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Course: MAE 91

Set : #2

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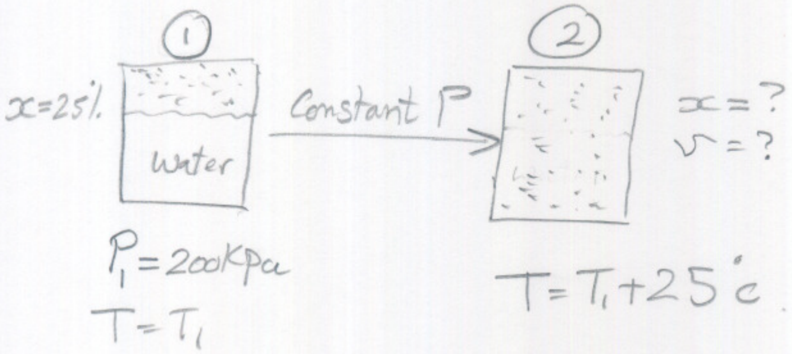
138/140

Problem 3.14

19p statement

given water at 200kPa, $x = 25\%$ (i.e. mass of water is 75% of the control mass total). Now temp is raised by 20°C in constant pressure process. Find new quality and new volume.



given
$x_1, P_1, P_2, \Delta T = 20°c$

Find
x_2, v_2

assumptions

Pure substance

ideal process (quasi-equilibrium process)

Laws

$$v = v_f + x(v_g - v_f)$$

IF $T > T_{saturation}$ at constant P $\Longrightarrow$ superheated vapor state!

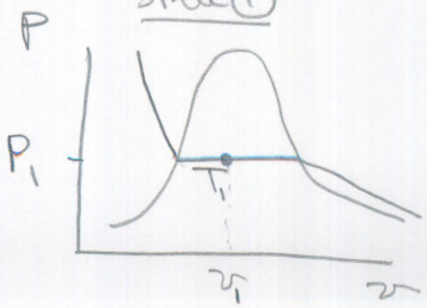
steps

Find specific volume in state ①

$$v_1 = v_f + x(v_g - v_f)$$

Since P is given, we can look up from Table B.1.2 (Saturated water pressure table) to find, at $P = 200\text{kPa}$ the values for v_f, v_g. also we find $T_{1(sat)}$ from same entry.

State ①



→

T in state 2 is T_2

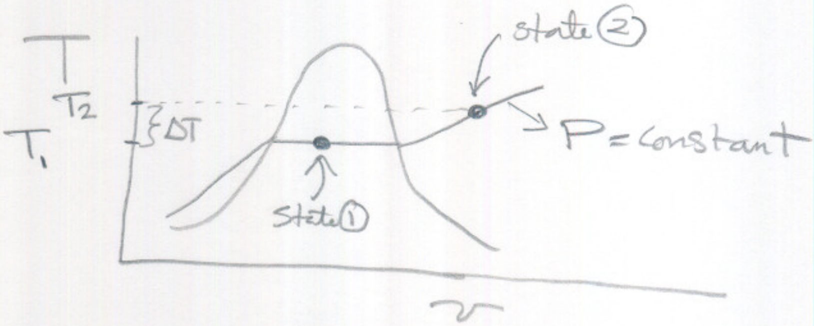
where $\boxed{T_2 = T_1 + \Delta T}$

Since P is constant, and $T_2 > T_1$, we are in superheated vapor state.

so $\boxed{x_2 \text{ is undefined}}$

To find v_2, use Table B.1.3 (superheated vapor water Table).

need to use interpolation here.



numerical

From Table B.1.2, for P = 200 kPa, $v_f = 0.001061$, $v_g = 0.88573$

but $x_1 = 0.25$

hence $v_{\text{state}_1} = v_f + x(v_g - v_f) = 0.001061 + 0.25(0.88573 - 0.001061)$
$= \boxed{0.222228 \text{ m}^3/\text{Kg}}$

$T_2 = T_1 + \Delta T$

$T_2 = 120.23 + 20 = 140.23\ ^\circ\text{C}$

From Table B.1.2 for P = 200 kPa.

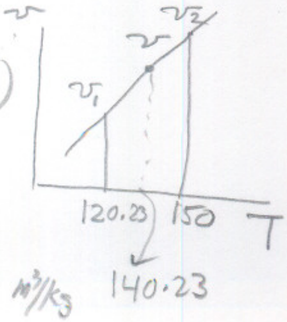
$\boxed{\text{hence } x_2 \text{ undefined}}$

from Table B.1.3 (superheated vapor). from block for P = 200 kPa

we see that $v_1 = 0.88573$, $v_2 = 0.95964$

so $\dfrac{v - v_1}{20} = \dfrac{v_2 - v_1}{150 - 120.23} \Rightarrow$ (Interpolation)

$v = \dfrac{20(0.95964 - 0.88573)}{150 - 120.23} + 0.88573 = \boxed{0.93538 \text{ m}^3/\text{Kg}}$



so v changed from $v_{\text{state}_1} = 0.2223 \text{ m}^3/\text{Kg}$ To $v_{\text{state}2} = 0.9354 \text{ m}^3/\text{Kg}$

Problem 3.32

10/16 Determine whether R-22 in each of following state is in a compressed liquid, superheated vapor, or saturated liquid and vapor.

a) 50°C, $v = 0.05\ m^3/Kg$ c) 0.1 MPa, 0.1 m^3/Kg
b) 1 MPa, 20°C d) -20°C, 200kPa.

So, we are given 2 properties in each state. from these 2 properties, we look up from Table to find the state.

Assumptions

system in equilibrium.

Laws

saturated superheated.

use R-22 Tables. (B.4.1, B.4.2)

Steps.

a) From B.4.1 look up entry of v_f, v_g for T, and determine where given v is located.

b) From B.4.1, lookup P_{sat} for given T=20°C. compare if P in Table is less than or greater than 1MPa. This tell us the phase.

c) From B.4.1, look up v_f, v_g for given P (0.1MPa) and compare given v to see which phase.

d) From table B.4.1, for given T=-20°C, look up P_{sat} and compare to given P to determine phase.

→

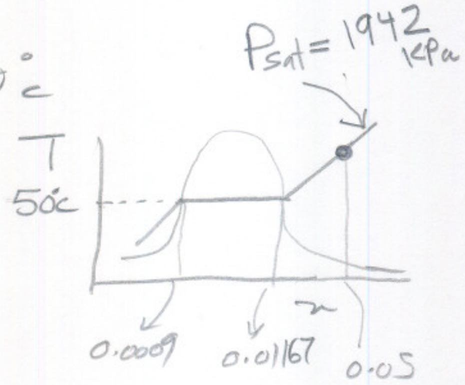
Numerical

a) From Table B.4.1, for $T = 50^\circ c$

$v_f = 0.000922$, $v_g = 0.01167$.

but $v = 0.05\ m^3/kg$

So, $\boxed{\text{Super heated Vapor}}$

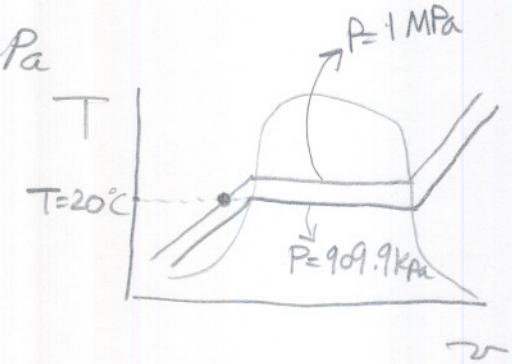


b) from B.4.1.

