Definition

g mole (n)

a mole is 6.02×10^{23} it is a number

1 Kmole $= 10^3$ moles $= 6.02 \times 10^{26}$

Molecular Mass (sometimes referred to as molecular wt.)

no units are given.

ie. $M(c) = 12$ $\boxed{\text{found in table A.8 pg 752}}$

but units are understood to be $\frac{g}{mole} \cdot \frac{10^3}{10^3}$ or $\frac{kg}{kmole}$

$$n\,(\text{moles}) \cdot M\left(\frac{g}{mole}\right) = (g)\ m$$

$$n\,(\text{kmol}) \cdot M\left(\frac{kg}{kmol}\right) = (kg)\ m$$

in this class we will use kg & kmoles

H_2O has molecular mass $= 18$

∴ 25 kmoles has mass

$$n \cdot M = m$$

$$25\ kmol \cdot \frac{18\ kg}{kmol} = 450\ kg$$

IN ENGLISH UNITS

lb mole – is the unit for n (best defined by M)

M has same numerical value as w/ SI

BUT units are $\frac{lbm}{lb\text{-}mol}$

$$n \cdot M = m$$

∴ lb-mole is actually

2.2 lbmole = 1 kmole

Last time.

we defined phase – a quantity of matter that is homogeneous throughout.

property (any characteristic that can be observed or measured)
intensive, extensive

state (condition of system as described by its properties)

A pure substance

a substance that is chemically homogeneous with a fixed chemical composition.

gases – compressible
fluid (flow under stress)
molecules rarely exert forces on each other

solids – incompressible
rigid
strong intermolecular forces
dense

liquids – relatively incompressible
fluid
dense
properties determined by intermolecular forces

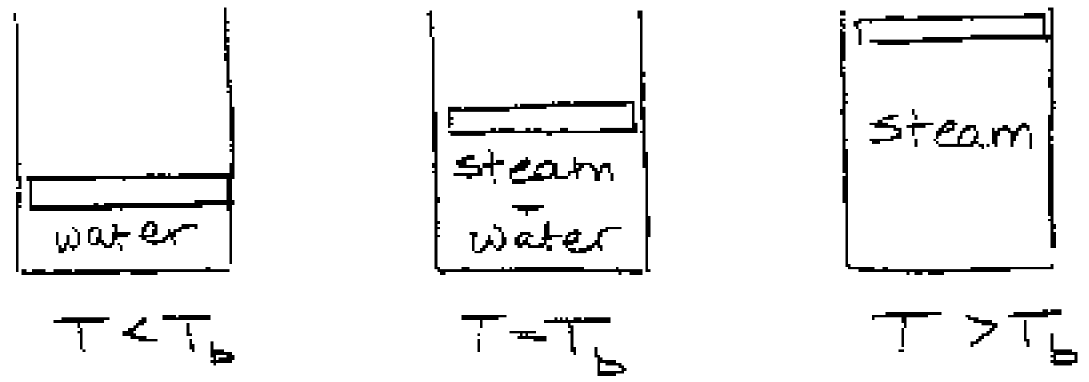
boiling point – at given pressure
temp above which liquid is no longer present
(all vapor)

freezing point – at given pressure
temp below which no liquid is present
(all solid)

Both BP & FP are pressure dependent

* We'll also give these states new names.

Consider a piston/cylinder filled w/ water



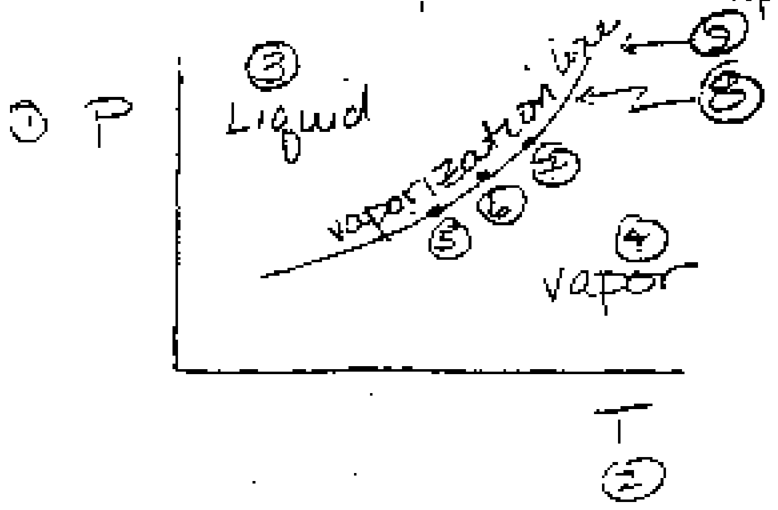
New Definition for BP

SATURATION TEMPERATURE

temperature at which vaporizaton occurs at a given pressure. (This pressure is called Saturation Pressure)

saturated liquid — liquid @ T_{sat} & P_{sat}

saturated vapor — vapor @ T_{sat} & P_{sat}



liquid @ $T < T_{sat}$ for given pressure is called

subcooled liquid or

* compressed liquid $P > P_{sat}$ for given T

Vapor @ $T > T_{sat}$ for a given pressure is called

superheated vapor

Along vap line T & P are dependent properties

(if one varies, the other can not vary arbitrarily & still be on line)

[At saturation temp P & T are dependent, yet states can vary]

New Property for sat liq + sat vap in equil.

