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B20CS039

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Q.1 After the partition is removed, the gas expands freely
for a free expansion, $dU = 0$

$\Rightarrow mC_v \Delta T = 0 \Rightarrow \Delta T = 0 \Rightarrow T = C$ (const)

$\therefore$ isothermal process.

$P_1V_1 = P_2V_2 \Rightarrow P_1V_1 = P_2(2V_1)$ (as 2 equal parts).

$\Rightarrow P_1 = 2P_2$ [as, $P_1 = 250kPa$]

$\Rightarrow P_2 = \frac{P_1}{2} = \frac{250}{2} = 125\ kPa$

Calculating the total entropy change in the process,

$$\Delta S = N\left[C_p \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)\right] = 5\left[C_p \ln\left(\frac{T_1}{T_1}\right) - 8.314\ln\left(\frac{125}{250}\right)\right]$$

$$\Delta S = 5\left[0 - 8.314\ln\left(\frac{1}{2}\right)\right] \Rightarrow \boxed{\Delta S = 28.81\ kJ/k}$$

Q.2 mass of air in tank $m = 5kg$
temp. of air in tank $T_1 = 327°C = 600k$
Pressure of air in tank $P_1 = 100kPa$
temp. of surroundings $T_2 = 27°C = 300k$

a) Entropy change of air in tank $\Delta S_{air} = mC_v \ln\left(\frac{T_2}{T_1}\right)$
sp. heat of air $C_v = 0.718\ kJ/kgk$.

$$\Delta S_{air} = (5)(0.718)\ln\left(\frac{300}{600}\right) = -2.488\ kJ/k$$

Entropy change of the air in tank during the process,

$$\Delta S_{air} = -2.488\ kJ/k$$

b) From energy balance, $Q_{out} = mC_v(T_2 - T_1)$

$$Q_{out} = (5)(0.718)(327 - 27)$$

$$Q_{out} = 1077\ kJ$$

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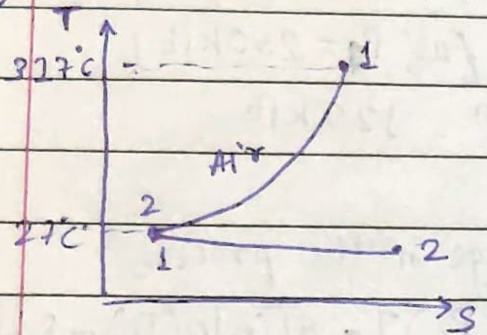
Entropy change of surroundings, $\Delta S_{surr} = \frac{1077\ kJ}{300\ K}$

$\therefore \quad \Delta S_{surr} = 3.59\ kJ/k$

net entropy change of the universe due to the process,

$\Delta S_{total} = \Delta S_{air} + \Delta S_{surr} = -2.488 + 3.59 = \underline{1.10\,kJ/k}$

(c) Air in the tank & surroundings on a single T-S diagram



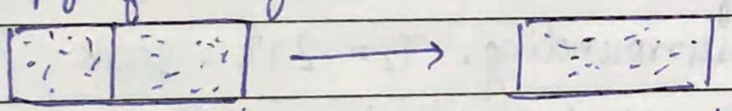
Q-3 Entropy of mixing is $= -R\sum x_i \ln(x_i)$

$= -R\left[0.5\ln(0.5) + 0.5\ln(0.5)\right]$

work $= T\Delta S = T\left[-R\ln(0.5)\right]$

$= -RT\ln(0.5) = RT\ln(2)$

Q-4 Entropy of mixing.



$N_A V_A$ $\quad N_B V_B$ $\quad V_{total} = V_A + V_B$

$\delta S = \frac{\delta q_{rev}}{T} = \frac{1}{T}\left[\frac{nRT\,dv}{V}\right] \Rightarrow \delta S = \frac{nR\,dv}{V}$

$\therefore \Delta S = \int \frac{nR}{V}\,dV \Rightarrow \boxed{\Delta S = nR\ln\left[\frac{V_f}{V_i}\right]}$

$\Delta S_A = n_A R\ln\left[\frac{V_{total}}{V_A}\right]$ $\qquad \Delta S_B = n_B R\ln\left[\frac{V_{total}}{V_B}\right]$

$\Delta S_{mix} = n_A R\ln\left[\frac{V_{total}}{V_A}\right] + n_B R\ln\left[\frac{V_{total}}{V_B}\right]$ $\quad$ as $V = \frac{nRT}{P}$

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$$\Delta S_{mix} = n_A R \ln\left[\frac{n_{total} RT/P}{n_A \frac{RT}{P}}\right] + n_B R \ln\left[\frac{n_{total}}{n_B}\right]$$

$$\frac{\Delta S_{mix}}{n_{total}} = \frac{n_A}{n_{total}} R \ln\left[\frac{n_{total}}{n_A}\right] + \frac{n_B}{n_{total}} R \ln\left[\frac{n_{total}}{n_B}\right]$$

$$\left[X = \frac{n_i}{n_{total}}\right]$$

$$\frac{\Delta S_{mix}}{n_{total}} = X_A R \ln\left[\frac{1}{X_A}\right] + X_B R \ln\left[\frac{1}{X_B}\right]$$

$$\Delta S_{mix} = -n_{total} R\left[X_A \ln(X_A) + X_B \ln(X_B)\right]$$

$$\boxed{\Delta S_{mix} = -n_{total} R \sum_i X_i \ln(X_i)}$$