For $T = 20^\circ c$, $P_{sat} = 909.9$ kPa

but given $P > P_{sat}$.

hence in $\boxed{\text{compressed liquid}}$

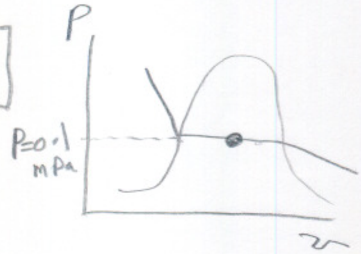


c) From B.4.1, for P=0.1 MPa, this entry in second column does not exist, but P= 101.3 KPa is almost 0.1 MPa, so for P=101.3 KPa,

$v_f = 0.000708$, $v_g = 0.21261\ m^3/kg$.

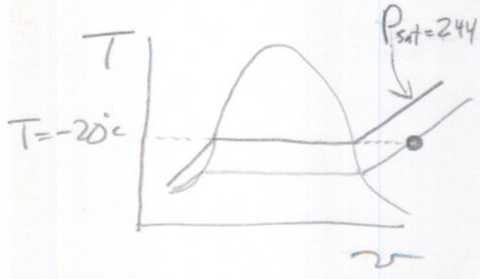
so v given which is $0.1\ m^3/kg$ is between Those

hence $\boxed{\text{Saturated liquid and Vaper}}$



d) From B.4.1, for $T = -20^\circ c$, $P_{sat} = 244.8$ KPa.

Since $P_{given} > P_{sat}$, we see That R22 is in $\boxed{\text{Super heated Vapor}}$



Problem 3.33

10/10

Statment we are given a table and asked to fill it in. we will use the tables for water to do this. in each entry, we are given 2 properties. this is the table

	P(KPa)	T °c	v [m^3/Kg]	x
a	500	20	?	?
b	500	?	0.2	?
c	1400	200	?	?
d	?	300	?	0.8.

assumptions

Pure substance in equilibrium.

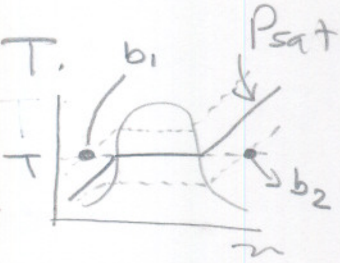
Laws

use tables B.1.1, B.1.2, B.1.3, $v = v_f + x(v_g - v_f)$

IF $v < v_f \Rightarrow$ solid. IF $v > v_g \Rightarrow$ superheated.

Steps

a) we can use table B.1.1 or B.1.2.
use table B.1.1. lookup P_{sat} for given T.
if $P_{sat} < P_{given}$ Then intersection Point b_1 will occure in the Solid phase.
IF $P_{sat} > P_{given}$, then intersection point b_2 will occure in the superheated phase.
if $P_{sat} = P_{given}$, then in liquid-vapor phase.



After we know which Phase, we can now use table B.1.4 (compressed liquid) or B.1.3 (superheated) to find v.

$\longrightarrow$

b) use B.1.2 (Saturated water pressure table) to find v_f, v_g for given P. compare given v to these to determine which phase. if $v < v_f$ then solid. if $v > v_g$ then superheated. else mixed phase. depending on the Phase, use table B.1.3 (superheated) to lookup T for given P, or use table B.1.4 to lookup T for given P, or use B.1.2 to lookup T for given P if in mixed Phase.

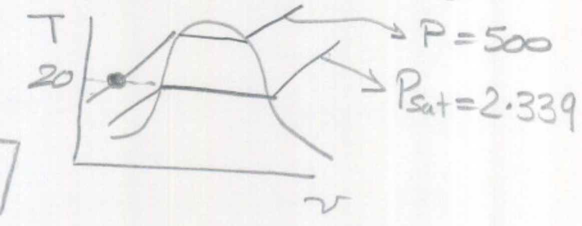
x is undefined if in Solid or superheated.
else x is found from $v = v_f + x(v_g - v_f)$.

c) use same steps as ⓐ.

d) since x is defined, we know we are in mixed liquid-vapor. so use table B.1.1 to lookup P_{sat} and v_f, v_g. then find $v = v_f + x(v_g - v_f)$.

Numerical

a) From table B.1.1, $P_{sat} = 2.339$ KPa, but given $P = 500$ KPa.
so $P > P_{sat}$
hence in liquid phase.
hence $\boxed{x \text{ undefind}}$



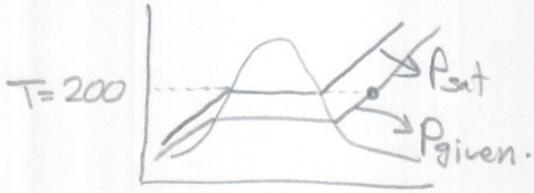
since in liquid Phase, then use table B.1.4. For P = 500 KPa lookup for T = 20 $\Rightarrow \boxed{v = 0.001002 \text{ m}^3/\text{kg}}$

b) From Table B.1.2, For $P = 500^{\text{kPa}} \Rightarrow v_f = 0.001093$ m³/kg, $v_g = 0.37489$ m³/kg
we are given $v = 0.2$ m³/kg. Hence in mixed liquid-vapor Phase.
so from $v = v_f + x(v_g - v_f) \Rightarrow \frac{v - v_f}{v_g - v_f} = x \Rightarrow x = \frac{0.2 - 0.001093}{0.37489 - 0.001093}$

$\Rightarrow \boxed{x = 0.5321}$. $\boxed{T_{sat} = 151.86°c}$ From same table B.1.2
since in Saturated water–Satured vapor Phase.

c) From Table B.1.1, lookup P_{sat} for given $T = 200°c$. we find $P_{sat} = 1553.8$ kPa. As in step ⓐ, we see here that $P_{sat} > P_{given}$. hence in $\boxed{\text{super heated}}$ vapor phase

hence $\boxed{x \text{ undefined}}$



to find v, now use table B.1.3

Since P_{given} is 1400 kPa, use table for $P = 1400$ kPa, entry for $T = 200°c$ $\Rightarrow v = 0.14302 \ m^3/kg$.

d) since x is defined, this is mixed liqrid-vapor phase.

From Table B.1.1, lookup P_{sat} for $T = 300°c$.

