MIH-106 - Tutorial 2

Q.1 (a) 10 MPa , 0.003 m^3/kg
(= 100 bar)

For saturated vapour-liquid mixture,

$\Rightarrow V_f = 0.001452 \ m^3/kg$

$V_g = 0.018005 \ m^3/kg$

~~$\because$ $V > V_g \Rightarrow$ State Super~~

$\because V_f < V < V_g \Rightarrow$ $\boxed{\text{Saturated liquid \& vapour mixture}}$

(b) 1 MPa , 190°C
(= 10 bars)

At 190°C, pressure of saturated mixture = 12.551 bars

$\Rightarrow \because P_{given} < P_{sat} \Rightarrow$ $\boxed{\text{Superheated vapor}}$

(c) 200°C, 0.1 m^3/kg

At 200°C, $V_f = 0.0011565 \ m^3/kg$, $V_g = 0.12716 \ m^3/kg$

$\because V_f < V < V_g \Rightarrow$ $\boxed{\text{Saturated liquid \& vapour mixture}}$

(d) 200 kPa, 10°C
(= 2 bar)

At 10°C, $P_{sat} = 0.01227$ bars

$\because P > P_{sat} \Rightarrow$ $\boxed{\text{Compressed liquid}}$

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

At $T = 120°C$, $V_f = 0.0010606 \ m^3/kg$ & $V_g = 0.8915 \ m^3/kg$

$\because V_f < V < V_g \Rightarrow$ $\boxed{\text{Saturated liquid \& vapour mixture.}}$

Phase

$\Rightarrow \boxed{P = 1.9854 \text{ bars}}$

$0.5 = 0.0010606 + x(0.8905)$

$\Rightarrow \boxed{x = 0.5602}$

Q-2 (b) H_2O : $P = 100 kPa$, $v = 1.8\ m^3/kg$
(= 1 bar)

→ At $P = 100 kPa$, $v_f = 0.001452\ m^3/kg$

$V_g = 0.018005\ m^3/kg$

∴ $v > v_g$ ⇒ $\boxed{\text{Superheated vapor}}$ ← Phase

⇒ $\boxed{\text{Quality is undefined}}$

$\boxed{T_{sat} = \cancel{311.06°C}\ 99.62°C}$ ~~(V_{sat})~~ $v = 1.677\ m^3/kg$

at $T = 150°C$ $v = 1.93636\ m^3/kg$

$$\Rightarrow 1.8 = 1.677 + \left(\frac{1.93636 - 1.677}{150 - 99.62}\right) \times \Delta T$$

$$\Rightarrow \Delta T = \frac{(1.8 - 1.677) \times (150 - 99.62)}{1.9363 - 1.677}$$

$\Delta T = 23.892°C$

⇒ $T = 99.62 + 23.89$

$\boxed{T = 123.51°C}$

Q.3. $V = 1 m^3$, $m = 2kg$ at $100°C$, $T_{final} = 200°C$

$\boxed{v = 0.5\ m^3/kg}$

At $200°C$, $v_f = 0.0011565\ m^3/kg$

$V_g = 0.12716\ m^3/kg$

~~⇒ Phase: Saturated liquid & vapor mixture.~~

→ $\boxed{v > v_g \Rightarrow \text{Superheated vapor}}$

At $T = 200°C$, $P = 4$ bar, $v = 0.53422\ m^3/kg$
(400 kPa)

$T = 200°C$, $P = 5$ bar, $v = 0.42492$
(500 kPa)

~~$0.5 = 0.42492 + \frac{0.53422 - 0.42492}{500 - 400} \times \Delta P$~~

$\Rightarrow \cancel{\Delta P = \frac{(0.5-0.42492)\times 100}{0.53422-0.42492}}$

$$\Rightarrow 0.5 = 0.53422 - \frac{0.53422-0.42492}{500-400}\Delta P$$

$$\Rightarrow \boxed{\Delta P = 31.3 \text{ kPa}}$$

$$\Rightarrow P = 400 + 31.3 = 431.3 \text{ kPa}.$$

Q.4. $P_{atm} = 101.3$ kPa , $T = 120°c$, area = $5\ mm^2$

At $120°C$, $P_{sat} = 1.9854$ bar
$= 198.54$ kPa

$$\Rightarrow mg = (198.54 - 101.3)\times 10^3 \times 5 \times 10^{-6}$$

$$\Rightarrow m = \frac{97.24\times 5}{1000\times 9.8} = \frac{0.4862 kg}{9.8} = 49.61 g.$$

Q.5. $T = 100°C$, $V_{liq} = \frac{V_{vap}}{10}$ Here volume = constant.

