Solution

ES 3053 **EXAM I** **September 30, 2019**

Open Books and Notes

A frictionless piston and cylinder arrangement initially contains V_1=2500 cm^3 of pure, *saturated liquid* R-134a at P_1=400 kPa. Use the R-134a tables in the back of your book for part I below.

I. 20 points total

A. 5 points
How many kg (kilograms) of R-134a does the piston and cylinder arrangement contain?

B. 5 points
What is the temperature in °C?

B. 10 points
What are the total enthalpy (H_1) and internal energy (U_1) of the R-134a in kJ?

The piston and cylinder arrangement is then heated reversibly on a hot plate holding the temperature constant, until only saturated *vapor* exists. Use the R-134a tables for part II below.

II. 55 points total

A. 10 points
What is the total volume (V_2) of the R-134a in cm^3?

B. 10 points
What are the total enthalpy (H_2) and internal energy (U_2) of the R-134a in kJ?

C. 30 points
For the process I→II, what are ΔU, ΔH, Q, and W (all in kJ)?

D. 5 points
Why doesn't $\Delta H=\int C_p dT$ and $\Delta U=\int C_v dT$ for the process I→II?

The piston is then locked in place so that the volume is constant at $V=V_2$. The piston and cylinder arrangement is then returned to the hot plate and heating is continued until T_2 = 80°C.

III. 25 points total

A. 10 points
Estimate the pressure using the ideal gas law for P-V-T behavior of the R-134a vapor.

B. 15 points
Find the pressure using the R-134a table.

R = 83.14 (cm^3 - bar)/(gmole - K) = 0.008314 (m^3 - kPa)/(gmole - K) = 0.08314 (L - bar)/(gmole - K)
MW of R-134a is 102.03 g/gmole
Or you can use the value on a per kg basis in your book on pg 883.

Your Name: Solution

Show your work. Your exam paper *must* include this work to get credit for any part.
Transfer the following answers from your pages of calculations and turn in with your calculations:

I. 20 points total

A. 5 points: mass of R-134a = 3.1626 kg

B. 5 points T_1 = 8.91 °C

B. 10 points: H_1 = 202.15 kJ

U_1 = 201.15 kJ

II. 55 points total

A. 10 points: V_2 = 0.162132 m^3

B. 10 points: H_2 = 808.38 kJ

U_2 = 743.52 kJ

C. 30 points: ΔU = 542.35 kJ

ΔH = 606.23 kJ

Q = 606.20 kJ

W = 63.85 kJ

D. 5 points: Why doesn't $\Delta H=\int C_p dT$ and $\Delta U=\int C_v dT$ for the process I→II?

Answer: not ideal gas (it's liquid!)

III. 25 points total

A. 10 points: P = 561.1 kPa (idea gas law)

B. 15 points: P = 531.9 kPa (R-134a table)

ES 3053 Exam I Sept. 30, 2019

Solution

I. A. $P = 400\,kPa$, sat. liquid

$V = 2500\,cm^3 = 0.0025\,m^3$

$v\,(\text{sat. L @ }400\,kPa) = 0.000791\,m^3/kg$

$$\boxed{m = \frac{0.0025\,m^3}{0.000791\,m^3/kg} = 3.163\,kg}$$

B. $\boxed{\text{sat } T \text{ @ } 400\,kPa \text{ is } 8.91^\circ C}$

C. $u_1\,(\text{sat L @ }400\,kPa) = 63.61\,kJ/kg$

$h_1\,(\quad \text{"} \quad) = 63.92\,kJ/kg$

$$\boxed{\begin{aligned} U_1 &= 63.61\,kJ/kg \times 3.163\,kg = 201.17\,kJ \\ H_1 &= 63.92\,kJ/kg \times 3.163\,kg = 202.15\,kJ \end{aligned}}$$

~~B.~~ II. A. $v_2\,(\text{sat. V @ }400\,kPa) = 0.051266\,m^3/kg$

$$\boxed{V_2 = 0.051266\,m^3/kg * 3.163\,kg = 0.1621\,m^3}$$

B. $$\boxed{\begin{aligned} U_2\,(\text{sat. V @ }400\,kPa) &= 235.10\,kJ/kg \times 3.163\,kg = 743.52\,kJ \\ H_2\,(\text{"} \quad \text{"}) &= 255.61\,kJ/kg \times 3.163\,kg = 808.38\,kJ \end{aligned}}$$

C. $$\boxed{\begin{aligned} \Delta U &= 743.52\,kJ - 201.15\,kJ = 542.35\,kJ \\ \Delta H &= 808.38\,kJ - 202.15\,kJ = 606.23\,kJ \end{aligned}}$$

Since const P, reversible: $\Delta H = \boxed{Q = 606.23\,kJ}$

$W = P\Delta V\,(\text{const. } P) = 400\,kPa\,(0.16213 - 0.0025)\,m^3$

$$\boxed{W = 63.85\,m^3\cdot kPa = 63.85\,kJ}$$

II. D. This is not an ideal gas, which $\int c_p dT$ is useful for (it's liquid!)

III. A. $P = \frac{RT}{V} = \dfrac{\frac{0.008314\, m^3 kPa}{mole \cdot K} * (80+273)K}{0.051266\, m^3/kg \times \frac{102.3\, g}{mole} * \frac{1\, kg}{1000\, g}}$

per mole calc $\Rightarrow$

$$\boxed{P = 561.1\ kPa}$$

or, per kg calc:

$$P = \frac{0.08149 \frac{kJ}{kg \cdot K} * (80+273)K}{0.051266\, m^3/kg} = 561.1 \frac{kJ}{m^3}$$

$$\frac{kJ}{m^3} = \frac{\cancel{m^3} \cdot kPa}{\cancel{m^3}} = kPa$$

$$\boxed{P = 561.1\ kPa}$$

B. from the R-134a table @ $T = 80°C$ & $V = 0.05166 \frac{m^3}{kg}$

$$\boxed{P = 531.9\ kPa}$$