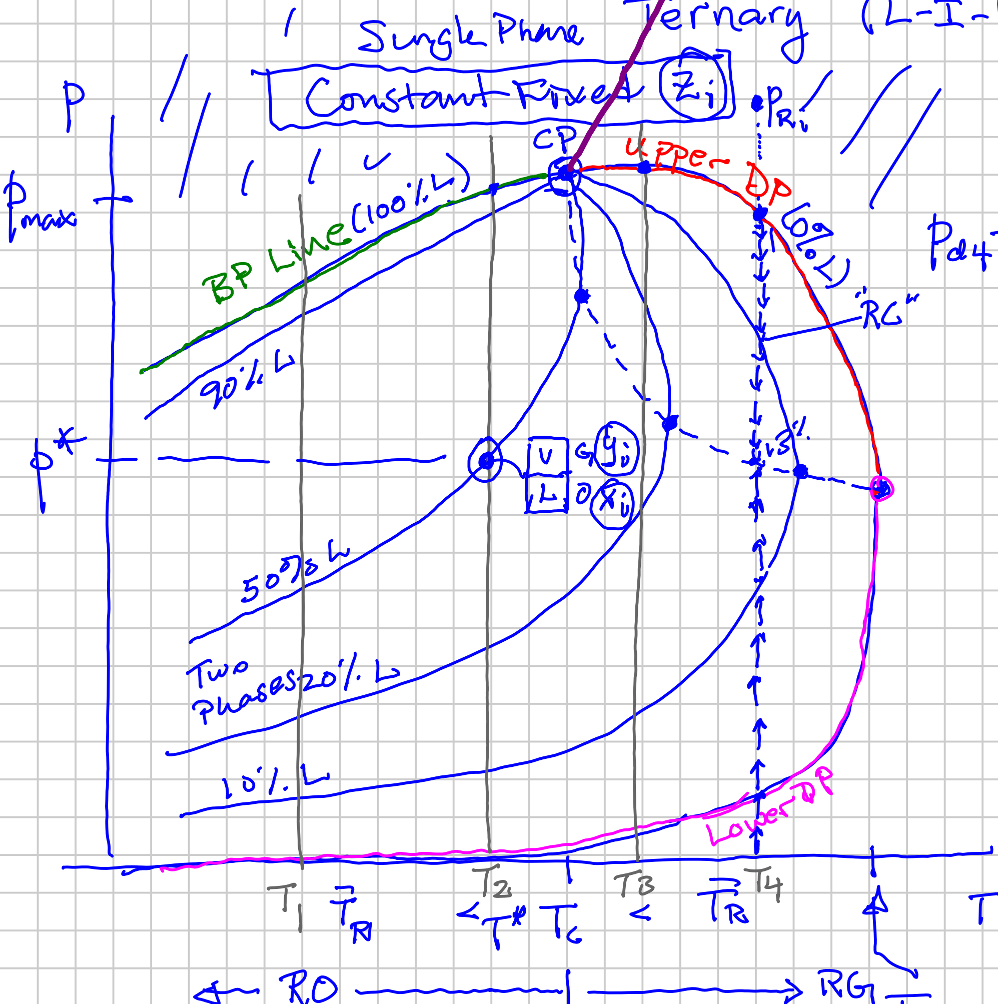
Note Title 1/21/2016

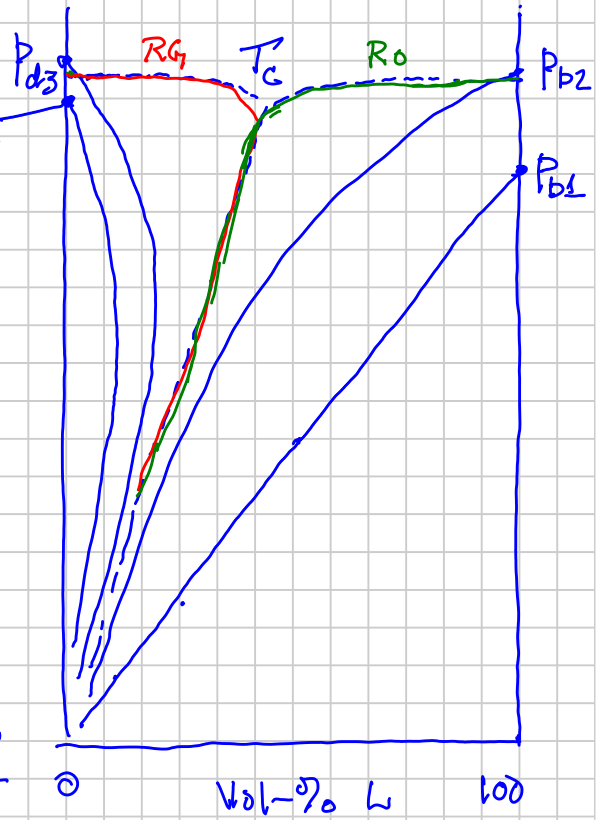
Multi (>2) Component Phase Diagrams

Naturally-occuring petroleum reservoir fluids

p-T ($\rho = \rho_c$)
p-V ($p - V_{ro}$)
p-z_i
Ternary (L-I-H) Diagram

Orientation about ?





$T_{cricondentherm} = T_{max}$

CP, $P_b(T)$, $P_d(T)$: $f(z_i)$

P_{max} = Cricondenbar

Condensation : Appearance of a liquid phase from a gas phase

Retrograde Condensation : Increasing liquid volume as pressure decreases

Revaporization : below the --- (Retrograde Cond) where liquid volume decreases as P decreases

Ternary Diagram (Typically|Only used Inj. Gas into Ro)

