CHEG231 exam 1 sheet

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mass balances

$$\Delta M = \Delta M_{\text{in}} - \Delta M_{\text{out}} \qquad \frac{dM}{dt} = \dot{M_{\text{in}}} - \dot{M_{\text{out}}}$$

energy balance, difference form

$$\left[U + m\left(\frac{v^2}{2} + gh\right)\right]_f - \left[U + m\left(\frac{v^2}{2} + gh\right)\right]_i = Q + W_S + W_{PV} \ldots + \sum_{k=1}^{K} \Delta m_k \left(\hat{U} + P\hat{V} + \frac{v^2}{2} + gh\right)_k$$

energy balance, differential form

$$\frac{d}{dt}\left\{U + M\left(\frac{v^2}{2} + mg\right)\right\} = \dot{Q} + \dot{W_s} + \dot{W_{PV}} + \sum_{k=1}^{K} \dot{m}_k \left(\hat{U} + P\hat{V} + \frac{v^2}{2} + mg\right)$$

entropy balances

$$S_2 - S_1 = \sum_k \int_{t_1}^{t_2} \dot{m}_k \hat{S}_k \; dt + \int_{t_1}^{t_2} \frac{\dot{Q}}{T} \; dt + S_{\text{gen}} \qquad \frac{dS}{dt} = \sum_{k=1}^{K} \dot{m}_k \hat{S}_k + \frac{\dot{Q}}{T} + \dot{S}_{\text{gen}}$$

$$C_V = \left(\frac{\partial \underline{\text{U}}}{\partial T}\right)_V \qquad C_P = \left(\frac{\partial \underline{\text{H}}}{\partial T}\right)_P$$

For Ideal Gasses: $C_P^* = C_V^* + R$ and $C_V^* = df/2$

$$\underline{\text{U}}^{IG} = C_V^* T \qquad \underline{\text{H}}^{IG} = C_P^* T$$

For solids and liquids: $\underline{\text{H}} \approx \underline{\text{U}}$ and incompressible. Also $C_{\text{P}} = 3NR = 24.924$ J/mol*K approx for solids.

lever rule (properties of one component system w/ two phases)

$$\hat{\theta} = \omega^I \hat{\theta}^I + \omega^{II} \hat{\theta}^{II} = \omega^I \hat{\theta}^I + (1 - \omega^I)\hat{\theta}^{II}$$

entropy stuff

$$\Delta \underline{\text{S}}_{\text{ideal gas}} = C_p^* \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)$$

$$\Delta \underline{\text{S}}_{\text{Liquid}} = C_p^* \ln\left(\frac{T_2}{T_1}\right)$$

Helmholts Energy: difference is work required to bring closed, isothermal, constant volume system from state 1 to state 1

$$A = U - TS$$

Gibbs energy: helpmholtz but for closed, isothermal, isobaric system

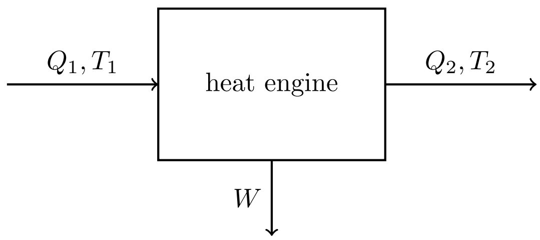
$$G = U + PV - TS = H - TS$$

Gibbs equation

$$d\underline{U} = T\, d\underline{S} - P\, d\underline{V}$$

1 Carnot Derivation

Consider a closed system of a heat engine



energy balance:

$$\cancel{\frac{dU}{dt}} = \dot{Q} + \dot{W} + \cancel{\sum \dot{m}_k ()_k}$$
$$0 = Q_1 + Q_2 + W$$

entropy balance:

$$\cancel{\frac{dS}{dt}} = \frac{\dot{Q}_1}{T_1} + \frac{\dot{Q}_2}{T_2} + \cancel{\sum_{k=1}^{K} \dot{m}_k \hat{S}_k} + \dot{S}_{\text{gen}}$$

$$0 = \frac{\dot{Q}_1}{T_1} + \frac{\dot{Q}_2}{T_2} + \dot{S}_{\text{gen}}$$

integrating, and remembering that reversible processes are more efficient than irreversible processes

$$0 = \frac{Q_1}{T_1} + \frac{Q_2}{T_2}$$

$$\frac{Q_1}{T_1} = \frac{-Q_2}{T_2}$$

$$Q_2 = \frac{-Q_1 T_2}{T_1}$$

and taking this into the energy balance

$$-W = Q_1 + \frac{-Q_1 T_2}{T_1} = Q_1 \left(\frac{T_1 - T_2}{T_1}\right)$$

$$\eta = \frac{-W}{Q_1} = \left(\frac{T_1 - T_2}{T_1}\right)$$