$\Rightarrow \boxed{P_{sat} = 8581.0 \text{ kPa}}$. $\Rightarrow v_f = 0.001404 \ m^3/kg$, $v_g = 0.02167 \ m^3/kg$

$v = v_f + x(v_g - v_f) \Rightarrow v = 0.001404 + 0.8(0.02167 - 0.001404)$

$\Rightarrow \boxed{v = 0.0176168 \ m^3/kg}$

So Final Table is

	P (KPa)	T (°c)	v (m^3/kg)	x
a	500	20	0.001002	undefined
b	500	151.86	0.2	0.532
c	1400	200	0.14302	undefined
d	8581	300	0.01762	0.8

Problem 3.34

Statment Place the 4 states a-d listed in Problem 3.33
10/10 as labled dots in a sketch of P-v and T-v diagrams.

here we are asked to use P-v and T-v and result of problem 3.33 to locate the states.

assumptions

Pure substance in equilibrium

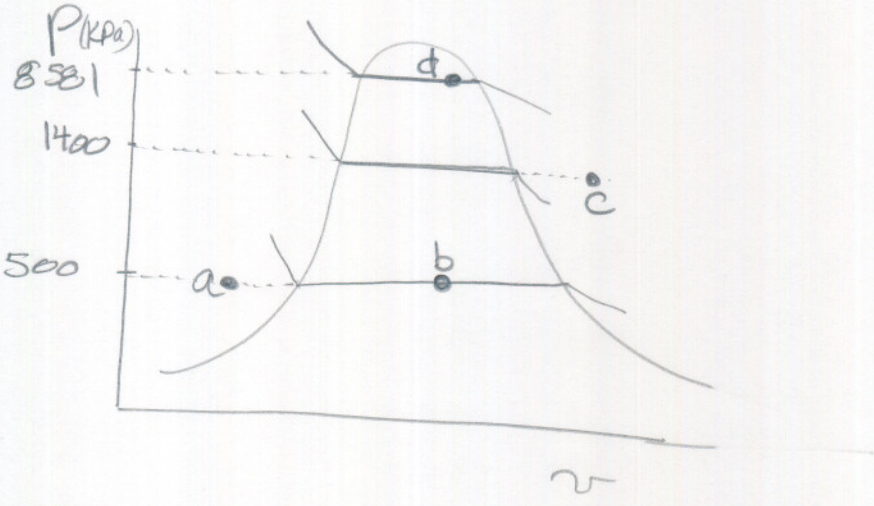
Laws

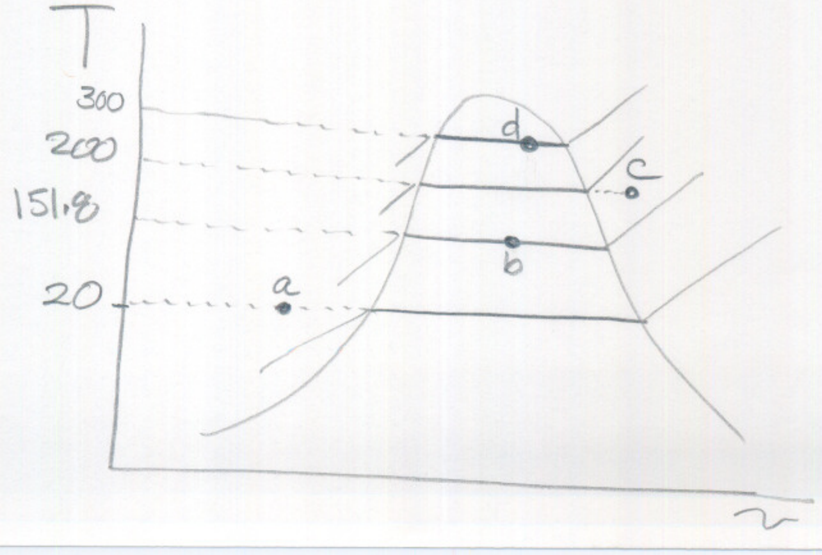
P-v , T-v diagrams.

steps

draw P-v diagram. Then use result of 3.33 to locate state in diagram. similarly for T-v diagram.

Numerical





Problem 3.36

Statment give phase and specific volume for the following:

10/10

a. R22, $T = -25°C$, $P = 100$ kPa
b. R22, $T = -25°C$, $P = 300$ kPa
c. R12, $T = 5°C$, $P = 200$ kPa

here we are given 2 properties (P, T) and from these need to determine additional property (v) and the phase.

assumptions

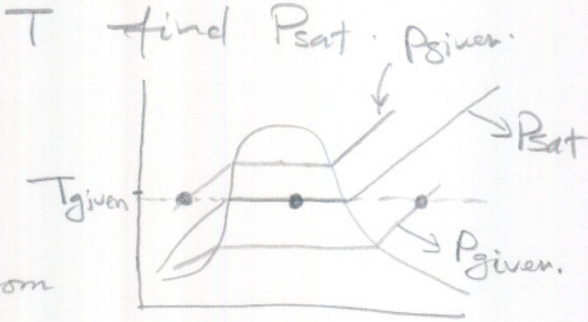
Pure substance. In equilibrium.
For compressed liquid v, assume $v = v_f$.

Laws

use T-v diagram.
IF $P_{sat} > P \Rightarrow$ superheated. IF $P_{sat} < P \Rightarrow$ liquid phase.

Steps

For a, b, follow these steps:
From table B.4.1, for given T find P_{sat}.



Then compare P_{sat} with P_{given}.

IF $P_{sat} > P_{given}$ then R22 is in superheated phase as seen from diagram.

IF $P_{sat} < P_{given}$, then in liquid phase.

IF $P_{sat} = P_{given}$, then in mixed liquid-vapor phase.

then depending on phase, use B.4.2 (for superheated) or B.4.1 for saturated or liquid. (take $v = v_f$ if liquid phase.

For Part c, use Table B.3.1, B.3.2. and follow same logic as above. ⟶

Numerical

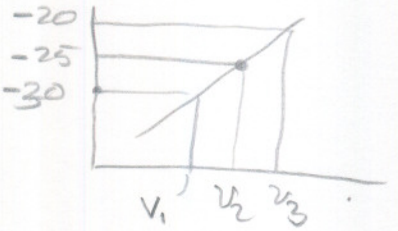
a) From table B.4.1

$T = -25°c \Rightarrow P_{sat} = 201.0$ KPa.

hence $P_{sat} > (P_{given} = 100)$. $\Rightarrow$ $\boxed{\text{superheated Phase}}$

So from table B.4.2, For entry for P = 100 KPa, use interpolation to find v for $T = -25°c$.

we want to find v_2.



$$\text{so } \frac{(-20)-(-30)}{0.23706-0.22675} = \frac{(-25)-(-30)}{v_2 - 0.22675}$$

$$\Rightarrow \frac{10}{0.23706-0.22675} = \frac{5}{v_2 - 0.22675}$$

$$10v_2 - 2.2675 = 5(0.23706-0.22675).$$

$$v_2 = \frac{5(0.23706-0.22675)+2.2675}{10} = \boxed{0.231905 \text{ m}^3/\text{kg}}$$

b) From Table B.4.1

$T = -25°c \Rightarrow P_{sat} = 201.0$ KPa

So $P_{sat} < (P_{given} = 300 \text{ KPa})$. $\Rightarrow$ $\boxed{\text{liquid Phase}}$

hence use $v = v_f$. $\Rightarrow$ $\boxed{v = 0.000733 \quad \text{m}^3/\text{Kg}}$

c) From Table B.3.1

$T = 5°c \Rightarrow P_{sat} = 362.6$ KPa.

