classmate
Date
Page

MIN-106, Tutorial - 2, 19114018, Ayushman Tripathy

① ⓐ 10 MPa, 0.003 m^3/kg

In saturated table, at 10 MPa = 100 bar,
$v_f = 0.001452\ m^3/kg$
$v_g = 0.0018005\ m^3/kg = 0.018005\ m^3/kg$

$\because$ $v_f < v < v_g$ {0.001452 < 0.003 < 0.18005}

$\therefore$ the state is $\boxed{\text{Saturated Liquid Vapour Mixture}}$

ⓑ 1 MPa, 190°C

In saturated table, at 190°C, P = 12.551 bar
= 1.2551 MPa

But P < P_{sat} at 190°C
$\therefore$ the given state is $\boxed{\text{Superheated Vapour}}$

ⓒ 200°C, 0.1 m^3/kg

In saturated table, at 200°C,
$v_f = 0.0011565\ m^3/kg$
$v_g = 0.12716\ m^3/kg$
$\because$ $v_f < v < v_g$
$\therefore$ the given state is $\boxed{\text{mixture of saturated liquid and vapour}}$

classmate

Date

Page

(d) 200 kPa, 10°C

At 200 kPa = 2 bar in saturated table the T_{sat} = 120.23°C

But $T < T_{sat}$, $\therefore$ given state is $\boxed{\text{Compressed Liquid}}$

---

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

At $T = 120°C$, in sat. table, $v_f = 0.0010606\ m^3/kg$
$v_g = 0.8915\ m^3/kg$

as $v_f < v < v_g$

$\therefore$ saturated mix $\therefore$ 'x' is defined.

$v = v_f + x v_{fg}$

$\Rightarrow \quad x = \dfrac{v - v_f}{v_{fg}} = \dfrac{0.5 - 0.0010606}{0.8905}$

$= 0.56029$

$\boxed{x \approx 0.5603}$

(b) H_2O $P = 100\ kPa = 1\ bar$, $v = 1.8\ m^3/kg$

At 1 bar in sat. table $v_f = 0.001043\ m^3/kg$
$v_g = 1.677\ m^3/kg$

As $v > v_g$ $\therefore$ superheated vapour

$\therefore$ 'x' is $\boxed{\text{not defined}}$

(3) Given: $V = 1 m^3$, $m = 2 kg$ {V_{tot} & m_{tot}}

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

As in this process container is closed,
∴ 'v' will remain constant throughout the process.

As finally given $T_{max} = 200°C$,

At $T = 200°C$ in sat. table, $v_f = 0.0011565 \, m^3/kg$
$v_g = 0.12716 \, m^3/kg$

as given, $v = 0.5 \, m^3/kg > v_g$

∴ final mix. would have become super-saturated.

So, we check the value of P for $v = 0.5 \, m^3/kg$ and $T = 200°C$

At $T = 200°C$, $P = 4 bar$, $v = 0.53422 \, m^3/kg$
At $T = 200°C$, $P = 5 bar$, $v = 0.42492 \, m^3/kg$

By interpolation, $0.5 = 0.53422 + \Delta P \left(\frac{0.53422 - 0.42492}{4-5}\right)$

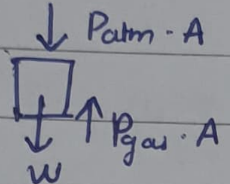
$$\therefore \Delta P = \frac{(0.53422 - 0.5)}{(0.53422 - 0.42492)} = 0.31308 \text{ bar}$$

$$\therefore P = 4bar + \Delta P = \boxed{4.31308 \text{ bar}} = \boxed{431.308 \text{ kPa}}$$

(4) As it is a saturated liq - vap mixture,
$P = P_{sat}$ at $T_{sat} = 120\,^{\circ}C$

$\therefore P = 1.9854 \text{ bar} = 198.54 \text{ kPa}$

As the petcock is in equilibrium



$$P_{atm} \cdot A + w = P_{gas} \cdot A$$

$$\Rightarrow w = (P_{gas} - P_{atm})\,A$$

$$\Rightarrow mg = (P_{gas} - P_{atm})\,A$$

$$\Rightarrow m = \frac{(P_{gas} - P_{atm})\,A}{g}$$

$$\therefore m = \frac{(198.54 - 101.3) \times 10^{3} \times 5 \times 10^{-6}}{9.8}$$

$$\boxed{m = 0.04961 \text{ kg}} = 49.61 \text{ grams}$$

$$\boxed{\begin{aligned}\therefore \text{mass of petcock} &= 0.04961 \text{ kg} \\ &= 49.61 \text{ g}\end{aligned}}$$

(5) As given both liquid and vapour are present
$\therefore$ sat. liq. - vap. mixture.

