Homework 3 SOLUTIONS

1. State 1 (7 points – 1 each for a–g)

a) $v \approx 0.001\ m^3/kg$ (A-4) $\frac{V_1}{v_1} = m = \frac{0.05\ m^3}{0.001\ m^3/kg} = 50\ kg$

b) $v_2 = 0.79645\ \frac{m^3}{kg}$ (A-6)

7 points

$V_2 = 50\ kg\,(0.79645\ m^3/kg) = \boxed{39.8\ m^3}$

c) $h_1 \simeq h_f\ @\ 10^\circ C = 42.022\ kJ/kg$ (A-4)

$h_2 = 2967.9\ kJ/kg$ (A-6)

$\Delta H = m(h_2 - h_1) = 50\ kg\,(2967.9 - 42.022)\frac{kJ}{kg}$

$= \boxed{146{,}294\ kJ} \times 10^{-3}\ \frac{MJ}{kJ} = 146\ MJ$

d) $X_3 = 0.5$

$v_3 = 0.5(v_{fg}) + v_f\ @\ 250^\circ C$

$= 0.5(0.050085 - 0.001252) + 0.001252\ \frac{m^3}{kg}$ (A-4)

$v_3 = 0.02567\ m^3/kg$

$V_3 = 50\ kg\,(0.02567\ \frac{m^3}{kg}) = \boxed{1.28\ m^3}$

e) $P_3 = P_{sat}\ @\ 250^\circ = \boxed{3976.2\ kPa}$ ($\simeq 4\ MPa$)

f) $h_3 = 0.5(h_{fg}) + h_f\ @\ 250^\circ C = 0.5(1715.3) + 1085.7\ \frac{kJ}{kg}$

$h_3 = 1943.4\ kJ/kg$

1. f) $\Delta H = m(h_3 - h_1) = 50\,kg\,(1943.4 - 42.022)\frac{kJ}{kg}$

$\boxed{\Delta H = 95{,}066\ kJ}$ OR $\sim 95\ MJ$

(see graph)

2. (2 points) Compressed liquid water @ 100°C, 15 MPa
find v, u, h from

$v \cong v_f$ @ 100°C = 0.001043 m^3/kg

$u \approx u_f$ @ 100°C = 419.06 kJ/kg

$h \approx h_f$ @ 100°C = 419.07 kJ/kg

from Table A.7

$v = 0.0010361\ m^3/kg$ (< 1% difference)

$u = 414.85$ kJ/kg (1% difference)

$h = 430.39$ kJ/kg (3% difference)

3. (3 points) Piston-cylinder with 0.8 kg steam @ 300°C and 1 MPa (superheated) is cooled @ 300°C until x = 0.25 (1)

$T_2 = T_{sat}$ @ 1 MPa = $\boxed{179.9°C}$ (A.5)

$v_2 = (x\, v_{fg}) + v_f$ @ 1 MPa

$= 0.25(0.19436 - 0.001127) + 0.001127\ m^3/kg$

$v_2 = 0.04944\ m^3/kg$

$V_2 = 0.8\,kg\,(0.04944\,\frac{m^3}{kg}) = \boxed{0.04\ m^3}$

(see graph) $V_1 = 0.8\,kg\,(0.25799\ m^3/kg) = 0.2064\ m^3$

$|\Delta V = -0.167\ m^3|$ (2)

4. Rigid tank with R-134a (isochoric process)
(3 points)

$V = vm = 0.1450 \,(1\,kg) = 0.1450\, m^3$

$T_1 = -40°C \qquad v_f < v < v_g \text{ @ } -40°C$

sat. mixture

(1) a) $P_1 = P_{sat} @ {-40°C} = \boxed{51.25\ kPa}$

(1) b) $P_2 = 200\,kPa$

$v > v_g \text{ @ } 200\,kPa \Rightarrow$ superheated R-134a

from A-13, $\boxed{T_2 = 90°C}$

(1) (see diagram)

