PVT Fluid Behavior

Note Title 2013-09-05

Phase & Volumetric Behavior (++)

Gas

Oil

Water

(Solid)

$V = f(p, T, n_i)$ composition

Gas	y_i	
Oil	x_i	liquid (oil)
Water	x_{wi}	liquid (water)

$$n_i \equiv \frac{n_{ip}}{n_p}$$

$$y_i = \frac{n_{ig}}{n_g} = \frac{n_{ig}}{\sum_i n_{ig}}$$

Pa·s ; cp *

Viscosity (μ)

Interfacial Tension (σ)

IFT **

(Surface) Tension

σ_{go} σ_{gw} σ_{ow}

* 1 mPa·s = 1 cp

** N/m

dynes/cm

$1\,mN/m \equiv 1\,\frac{dyne}{cm}$

Thermodynamics

Phase Equilibria

Chemical Equilibria

$$v \equiv \frac{V}{n}$$

$$Z \equiv \frac{pV}{nRT} = \frac{pv}{RT}$$

$$\rho \equiv \frac{m}{V} = \frac{pM}{RTZ}$$

Mass : $\rho \cdot g$

Equation of State

Gas: $pV = nRT$ (Ideal)

$pV = nRTZ_g$ (Real)

$Z_g(p_r, T_r, y_i)$

Purely Volumetric

Oils : e.g. $c_o \equiv -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T \doteq$ constant

General EOS works for both G & O

Cubic EOS (other more complicated)

Ch. 4

$$p = \frac{RT}{v - b} - \frac{a}{[v^2]}$$

Repulsive Attractive

vdW : [ ] = v^2

* SRK : [ ] = $v(v+b)$

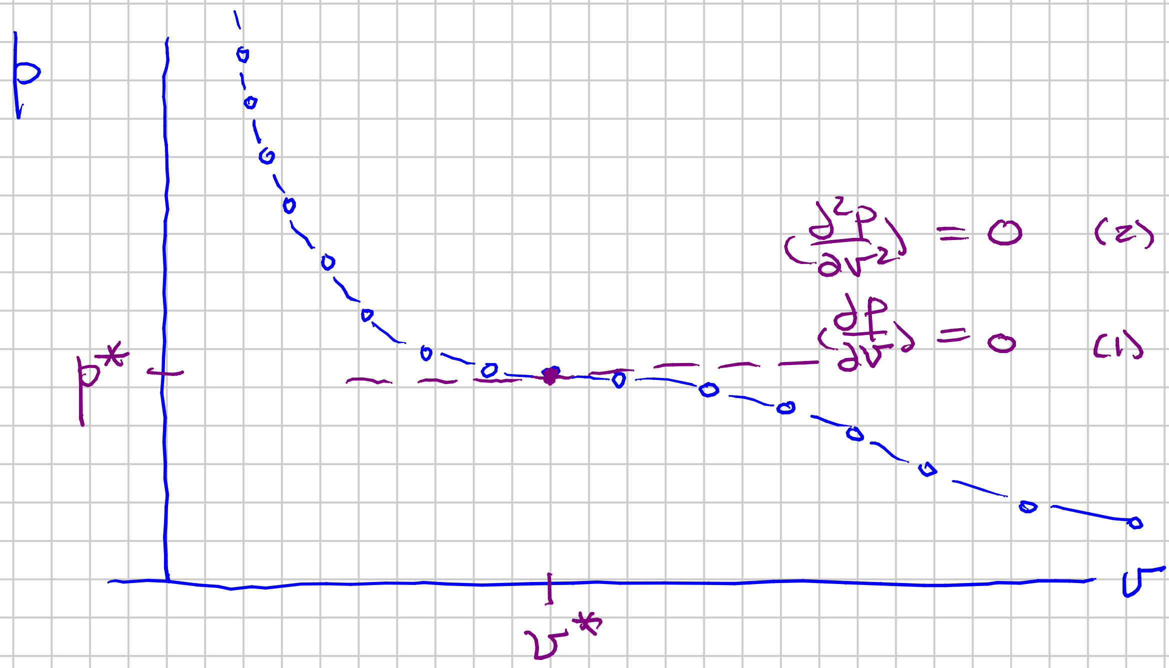
* PR : [ ] = $v(v+b) + b(v-b)$

van der Waals

$v \to \infty$: $p = \frac{RT}{v}$ Ideal Gas

Need a & b to use this equation!

vdW: At some special temperature T^*



$T^* = T_c$

$p^* = p_c$

vdW

$\Rightarrow \quad a_i = \Omega_a \dfrac{R^2 T_{ci}^2}{p_{ci}}$ $\quad$ 27/64 $\quad \Omega_a$ = number "1" ~ 0.4