so $P_{sat} > P_{given}$ $\Rightarrow$ $\boxed{\text{Superheated vapour}}$

So use table B.3.2. From subtable for P = 200 KPa use interpolation

$$\frac{10-0}{0.09255-0.08861} = \frac{5-0}{v_2 - 0.08861}$$

$$\Rightarrow 10v_2 - 0.8861 = 5(0.09255-0.08861)$$

$$v_2 = \frac{5(0.09255-0.08861)+0.8861}{10} = \boxed{0.09058 \text{ m}^3/\text{kg}}$$

⟶

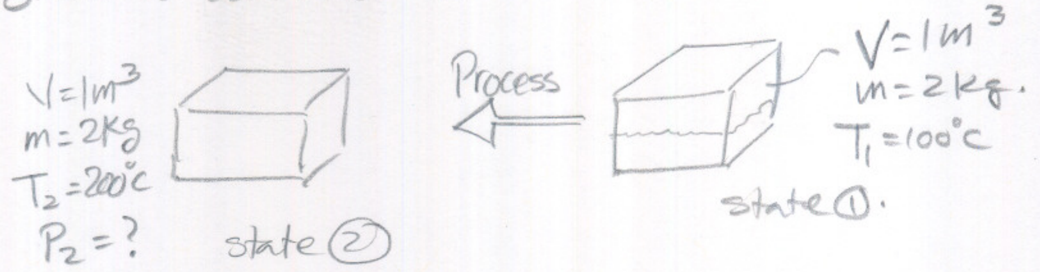
So, summary result:

	Phase	v m^3/kg
a	superheated vapor	0.231905
b	liquid	0.00073
c	superheated	0.09058

Problem 3.41

Statment. A sealed rigid vessel has $V = 1 m^3$, contains 2 Kg of water at 100°C.
10/10 Vessel is now heated. If safety pressure valve is installed, at what Pressure should valve be set to have a max. temp of 200°C ?

here we are given a controlled mass. we have 2 states.



temp was increased from state ①, and need to find P in state ②.

assumption

Pure substance.

ideal process (quasi-equilibrium process)

Laws

$v = \frac{V}{m}$, constant v process.

Steps

Since V is fixed, and mass is controlled, then v is constant. $\boxed{v = \frac{V}{m}}$ ——— ①.

From table B.1.1, we look up entry for T_1, check if supplied v is $< v_f$ or $> v_g$ or in between. This gives phase in state ①.

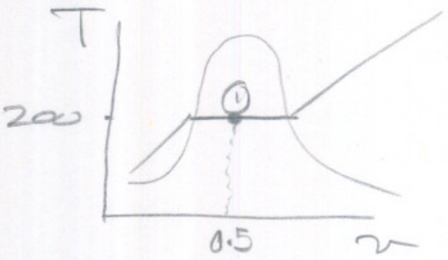
From table B.1.1. we lookup entry for T_2. again since v is constant, we can find phase by comparing to v_f and v_g. by knowing phase in state ②, use B.1.3 or B.1.4 to find P for T_2 at this v.

→

Numerical

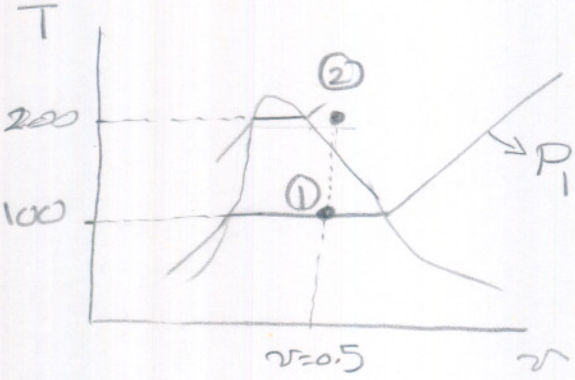
$$v = \frac{V}{m} = \frac{1}{2} = \boxed{0.5 \ m^3/kg}$$

From B.1.1 (saturated water), $v_f = 0.001044 \ m^3/kg$. $v_g = 1.6729 \ m^3/kg$. $\Longrightarrow$ mixed liquid-vapor phase



again, from B.1.1, for $T = 200°C$, $v_f = 0.001156 \ m^3/kg$.
$v_g = 0.12736 \ m^3/kg$. $\Longrightarrow$ $v > v_g$ i.e $\boxed{\text{superheated Vapor}}$

since in superheated phase, use table B.1.3



looking at B.1.3, I see that at 400 kPa, for $T=200$, $v=0.53422$.
and at 500 kPa, $T=200$, $v=0.42492$.

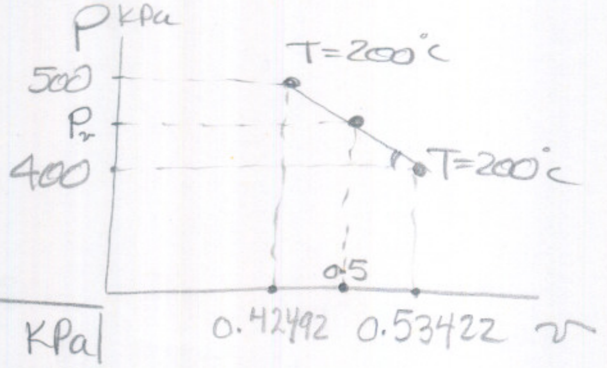
$\Longrightarrow \boxed{400 \text{ kPa} < P_2 < 500 \text{ kPa}}$

To find correct P_2, use interpolation.

so $$\frac{500-400}{0.53422-0.42492} = \frac{P_2 - 400}{0.53422-0.5}$$

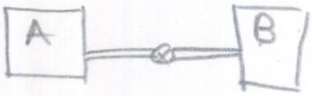
$$(P_2-400)(0.53422-0.42492) = 100\,(0.03422)$$

$$P = \frac{3.422}{0.53422-0.42492} + 400 = \boxed{431.308 \ \text{kPa}}$$



Problem 3.49 10/10

statment two tanks are connected



. tank

A at $P_A = 200\,kPa$, $v_A = 0.5\ m^3/kg$. $V_A = 1\,m^3$. tank B contains $m_B = 3.5\,kg$ $P_B = 0.5\,MPa$, $T_B = 400°C$. Valve is opened. Find Final state speific Volume.

here we are given an initial state (Valve closed), and Final state (Valve open):

assumptions

Pure Substance ideal process.

Final Volume $= V_A + V_B$, ignore Volume of pipe connecting 2 tanks.

