Example 10.2: Chemical Potential in Air

Repeat the calculations of the previous example if the reference state for all components is the pure component at $P_0 = 0.5$ bar, $T_0 = 800$ K.

Solution We outline the solution and leave the calculations as an exercise. The chemical potential of component i is

$$\mu_i = G_i^{\mathrm{ig}} + RT \ln x_i.$$

Therefore, the only additional task is the calculation of the Gibbs energy of pure component. To calculate the Gibbs energy of pure component at the temperature and pressure of the mixture, T and P, we first calculate the enthalpy and entropy at this state. To do this we use the ideal-gas equations

$$H_i^{\mathrm{ig}} = H_{0i} + \int_{T_0}^{T} C_{P\,i}^{\mathrm{ig}} \, dT,$$

$$S_i^{\mathrm{ig}} = S_{0i} + \int_{T_0}^{T} C_{P\,i}^{\mathrm{ig}} \frac{dT}{T} - R \ln \frac{P}{P_0}.$$

Both H_{0i} and S_{0i} are equal to zero but we leave them in the equations until numerical substitution. The Gibbs energy of pure component at T, P, is

$$G_i^{\mathrm{ig}} = H_i^{\mathrm{ig}} - TS_i^{\mathrm{ig}} = G_{i0}^{\mathrm{ig}} + \int_{T_0}^{T} C_{P\,i}^{\mathrm{ig}} \, dT - T \int_{T_0}^{T} C_{P\,i}^{\mathrm{ig}} \frac{dT}{T} + RT \ln \frac{P}{P_0}.$$

The only piece of information needed to perform this calculation is the ideal-gas heat capacity as a function of temperature. If the heat capacity may be assumed to be independent of temperature in the interval T_0, to T, the result is simplified to

Replace R with T

$$G_i^{\mathrm{ig}} = C_P^{\mathrm{ig}}(T - T_0) - \overset{T}{\cancel{R}} C_P^{\mathrm{ig}} \ln \frac{T}{T_0} + RT \ln \frac{P}{P_0}.$$

Comments Notice that the value of ΔG_{mix} is not affected by the change of the reference states. The Gibbs energy of the mixture by the new reference state is

$$G_{\mathrm{mixture}} = \sum_i x_i G_i^{\mathrm{ig}} + RT \sum_i \ln x_i,$$

and the Gibbs energy of the pure components at the temperature and pressure of the mixture is

$$G_{\text{pure comp.}} = \sum_i x_i G_i^{\mathrm{ig}}.$$

Upon taking the difference, the G_i^{ig} terms cancel and the result is the familiar Gibbs energy of mixing.