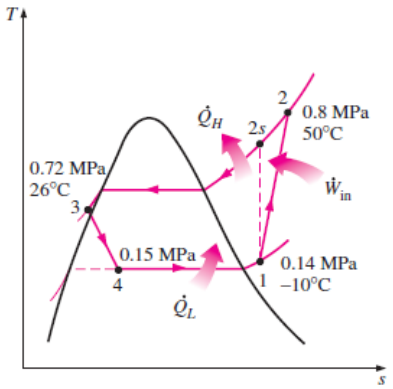
Example 12

Refrigerant-134a enters compressor as superheated vapor at 0.14 MPa and -10°C at a rate of 0.05kg/s and leaves at 0.8MPa and 50°C. The refrigerant is cooled in condenser to 26°C and 0.72 MPa and is throttled to 0.15 MPa. Disregarding any heat transfer and pressure drops in the connecting lines between the components, determine (*a*) the rate of heat removal from the refrigerated space and the power input to the compressor, (*b*) the isentropic efficiency of the compressor, and (*c*) the coefficient of performance of the refrigerator.



$P_1 = 0.14\ \text{MPa}$

$T_1 = -10°\text{C}$

$$\Rightarrow h_1 = 246.36\ \text{kJ/kg}$$

$$\Rightarrow s_1 = 0.9724\ \text{kJ/kg}$$

$P_2 = 0.8\ \text{MPa}$

$T_2 = 50°\text{C}$

$$\Rightarrow h_2 = 286.69\ \text{kJ/kg}$$

$P_3 = 0.72\ \text{MPa}$

$T_3 = 26°\text{C}$

$$\Rightarrow h_3 \approx h_{f@26°C} = 87.83\ \text{kJ/kg}$$

a) Rate of heat removal from the refrigerated space and power input to compressor are:

$$\dot{Q}_L = \dot{m}(h_1 - h_4) = 0.05\ \text{kg/s}[(246.36 - 87.83)\ \text{kJ/kg}] = 7.93\ \text{kW}$$

$$\dot{W}_{in} = \dot{m}(h_2 - h_1) = 0.05\ \text{kg/s}[(286.69 - 246.36)\ \text{kJ/kg}] = 2.02\ \text{kW}$$

b) The isentropic efficiency of the compressor

$$P_{2s} = 0.8\ \text{MPa}$$
$$s_{2s} = s_1 = 0.9724 \text{kJ/kg} \cdot \text{K}$$
$$\Rightarrow h_{2s} = 284.21\ \text{kJ/kg}.$$

$$\eta_C = \frac{h_{2s} - h_1}{h_2 - h_1} = \frac{284.21 - 246.36}{286.69 - 246.36} = 0.939@93.95\%$$

c) The coefficient of performance of the refrigerator is;

$$COP_R = \frac{\dot{Q}_L}{\dot{W}_{in}} = \frac{7.93\ \text{kW}}{2.02\ \text{kW}} = 3.93$$

This problem is identical to the one worked out in Example 11, except that the refrigerant is slightly superheated at the compressor inlet and subcooled at the condenser exit. Also, the compressor is not isentropic. As a result, the heat removal rate from the refrigerated space increases (by 10.4 percent), but the power input to the compressor increases even more. Consequently, the COP of the refrigerator decreases from 3.97 to 3.93.