$b_i = \Omega_b \dfrac{R T_{ci}}{p_{ci}}$ $\quad$ 1/8 $\quad \Omega_b$ = number "2" ~ 0.1

Mixture Phase : u_i $(y_i \quad x_i \quad x_{wi})$ phase p (g o w)

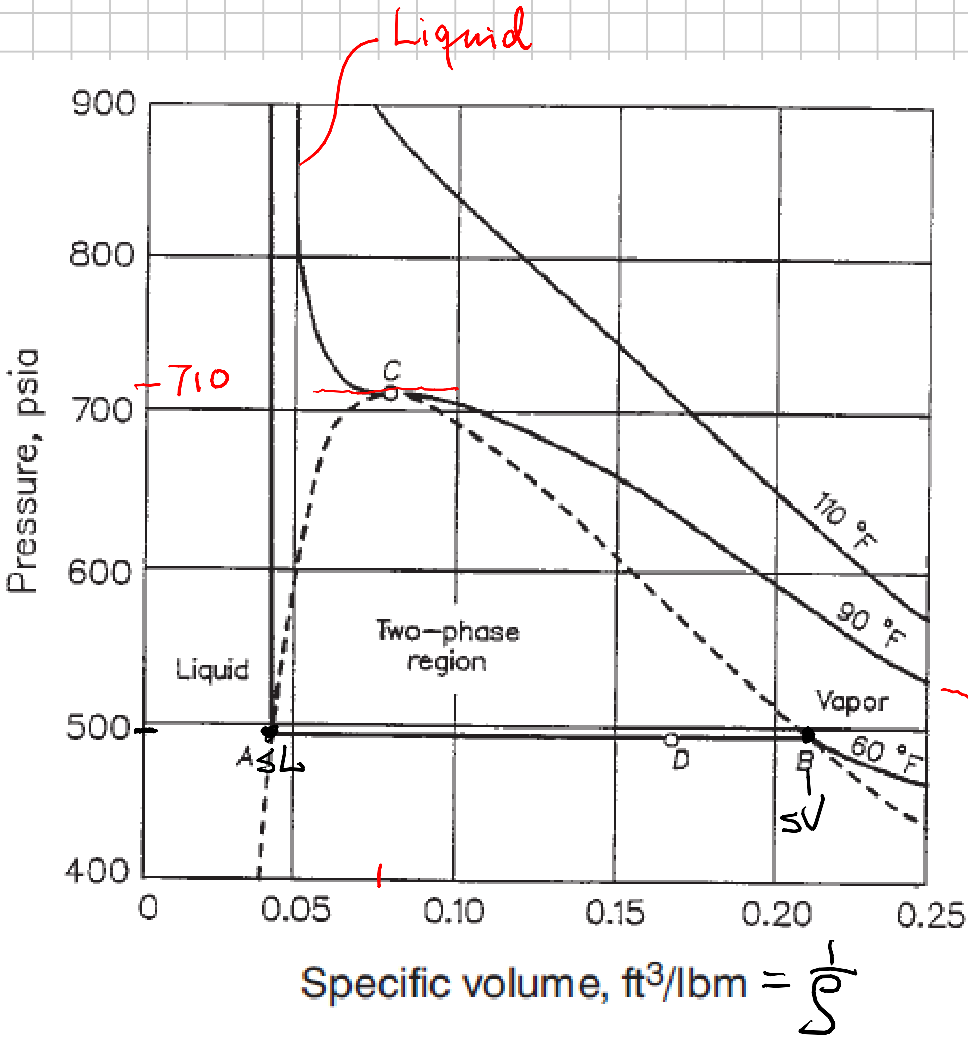
$$\bar{a}_p = \sum_{i=1}^{N} \sum_{j=1}^{N} u_i u_j (a_i a_j)^{1/2}$$

$$\bar{b}_p = \sum_{i=1}^{N} u_i b_i$$

g
o

y_i: $\bar{a}_g$, $\bar{b}_g$

x_i: $\bar{a}_o$, $\bar{b}_o$



$p_{vC_2}(T=60°F) =$ 490 psia

$\rho_{vs} \sim 5 \frac{lb}{ft^3}$

$\rho_{Ls} \sim 25 \frac{lb}{ft^3}$

→ Ideal Gas

Fig. 2.7—*p-V* diagram for ethane at three temperatures (from Standing[26]).