5. Ideal gas (O_2)
(2 points)

$P_g = 500\,kPa, \quad V_1 = 1.3\ m^3$

$T_1 = 24°C, \quad P_{atm} = 97\,kPa$

find m

$PV = mRT \qquad R = 0.2598\ \frac{kJ}{kg\,K}$

$$m = \frac{(500+97)\,kPa\,(1.3)\,m^3}{0.2598\,\frac{kJ}{kg\,K}\,(273+24)\,K} = \boxed{10\ kg}$$

6. (3 points) for $T = 25°C = 298\,K$

$P_g = 210\,kPa, \quad P_{atm} = 100\,kPa, \quad P = 310\,kPa$

$V = 0.025\ m^3$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

@ $T = 50°C = 323\,K$ find $m_2 - m_1$ such that

$P = 310\,kPa$, assume $V_2 = V_1$

6. (3 points)

① $P_2 = T_2(P_1/T) = 323\text{K}\left(\frac{310\text{kPa}}{298\text{K}}\right) = 336\text{kPa}$, $\boxed{\Delta P = 26\text{kPa}}$ (4)

$P_1 V_1 = m_1 R T_1$ $\qquad m_1 = \frac{310\,(0.025)\,\text{kN-m}}{0.287\,\frac{\text{kJ}}{\text{kgK}}\,(298\text{K})}$

$P_1 V_1 = m_2 R T_2$ $\qquad = 0.0906\ \text{kg}$

$m_1 T_1 = m_2 T_2$

$\frac{m_2}{m_1} = \frac{T_1}{T_2}$, $\quad m_2 = 0.0906\left(\frac{298}{323}\right)$

$m_2 = 0.084\ \text{kg}$

$m_1 - m_2 = 0.0906 - 0.084 = \boxed{0.007\ \text{kg}}$ (2)

7. (2 points) Ar, 0.2 kg, piston-cylinder, $V = 0.05\ m^3$

$P_1 = 400\text{kPa}$ isothermal expansion

$V_2 = 2V_1 = 0.1\ m^3$

find P_2 for ideal gas, isothermal expansion, closed system,

$P_1 V_1 = P_2 V_2$

$P_2 = P_1\left(\frac{V_1}{V_2}\right) = 400\text{kPa}\,(0.5)$

$= \boxed{200\text{kPa}}$

8. (2 points) rigid tank, ideal gas @ 300kPa, 600K

$m_2 = 0.5\,m_1$ $\quad P_2 = 100\ \text{kPa}$

(1) a) find T_2 $\quad P_1 V_1 = m_1 R T_1$, $\quad P_2 V_1 = m_2 R T_2$

8. a) $\frac{m_1 T_1}{P_1} = \frac{m_2 T_2}{P_2}$ $m_1 = 2m_2$

$$\frac{2T_1}{P_1} = \frac{T_2}{P_2}$$

$$T_2 = 2\left(\frac{P_2}{P_1}\right)T_1 = 2\left(\frac{100}{300}\right)600k$$

$$T_2 = \boxed{400k}$$

b) now $m_1 = m_2$

(1) $T_2 = 400k$, find P_2

$$\frac{T_1}{P_1} = \frac{T_2}{P_2} \qquad P_2 = \frac{T_2}{T_1}(P_1)$$

$$P_2 = 300kPa\left(\frac{400}{600}\right) = \boxed{200\,kPa}$$

9. (6 points) R-134a in piston cylinder (not isobaric in process 1)

$m = 25kg$, $P_1 = 320kPa$, $v_1 = 0.0834\,m^3/kg$

$v_1 > v_g$ @ 320 kPa, superheated

(1) a) $T_1 = \boxed{70°C}$ (A-13)

(1) b) $v_2 = v_1 = v_g$ ● $\Rightarrow$ $\boxed{P_2 = 240\,kPa \quad T_2 = -5.38°C}$

(6)

9 c) isobaric condensation $T_3 = T_2 = \boxed{-5.38°C}$

(1)

