 = 30\ kg)$

$\Delta U = m\Delta u = mC_v\Delta T = 30 \times 1385 \times 100 = 4.1\ MJ$

According to the first law in the integrated form, $W = Q - \Delta U = 1.7\ MJ$.