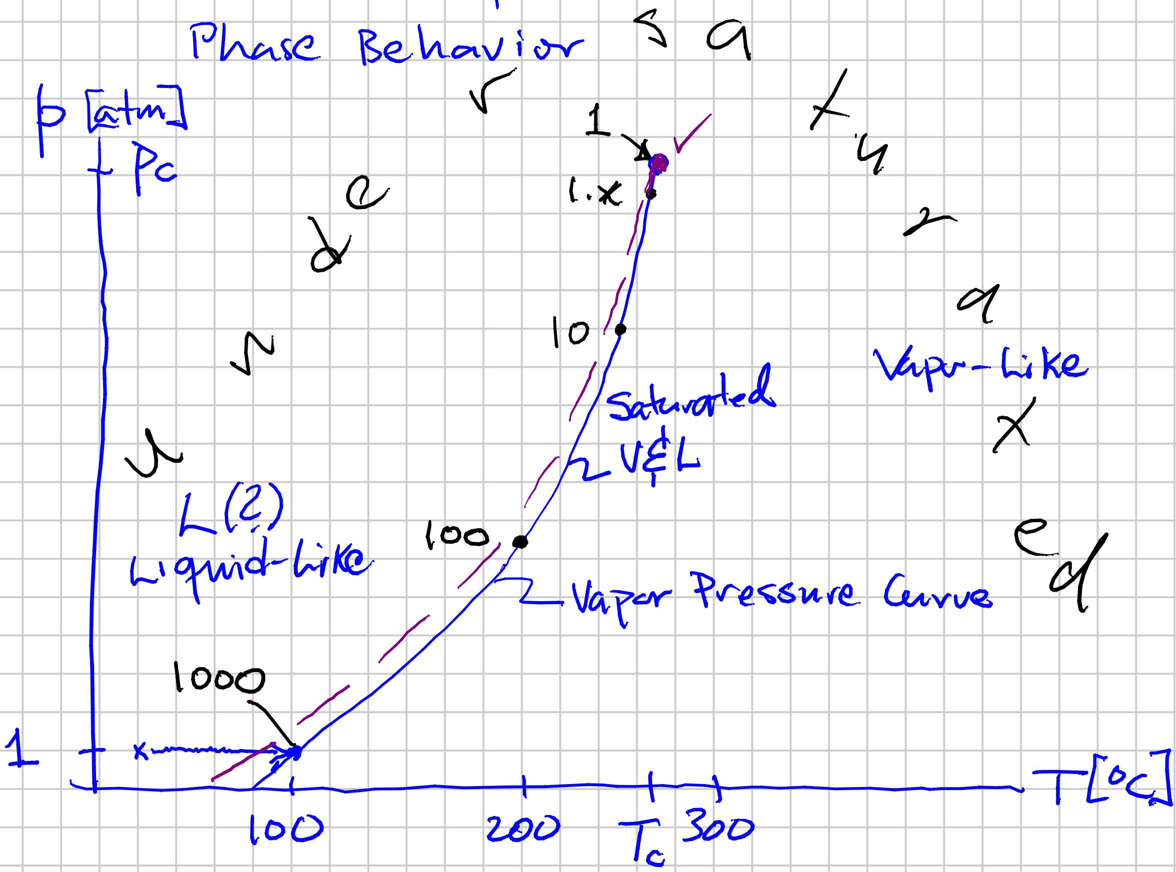
Single-Component Phase Equilibria

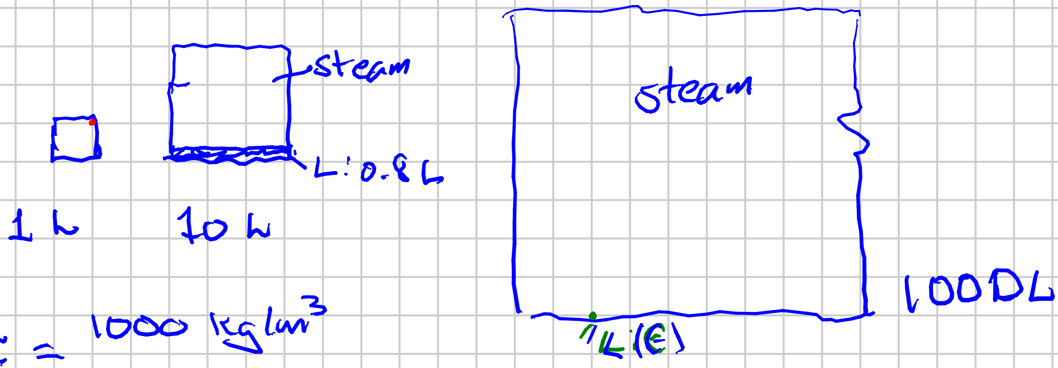
(Chemical Equilibria)

