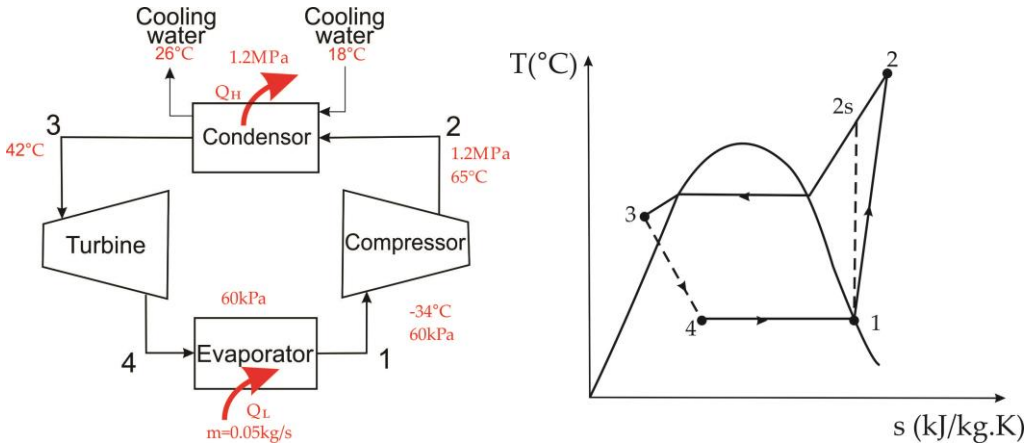
A commercial refrigeration with refrigerant-134a as the working fluid is used to keep the refrigerated space at -30°C by rejecting its waste heat to cooling water that enters the condenser at 18°C at a rate of 0.25kg/s and leaves at 26°C. The refrigerant enters the condenser at 1.2MPa and 65°C and leaves at 42°C. The inlet state of the compressor is 60kPa and -34°C and the compressor is estimated to gain a net heat of 450W from the surroundings. Determine,

a. the quality of the refrigerant at the evaporator inlet
b. the refrigeration load
c. the COP of the refrigerator
d. the theoretical maximum refrigeration load for the same power input to the compressor



a)

From table,

$$h_{1,60kPa,-34°C} = 230.03\,kJ/kg$$

$$h_{2,1200kPa,65°C} = 295.16\,kJ/kg$$

$$h_{3,f,1200kPa,42°C} = 111.23\,kJ/kg$$

$$h_3 = h_3 = 111.23\,kJ/kg$$
$$P_4 = 60kPa$$

$$h_4 = h_{f,4} + x_4 h_{fg,4}$$
$$x_4 = \frac{111.23 - 3.841}{227.79} = 0.47$$

b) Using saturated liquid enthalpy at given temperature for water

$$h_{water,1} = h_{f,18°C} = 75.47\,kJ/kg$$
$$h_{water,2} = h_{f,26°C} = 108.94\,kJ/kg$$

Using energy balance:

$$\dot{m}_{R134}(h_2 - h_3) = \dot{m}_{water}(h_{water,2} - h_{water,1})$$
$$\dot{m}_R(295.16 - 111.23) = 0.25(108.94 - 75.47)$$
$$\dot{m}_R = 0.0455 kg/s$$

The waste heat transferred from the refrigerant are;

$$\dot{Q}_H = \dot{m}_{R134}(h_2 - h_3) = 0.0455(295.16 - 111.23) = 8.367kW$$
$$\dot{W}_{in} = \dot{m}_R(h_2 - h_1) - \dot{Q}_{in} = 0.0455(295.16 - 230.03) - 0.45kW = 2.513kW$$
$$\dot{Q}_L = \dot{Q}_H - \dot{W}_{in} = 8.367 - 2.513 = 5.85kW$$

c)

$$COP = \frac{\dot{Q}_L}{\dot{W}_{in}} = \frac{5.85}{2.513} = 2.33$$

d)

$$COP_{max} = \frac{1}{\frac{T_H}{T_H} - 1} = \frac{1}{\frac{18 + 273}{-30 + 273} - 1} = 5.063$$

$$\dot{Q}_{L,max} = COP_{max}\dot{W}_{in} = 5.063 \times 2.513 = 12.72kW$$