3.29/ GIVEN: R410a a) $T = 50°C$, $v = 0.05\ m^3/kg$
b) $P = 1.0\ MPa$, $T = 20°C$
c) $P = 0.1\ MPa$, $v = 0.1\ m^3/kg$
d) $T = -20°C$, $P = 200\ kPa$.

FIND: Phase

SOLN: a) From table B.4.1 when $T = 50°C$

$v_g = 0.007\ m^3/kg$

$v > v_g$ ∴ we have superheated vapour

b) From table B.4.1 when $T = 20°C$

$P_{sat} = 1444.2\ kPa$.

$P < P_{sat}$ ∴ we have a superheated vapour.

c) From table B.4.1 when $P = 0.1\ MPa$

$T_{sat} \approx -51.4°C$

$v_f \approx 0.000741\ m^3/kg$

$v_g \approx 0.23949\ m^3/kg$

$v_f < v < v_g$ ∴ we have a mixture of liquid + vapour.

d) From table B.4.1 when $T = -20°C$

$P_{sat} = 399.6\ kPa$

$P < P_{sat}$ ∴ we have a Superheated vapour.

3.39/ a) Given: R-134a $T = 50°C$
$X = 80\%$ ∴ 2-phase state

Soln: $v = v_f + X v_{fg}$

from table B.5.1:

$v = 0.000908 + (0.80)(0.01422)$
$v = 0.011228 \ m^3/kg$

b) Given: water $P = 4 \ MPa$
$X = 90\%$ ∴ 2-phase state

Soln: $v = v_f + X v_{fg}$

from table B.1.2:

$v = 0.001252 + (0.90)(0.04853)$
$v = 0.04493 \ m^3/kg$

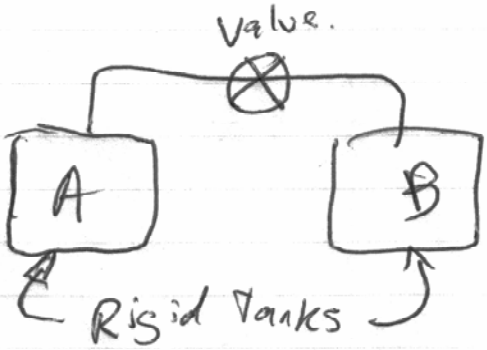
c) Given: Nitrogen $T = 120K$
$X = 0.60$ ∴ 2-phase State

Soln: $v = v_f + X v_{fg}$

$v = 0.001915 + (0.60)(0.00608)$
$v = 0.005563 \ m^3/kg$

3.49/ Given: State 1

$P_{A1} = 200 kPa$
$v_{A1} = 0.5 m^3/kg$
$V_{A1} = 1 m^3$
$m_{B1} = 3.5 kg$
$P_{B1} = 0.5 MPa$
$T_{B1} = 400°C$
water in A+B



Find: v_2

Sol'n: A+B are rigid tanks.
$\therefore V_{A1} = V_{A2}$ and $V_{B1} = V_{B2}$ or $V_1 = V_2$
also $m_{A1} + m_{A2} = m_{B1} + m_{B2}$ (cons. of mass)
or $m_1 = m_2$
- Valve is open until uniform state in A+B
$\therefore P_{B2} = P_{A2} = P_2$ and $v_{A2} = v_{B2} = v_2$
and $T_{B1} = T_{B2} = T_2$

at state A1: given v_{A1} and V_{A1}

$$m_{A1} = \frac{V_{A1}}{v_{A1}} = \frac{1 m^3}{0.5 m^3/kg} = 2 kg$$

state B1: given T_{B1} and P_{B1} from table B.1.3
$v_{B1} = 0.6173 m^3/kg$

$\therefore V_{B1} = m_{B1} v_{B1} = (3.5 kg)(0.6173 m^3/kg)$
$V_{B1} = 2.1606 m^3$

final state: $m_{tot} = m_{A1} + m_{B1} = 5.5 kg$
$V_{tot} = V_{A1} + V_{B1} = 3.1606 m^3$
$\therefore v_2 = \frac{V_{tot}}{m_{tot}} = 0.5746 m^3/kg$

3.51/ Given: Sat water vapour ($X=1$)
$T_1 = 60°C = T_2$ (constant Temp)
$V_2 = 1.1 V_1$