Phase Behavior

(2)

H_2O

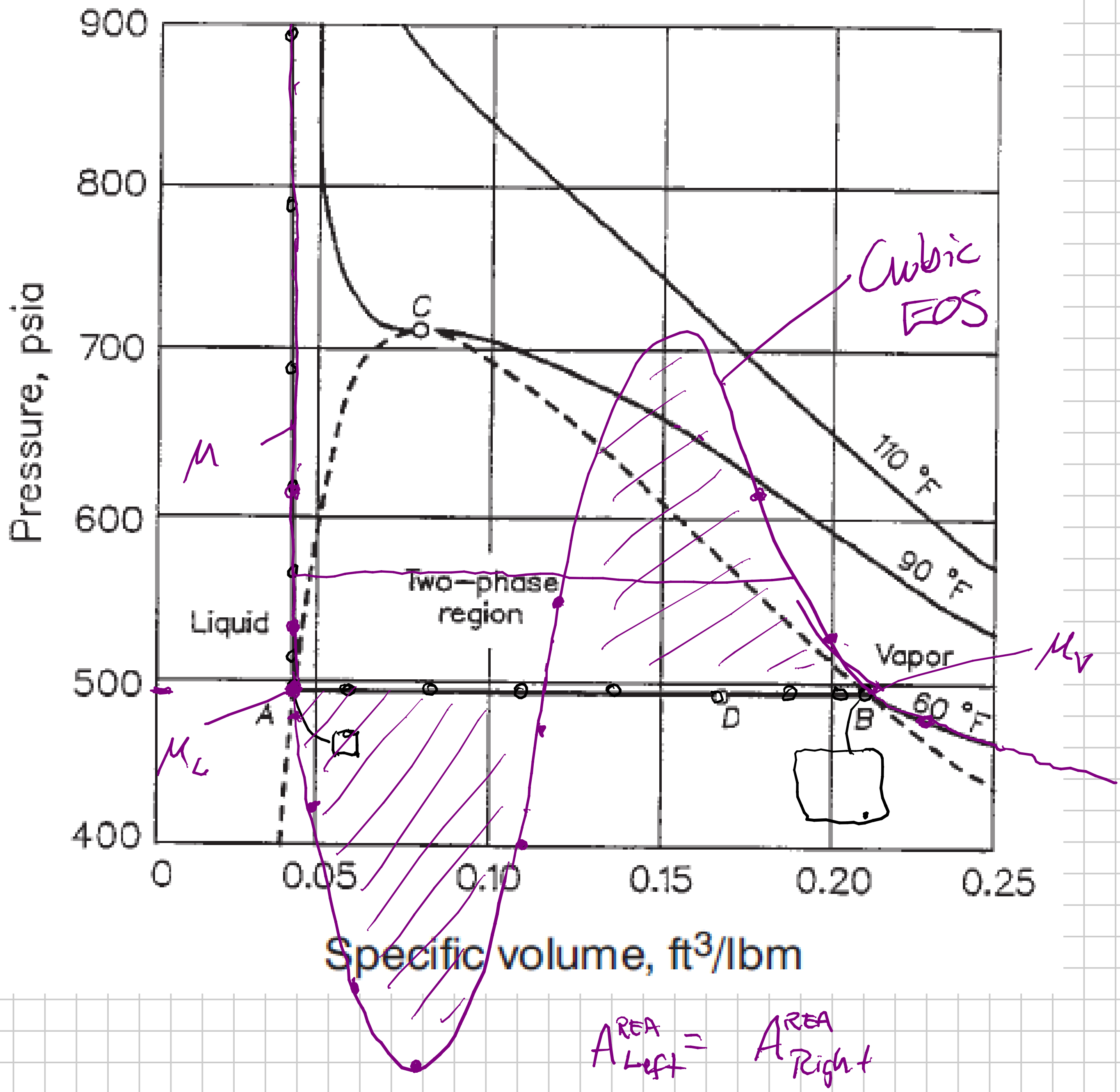




Liquid	ρ_L	$=$	1000 kg/m³
Steam	ρ_V		1 kg/m³

$$p = \frac{RT}{v-b} - \frac{a}{v^2} = \frac{RTv^2 - a(v-b)}{v^3 - bv^2}$$

Cubic in Volume ... $v^3 + \quad v^2 + \quad v + \quad = 0$



$A^{REA}_{Left} = A^{REA}_{Right}$

$$\mu = \text{chemical energy} = \int_0^p \left(v - \frac{RT}{p}\right) dp$$

