Homework 2 SOLUTIONS

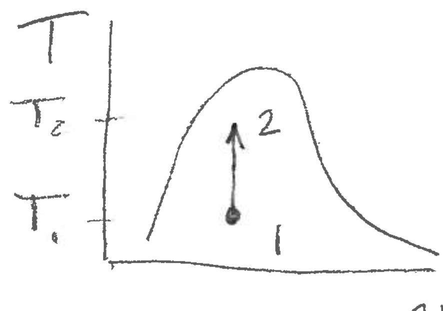
1. Saturated liquid has temperature and pressure at saturation values. If heat added, some liquid will become saturated vapor, and temp will be constant @ P constant

(1 point)

Compressed liquid has temperature below saturation temperature for its pressure. If heat added, temperature will increase if P constant.

2. Yes. Since v is constant, both T & P will increase

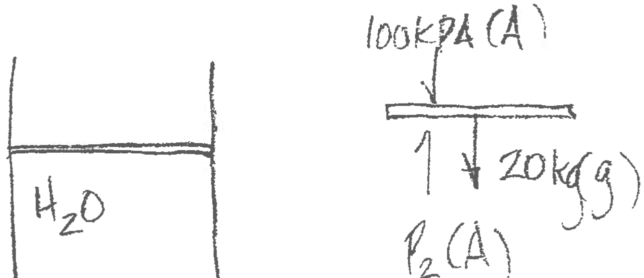
(1 point)



$T_2 > T_1$, $P_2 > P_1$

3.

(2)



$P_1(A) + 20\,kg(g) = P_2 A$

Solution: find P_2 and T_{sat} @ P_2

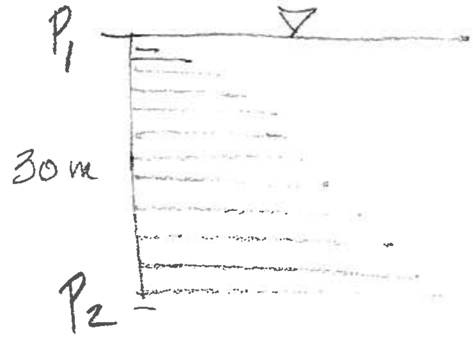
$$P_1(A) + 20kg(g) = P_2 A$$

$$P_2 = P_1 + \frac{20\,kg\left(9.81\,\frac{m}{s^2}\right)10^{-3}\,\frac{kN}{N}}{100\,cm^2\left(10^{-4}\,m^2/cm^2\right)}$$

$P_2 = 100\,kPa + 19.6\,kPa \cong 120\,kPa$

table A-5, T_{sat} @ 120 kPa $\cong$ **105°C**

(2)

4. 

(2)

$P_1 = 101\,kPa$

$\rho = 1.03\,(10^3)\,\frac{kg}{m^3}$

$h = 30\,m$

$$P_2 = P_1 + \rho g h = 101\,kPa + \frac{1.03\times10^3 \frac{kg}{m^3}\; 9.81\frac{m}{s^2}\; 30m}{\left(10^3 \frac{Pa}{kPa}\right)}$$

$$P_2 = 101 + 303 = \boxed{404\,kPa}$$

5. molecular weight is $\frac{m}{N}\left(\frac{kg}{kmol}\right) = \frac{R_u}{R}$ since $PV = NR_uT$, $PV = mRT$, $\frac{R_u}{R} = \frac{m}{N}$

(1)

$R_u = 8.314\,\frac{kJ}{kmol\,K}$

$R = 0.4119\,\frac{kJ}{kg\,K}$

$MW = \frac{8.314}{0.4119}\,\frac{kg}{kmol} = 20.1$ ideal gas is $\boxed{\text{NEON}}$

6. Heat absored in boiling @ P (h_{fg}) must equal
(1) heat released in condensing to satisfy conservation of energy, since beginning and end states of the system are the same.