At $100°C$, $v_f = 0.0010437\ m^3/kg$.
$v_g = 1.6730\ m^3/kg$

$$\Rightarrow V_f = m_f(v_f) \quad ; \quad V_g = m_g(v_g)$$

Now, $V_g = 10 V_f$

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

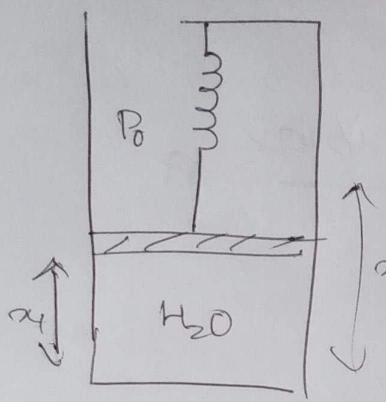
$$\Rightarrow \frac{m_f}{m_g} = \frac{1}{10}\times\frac{1.6730}{0.0010437} = 160.295 \Rightarrow \boxed{m_f = 160.295 m_g}$$

Now, temperature at 2 MPa = $212.42°C$ (From steam table)

$\cancel{x = \frac{\frac{m_{tot}}{V_{tot}} - v_f}{v_{fg}} = \frac{\frac{161.295 m_g}{V_{tot}} - v_f}{v_{fg}}}$

As we are heating, amount of vapour will be higher than $100°C$.

Q-6.



Water: 5 MPa, 400°C, volume = 0.1 m^3

~~Force by spring = 200 kPa × A + kx~~

~~Pressure = 200 kPa + $\frac{kx}{A}$~~

At 50 Bar,

$v_f = 0.001287 \ m^3/kg$

$v_{fg} = 0.038070 \ m^3/kg$

$v_g = 0.039356 \ m^3/kg$

$\cancel{V = 0.1 m^3}$ $\because$ T = 400°C, initial $\Rightarrow$ superheated vapor

$\Rightarrow v = 0.05781 \ m^3/kg$

$\Rightarrow$ Mass = $\cancel{0.05}$ $\frac{0.1}{0.05781}$ = $\underline{1.7298 \ kg}$.

At 5 MPa, V = 0.1 m^3

At 1200 kPa, V = ? (say V_x)

200 kPa, V = 0

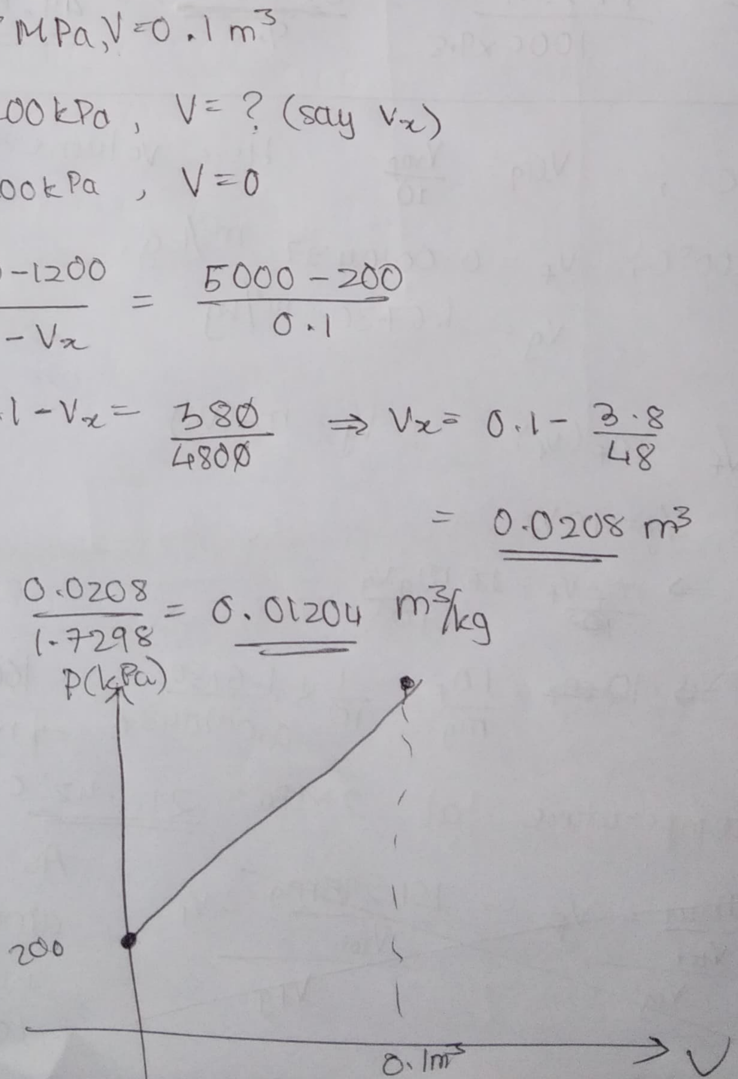
$$\Rightarrow \frac{5000-1200}{0.1 - V_x} = \frac{5000-200}{0.1}$$

