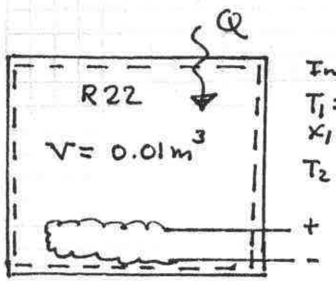
PROBLEM 3.63

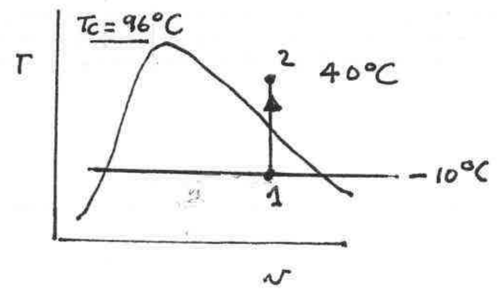
KNOWN: A closed, rigid tank fitted with a resistor is filled with Refrigerant 22, initially a two-phase liquid-vapor mixture. State data and operating data are provided.

FIND: Determine the heat transfer from the refrigerant, in kJ.

SCHEMATIC & GIVEN DATA:



Initially
$T_1 = -10°C$
$x_1 = 0.8$
$T_2 = 40°C$



ENGINEERING MODEL:

1. The closed system is the R22 plus resistor.
2. The mass and volume of the fine-wire resistor are negligible.
3. Kinetic and potential energy can be ignored.

ANALYSIS:

Since the total mass and volume of the R22 remain constant, the refrigerant undergoes a constant specific volume process, as shown in the T-v diagram.

An energy balance reduces as follows:

$$(\Delta U]_{R22} + \underbrace{\cancel{\Delta U}]_{Resistor}}_{\text{by assumption 2}}^{0}) + \cancel{\Delta KE} + \cancel{\Delta PE} = Q - W$$

$$\Rightarrow \quad Q = \Delta U]_{R22} + W = m(u_2 - u_1) + W \qquad (1)$$

With data from Table A-7,

$$\begin{cases} u_1 = u_f + x_1(u_g - u_f) = 33.27 + 0.8(223.02 - 35.27) = 185.07 \text{ kJ/kg} \\ v_1 = v_f + x_1(v_g - v_f) = (0.7606/10^3) + 0.8(0.0652 - (0.7606/10^3)) = 0.0523 \text{ m}^3/\text{kg} \end{cases}$$

Interpolating in Table A-9 with $T_2 = 40°C$ and $v_2 = v_1$, $u_2 = 250.33$ kJ/kg

The mass is $m = \dfrac{V}{v_1} = \dfrac{0.01 \text{ m}^3}{0.0523 \text{ m}^3/\text{kg}} = 0.191$ kg

With Eq. 2.21, $W = -\mathcal{E}\, i\, \Delta t$

$$= -(12\text{ V})(5\text{ amp})(5\text{ min})\left|\frac{1\text{ Watt/amp}}{1\text{ volt}}\right|\left|\frac{60\text{ s}}{1\text{ min}}\right|\left|\frac{1\text{ J/s}}{1\text{ W}}\right|\left|\frac{1\text{ kJ}}{10^3\text{ J}}\right|$$

$$= -18\text{ kJ}$$

Collecting results, Eq. (1) gives

$$Q = (0.191\text{ kg})(250.33 - 185.07)\frac{\text{kJ}}{\text{kg}} + (-18\text{ kJ}) = -5.54\text{ kJ}$$

With assumption 2, we associate this heat transfer with the R22. Accordingly, the heat transfer from the refrigerant is 5.54 kJ.