3.29 Residual functions of enthalpy and Gibbs potential

To calculate the residual function of the enthalpy $H^{res}(T,p)$ we now start with

$$H(T,0) - H^{ideal}(T,0) = 0 \qquad \left(\frac{\partial H}{\partial p}\right)_T = V - T\left(\frac{\partial V}{\partial T}\right)_p \qquad \left(\frac{\partial H^{ideal}}{\partial p}\right)_T = V^{ideal} - T\frac{nR}{p} = 0 \tag{3.71}$$

and get

$$\begin{aligned} H^{res}(T,p) =& \; H(T,p) - H^{ideal}(T,p) \\ =& \; H(T,0) - H^{ideal}(T,0) + \int_0^p \left(\left(\frac{\partial H}{\partial p}\right)_T - \left(\frac{\partial H^{ideal}}{\partial p}\right)_T\right) dp \\ \Rightarrow H^{res}(T,p) =& \; \int_0^p \left(V - T\left(\frac{\partial V}{\partial T}\right)_p\right) dp \end{aligned} \tag{3.72}$$

Combining Eq. (3.70) and Eq. (3.72) we find according to the definition of the Gibbs potential

$$\begin{aligned} G^{res}(T,p) =& \; H^{res}(T,p) - T\,S^{res}(T,p) \\ =& \; \int_0^p \left(V - T\left(\frac{\partial V}{\partial T}\right)_p\right) dp - T\left[\int_0^p \left(-\left(\frac{\partial V}{\partial T}\right)_p + \frac{n\,R}{p}\right) dp\right] \\ =& \; \int_0^p \left(V - \frac{n\,R\,T}{p}\right) dp \end{aligned} \tag{3.73}$$