$\mu_L(p) = \mu_V(p) \qquad p = p_v$

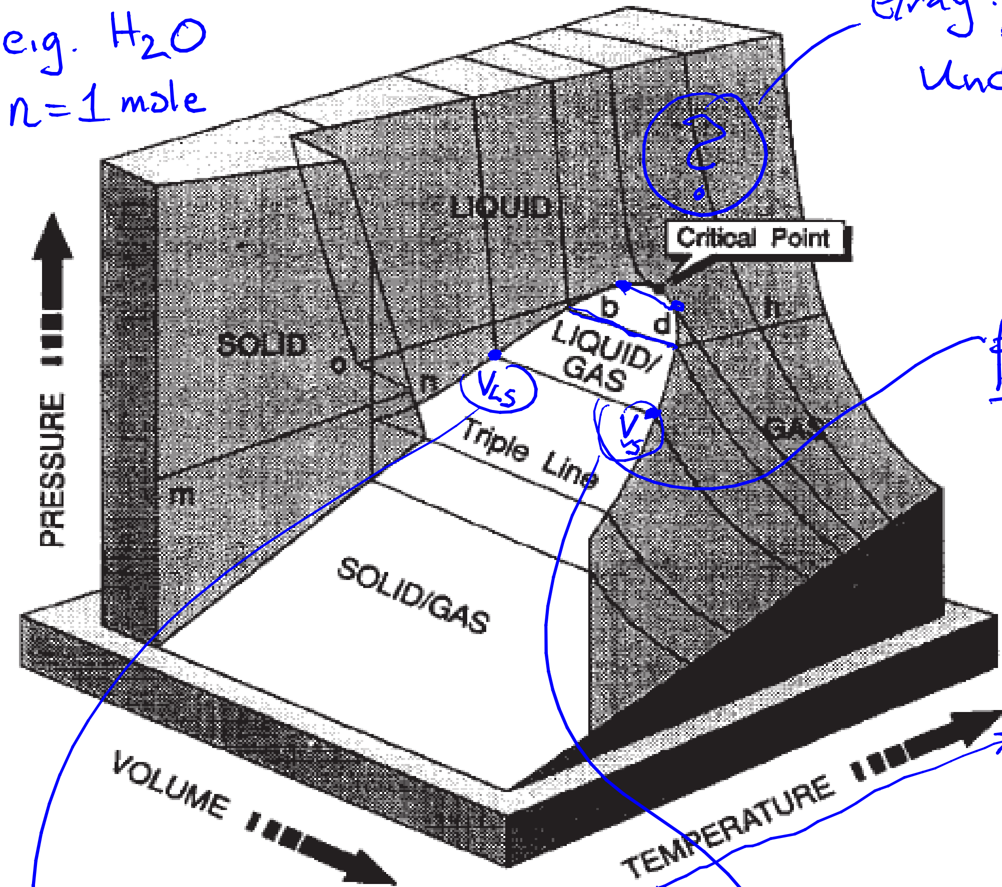
PURE COMPOUND

e.g. H_2O

$n = 1$ mole

Gray: Single Phase

Undersaturate Phase



$p = 1$ atm

$T = 100\,°C$

$212\,°F$

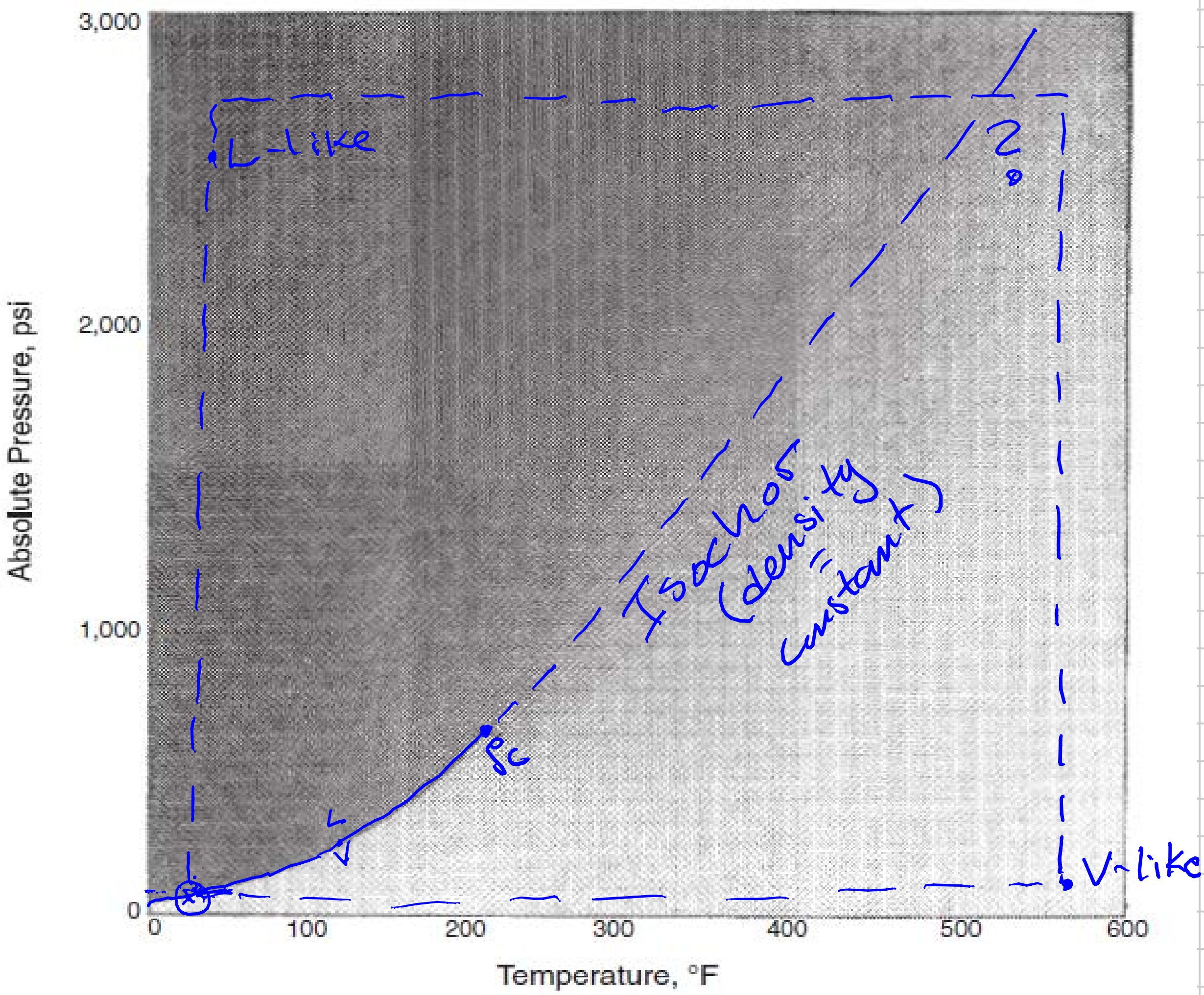
V_{sL} saturated liquid

1

V_{sV} = saturated vapor

1000

Propane

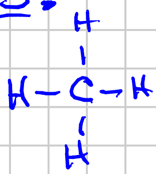


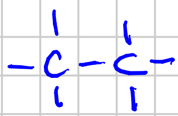