7. line 1

(4 points)

@ 50°C, (A-4) $v_f < v < v_g$

$0.001012 < 4.16 < 12.026 \; m^3/kg$ — saturated mixture liquid + vapor

so $P = P_{sat} = 12.352$ kPa

line 2 (A-5), sat vapor @ 200 kPa, $T = T_{sat}$ (120.21°C), $v = v_g = 0.88578 \; \frac{m^3}{kg}$

line 3 (A-5), $T = 250°C > T_{sat}$ @ 400 kPa (143.61°C)

So water is superheated

(A-6) $v = 0.5952 \; m^3/kg$

line 4 (A-5) $T = 110°C < T_{sat}$ @ 600 kPa (158.83°C)

so water is compressed liquid

(A-4) $v \approx v_f$ @ 110°C $= 0.001052 \; \frac{m^3}{kg}$

8. line 1 for $0 < X < 1$, saturated mixture

(A-5) $T = T_{sat}$ @ 200 kPa $= 120.21°C$

$h = X h_{fg} + h_f$ @ 200 kPa

$= 0.7(2201.6) + 504.71 \; kJ/kg$

$h = 2{,}045.83 \; \frac{kJ}{kg}$

line 2 (A-4) @ 140°C, $h_f < h < h_g$

$589.16 < 1800 < 2733.5 \; kJ/kg$

So state is sat. liquid - vapor mixture, $P = P_{sat} = 361.53$ kPa

$X = \frac{h - h_f}{h_{fg}} = \frac{1800 - 589.16}{2733.5} = 0.443$

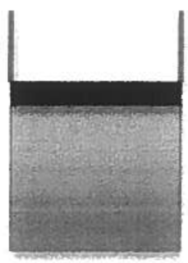
AREN 2110
Spring 2011

Homework #2: Due Friday, Jan 28, 6 PM

1. What is the difference between a saturated liquid and a compressed liquid?

2. A mixture of liquid water and water vapor fills a rigid-wall tank. Heat is added until all the liquid is converted to saturated vapor. Will the temperature and pressure of the water change during the process.

3. Water is heated in a vertical piston-cylinder device. The piston has a mass of 20 kg and cross sectional area of 100 cm^2. The local atmospheric pressure is 100 kPa. At what temperature will the water begin to boil?



4. Determine the pressure exerted on a diver at 30 m below the free surface of the ocean. Assume the barometric pressure is 101 kPa and the specific gravity of seawater is 1.03.

5. The value for the gas constant, R, for an ideal gas is 0.4119 kJ/kg-K. What is the gas?

6. Does the amount of heat absorbed as 1 kg of saturated liquid water boils to saturated vapor have to the same as the heat released when 1 kg saturated water vapor condenses at 100 °C? Explain.

7. Complete the following table for H_2O

P (kPa)	T (°C)	v (m^3/kg)	phase
12.352	50	4.16	sat. mixture
200	120.21	0.88578	Saturated vapor
400	250	0.5952	superheated vapor
600	110	0.001052	compressed liquid

8. line 3 (A-5)

5 points

$x = 0$ means sat. liquid, $T = T_{sat}$ @ 950kPa = 177.66°C

$h = h_f = 752.74$ kJ/kg

line 4 (A-5)

T_{sat} @ 500kPa = 151.83, 80°C < T_{sat}

compressed liquid, X not applicable

(A-4) $h \approx h_f$ @ 80°C = 335.02 kJ/kg

line 5

(A-5) @ 800kPa, $h = 3162.2 > h_g$, so superheated vapor

(A-6) $h = 3162.2$ corresponds to $T = 350°C$

9. line 1 (A-4)

4 points

$0 < x < 1$ is saturated liq.-vapor mixture (0.4)

$P = P_{sat} = 476.16$ kPa

$v = x v_{fg} + v_f = 0.4(0.39248 - 0.001091) + 0.001091$ m³/kg

$v = 0.15765$ m³/kg

line 2 (A-4)

$v > v_g$ @ T = 150°C → 0.39248 so superheated

(A-6) $v = 0.4708$ corresponds to P = 400kPa @ 150°C

line 3 (A-11)

@ 0°C, $v_f < v < v_g$

$0.0007723 < 0.05 < 0.069255$ m³/kg

sat. liquid vapor mixture $P = P_{sat} = 293.01$ kPa

$$x = \frac{0.05 - 0.0007723}{0.069255 - 0.0007723} = 0.719$$

line 4 (A-12) (A-11)