Find: P_2

Soln: Assume conservation of mass $\therefore m_2 = m_1$
$\therefore v_2 m_2 = V_2 = 1.1 V_1 = 1.1 m_1 v_1$

or $v_2 = 1.1 v_1$

initial state $v_1 = 7.6707 \, m^3/kg = v_g$
from table B.1.1 at $T = 60°C$

final state $v_2 = 1.1 v_1 = 1.1(7.6707) = 8.4378 m^3/kg$
$v_2 > v_g$ for $T_2 = 60°C$
$\therefore$ Superheated vapour

then from tables B.1.3 and B.1.1, Interpolate to find P_2 given that $v_{g@60°C} = 7.6706$
$P_{sat@60°C} = 19.941$ kPa

at $P = 10$ kPa and $T = 60°C$, $v = ?$
- Interpolate between $T = 50°C$ and $100°C$
(By inspection we can see that P_2 will be less than 10 kPa at 60°C)

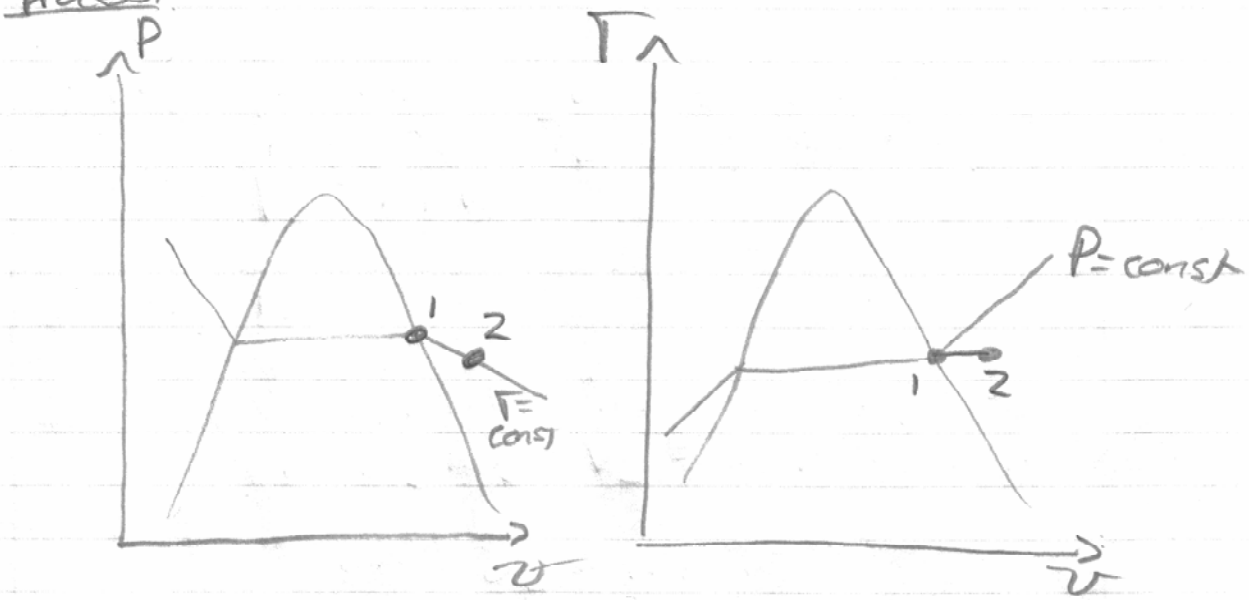
$$v_{@10kPa} = \left(\frac{60°C - 50°C}{100°C - 50°C}\right)(17.19561 - 14.86920) + 14.86920$$

$$v_{@10kPa} = 15.3345 \, m^3/kg$$

$$\therefore P_2 = 19.941 + (10 - 19.941)\left(\frac{8.4378 - 7.6707}{15.3345 - 7.6707}\right)$$

$$\boxed{P_2 = 18.9 \text{ kPa}}$$

Process:



3.53/ Given: water

$\dot{V}$ = volume flow rate = $\frac{V}{t}$ = 0.05 m³/s

T = 240°C

P = 20 MPa

a) Find $\dot{m}$ = mass flow rate.

Sol'n: $\dot{m} = \frac{\dot{V}}{v}$

compressed liquid

v = 0.001205 m³/kg from table B.1.4

$$\therefore \boxed{\dot{m} = \frac{0.05\ m^3/s}{0.001205\ m^3/kg} = 41.5\ kg}$$

b) if properties of sat. liquid at T=240°C find % error in calculation

$v_{f@T=240°C}$ = 0.001229 m³/kg

$$\therefore \dot{m} = \frac{0.05}{0.001229} = 40.68\ kg$$

$$\boxed{\%\ error = \left(1 - \frac{40.68}{41.5}\right) \times 100 = 2\%}$$

c) Find % error for sat liquid properties at P=20 MPa

$v_{f@P=20MPa}$ = 0.002036 m³/kg

$$\therefore \dot{m} = \frac{0.05}{0.002036} = 24.56\ kg.$$

$$\boxed{\%\ error = \left(1 - \frac{24.56}{41.5}\right) \times 100 = 41\%}$$

3.55/ Given: methane
$T_1 = 120\,K$
$X_1 = 0.25$
$X_2 = 1$ or 0 (single phase)
$\Delta T/\Delta t = 5°C/h$