Given: $V_f = \frac{1}{10} V_g \Rightarrow m_f v_f = \frac{1}{10} m_g v_g$

$\Rightarrow \frac{m_g}{m_f} = \frac{10 v_f}{v_g} =$

At $100^\circ C$, $v_g = (v_g)_{100}$, $v_f = (v_f)_{100}$
$= 1.6730 \ m^3/kg$ $= 0.0010437 \ m^3/kg$

$$\frac{m_g}{m_f} = \frac{10 v_f}{v_g} = \frac{10 \times 0.0010437}{1.6730} = 6.238 \times 10^{-3}$$

$$x = \frac{m_g}{m_g + m_f} = \frac{6.238 \times 10^{-3}}{1 + 6.238 \times 10^{-3}} = 6.1998 \times 10^{-3}$$

$$v = v_f + x v_{fg}$$

$$= 0.0010437 + 6.1998 \times 10^{-3} \times 1.673$$

$$\boxed{v = 0.011416 \ m^3/kg}$$

At $2 \ MPa = 20 \ bar$ in sat. table,
$v_f = 0.001176 \ m^3/kg$
$v_g = 0.099367 \ m^3/kg$

$\because \quad v_f < v < v_g$

$\therefore$ mix. is saturated mix. [sat. liq-vap mix]

$\therefore T = T_{sat} = \boxed{212.42^\circ C}$ at $P = 20$ bar

$\therefore \boxed{T = 212.42^\circ C}$

classmate

Date

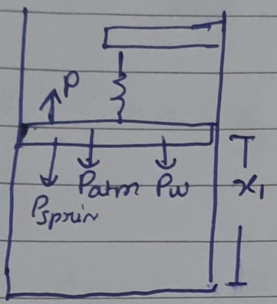
Page

(6) At bottom no other force acts, thus, we see that $P_{atm} + P_{weight\ of\ piston}$ is balanced by P_{lift}

$\Rightarrow \quad P_{lift} = P_{atm} + P_w = 200\,kPa$

When, $V = 0.1\,m^3$, let elongation {compression} be x_1

Initial:



$V = Ax_1 = 0.1\,m^3$

Here, Given $P = 5\,MPa = 5000\,kPa$

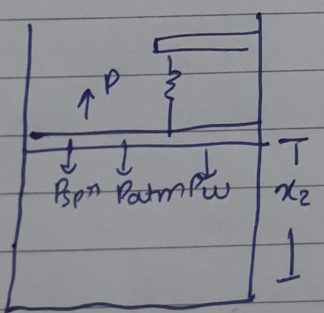
$P = P_{spring} + P_{atm} + P_w$

$5000 = P_{spring} + 200$

$\Rightarrow P_{spring} = 4800\,kPa$

But $P_{spring} = \frac{Kx_1}{A} = 4800\,kPA$

Final:



Here, $P = 1200\,kPa$

$P = P_{spr} + P_{atm} + W$

$\Rightarrow P = 1200 = P_{spr} + 200$

$\Rightarrow P_{spr} = \frac{Kx_2}{A} = 1200 - 200 = 1000\,kPa$

Now, $\frac{\frac{Kx_1}{A}}{\frac{Kx_2}{A}} = \frac{x_1}{x_2} = \frac{4800}{1000} = \frac{24}{5} \Rightarrow \frac{x_2}{x_1} = \frac{5}{24}$

$\Rightarrow V_2 = Ax_2 = (Ax_1)\frac{x_2}{x_1} = 0.1\,m^3 \times \frac{5}{24}$

$\Rightarrow V_2 = 0.02083\,m^3$

P.T.O

Initial state: given $P = 5 MPa = 50 bar$, $T = 400°C$

in sat. table at 50 bar, $T_{sat} = 263.99°C$

$\because$ $\underset{\{400\}}{T} > \underset{\{263.99\}}{T_{sat}}$, it is superheated vapour.