Laws

$v = \frac{V}{m}$, tables B.1

since controlled mass and Volume, $v_{A+B} = \frac{V_A + V_B}{m_A + m_B}$

steps

First analyse state ① Find m_A from given properties of tank A.

next find V_B from given properties of tank B.

hence $\boxed{v_{Final} = \frac{V_A + V_B}{m_A + m_B}}$

Numerical

From B.1.1, for tank A, at $P = 200\,kPa \Rightarrow v_f < v < v_g$. hence in mixed phase. $m_A = \frac{V_A}{v_A} = \frac{1}{0.5} = \boxed{2\,kg}$

For tank B, still in initial state. From B.1.1, we see that for $P = 0.5\,MPa$, $T_{sat} = 151.86° \Rightarrow$ Super heated Vapor. so use B.1.3. For $P = 0.5\,MPa$ and $T = 400°C \Rightarrow \boxed{v_B = 0.61728\ \frac{m^3}{kg}}$

hence $V_B = v_B m_B = (0.61728)(3.5) = \boxed{2.16048\ m^3}$

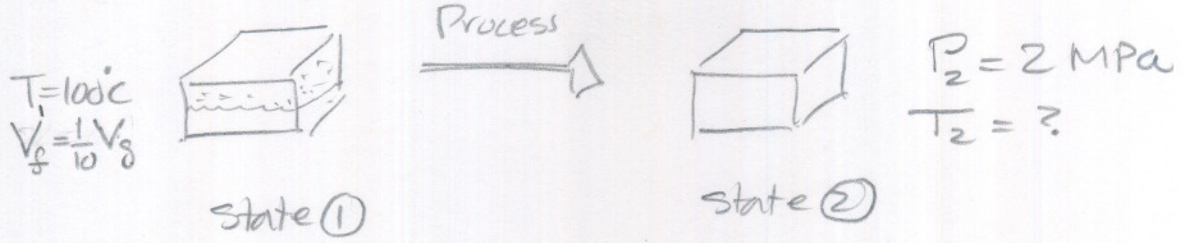
so $v_{final} = \frac{V_A + V_B}{m_A + m_B} = (1 + 2.16048)/(2 + 3.5) \Longrightarrow \boxed{0.57463\ m^3/kg}$

Problem 3.61

Statment

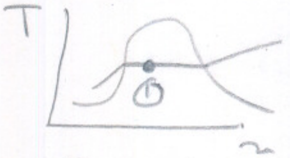
9/10

Pressure cooker (closed tank) contains water at 100°C, with liquid Volume at 1/10 of vapour volume. it is heated until Pressure reaches 2 MPa. Find Final T. has final state more or less vapor than initial state?



we are given 2 properties in state ①, T and x. so we know already we are in mixed Phase phase.

-1 Show process



For state ②, we are given one property, P. and asked to find second independent property T. also need to find if in state 2 there is more or less vapor than state ①. hence need to find x (if defined).

Assumptions

Pure substance.
ideal Process.

Laws

$$x = \frac{\text{Mass of Vapor}}{\text{total mass}} = \frac{m_g}{m_f + m_g} = \frac{\frac{V_g}{v_g}}{\frac{V_f}{v_f} + \frac{V_g}{v_g}}$$

$$v = \frac{V}{m}, \quad v = v_f + x(v_g - v_f)$$

Steps

Find x_1 (x in state ①).

in state 1

$$x_1 = \frac{V_g/v_g}{\frac{V_f}{v_f} + \frac{V_g}{v_g}} \qquad \text{but } V_f = \frac{V_g}{10}$$

$$x_1 = \frac{10V_f/v_g}{V_f/v_f + 10V_f/v_g} = \frac{\frac{10}{v_g}}{\frac{1}{v_f} + \frac{10}{v_g}} = \boxed{\frac{10 v_f}{v_g + 10 v_f}} \rightarrow$$

so can find x_1 if know v_f and v_g.
now use properties given in state ① to find v_f and v_g.

From table B.1.1, For $T = T_1$ look up v_f and v_g.

now can find v_1:

$$\boxed{v_1 = v_f + x_1 (v_g - v_f)}$$

now in state ②. since closed tank, hence Volume does not change. so $\boxed{v_2 = v_1}$

Find x_2 from $v_1 = v_f + x_2 (v_g - v_f)$

$$\Rightarrow \boxed{x_2 = \frac{v_1 - v_f}{v_g - v_f}}$$

to find v_f, v_g in state ② use tables B.1 again, since we are given $P_2 = 2$ MPa.

now we have x_1 and x_2, we can find if there is more or less vapor.

if $x_2 > x_1 \Rightarrow$ more vapor in state ②

to find T_2, look up table B.1 again given P_2.

→

Numerical

$$x_1 = \frac{10 v_f}{v_g + 10 v_f}.$$

From Table B.1.1, For $T = 100°c \Rightarrow v_f = 0.001044 \ m^3/kg$.
$v_g = 1.67290 \ m^3/kg$.

$$\Rightarrow x_1 = \frac{10(0.001044)}{1.67290 + 10(0.001044)} = \boxed{0.0062019}$$

So $v_1 = v_f + x_1(v_g - v_f)$

$$= 0.001044 + 0.0062019(1.67290 - 0.006368)$$

$$= \boxed{0.011379 \ m^3/kg}$$

State 2:

since closed Vessel $\Rightarrow v_2 = v_1 = 0.011379 \ m^3/kg$.

From table B.1.1, at $P = 2 mPa$, $v_f < v_2 < v_g$

hence in state 2, $\boxed{\text{still in mixed phase}}$

$v_f = 0.001177 \ m^3/kg$, $v_g = 0.09963 \ m^3/kg$.

$$\text{so } x_2 = \frac{v_2 - v_f}{v_g - v_f} = \frac{0.011379 - 0.001177}{0.09963 - 0.001177}$$

$$= \boxed{0.10362}$$

hence $\boxed{x_2 > x_1} \Rightarrow \boxed{\text{Mass of Vapor in state ② is more than in state ①}}$

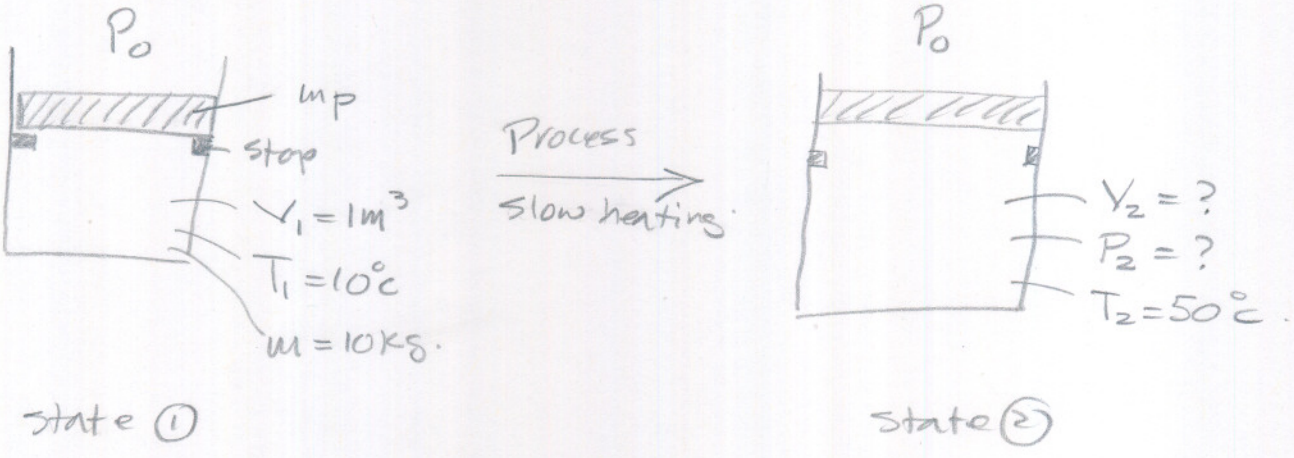
to Find T_2, since in mixed phase, again from B.1.1, we see that for $P = 2MPa$, $\boxed{T_{sat} = 212.42°C}$