Find: Δt (time from X_1 to X_2)
P_2

Sol'n: Assumptions: Constant mass
+ Constant volume (rigid tank)
$\therefore m = m_1 = m_2$, $V_1 = V_2 = V$
and $v_1 = v_2 = v$

$v = v_f + x v_g$
from table B.7.1:
$v = 0.002439 + (0.25)(0.30367) = 0.078366\,m^3/kg$

→ we see that $v > v_c = 0.00615\,m^3/kg$ from the table B.7.1
$\therefore X_2 = 1$ and $v = v_g$
from the table, $v \cong v_g$ at $T \cong 145\,K$.

$\therefore \boxed{\Delta t = \Delta T/5°C/h = \frac{(145-120)}{5} = 5 \text{ hours}}$

and $\boxed{P = P_{sat} = 824\,kPa}$

11.8
13.1

3.59 / Given: LNG – pure methane (CH_4)
$V = 400\ m^3$
90% liquid and 10% vapour by volume.
$P = 100\ kPa$

Find: m and X

Soln: from table B.7.1:
Interpolate to find v_f at $P = 100\ kPa$.

$$v_f = \left(\frac{100\ kPa - 88.2\ kPa}{101.3\ kPa - 88.2\ kPa}\right)(0.002367 - 0.002353) + 0.002353$$

$$v_f = 0.002366\ m^3/kg$$

from table B.7.2:
$v_g = 0.55665\ m^3/kg$ at $P = 100\ kPa$

$$\therefore m_{liq} = \frac{V_{liq}}{v_f} = \frac{0.9(400\ m^3)}{0.002366\ m^3/kg} = 152155.5\ kg$$

$$m_{vap} = \frac{V_{vap}}{v_g} = \frac{0.1(400\ m^3)}{0.55665\ m^3/kg} = 71.86\ kg$$

$$\therefore \boxed{m = m_{liq} + m_{vap} = 152\,227\ kg} \text{ total mass}$$

and $$\boxed{X = \frac{m_{vap}}{m_{total}} = 4.72 \times 10^{-4}}$$

3.63/ Given: Ammonia

$T_1 = 10°C$

$m_1 = 10\ kg$

$V_1 = 1\ m^3$

$T_2 = 50°C$

Piston requires 900 kPa to float it. ($\therefore$ 2 step process)

$P_{1a} = 900\ kPa$

Find: P_2 and V_2.

Soln: assume constant mass, i.e. $m_2 = m_1 = m$

process: 2-Step $\Longrightarrow$ step 1, constant vol from P_1 to P_{1a}

step 2, volume increases with piston movement

State 1 $T_1 = 10°C$, $v_1 = \frac{V_1}{m_1} = \frac{1\ m^3}{10\ kg} = 0.1\ m^3/kg$

from table B.2.1 at $T_1 = 10°C$

$v_f < v_1 < v_g$ $\therefore$ mixed phase.

$$x_1 = \frac{v - v_f}{v_{fg}} = \frac{0.1 - 0.0016}{0.20381} = 0.4828$$

also $P_1 = 615.2\ kPa$

State 1a $P_{1a} = 900\ kPa$, $v_{1a} = v_1 = 0.1\ m^3/kg < v_g$ at 900 kPa

$\therefore$ state is two phase

then from table B.2.1 interpolate to find T_{1a}

$$T_{1a} = \left(\frac{900\ kPa - 857.5\ kPa}{1003.2\ kPa - 857.5\ kPa}\right)(25°C - 20°C) + 20°C$$

$T_{1a} = 21.52°C$ $\quad T_2 > T_{1a} \therefore v_2 > v_{1a}$

State 2: from state 1a to state 2
process is constant pressure since piston is now free to move to allow C.V to expand.

$$P_2 = P_{1a} = 900\ kPa$$

which is a superheated vapour at $T_2 = 50°C$

from table B.2.2, interpolate to find v_2

$$v_2 = \left(\frac{900\ kPa - 800\ kPa}{1000\ kPa - 800\ kPa}\right)(0.14499 - 0.18465) + 0.18465$$

$$v_2 = 0.16482\ m^3/kg$$

$$V_2 = m v_2 = (10\ kg)(0.16482\ m^3/kg) = 1.6482\ m^3$$