@ 400kPa, T = 0 < T_{sat} (8.9°C) ⇒ compressed liquid

$v \approx v_f$ @ 0°C = 0.0007723 m³/kg

8. Complete the following table for H_2O:

P (kPa)	T (°C)	h (kJ/kg)	x	phase
200	120.21	2045.83	0.7	Sat. liq-vapor mix
361.53	140	1800	0.443	Sat liq-vapor mix
950	177.66	752.74	0.0	Sat liquid
500	80	335.02	na	Compressed liquid
800	350	3162.2	na	superheated vapor

9. Complete the following table for the various substances

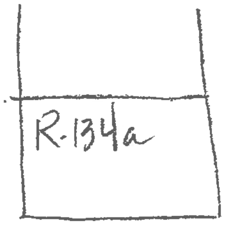
substance	P (kPa)	T (°C)	v (m^3/kg)	x*	phase
H_2O	476.16	150	0.15765	0.4	sat liq vapor mix
H_2O	400	150	0.4708	na	superheated vapor
R-134a	293.01	0	0.0500	0.719	sat liq vapor mix
R-134a	400	0	0.0007723	na	compressed liquid

* use "na" for "not applicable" where quality does not apply

10. A piston-cylinder device contains 0.85 kg of refrigerant 134a at -10 °C (263 K). The piston has a mass of 12 kg and a diameter of 25 cm. The local atmospheric pressure is 88 kPa. Now, heat is transferred to the refrigerant until the temperature is 15 °C. Determine:
    a. The final pressure
    b. The change in volume of the cylinder space
    c. The change in enthalpy of the refrigerant

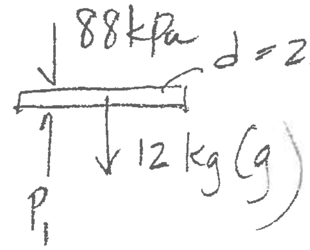
11. A rigid-wall tank with a volume of 2.5 m^3 initially contains 15 kg of saturated liquid-vapor mixture of water at 75 °C. The water is slowly heated until all the water is saturated vapor.
    d. What is the quality of the mixture at the initial state (before heating)?
    e. Determine the temperature at with the liquid in the tank is completely vaporized to saturated vapor.
    f. What is the pressure in the tank?
    g. Show the process on the T-v diagram on the next page.

10.



3 points

$m = 0.85\ kg$
$T_1 = -10°C$



$A = \pi \frac{(0.25)^2}{4}$
$A = 0.05\ m^2$

$$P_1 = 88\,kPa + \frac{12\,kg\,(9.81\,\frac{m}{s^2})}{0.05\,m^2} 10^{-3} \frac{kPa}{Pa}$$

a) $P_1 = 88 + 2.35 = 90.35\ kPa$

isobaric process, $P_2 = P_1 = \boxed{90.35\ kPa}$

b) $T_2 = 15°C$

T_{sat} @ 90 kPa $= -28.65\ °C \ll T_2$

superheated vapor @ state 2

state 1: superheated vapor @ 90 kPa, $-10°C$
(A-13)

$$\frac{90-60}{40} = 0.75 = \frac{v_1 - 0.35048}{0.20743 - 0.35048}$$

$$v_1 = 0.2432\ m^3/kg$$

$$V_1 = m v_1 = 0.85\,kg\left(0.2432\ \frac{m^3}{kg}\right) = 0.207\ m^3$$

$$v_2 :\ 0.75 = \frac{v_2 - v_{15,60}}{v_{15,100} - v_{15,60}}$$

$$v_{15,60} = \frac{0.37893 + 0.39302}{2} = 0.3860\ m^3/kg$$

$$v_{15,100} = \frac{0.22506 + 0.23373}{2} = 0.2294\ m^3/kg$$

$$v_2 = 0.75(0.2294 - 0.386) + 0.386 = 0.269\ m^3/kg$$

$$V_2 = 0.85\,kg\left(0.269\,\frac{m^3}{kg}\right) = 0.228\ m^3$$

10' R-134 (7a)

a) $P_1 = 98\,kPa + \frac{12\,kg\,(9.81\,m/s^2)}{0.05\,m^2} 10^{-3} \frac{kPa}{Pa} = 100.35\,kPa$

