Example 9.5: Compression of Real Mixture

A mixture of carbon dioxide (75% by mol) and pentane (25% by mol) is compressed from 1 bar, 250 K to 20 bar. Determine the work for compression the final temperature and the entropy generation, if the efficiency of the compressor is 80%. Use the SRK equation with $k_{12} = 0.12$.

Solution The procedure for the calculation of the ~~compressor~~ compressor work is the same as for pure fluids (see Chapter 5). The calculation will be done in two steps, one for reversible operation and one for the actual process. The enthalpy and entropy of the mixture will be calculated as in Example 9.3, using the same reference states as in that example. First, we calculate the properties at the inlet state. These are summarized below:

$$T_1 = \text{~~295.15~~ } 250 \text{ K}, \quad P_1 = 1 \text{ bar}, \quad H_1 = -247.657 \text{ kJ/kg}, \quad S_1 = 3.92219 \text{ kJ/kg K}.$$

For the subsequent calculations it will be useful to tabulate the properties of the compressed stream at various temperatures. This is done below.

T (K)	P (bar)	H (J/mol)	S (J/mol K)
400	20	5517.11	−3.41831
425	20	7383.45	1.10696
450	20	9297.33	5.48221
475	20	11261.5	9.72966
500	20	13277.2	13.8648

Reversible operation. For reversible operation, the exit state is defined by the conditions $P_2 = 20$ bar, $S_{2'} = S_1 = 3.92219$ kJ/kg. By interpolation in the above table we find,

$$T_{2'} = 441.086, \quad H_{2'} = 8614.93 \text{ J/mol K}.$$

Actual operation. The enthalpy of the actual outlet is

$$H_2 = H_1 + \frac{H_{2'} - H_1}{\eta} = (-247.657) + \frac{8614.93 - (-247.657)}{0.8} = 10830.6 \text{ J/mol}.$$

The work for compression is

$$W = H_2 - H_1 = (10830.6) - (-247.657) = 11078.2 \text{ J/mol}.$$

The exit state is obtained by interpolation at $P_2 = 20$ bar, $H_2 = 10830.6$ J/mol. We find

$$T_2 = 444.51 \text{ K}, \quad S_2 = 4.42249 \text{ J/mol K}.$$

Entropy generation. The entropy generation is

$$S_{\text{gen}} = S_2 - S_1 = 0.500 \text{ J/mol K}.$$

Comments Energy balances involving mixtures are performed in the same manner as for pure fluids. All that is required is a method for the calculation of enthalpy and entropy at given pressure, temperature, and composition.