$\Rightarrow 0.1 - V_x = \frac{380}{4800} \Rightarrow V_x = 0.1 - \frac{3.8}{48}$

$= \underline{0.0208 \ m^3}$

$\Rightarrow v = \cancel{\frac{1.7298}{0.0208}} \ \frac{0.0208}{1.7298} = \underline{0.01204 \ m^3/kg}$

$\Rightarrow$



Q.7. Argon – $T_c = 150.8K$, $P_c = 4.87 MPa$, $R = 0.2081$

$V = 5m^3$, $T = -30°C$, $P = 3 MPa$

$= 243K$

~~$\rho = \frac{P_c}{R_M Z T_c}$~~ ~~$Z = \frac{P_c V_a}{R T_c}$~~

$$Z = \frac{PV}{nRT} = \frac{PV}{mR_MT}$$

$$\Rightarrow 0.96 = \frac{\overset{3}{\cancel{4.87}} \times 10^6 \times 5}{m \times 0.2081 \times 243}$$

$$\Rightarrow m = \frac{\overset{3}{\cancel{4.87}} \times 5 \times 10^6}{0.2081 \times 243 \times 0.96 \times 10^3} = \underline{\underline{308.98 kg}}$$

Ideal gas $\Rightarrow Z = 1$

$$\Rightarrow m = \frac{5 \times 3 \times 10^6}{0.2081 \times 243 \times 10^3}$$

$$= \underline{\underline{296.628 kg}}$$

$$\text{Error} = \frac{308.93 - 296.628}{308.93} \times 100 = \underline{\underline{3.98\%}}$$

Q.8. $NH_3 \Rightarrow T_c = 405.5K$, $P_c = 11.35 MPa$, $R = 0.48819\ kJ/kmK$,

compressibility factor $= \underline{0.97}$.

~~Ideal gas~~ : $Z = \frac{PV}{nRT} \Rightarrow PV = nRT$

$$\Rightarrow P = vR_MT$$

$$\Rightarrow v = \frac{P}{R_MT} = \frac{\overset{0.5}{\cancel{11.35}} \times 10^6}{0.48819 \times 10^3 \times 313}$$

$$= \frac{500}{313 \times 0.48819}$$

$$= 3.272177\ m^3/kg$$

Using compressibity factor $\Rightarrow$ $v = \frac{P}{ZR_MT}$

$$= \frac{500}{0.97 \times 313 \times 0.48819} = \frac{v_{Ideal}}{Z}$$

$$= 3.272177$$

$\Rightarrow$

Q 8. For NH_3, compressibility factor = 0.97, $R = 0.48819$

From ~~saturation~~ superheated table, $V = 0.29227\ m^3/kg$

Ideal ⇒ $PV = nRT$

$$\Rightarrow \cancel{PV}\ Pv = R_M T$$

$$\Rightarrow v = \frac{R_M T}{P}$$

$$= \frac{0.48819 \times 10^3 \times 313}{500}$$

$$= 0.3056\ m^3/kg$$

Using compressibility factor ⇒ $PV = ZnRT$

$$\Rightarrow Pv = Z R_M T$$

$$\Rightarrow v = \frac{Z R_M T}{P}$$

$$= 0.97 \times 0.3056$$

$$= 0.2964\ m^3/kg$$

~~Error = $\frac{0.3056 - 0.2964}{0.2964} \times 100$~~

$$(\text{Error})_{ideal} = \frac{0.3056 - 0.29227}{0.29227} \times 100$$

$$= 4.56\%$$

$$(\text{Error})_{CF} = \frac{0.2964 - 0.29227}{0.29227} \times 100$$

$$= 1.41\%.$$