$\simeq 100\,kPa$

b) T_{sat} @ 100 kPa = −26.37

@ $T_2 = 15°C \gg T_{sat} \Rightarrow$ superheated vapor

AND @ $T_1 = -10°C \gg T_{sat} \Rightarrow$ superheated vapor

need v_1 and v_2 to find ΔV

A-13 $v_1 = 0.20743\ m^3/kg$ @ 100kPa

interpolate btn 10 & 20°C $v_2 = \frac{0.23373 + 0.22506}{2} = 0.2294\ \frac{m^3}{kg}$

$\Delta V = m(v_2 - v_1) = 0.85kg\,(0.2294 - 0.20743)\frac{m^3}{kg}$

$\Delta V = \boxed{0.019\ m^3}$

$\Delta H = m(h_2 - h_1)$ $h_1 = 247.49\ kJ/kg$ @ −10°C 100kPa (A-13)

$h_2 = \frac{272.17 + 263.81}{2} = 268.0\ \frac{kJ}{kg}$ @ 15°C 100kPa (A-13)

$\Delta H = 0.85kg\,(268.0 - 247.49)\frac{kJ}{kg}$

$\Delta H = \boxed{17.4\ kJ}$

10 b) $\Delta V = 0.228 - 0.207 = \boxed{0.021\ m^3}$

c) (A-13)

$h_1 = 0.75(247.49 - 248.58) + 248.58 = 247.76\ \frac{kJ}{kg}$

$h_{15,60} = \frac{264.66 + 272.94}{2} = 268.8\ kJ/kg$

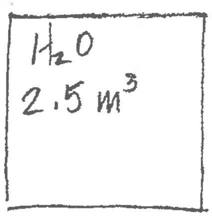
$h_{15,100} = \frac{263.81 + 272.17}{2} = 267.99\ kJ/kg$

$h_2 = 0.75(267.99 - 268.8) + 268.8 = 268.19\ kJ/kg$

$\Delta H = m(h_2 - h_1) = 0.85\,kg\,(268.19 - 247.76)\frac{kJ}{kg}$

$\boxed{\Delta H = 17.4\ kJ}$

11. (3 points)



$m = 15\,kg$

① mixture, $T_1 = 75°C$

$v_1 = \frac{2.5\ m^3}{15\ kg} = 0.1667\ \frac{m^3}{kg}$

(A-4) a) $X_1 = \frac{0.1667 - 0.001026}{4.1291 - 0.001026} = \boxed{0.04}$

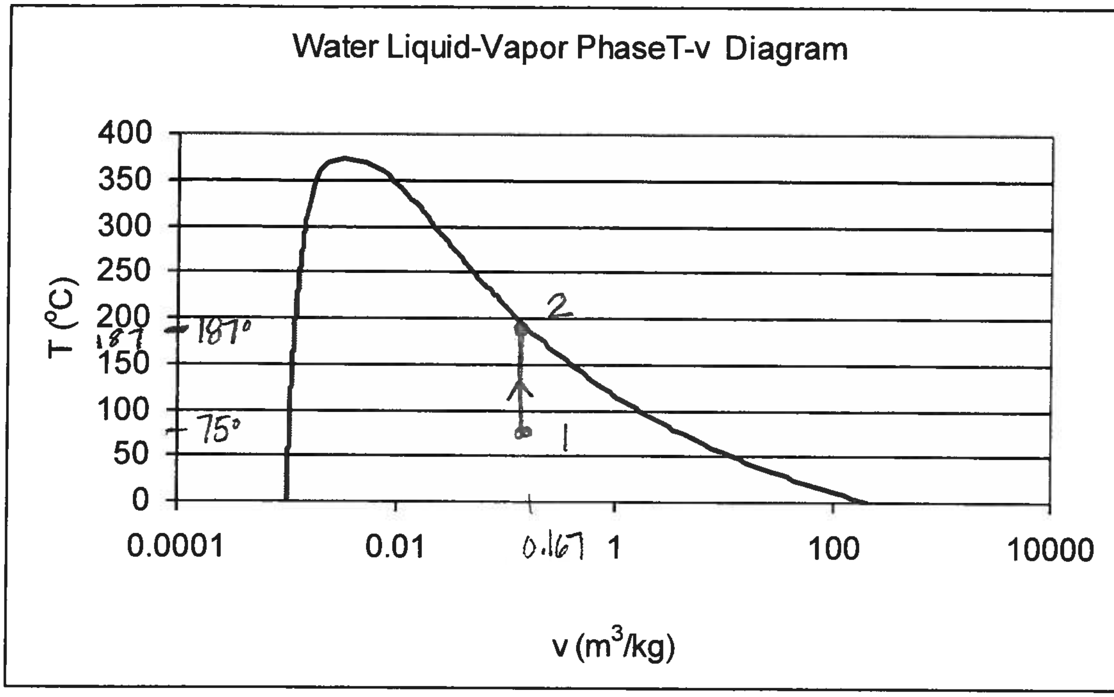
b) @ $X = 1$, $v = 0.1667\ \frac{m^3}{kg} = v_g$