$V_3 = m v_3 = m v_f$ @ 240kPa

$V_3 = 25kg(0.000762 \frac{m^3}{kg}) = \boxed{0.02\ m^3}$

(1) d) $\Delta H = m(h_3 - h_1)$ $h_1 = 313.48 \frac{kJ}{kg}$ (A-13)

$= 25kg(44.66 - 313.48)\frac{kJ}{kg}$ $h_3 = h_f$ @ 240kPa $= 44.66 \frac{kJ}{kg}$

$\Delta H = \boxed{-6{,}720\ kJ}$

(1) e) $Work = \int_{V_1}^{V_3} P dV = \int_{V_2}^{V_3} P dV$

since $\int_{V_1}^{V_2} P dV = 0$ (constant v)

for 2→3, Work @ P = Constant $W = P \int_{V_2}^{V_3} dV$

$= P(V_3 - V_2)$

$W = P m(v_3 - v_2) = 240kPa\ (kN/m^2)\ (25kg)(0.000762 - 0.0834)\frac{m^3}{kg}$

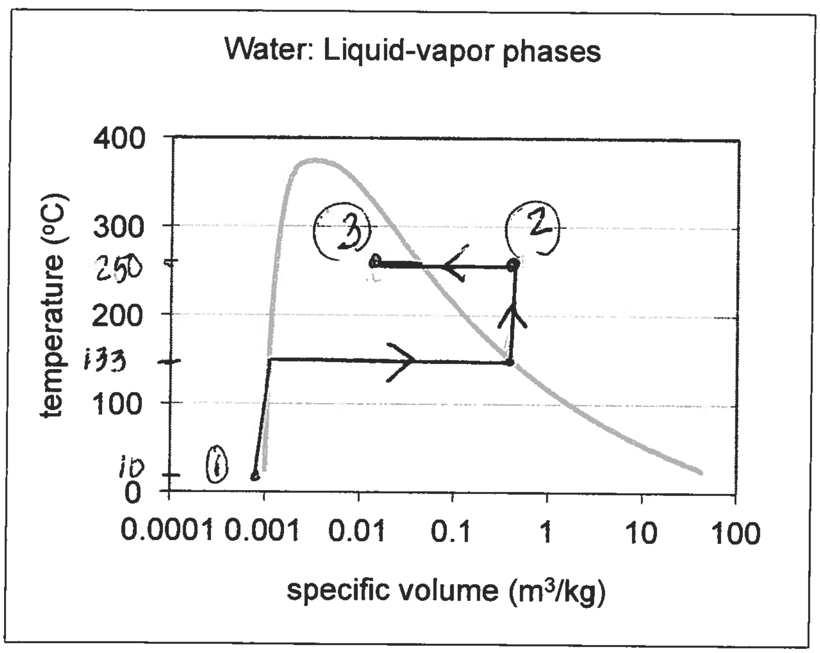
$Work = \boxed{-496\ kJ}$ work done ON R-134a

AREN 2110
Spring 2011

Homework #3: Due Friday, Feb. 4, 6 PM

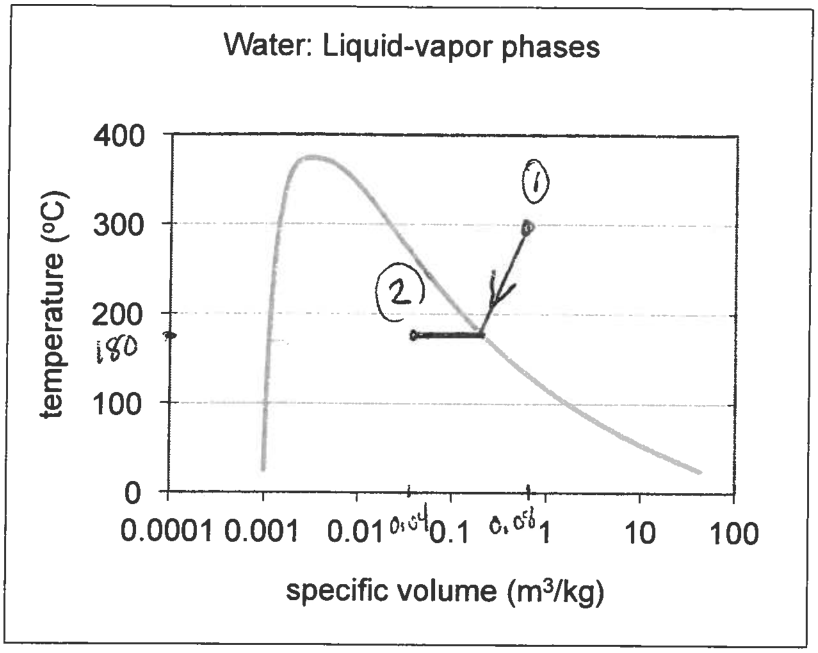
1. A piston-cylinder device initially contains 50L of liquid water at 10 °C and 300 kPa. Heat is added to the water at constant pressure until the temperature reaches 250 °C. Determine the following:
    a) the mass of the water
    b) the volume after heating in m^3
    c) the enthalpy change after heating in kJ

