Homework 3

Saturday, February 27, 2021 7:44 PM

"I pledge my honor I have abided by the Stevens Honor system."

- Alex [signature]

1. A (rigid) container of R-134a is shown. [15]

R-134a
300 kPa
10 kg
14 L

a) Find the total enthalpy and temperature of the refrigerant.

$v_s = \frac{V}{m} = \frac{.014}{10} = .0014$

$h = h_f + x h_g$

$x = \frac{.0014 - .0007734}{.0680575 - .0007734} = .009$

$h = 52.65 + (.009)(198.195)$

$\boxed{h = 54.43 \text{ kJ/kg} \quad T = .6°C}$

b) If the container is heated until P = 600 kPa, what is the final temperature and total enthalpy in the container?

@ 600 kPa (using table)

$\boxed{T = 21.6°C}$

$x = \frac{.0014 - .0008918}{.034335 - .0008918}$

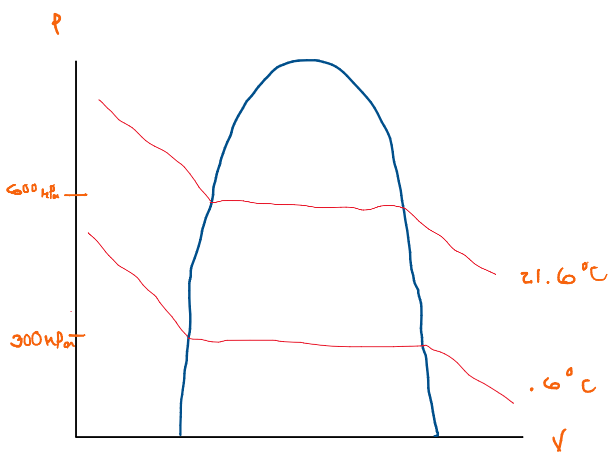
$x = .017$

$h = h_f + x h_g$

$h = 81.5 + (.017)(180.95)$

$\boxed{h = 84.58 \text{ kJ/kg}}$

c) Draw this process on a P-V diagram.



2. A piston–cylinder device contains 0.6 kg of steam at 200°C and 0.5 MPa. Steam is cooled at constant pressure until one-half of the mass condenses. [15]

(a) Show the process on a T-v diagram.

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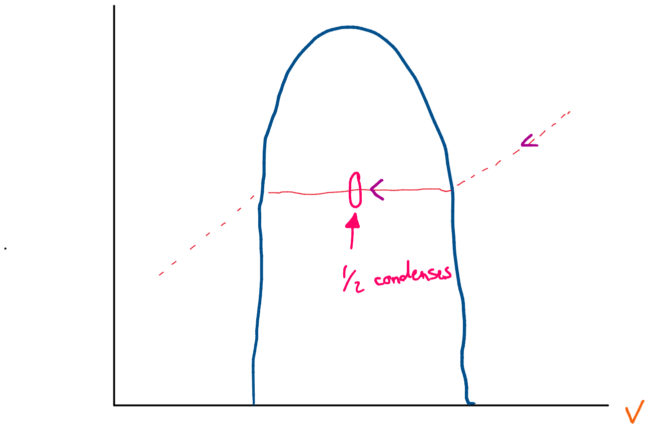


(b) Find the final temperature.

From table @ .5 MPa

$\boxed{T = 151.83\ ^\circ C}$

(c) Determine the volume change.

$V_s' = V_f + V_g = mv + m'v' = .3(.001093) + .3(.37483)$

$V_s' = .1128\ m^3$

$\Delta V = V_s' - V_s = .1128 - .6(.42503)$

$\boxed{\Delta V = -.142\ m^3}$

3. Can water vapor be treated as an ideal gas? Discuss briefly. [5]

Because of the polarity in water molecules (and hydrogen bonds) it is difficult for water to conduct a perfect phase change like an ideal gas would.