(A-4) $\frac{T_2 - 185}{190 - 185} = \frac{0.1667 - 0.1739}{0.15636 - 0.1739}$, $\boxed{T_2 = 187°C}$

c) $P = P_{sat}$ @ $187°C$, $\frac{187 - 185}{190 - 185} = \frac{P_2 - 1123.5}{1255.2 - 1123.5}$

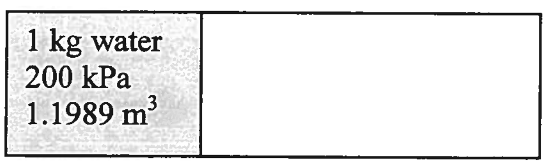
$\boxed{P_2 = 1176.2\,kPa}$

9



3 points

12. One kilogram (1 kg) of water vapor at 200 kPa fills the left chamber of a partitioned system shown below. The volume of this chamber is 1.1989 m^3. The right chamber has twice the volume of the left chamber and is evacuated at the initial state.



Now the partition is removed and heat is transferred so that the temperature of the water is 3 °C.

a. What is the initial temperature of the water (before the partition is removed)?
b. What is the pressure of the water after the partition is removed and heat transferred?
c. What is the quality of water at the final equilibrium state?

12.

$1.1989\ m^3$ 1kg 200kPa	$2.3978\ m^3$

state 1: $\frac{V}{m} = \frac{1.1989\ m^3}{1\ kg} = v = 1.1989\ \frac{m^3}{kg}$

@ 200kPa (A-5), $v > v_g$ (superheated)

a) (A-6) $T_1 = 250°C$

b) $T_2 = 3°C$

$v_2 = 3(1.1989\ m^3/kg) = 3.5967\ \frac{m^3}{kg}$

$v_f < v_2 < v_g$ @ 3°C

sat. liquid vapor mixture, $P_2 = P_{sat}$ @ 3°C

(A-4) $\frac{3-0.01}{5-0.01} = \frac{P_2 - 0.6117}{0.8725-0.6117} \rightarrow P_2 = 0.768\ kPa$

c) $X = \frac{v_2 - v_{f,3}}{v_{g,3} - v_{f,3}}$

$v_{f,3} = 0.001\ \frac{m^3}{kg}$

$v_{g,3} = 0.6(206-147)+147$

$= 182.4\ m^3/kg$

$X = \frac{3.5967-0.001}{182.4-0.001}$

$X = 0.02$

(12) (11)

a) $T_1 = 250°C$

b) $T_2 = 5°C$

$v_2 = 3.5967 \; m^3/kg$

$v_f < v < v_g$ @ 5°C (sat. mixture)

$$X_2 = \frac{v - v_f}{v_g - v_f} \text{ @5°C (A-4)} = \frac{3.5967 - 0.001}{147.03 - 0.001}$$

$$\boxed{X_2 = 0.024}$$