Equations, Units, and Tables
Midterm 1

First Law for closed systems:

$$dU + dE_{\mathrm{K}} + dE_{\mathrm{P}} = \delta Q + \delta W$$

$$\frac{dU}{dt} + \frac{dE_{\mathrm{K}}}{dt} + \frac{dE_{\mathrm{P}}}{dt} = \dot{Q} + \dot{W}$$

PV work:

$$\delta w_{\mathrm{m}} = -P_{\mathrm{E}} dv_{\mathrm{m}}$$

First Law for open systems with one input and one output stream:

$$\begin{aligned} dU + dE_{\mathrm{K}} + dE_{\mathrm{P}} = {} & dn_{\mathrm{in}}\left[h_{\mathrm{m}} + \frac{1}{2}|v|^2\,(MW) + gz(MW)\right]_{\mathrm{in}} \\ & -dn_{\mathrm{out}}\left[h_{\mathrm{m}} + \frac{1}{2}|v|^2\,(MW) + gz(MW)\right]_{\mathrm{out}} \\ & +\delta Q + \delta W_{\mathrm{s}} \end{aligned}$$

$$\begin{aligned} \frac{dU}{dt} + \frac{dE_{\mathrm{K}}}{dt} + \frac{dE_{\mathrm{P}}}{dt} = {} & \dot{n}_{\mathrm{in}}\left[h_{\mathrm{m}} + \frac{1}{2}|v|^2\,(MW) + gz(MW)\right]_{\mathrm{in}} \\ & -\dot{n}_{\mathrm{out}}\left[h_{\mathrm{m}} + \frac{1}{2}|v|^2\,(MW) + gz(MW)\right]_{\mathrm{out}} \\ & +\dot{Q} + \dot{W}_{\mathrm{s}} \end{aligned}$$

Enthalpy definition:

$$h_{\mathrm{m}} = u_{\mathrm{m}} + Pv_{\mathrm{m}}$$

Enthalpy of vaporization:

$$\Delta h_{\mathrm{m,vap}}(T) = \Delta h_{\mathrm{m,vap}}(T_0) + \int_T^{T_0} c_{\mathrm{p,m}}^{\mathrm{liq}} dT + \int_{T_0}^{T} c_{\mathrm{p,m}}^{\mathrm{vap}} dT$$

Property data for ideal gases:

$$du_{\mathrm{m}} = c_{\mathrm{v,m}} dT$$

$$dh_{\mathrm{m}} = c_{\mathrm{p,m}} dT$$

Carnot efficiency:

$$\eta = \frac{T_{\mathrm{H}} - T_{\mathrm{C}}}{T_{\mathrm{H}}}$$

Entropy changes:

$$ds_{\mathrm{m}} = \frac{\delta q_{\mathrm{rev,m}}}{T}$$

Differential entropy change for an ideal gas:

$$ds_{\mathrm{m}} = c_{\mathrm{p,m}} \frac{dT}{T} - R\frac{dP}{P}$$

Second Law for closed systems:

$$\frac{dS}{dt} - \frac{\dot{Q}}{T_{\mathrm{surr}}} \geq 0$$

$$\Delta S - \frac{Q}{T_{\mathrm{surr}}} \geq 0$$

Second Law for open systems with one input and one output stream:

$$dS + s_{\mathrm{m,out}} dn_{\mathrm{out}} - s_{\mathrm{m,in}} dn_{\mathrm{in}} - \frac{\delta Q}{T_{\mathrm{surr}}} \geq 0$$

$$\frac{dS}{dt} + s_{\mathrm{m,out}} \dot{n}_{\mathrm{out}} - s_{\mathrm{m,in}} \dot{n}_{\mathrm{in}} - \frac{\dot{Q}}{T_{\mathrm{surr}}} \geq 0$$

Units and constants:

R = 8.314 J/(mol K)

g = 9.8 m/s^2

1 bar = 10^5 Pa = 10^5 kg/(m s^2)