So, v for superheated vapour at 50 bar, 400°C

$v = 0.05781 \ m^3/kg$

$$\Rightarrow \quad m = \frac{V}{v} = \frac{0.1}{0.05781} = \boxed{1.7298 \ kg = m}$$

$$\Rightarrow \quad v_{final} = \frac{V_f}{m} = \frac{V_2}{m} = \frac{0.02083}{1.7298}$$

$$\boxed{v = 0.012041 \ m^3/kg}$$

At 1200 kPa = 12 bar, in saturated table,

$v_f = 0.001139 \ m^3/kg$, $v_g = 0.162921 \ m^3/kg$

$\because$ $v_f < v < v_g$

$\therefore$ final mix is saturated liq.-vap. mixture

$$\Rightarrow \quad T_{final} = \underset{\text{at 12 bar}}{T_{sat}} = 187.99°C \approx \boxed{188°C}$$

$\therefore$
$$\boxed{\begin{aligned} m &= 1.7298 \ kg \\ v &= 0.012041 \ m^3/kg \\ T &= 188°C \end{aligned}}$$

classmate
Date
Page

(7) Ar is kept at $5 m^3$; $-30^\circ C = 273.15 - 30$;
$= 243.15 K$

at 3MPa.

We have $T_r = \frac{T}{T_c} = \frac{243.15 K}{150.8 K} = 1.6124$

We have $P_r = \frac{P}{P_c} = \frac{3000 kPa}{4870 kPa} = 0.6160$

From diagram, we find at $P_r = 0.6160$
(Z vs P_r for diff T_r) & $T_r = 1.6124$

we have $Z \approx 0.96$ {or 0.95}

$Z = \frac{Pv}{RT} = \frac{PV/m}{\frac{\bar{R}}{M} T} \Rightarrow m = \frac{PVM}{Z \bar{R} T}$

$= \frac{3 \times 10^6 \times 5 \times 39.9}{8.314 \times 243.15}$

$\boxed{m_0 \approx 308.75 \text{ kg}}$
{308.39 kg}

By ideal gas approximation $m = \frac{PV}{RT} = m_0 Z = 0.96 \times m_0$

$= 0.96 \times 308.75$
≈ 296.4 kg

$\therefore$ error $= \frac{m_0 - m_0 Z}{m_0} \times 100 = (1 - Z) \times 100 = \boxed{4 \%}$

classmate

Date

Page

(6) $T = 40^\circ C = 313.15\,K$, $P = 500\,kPa = 0.5\,MPa$

For NH_3, $T_c = 405.5\,K$, $P_c = 11.35\,MPa$

$\Rightarrow T_r = \frac{T}{T_c} = 0.7723$

$\Rightarrow P_r = \frac{P}{P_c} = 0.04405$

As we have table for superheated ammonia,

At $40^\circ C$, $500\,kPa$, $\boxed{v = 0.29227\ m^3/kg}$

If we use ideal behavior taking $z = 1$,

we have, $z = \frac{Pv}{RT}$, $\Rightarrow v = \frac{zRT}{P} = \frac{1 \times (8.314/17)\times 10^3 \times 313.15}{500 \times 10^3}$

$\approx \frac{0.4882 \times 313.15 \times 10^3}{5 \times 10^5}$

$\boxed{v \approx 0.306\ m^3/kg}$

$\{0.3056\ m^3/kg\}$

% error $= \frac{0.3056 - 0.29227}{0.29227} \times 100 = \boxed{4.55\ \%\ error}$

From diagram, we have $z = 0.97$ $\left\{ \begin{array}{l} \text{for } T_r = 0.7723 \\ P_r = 0.04405 \end{array} \right.$

(z v/s P_r)

≈ 0.97

$\Rightarrow v = 0.97 \times v_{ideal} = 0.2964\ m^3/kg$

$\Rightarrow$ % error $= \frac{0.2964 - 0.29227}{0.29227} \times 100 = \boxed{1.42\ \%\ error}$