Degree of Shading ∝ ρ

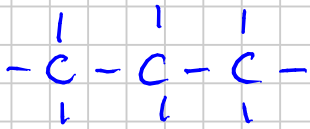
Compounds Making Up Petroleum Systems

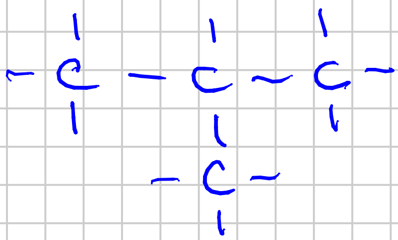
H_2O
N_2
CO_2
(H_2S)
} Non-Hydrocarbons

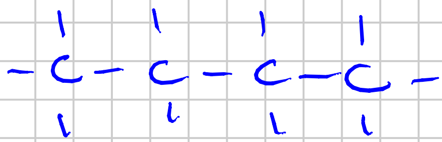
HYDROCARBONS:

C_1 CH_4

methane

C_2 C_2H_6

ethane C_nH_{2n+2}

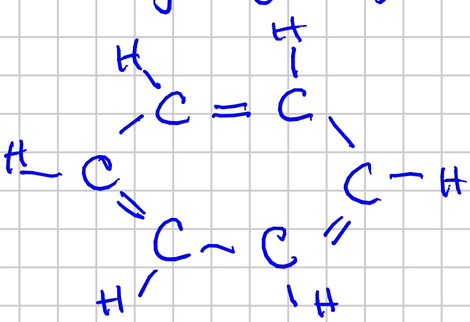
C_3 C_3H_8

propane

$i-C_4$ C_4H_{10} (isomer)