Problem 3.63

10/16

Statment

Ammonia at 10°C with mass 10kg in a piston/cylinder assembly with initial volume of $1 m^3$. Piston initialy rests on the stops has mass such that a pressure of 900 kPa will float it. Now ammonia is slowly heated to 50°c. Find final pressure and volume.



in state ①, Piston is resting on stops. in state ② new temp. is 50°c. need to find final pressure and final Volume.

assumptions

Pure substance
Frictionless Piston.
ideal process

Laws

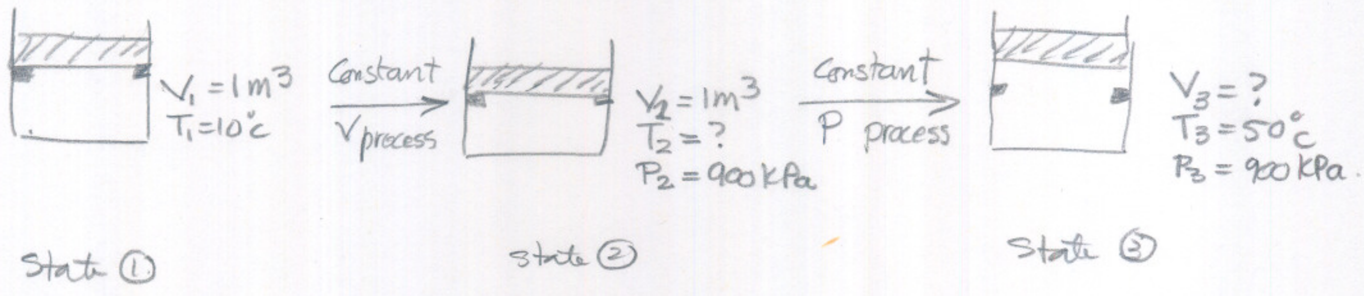
$$v = \frac{V}{m}$$

Steps

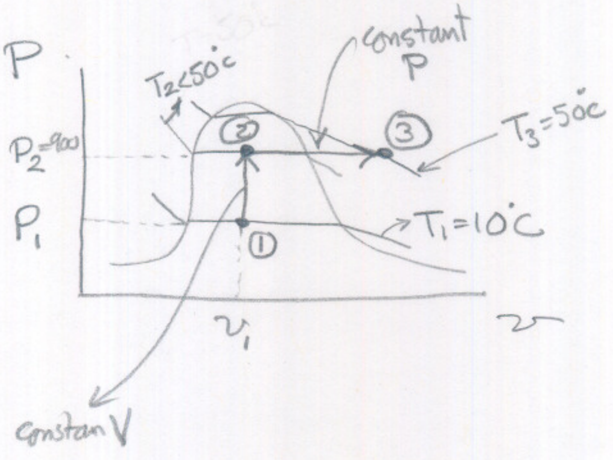
→

To reach Final state, Process can go via 2 different Paths. If final pressure < 900 kPa, then Piston will not rise, and so this is a constant Volume Problem. but if, as we raise temp. pressure reaches 900 kPa, then Piston will start to rise, but Pressure will remain constant at this final P untill Final temp. reaches 50°c.

so problem looks as follows



So, IF $T_2 = 50°c$, then Process is only ①→②.
but IF $T_2 < 50°c$, the process is ①→②→③



①→②→③ Process

→

$v_1 = \frac{V_1}{m}$. and knowing T_1 we can find x_1. hence know Phas

at state ②. $v_2 = v_1$. From tables B.2.1. lookup T corresponding to $P = P_{stop} = 900\ kPa$.

iF $T_2 < T_{Final}$, then this is now a constant Pressure process. use superheated amonia table, lookup under P_{Final} and T_{Final} to find v_{Final}.

Numerical

$$v_1 = \frac{V_1}{m} = \frac{1\ (m^3)}{10\ (Kg)} = 0.1\ m^3/Kg.$$

From B.2.1 . at $T_1 = 10°c$, we see $v_1 < v_g$.
hence Saturated amonia.

From same table, I see that for $P = 900\ kPa$, T is between 20°c and 25°c, this mean for $T = 50°c$, we must be in superheated Phase.

From table B.2.2, For $P = 900\ kPa$:

For $P = 800\ kPa$, $T = 50°c \longrightarrow v = 0.18465\ m^3/kg$.
$P = 1000\ kPa$, $T = 50°c \longrightarrow v = 0.14499\ m^3/kg$.

so interpolation to final at $P = 900\ kPa$:

$$\frac{1000-800}{0.14499-0.18465} = \frac{1000-900}{0.14499-v}$$

$$200(0.14499-v) = 100(0.14499-0.18465)$$

$$(200)(0.14499) - 200v = 14.499 - 18.465$$

$$v = \frac{(200)(0.14499) - (14.499-18.465)}{200} = \boxed{0.16482\ m^3/kg}$$

$$\text{so } V_2 = v_2 m = (0.16482)(10) = \boxed{1.6482\ m^3}$$

Problem 3·75

Statment given saturated R-134a at 3 different T, $T_1 = -40°C$, $T_2 = 0°C$, $T_3 = +40°C$. need to Find specific 19/16 volume at these Temps. Find % relative error = $100(v - v_g)/v_g$ at each T.

assumptions

ideal gas, R at 25°C, 100 kPa in equilibrium.

Laws

ideal gas law $PV = mRT$, $T(K) = 273.15 + T(C)$

$$v = \frac{V}{m}$$

relative % error $= 100(v - v_g)/v_g$.

steps

since we are told this is saturated R-134a, then use table B.5.1. For each given T, Find P_{sat}. then

Constant From table A.5

$$v = \frac{V}{m} = \frac{RT}{P_{sat}}$$

given

From Table B.5.1

now find % relative error, since we know v_g as well from table B.5.1.

Numerical

→

From A.5, $R = 0.08149$ KJ/kg-K

T	v_g (m³/kg)	P_{sat} (KPa)	$v = \frac{RT}{P_{sat}}$ (kg/m³)	% error
−40°c	0.35696	51.8	$v = \frac{(0.08149)(273.15-40)}{51.8}$ $= 0.36678$	$\frac{100(0.36678-0.35696)}{0.35696}$ $= 2.751$
0°c	0.06919	294.0	$v = \frac{(0.08149)(273.15)}{294.0}$ $= 0.07571$	$\frac{100(0.07571-0.06919)}{0.06919}$ $= 9.4233$
40°c	0.02002	1017.0	$v = \frac{(0.08149)(273.15+40)}{1017.0}$ $= 0.02509$	$\frac{100(0.02509-0.02002)}{0.02002}$ $= 25.324$

notice that % error increases with temp. increase.