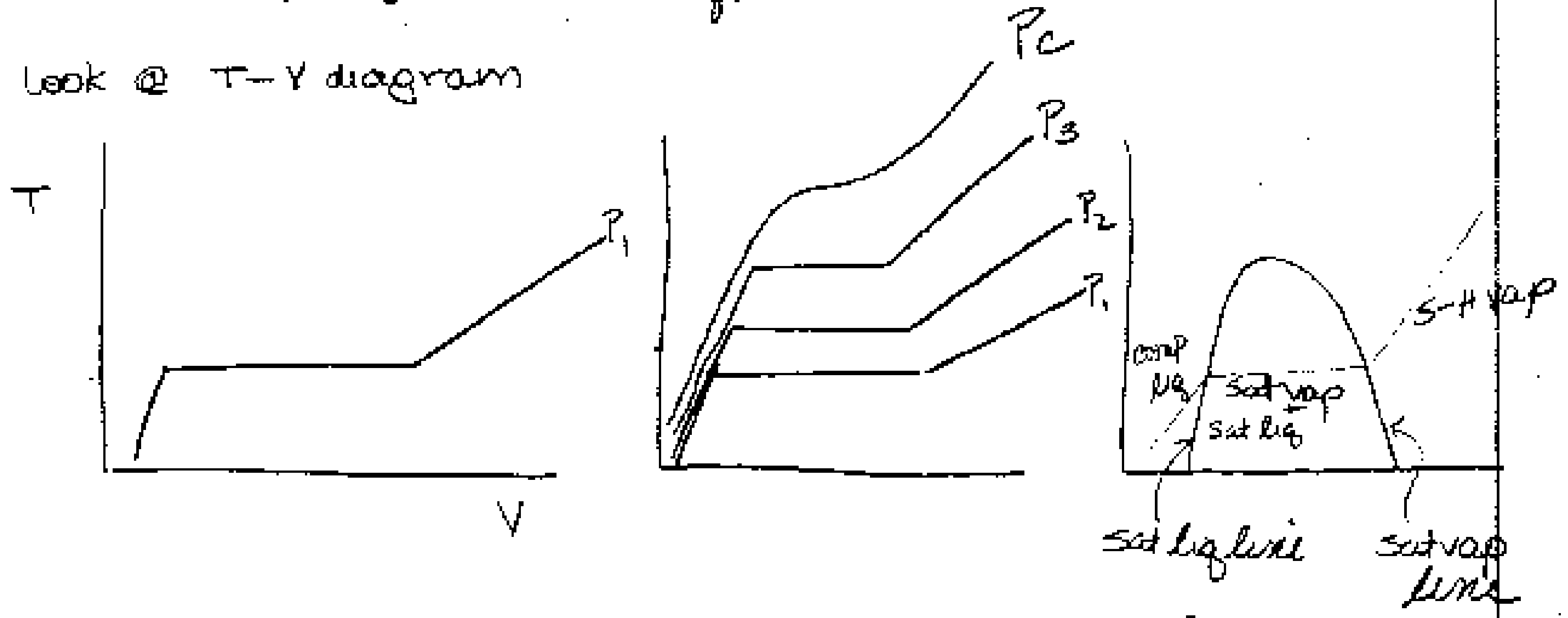
QUALITY x is defined @ saturation point

$$x = \frac{\text{Mass Sat vap}}{\text{total mass}} = \frac{\text{Mass sat vap}}{\text{Mass sat vap} + \text{Mass sat liq}} = \frac{m_g}{m_g + m_f}$$

subscript g → sat vap

subscript f → sat liquid

lets look @ T-V diagram



Point where sat liq & sat vapor states are identical is called CRITICAL POINT

2 distinct phases are not present — 1 phase fluid

above critical point we have fluid

for a given substance, we have a characteristic critical point

w/ critical temperature

critical pressure

critical volume (critical specific volume)

