Problem 11.1

What is the change in entropy when 0.7 m^3 of CO_2 and 0.3 m^3 of N_2, each at 1 bar and 25 °C blend to form a gas mixture at the same conditions? Assume ideal gases.

Solution:

Label CO_2 and N_2 as (1) and (2) respectively

$$V_1 = 0.7 \text{ m}^3 \qquad V_2 = 0.3 \text{ m}^3$$

For ideal gases it follows that:

$$x_1 = 0.7 \qquad x_2 = 0.3$$
$$P = 1 \text{ bar} \qquad T = 298.15 \text{ K}$$
$$n = \frac{P\sum_i V_i}{RT}$$
$$n = 40.340 \text{ mol}$$
$$\Delta S = -nR\sum_i x_i \ln x_i$$
$$\boxed{\Delta S = 204.885 \text{ J K}^{-1}}$$

Problem 11.2

A vessel, divided into two parts by a partition, contains 4 mol of nitrogen gas at 75 °C and 30 bar on one side and 2.5 mol of argon gas at 130 °C and 20 bar on the other. If the partition is removed and the gases mix adiabatically and completely, what is the change in entropy? Assume nitrogen to be an ideal gas with $C_V = (5/2)R$ and argon to be an ideal gas with $C_V = (3/2)R$.

Solution:

Label N_2 and Ar as (1) and (2) respectively

$$n_1 = 4 \text{ mol} \qquad n_2 = 2.5 \text{ mol}$$
$$t_1 = 75 \text{ °C} \qquad t_2 = 130 \text{ °C}$$
$$P_1 = 30 \text{ bar} \qquad P_2 = 20 \text{ bar}$$
$$C_{V,1} = (5/2)R \qquad C_{V,2} = (3/2)R$$

Find T after mixing by energy balance:

$$n_1 C_{V,1}(T - T_1) = n_2 C_{V,2}(T_2 - T)$$
$$T = 363.15 \text{ K}$$

Find P after mixing:

$$V = V_1 + V_2$$
$$\frac{(n_1 + n_2)RT}{P} = \frac{n_1 R T_1}{P_1} + \frac{n_2 R T_2}{P_2}$$
$$P = 24.38 \text{ bar}$$

Calculate the entropy change:

$$\Delta S_i = n_i \left[C_{P,\,i} \ln\left(\frac{T}{T_i}\right) - R \ln\left(\frac{P}{P_i}\right) \right]$$
$$\Delta S_1 = 11.806 \text{ J K}^{-1} \qquad \Delta S_2 = -9.547 \text{ J K}^{-1}$$
$$\Delta S_{\text{mix}} = n \left[-R \sum_i x_i \ln x_i \right]$$
$$\Delta S_{\text{mix}} = 36.007$$
$$\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_m ix$$
$$\boxed{\Delta S = 38.27 \text{ J K}^{-1}}$$