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Thermo HW 5

1.) $\Delta(U + \frac{v^2}{2} + gz) = \underline{Q} + W_{EC} + \underline{W_s}$ $\quad Q=0,\ V_1 = 1.5L \quad T_1 = 295\,K$

$V_2 = 4L \quad T_2 = ?$

$\Delta U = W_{EC} \rightarrow \int C_v\, dt = \int -P\,dV \rightarrow C_v \int dt = -RT \int \frac{dV}{V}$

$C_v \ln\left|\frac{T_2}{T_1}\right| = -R \ln\left|\frac{V_2}{V_1}\right| \rightarrow \ln\left|\frac{T_2}{T_1}\right| = \frac{-R}{C_v} \ln\left|\frac{V_2}{V_1}\right|$

$\therefore \ln \frac{T_2}{T_1} = \frac{-8.314\ \frac{J}{mol\,K}}{12.5\ \frac{J}{mol\,K}} \ln\left|\frac{4L}{1.5L}\right| = -0.652$

$\therefore \frac{T_2}{T_1} = e^{-0.652} \rightarrow T_2 = T_1 e^{-0.652} = 295\,K\, e^{-0.652} = 154\,K$

$\Delta U = C_v \Delta T = 12.5\ \frac{J}{mol\,K}\,(154 - 295)\,K = -1.76\,kJ$

(2)

2.) $Q=0$ $\quad T_1=260°C$ $\quad P_1=300\,kPa$

$T_2=800°C$ $\quad P_2=2500\,kPa$

$$m\Delta\left(u+\frac{v^2}{2}+gz\right)=Q+W_{EC}+W_S \qquad \Delta u=\Delta(H-PV)$$

$$\rightarrow m\Delta u=W_{EC} \rightarrow m\left(\Delta H-\Delta(PV)\right)=W_{EC}$$

$V_1=.0422\frac{m^3}{kg}$ $\quad V_2=0.1972\frac{m^3}{kg}$

$H_1=2796.6\frac{kJ}{kg}$ $\quad H_2=4149.2\frac{kJ}{kg}$

$$W_{EC}=\Delta H-\Delta(PV)=\left(4149.2\frac{kJ}{kg}-2796.6\frac{kJ}{kg}\right)-\left(2500\,kPa\left(0.1972\frac{m^3}{kg}\right)-300\left(0.0422\right)\right)$$

$$=1352.6-480.34=\boxed{872\frac{kJ}{kg}}$$

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4) $q_1 = 0.30$ $P_1 = 1500\ kPa$ $P_2 = 300\ kPa$ $\quad u = u^L + q(u^v - u^L)$

$H_1^L = 844.55 \frac{kJ}{kg}$

$H_1 = H_2$ $\quad H_1 = H_1^L + q_1(H_1^v - H_1^L)$ $\quad H_1^v = 2791 \frac{kJ}{kg}$

$\therefore H_1 = H_2 = 844.55 \frac{kJ}{kg} + 0.30\left(2791 \frac{kJ}{kg} - 844.55 \frac{kJ}{kg}\right) = 1428.5 \frac{kJ}{kg}$

H_2 SAME $\quad q_2 = \frac{H_2 - H_2^L}{H_2^v - H_2^L}$

$H_2^L = 561.43 \frac{kJ}{kg}$

$H_2^v = 2724.9 \frac{kJ}{kg}$

$\therefore q_2 = \frac{1428.5 - 561.43}{2724.9 - 561.43} = 0.401$ $\quad T = 133.52\ °C$

$u^L = 561.11 \frac{kJ}{kg}$

$u = u^L + q(u^v - u^L)$ $\quad u^v = 2543.2 \frac{kJ}{kg}$

$\therefore u = 561.11 \frac{kJ}{kg} + 0.401\left(2543.2 - 561.11\right)\frac{kJ}{kg} = 1355.5 \frac{kJ}{kg}$

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5) $Q = 0$ $\quad P_1 = 100\ kPa$ $\quad T_1 = 300\ K$ $\quad P_2 = 500\ kPa$ $\quad T_2 = 450\ K$ $\quad \Delta mgh = 0$ $\quad \Delta \frac{mv^2}{2} = 0$

$$\dot{m}\left(\Delta\cancel{u} + g\cancel{h} + \frac{\cancel{v^2}}{2}\right) = \dot{m}\left(H + \frac{\cancel{v^2}}{2} + g\cancel{h}\right)^{in} - \dot{m}\left(H + \frac{\cancel{v^2}}{2} + g\cancel{h}\right)^{out} + \cancel{\dot{Q}} + \dot{W}_s + \cancel{\dot{W}_{PE}}$$

$$\therefore\ 0 = -\dot{m}\,\Delta H + \dot{W}_s \quad \therefore\ W_s = \Delta H$$

$$\Delta H = C_p \Delta T \quad \therefore \quad W_s = -C_p \Delta T = -\frac{7}{2} R \Delta T = -4365\ \frac{m^3 Pa}{mol}$$

~~$\frac{5\ kg}{sec} \cdot \frac{1\ mol}{5\ kg}$~~ $\qquad 5\ \frac{kg}{sec} \cdot \frac{1\ mol}{0.02897\ kg} = 172.6\ \frac{mol}{s}$

$$\dot{W} = -4365\ \frac{m^3 Pa}{mol} \cdot 172.6\ \frac{mol}{sec} = -753340\ \frac{J}{s} = +753\ Kw$$

(6)

6.) $\dot{m} = 5 \frac{kg}{sec}$ $P_1 = 1 MPa$ $P_2 = 100 kPa$ $q = 0.8$

$Q = 0$ $T = 600°C$ $\Delta mgh = 0$

$\Delta m\frac{v^2}{2} = 0$

$$\dot{m}\Delta\left(h + gz + \frac{v^2}{2}\right) = \dot{m}\left(H + gz + \frac{v^2}{2}\right)^{in} - \dot{m}\left(H + gz + \frac{v^2}{2}\right)^{out} + Q + W_{EC} + W_S$$

$$\therefore 0 = +\dot{m}(H_1 - H_2) + \dot{W}_S \rightarrow -\dot{W}_S = \dot{m}H_1 - \dot{m}H_2 \rightarrow W_S = \dot{m}H_2 - \dot{m}H_1$$

$$\therefore \dot{W}_S = \dot{m}\Delta H$$

$H_1 = 3698.6 \frac{kJ}{kg}$

$H_2 = H_2^L + q(H_2^V - H_2^L)$ $H_2^L = 417.5$ $H_2^V = 2674.95$

$H_2 = 417.5 \frac{kJ}{kg} + 0.8(2674.95 - 417.5)\frac{kJ}{kg}$

$= 2223.46 \frac{kJ}{kg}$

$H_2 - H_1 = -1475.14 \frac{kJ}{kg}$

$\dot{W}_S = \dot{m}\Delta H = 5 \frac{kg}{s} \cdot -1475.14 \frac{kJ}{kg} = -7376 \frac{kJ}{s}$