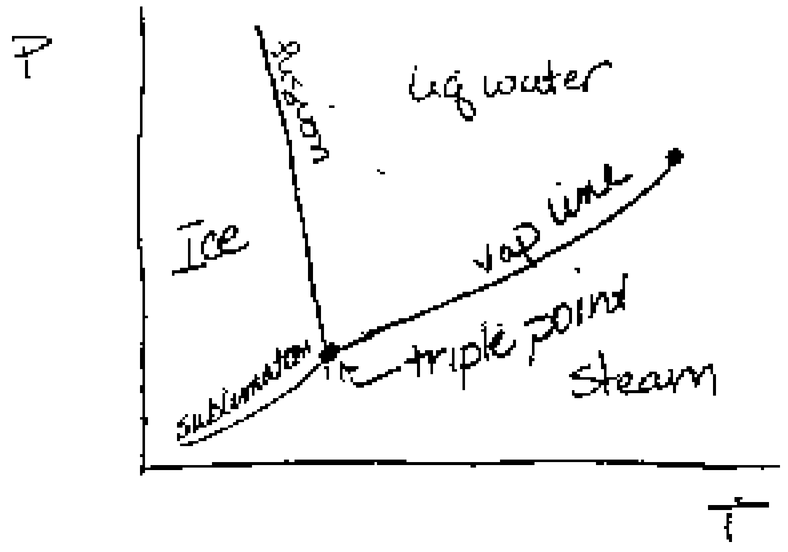
on graph:

region T, P vary [v depends on T & P]

line if T, then P however v can vary (depends on x)

at point T, P, v are fixed

Lets consider ice, water, steam



liq → solid fusion
liq → vap vaporization
sol → vap sublimation

note: can have sat sol$^{(i)}$ in equil
w/ sat vap. (g)

the $\chi = \frac{m_g}{m_i + m_g}$

TRIPLE POINT

- intersection of fusion, vaporization & sublimation lines
- all 3 phases can coexist in <u>equilibrium</u>.

State of a simple compressible substance is
defined by 2 independent properties
(P, v, T, χ)

note @ saturation, P & T are dependent
v & χ are dependent

Equation of state for vapor phase

remember from chemistry,

$pV = nRT$ where $R = 0.8205 \frac{l\,atm}{mol\,K}$ or $8.3145 \frac{J}{mol\,K}$ or $1.987 \frac{cal}{mol\,K}$

$\uparrow$ temp in K

well in this class it is a little different

$PV = n\bar{R}T$ where $\bar{R}$ is our old friend from chem.

$\uparrow$ (temp in K or R)

$\bar{R}$ (molal gas constant) $= 8.3145 \frac{kJ}{kmol\,K}$

$= 1545 \frac{ft-lbf}{lbmol-R}$

Same old R, new symbol

$\frac{PV}{n} = \frac{n\bar{R}T}{n} \Longrightarrow P\bar{v} = \bar{R}T$ where $\bar{v}$ is molal spec vol

$\bar{v} = \frac{V}{n}$

By def $v = \frac{V}{m}$ and $\bar{v} = \frac{V}{n}$ and $nM = m$

$M = \frac{m}{n}$

$P\bar{v} = \bar{R}T$ if ÷ by M

$P\frac{\bar{v}}{M} = \frac{\bar{R}}{M}T$ $\qquad \frac{\bar{v}}{M} = \frac{\bar{v}n}{m} = \frac{V}{m} = v$

$Pv = \frac{\bar{R}}{M}T$ define $R = \frac{\bar{R}}{M}$ has units of $\frac{kJ}{kg\,K}$ or $\frac{ft-lbf}{lbm\,R}$

$Pv = RT$ R is specific for each substance but instead of dealing w kmoles & lbmoles, one can use the familiar quantity MASS

R values in table A.10

For a closed system

m, n const

$PV = n\bar{R}T$

$\frac{PV}{T} = n\bar{R} = \text{const}$ $\quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Question arises,

when does a gas behave like an ideal gas?

\# substance must be gas!

$P\bar{v} = \bar{R}T$

$\frac{P\bar{v}}{RT} \Rightarrow 1$ if ideal

$\frac{P\bar{v}}{\bar{R}T} = Z$ compressibility factor

gases real

interactions attractions @ low P

repulsions @ high P

all Temp dependent

look @ behavior relative to critical P & T

$T_r = \frac{T}{T_c}$ $\quad T = (T_r)T_c$

$P_r = \frac{P}{P_c}$ $\quad P = (P_r)P_c$

IG beh. for ① $P << P_c$ $(< 0.1 P_c)$, all T

② if $T \geq 2T_c$ [illegible] $P < \sim 5P_c$

Fig w/ Z P_r, T_r

What about when not ideal?

equation of state such as

Benedict - Webb - Rubin w/ 6 terms & 8 constants

$A_0, B_0, C_0, a, b, c, \alpha, \gamma$

can be used - are calculated when needed

OR info can be put in tables

to be referred to when needed

(Also on computer)

Tables next time