4. Air fills an automobile tire with a volume of 0.53 ft³ and is at 90°F and 20 psig. Determine the amount of air that must be added to raise the pressure to the recommended value of 30 psig. Assume the atmospheric pressure to be 14.6 psia and the temperature and the volume to remain constant. [15]

$P_i = P_g + P_{atm} = 20 + 14.6 = 34.6$ psia $\qquad P_f = P_g' + P_{atm} = 30 + 14.6 = 44.6$ psia

$PV = mRT \;;\; m = \frac{PV}{RT}$

$m = \frac{34.6(.53)}{\ } = .09$ lbm. $\qquad m' = \frac{44.6(.53)}{(\ldots)} = .116$ lbm.

$$m = \frac{34.6(.53)}{.3704(550)} = .09 \text{ lbm.} \qquad m' = \frac{44.6(.53)}{.3704(550)} = .116 \text{ lbm.}$$

$$\Delta m = m' - m = .116 - .09$$

$$\boxed{\Delta m = .0206 \text{ lbm.}}$$

5. Determine the specific volume (v) of superheated water vapor at 15 MPa and 350°C, using (a) the ideal-gas equation, (b) the generalized compressibility chart, and (c) the steam tables. Assuming the steam tables give the correct answer, determine the error involved in methods (a) and (b) to find v[1].

A.) $R = .4615$; $P_{cr} = 22.06$ MP ; $T_{cr} = 647.1$ K

$$V_{ideal} = \frac{RT}{P} = \frac{.4615(623.15)}{15 \times 10^3} = .01917 \frac{m^3}{kg}$$

$$E\% = \frac{V_{ideal} - V_{table}}{V_{table}}(100) = \frac{.01917 - .01148}{.01148}(100) = 67\% \text{ error}$$

B.) $P' = \frac{15}{22.06} = .68$; $T' = \frac{623}{647.1} = .96$

$$Z = .65$$

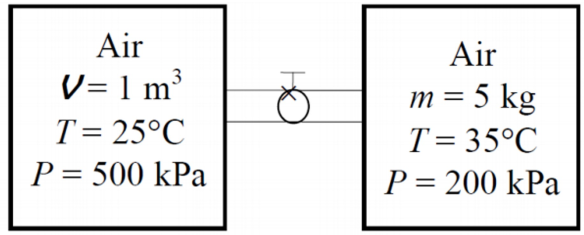
$$V' = z(V_{ideal}) = .65(.01917) = .01246 \frac{m^3}{kg}$$

$$E\% = \frac{V' - V_{table}}{V_{table}}(100) = \frac{.01246 - .01148}{.01148}(100) = 8.5\% \text{ error}$$

C.) $V_{table} = .01148 \frac{m^3}{kg}$

∴ Based on the percent error in each case compared to the table values, this correlates with my answer for number 3.

6. Two rigid tanks connected by a valve to each other contain air at the conditions shown in the diagram. When the valve is opened the entire system is allowed to reach thermal equilibrium at 20°C. The volume of the second tank and the final equilibrium pressure when the valve is opened are to be determined. [15]



$R = .287$

$V_1 = \frac{m_1 R T_1}{P_1} = \frac{5(.287)(308)}{200} = \boxed{2.21\ m^3}$

$m = \frac{PV}{RT} = \frac{500(1)}{.287(298)} = 5.846$ kg.

$V_f = V_1 + V_2 = 1 + 2.21 = 3.21\ m^3$ $\quad m_f = m + m' = 5.846 + 5 = 10.846$ kg.

$P_f = \frac{mRT}{V} = \frac{10.846(.287)(293)}{3.21} = \boxed{284.1\ kPa}$

7. Is it possible to compress an ideal gas isothermally in an adiabatic piston–cylinder device? Explain using the energy equation. [5]

$\Delta U = Q - W$

(Energy Equation)

For an isothermal process $\Delta U = 0$. For an adiabatic process $Q = 0$.

For this to be valid, W must be 0, which means the system can't do any work.

Thus, it is not possible.

8. A 20 ft³ rigid tank (constant volume) initially contains saturated vapor R134a at 160 psia. As a result of cooling the system, the pressure drops to 50 psia. Show the process on a P-v diagram with respect to saturation lines, and determine (a) the final temperature, (b) the amount of refrigerant that has condensed, and (c) the heat transfer. [15]

A.) Using the table: $\boxed{T = 40.23°C}$

B.) $v = .29339\ \frac{ft^3}{lbm}$

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$x = \frac{.29339 - .01252}{.94909 - .01252} = .2999$ $m = \frac{V}{v} = \frac{20}{.29339} = 68.169$ lbm.

$m = (1 - x) m = (1 - .2999) 68.169$

$\boxed{m = 47.725 \text{ lbm.}}$

C.) $u_1 = 108.51 \frac{Btu}{lbm}$

$u_2 = u_f + x_2 u_{fg} = 24.824 + .2999 (75.228) = 47.385 \frac{Btu}{lbm}$

$Q = m(u_2 - u_1) = 68.169 (47.385 - 108.51)$

$\boxed{Q = -4167 \text{ Btu}}$