Now the water is compressed in an isothermal process until half the mass is in the liquid form.
    d) What is the final volume?
    e) What is the final pressure?
    f) What is the enthalpy change in the water for the 2-step process?
    g) Show the two processes on the T-v diagram



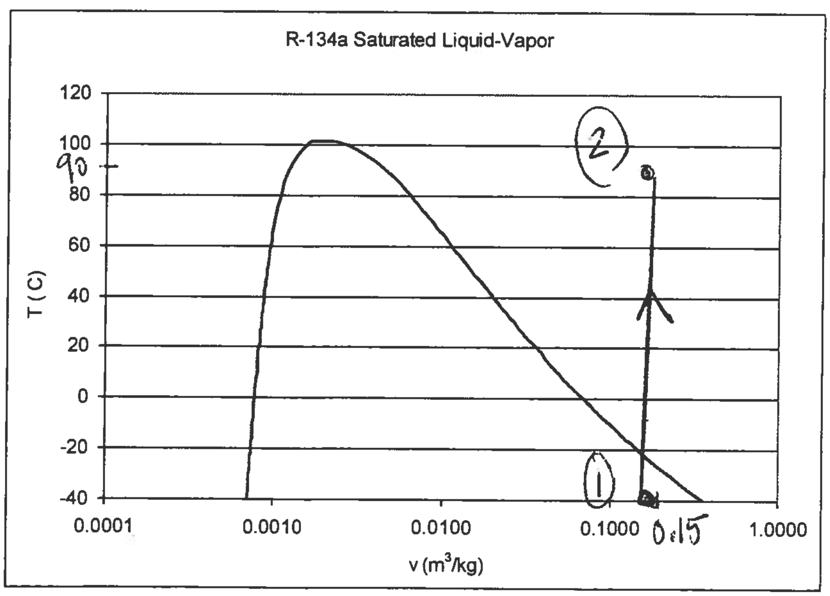
2. Determine the specific volume, internal energy and enthalpy of compressed liquid water at 100 °C and 15 MPa using the saturated liquid approximation. Compare these values to the ones obtained from the compressed liquid tables.

3. A piston-cylinder device contains 0.8 kg of steam at 300 C and 1 MPa. Steam is cooled at constant pressure until on 75% of its mass condenses. Show the process on a T-v diagram, find the final temperature and determine the volume change.



4. A rigid-wall tank with a volume of 0.1450 m^3/kg contains one kg of R-134a at a temperature of -40 °C (233K). The container is heated until the pressure of the R-134a is 200 kPa.

   a) What is the initial pressure?
   b) What is the final temperature of the R-134a?
   c) Draw the process on the T-v diagram



5. The pressure gage on a 1.3 m^3 oxygen tank reads 500 kPa. Determine the amount of oxygen in the tank if the temperature is 24 C and atmospheric pressure is 97 kPa.

calculate the work done between states 1 and 3. Is the work positive or negative?

f) Graph the process sequence on the P-V diagram (below)