Problem 3.92

10/10

Statment

Find phase, quality x if defined, and missing property P or T.

a) H_2O , $T = 120°C$, $v = 0.5\ m^3/kg$.

b) H_2O , $P = 100 kPa$, $v = 1.8\ m^3/kg$.

c) H_2O , $T = 263K$, $v = 200\ m^3/kg$.

Assumptions

Pure substance. In equilibrium.

Laws

Use thermodynamics tables.

Find x from $v = v_f + x(v_g - v_f) \Rightarrow x = \frac{v - v_f}{v_g - v_f}$

IF $v > v_g \Rightarrow$ superheated phase. IF $v < v_f \Rightarrow$ compressed liquid

Steps

For each problem, lookup under table B.1.1 or B.1.2 values for v_f and v_g. Can find phase by comparing v to v_f, v_g.

Find missing property by lookup from appropriate table.

Numerical

a). From B.1.1, for $T = 120°C$, $v_f = 0.001060\ m^3/kg$.
$v_g = 0.89186\ m^3/kg$. hence mixed phase
Saturated water - saturated vapor.
$\boxed{P_{sat} = 198.5\ kPa}$ From B.1.1. $x = \frac{0.5 - 0.00106}{0.89186 - 0.00106} = \boxed{0.56}$

b) From B.1.2, For $P = 100 kPa$, $v_f = 0.001043\ m^3/kg$,
$v_g = 1.694\ m^3/kg$ hence $v > v_g \Rightarrow$ super heated

From B.1.3, For $P = 100 kPa$, $v = 1.8$ do interpolation:

$$\frac{150 - 99.62}{1.93636 - 1.694} = \frac{150 - T}{1.93636 - 1.8}$$

$$\frac{(150 - 99.62)(1.93636 - 1.8)}{1.93636 - 1.694} = (150 - T) \Rightarrow T = \boxed{121.65449°C}$$

→

$\boxed{x \text{ undefind}}$ since superheated.

c) For $T = 263 - 273.15 = -10.15°$,

use B.1.5. $\Rightarrow \boxed{P = 0.2601 \text{ kPa}}$ (used $-10°c$).

$v_f = 0.0010891$, $v_g = 466.757$ m³/Kg.

hence $v_f < v < v_g \Rightarrow \boxed{\text{Saturated solid} - \text{Saturated Vapor}}$

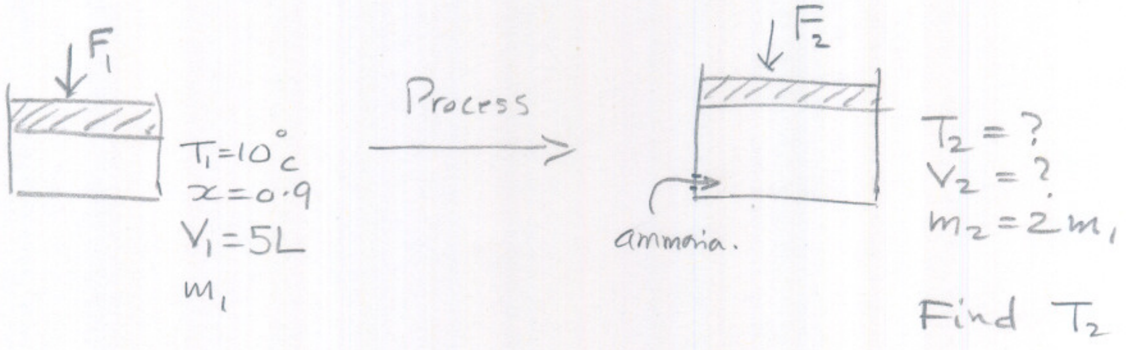
$$x = \frac{v - v_f}{v_g - v_f} = \frac{200 - 0.0010891}{466.757 - 0.0010891} = \boxed{0.428487}$$

Problem 3.104

10/10

statment

cylinder with ammonia fitted with Piston restrained by external Force that is Proportional to cylinder Volume squared. in state ①, $T = 10^\circ c$, $x = 0.9$, $V = 5L$. A valve on cylinder is opened and additional ammonia flows into cylinder until mass is doubled. If at this point $P = 1.2\ MPa$, Find Final T.



Find T_2

assumptions

Pure substance
ideal process.

Laws

$$\overset{\text{external Force}}{F} = \underset{\text{constant}}{K} V^2 \quad , \quad v = \frac{V}{m} \quad , \quad v = v_f + x(v_g - v_f)$$

Steps

$$F = KV^2.$$

so $F_1 = K V_1^2 \implies K = \frac{F_1}{V_1^2}$

but to balance Piston, $F_1 = P_1 A$

hence $\boxed{K = \frac{P_1 A}{V_1^2}}$ ——— ①

Find P_1 From table B.2.1 For $T_1 = 10^\circ c$

now find $v_1 = v_f + x_1 (v_g - v_f)$.

so we find $\boxed{m_1 = \frac{V_1}{v_1}}$ ——— ② $\longrightarrow$

now in state ②

balance Forces for Piston:

$$F_2 = P_2 A$$

$$K V_2^2 = P_2 A$$

$$\text{so } V_2^2 = \frac{P_2 A}{K} \Rightarrow V_2 = \sqrt{\frac{P_2 A}{K}} \quad \text{———} \quad ③$$

but From ①, subtitute into ③ we set

$$V_2 = \sqrt{\frac{P_2 A}{P_1 A} V_1^2} = \boxed{V_1 \sqrt{\frac{P_2}{P_1}}} \quad \text{———} \quad ④$$

$$\text{so } \boxed{v_2 = \frac{V_2}{m_2} = \frac{V_1 \sqrt{P_2/P_1}}{2 m_1}} \quad \text{———} \quad ⑤.$$

so now we have P_2 and v_2 values we Can find T_2 From table B.2.1 or B.2.2.

Numerical

From table B.2.1, For $T_1 = 10\,^\circ c$, $v_f = 0.0016\ m^3/kg$. $v_g = 0.20541\ m^3/kg$. $\boxed{P_1 = 615.2\ kPa.}$

$$\text{so } v_1 = v_f + x_1 (v_g - v_f)$$

$$= 0.0016 + 0.9\,(0.20541 - 0.0016) = \boxed{0.185029\ m^3/kg}$$

From eq ②
$$m_1 = \frac{V_1}{v_1} = \frac{5\times10^{-3}\ (m^3)}{0.185029\ (m^3/kg)} = \boxed{0.027\ kg}$$

From eq ④
$$V_2 = V_1 \sqrt{\frac{P_2}{P_1}} = 5\times10^{-3} \sqrt{\frac{1.2\times10^6}{615.2\times10^3}} = \boxed{0.006983\ m^3}$$

so From eq ⑤
$$v_2 = \frac{V_2}{m_2} = \frac{0.006983}{(0.027)\times2} = \boxed{0.129315\ m^3/kg}$$