iso-butane

$n-C_4$ C_4H_{10}

normal-butane

$i-C_5$
$n-C_5$
C_5H_{12} pentanes

$\{n-C_6\}$ C_6H_{14} "Paraffins"
⋮ } Isomers with "straight" chains Alkanes

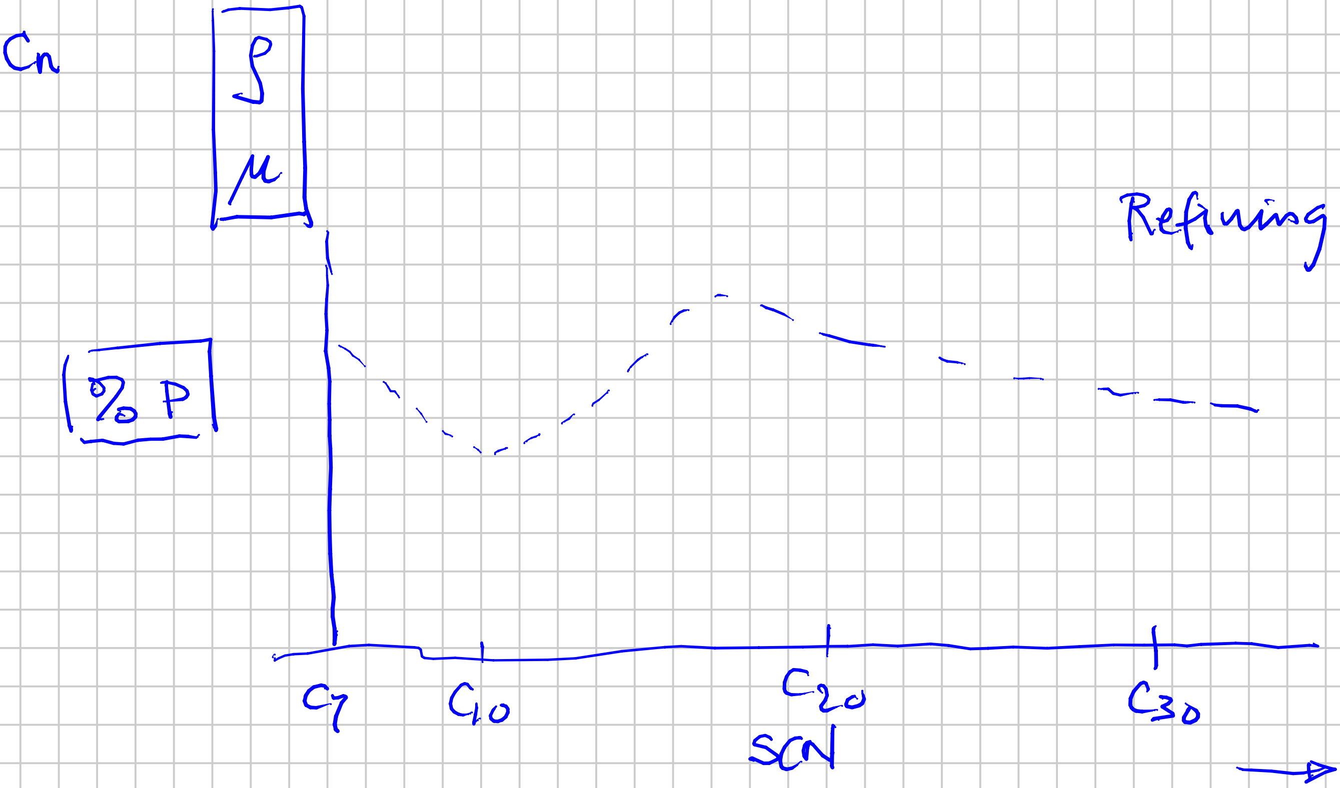
Benzene C_6H_6

Cyclic Ring "AROMATICS"

• Density much higher than ρ_{n-C_6}

875 kg/m³   655 kg/m³

Chemical Make-Up Character of HCs (PNA)

