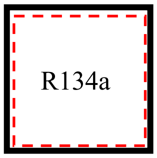
A closed, rigid tank contains Refrigerant 134a, initially at 100 °C. The refrigerant is cooled until it becomes saturated vapor at 20 °C. Kinetic and potential energy effects can be ignored. For the refrigerant, determine the initial and final absolute pressures, each in bar, and the heat transfer, in kJ/kg.

SOLUTION:
The system is the R134a contained in the tank.



Since the tank is rigid and closed, the system volume and mass are constant. Thus, the specific volume of the system also remains constant (recall that $v = V/m$), i.e., $v_2 = v_1$. We're told that the system is a saturated vapor at 20 °C. Using the SLVM-temperature table, at T_2 = 20 °C,

$\boxed{p_2 = 5.7171 \text{ bar (abs)}}$,
$v_2 = v_{2g} =$ 0.035997 m^3/kg,
$u_2 = u_{2g} =$ 241.02 kJ/kg.

Again, since $v_2 = v_1$,
v_1 = 0.035997 m^3/kg.

From the SLVM-temperature table with T_1 = 100 °C, v_{1g} = 0.0026809 m^3/kg (and p_{sat} = 39.724 bar (abs)), which is smaller than v_1. Thus, the R134a must be in a SHV phase at state 1. Using the SHV table with T_1 = 100 °C and v_1 = 0.035997 m^3/kg, the pressure at state 1 is between 7.0 bar (abs) where $(T, v)_{7\text{ bar}}$ = (100 °C, 0.040642 m^3/kg) and 8.0 bar (abs), where $(T, v)_{8\text{ bar}}$ = (100 °C, 0.035193 m^3/kg). Using linear interpolation,

$$p_1 = 8.0\text{ bar} + \left(\frac{7\text{ bar} - 8\text{ bar}}{v_{7\text{ bar}} - v_{8\text{ bar}}}\right)(v_1 - v_{8\text{ bar}}),$$

where,
$v_{7\text{ bar}}$ = 0.040642 m^3/kg,
$v_{8\text{ bar}}$ = 0.035193 m^3/kg,
v_1 = 0.035997 m^3/kg,
⇨ $\boxed{p_1 = 7.85 \text{ bar (abs)}}$.

Similarly, the specific internal energy at state 1 may be found via linear interpolation,

$$u_1 = u_{8\text{ bar}} + \left(\frac{u_{7\text{ bar}} - u_{8\text{ bar}}}{v_{7\text{ bar}} - v_{8\text{ bar}}}\right)(v_1 - v_{8\text{ bar}}),$$

where,
$u_{8\text{ bar}}$ = 309.15 kJ/kg,
$u_{7\text{ bar}}$ = 309.95 kJ/kg,
$v_{7\text{ bar}}$ = 0.040642 m^3/kg,
$v_{8\text{ bar}}$ = 0.035193 m^3/kg,
v_1 = 0.035997 m^3/kg,
⇨ u_1 = 309.268 kJ/kg.

The heat transfer may be found using the 1st Law applied to the system,

$$\Delta E_{sys} = Q_{into\ sys} - W_{by\ sys},$$

where,

$$\Delta E_{sys} = \Delta U_{sys} + \Delta KE_{sys} + \Delta PE_{sys} \approx \Delta U_{sys} = m\Delta u_{sys} = m(u_2 - u_1),$$

(assuming changes in KE and PE are small in comparison to changes in internal energy)

$W_{by\ sys} = 0$, (since the tank is rigid)

⇨ $Q_{into\ sys} = m(u_2 - u_1) \Rightarrow \frac{Q_{into\ sys}}{m} = (u_2 - u_1)$.

Using the previously calculated values,

$\boxed{\frac{Q_{into\ sys}}{m} = -68.2 \text{ kJ/kg}}$. (Energy is leaving the system.)

The process is shown in the following *p*-*v* sketch,