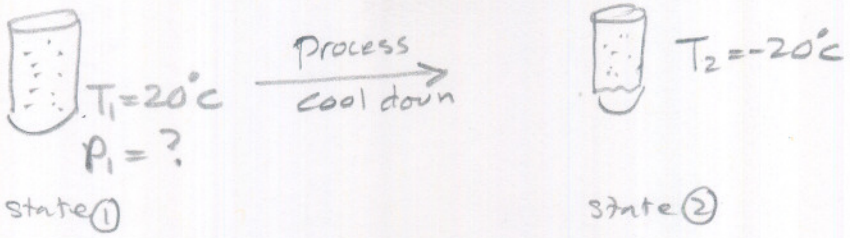
so for v_2, P_2 : From B.2.2, interpolation (superheated since From B.2.1 $v > v_g$ for $P = 1.2$ MPa)

$$\frac{80-70}{0.13387-0.1289} = \frac{80-T_2}{0.13387-0.129315} \Rightarrow \boxed{T_2 = 70.9\,^\circ c}$$

Problem 3.110

10/10

Statment given sealed tube contain R-22 vapor at 20°C. need to know P at this temp. tube cooled to -20°C, small droplets of liquid are observed on glass wall. Find initial pressure.



assumptions

Pure substance. ideal process.

when dropplets seen $\Rightarrow v=v_g$ as starts of condensation.

Laws

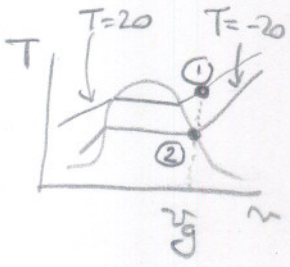
use R-22 thermodynamics tables.

droplets/vapor $\Rightarrow$ mixed phase.

Steps

since droplets and vapor at T_2 $\Rightarrow$ staurated mixed liquid-vapor phase.

hence use table B.4.1 to find v_g.



Since tube is sealed $\Rightarrow$ $\boxed{\text{constant } v}$ process.

hence use table B.4.2 (superheated phase) using v_g found above and using $T_1=20°C$ to find P_2.

Numerical

From B.4.1, for $T=-20°C$, $v_g=\boxed{0.09284 \ m^3/kg}$

From B.4.2, for $T=20°C$ and $v_g=$ ↑ Find P

I see for $P=300\,kPa$, $T=20°C$, $\Rightarrow v=0.08947 \ m^3/kg$

for $P=200\,kPa$, $T=20°C$ $\Rightarrow v=0.13651 \ m^3/kg$.

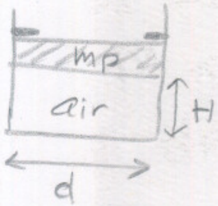
so interpolation:

$$\frac{300-200}{0.08947-0.13651}=\frac{300-P}{0.08947-0.09284} \Rightarrow \boxed{P=292.83\ kPa}$$

Problem 3.111

$P_o = 100$ kPa.

statment given



9/10

State ①

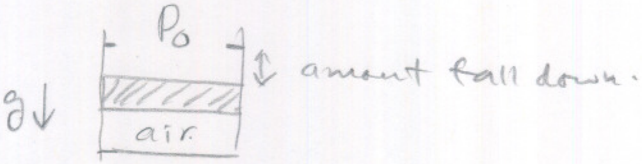
$P_1 = 250$ kPa
$T_1 = 300°C$
$H = 25 \times 10^{-2}$ m
$d = 0.1$ m
$m_p = 50$ kg.

atmosphere at 20°C. Piston in state① above originally Pushes against stops.

Cylinder is cooled down.

a) Find at what T piston begins to move down?

b) How far does it fall down when air temp reaches ambient?



-1 Draw Diagram

Final state. (state ②)

assumptions

ideal gas. so can use $PV = mRT$.

assume frictionaless piston.

ideal Process

Laws

ideal gas law. $PV = mRT$

Steps

a) pistons begins to fall down when air pressure inside cylinder just large enough to support weight of piston.

so From Piston balance Forces, we get

$$P_o A + m_p g = PA$$

$$\Rightarrow \boxed{P = P_o + \frac{m_p g}{A}} \text{ ——— } ①$$

→

From ideal gas law

$$PV = mRT.$$

so From ① into above, we get

$$\left(P_0 + \frac{m_p g}{A}\right) V = mRT$$

or $T = \left(P_0 + \frac{m_p g}{A}\right) \frac{V}{mR}$

but $V = AH$

so $T = \left(P_0 + \frac{m_p g}{A}\right) \frac{AH}{mR}$ ——— ②

to find m (mass of air inside cylinder), use initial state.

$$P_1 V_1 = mRT_1 \Rightarrow m = \frac{P_1 V_1}{RT_1} = \frac{P_1 AH}{RT_1} \text{ ——— ③}$$

Sub ③ into ②:

$$T = \left(P_0 + \frac{m_p g}{A}\right) \frac{\cancel{AH}\, \cancel{R}T_1}{P_1 \cancel{AH}\, \cancel{R}} = \boxed{\left(P_0 + \frac{m_p g}{A}\right) \frac{T_1}{P_1}} \text{ ——— ④}$$

the above give the temp. when pistons begin to move down.

b) to Find how far Piston falls down, need to find Final Volume. call it V_2.

From ideal gas Law: $P_2 V_2 = mRT_2$

so $V_2 = \frac{mRT_2}{P_2}$. but m is same as from eq ③ and T_2 is given as ambient temp. P_2 is pressure to support piston, hence same as eq ① hence →

$$V_2 = \frac{\frac{P_1 AH}{\cancel{R}T_1}\cancel{R}T_2}{P_0 + \frac{m_p g}{A}} = \boxed{\frac{P_1 A^2 H T_2}{AT_1P_0 + T_1 m_p g}} \text{ --- } ⑤.$$

$$\text{so} \quad \Delta h = \frac{\overset{\text{state}①}{\overset{\uparrow}{V_1}} - \overset{\rightarrow \text{state } ②}{V_2}}{A}$$

Numerical

a) From eq ④

$$T = \left(P_0 + \frac{m_p g}{A}\right)\frac{T_1}{P_1} = \left(100\times10^3 + \frac{(50)(9.81)}{\pi\frac{0.1^2}{4}}\right)\frac{(273+300)}{250\times10^3}$$

$$= 372.3409 \text{ K}$$

$$= \boxed{99.34\ °c}$$

b) From eq ⑤

$$V_2 = \frac{P_1A^2HT_2}{AT_1P_0 + T_1 m_p g} = \frac{(250\times10^3)\left[\pi\frac{0.1^2}{4}\right]^2(25\times10^{-2})(273+20)}{\left(\pi\frac{0.1^2}{4}\right)(273+300)(100\times10^3)+(273+300)\,50\times9.81}$$

$$= 1.5451\times10^{-3} \text{ m}^3 \qquad = 1.545 \text{ L}$$

hence $\Delta h = \frac{\Delta V}{A} \Rightarrow \Delta h = \frac{V_1 - V_2}{A} = \frac{AH - V_2}{A}$

$$= \frac{\left(\pi\frac{.1^2}{4}\right)(25\times10^{-2}) - 1.5451\times10^{-3}}{\pi\frac{.1^2}{4}} = 0.05327 \text{ m}$$

So piston falls down by $\boxed{5.327 \text{ cm}}$