Paraffins   Napthenes   Aromatics



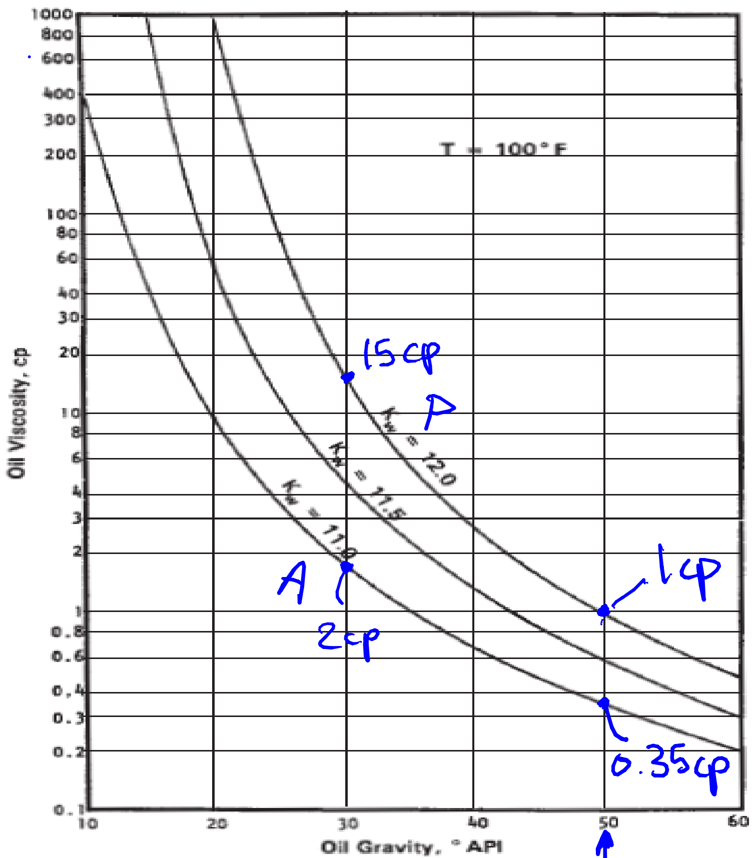


Fig. 3.21—Dead-oil (stock-tank-oil) viscosities at 100°F for varying paraffinicity (from Ref. 33).

← ρ_L kg/m³

1000 C_{30+} SCN   750   700 C_7

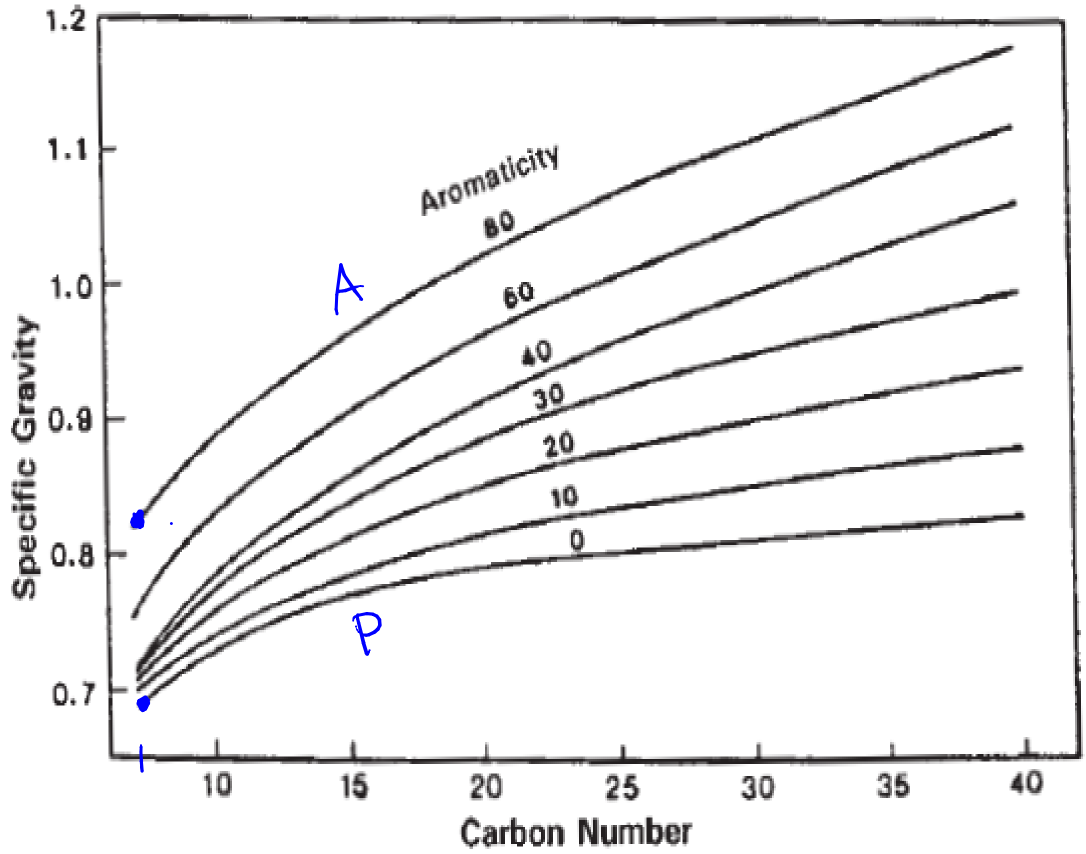


Fig. 5.15—Specific gravity vs. carbon number for constant values of the Yarborough aromaticity factor (after Yarborough[1]).