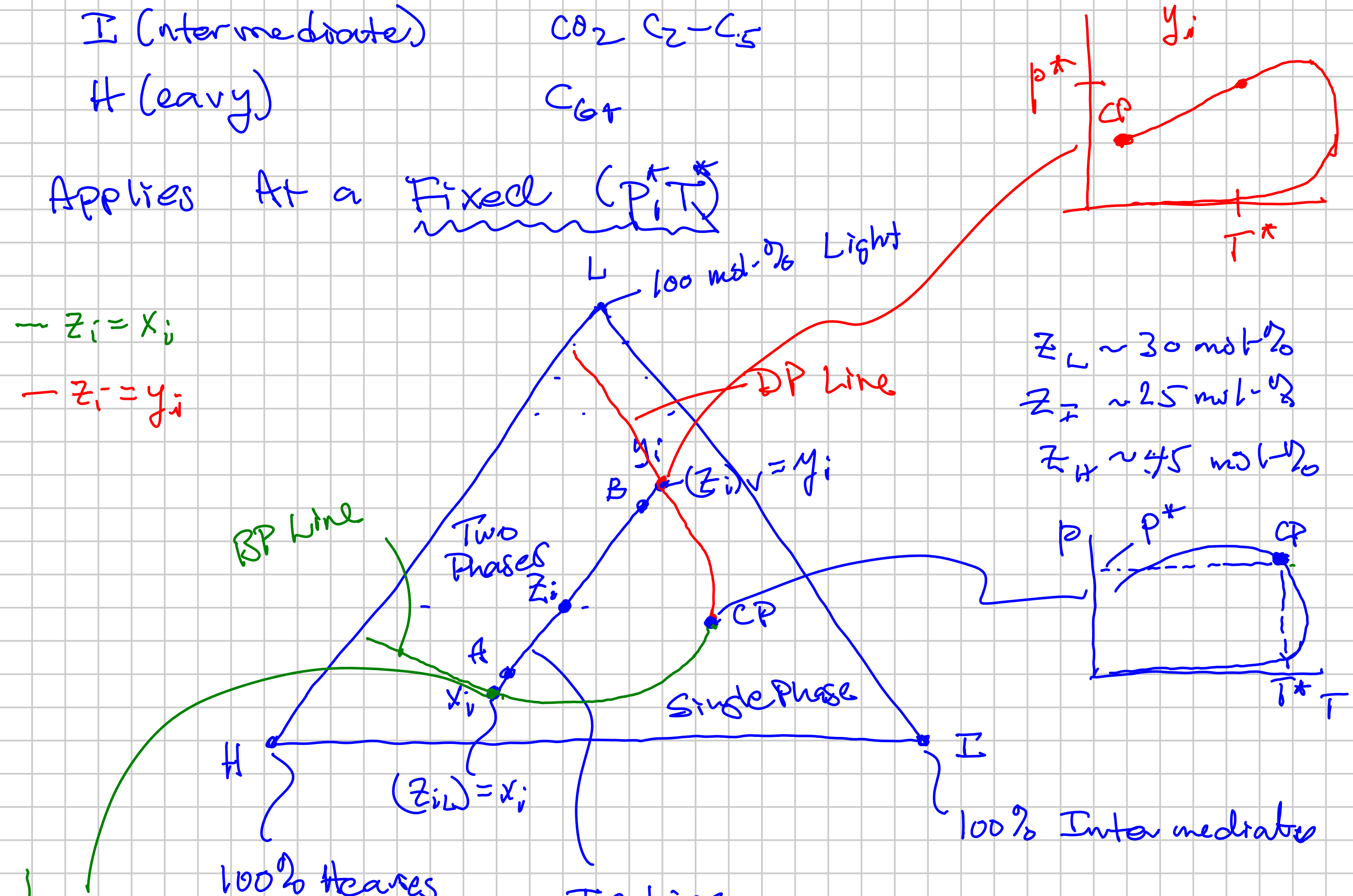
$z_i \Rightarrow 3$ "Pseudo" Compments

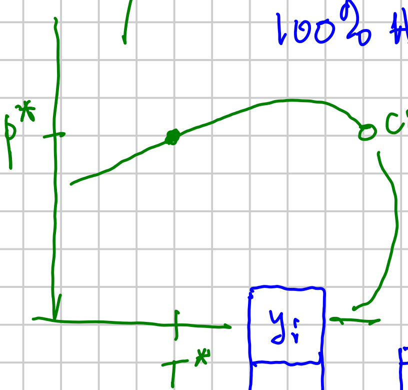
L (light)	C_1 N_2
I (intermediate)	CO_2 $C_2 - C_5$
H (eavy)	C_{6+}

Applies At a Fixed (p^*, T^*)

— $z_i = x_i$

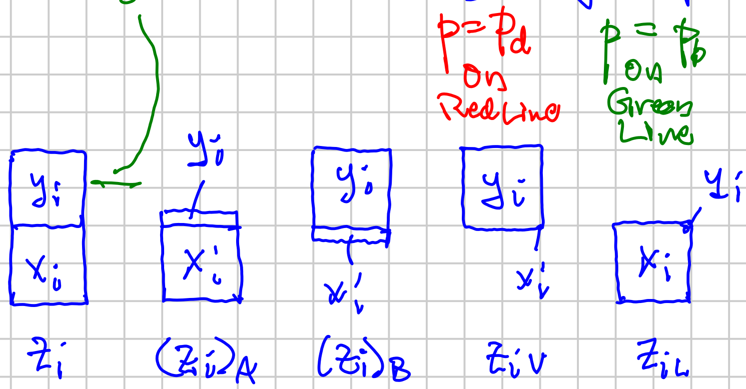
— $z_i = y_i$





Tie Line

Joins G (y_i) & O (x_i) & Total Mixture (z_i)



Identical Chemical Energy μ_t and $\mu_{iV} = \mu_{iL}$

f_V :	0.4	0.05	0.95	$1-\epsilon$	ϵ

$$\boxed{z_i = \underset{\uparrow}{f_V} \cdot y_i + \underbrace{(1 - f_V)}_{\uparrow} x_i}$$ Tie Line (Lever's Rule)?

$\frac{n_V}{n}$ $\qquad$ $\frac{n_L}{n}$

So far:

L		I		H	
	z_i				
C_1	72 mol-%	C_2	8 mol-%	C_6	2.3
N_2	8	⋮		C_7	2.1
		n-C_5	1.5	⋮	
	y_i			C_{36+}	1.4
C_1	95				
N_2	5				
	x_i				
C_1	16				
N_2	3				

Violating that the 3 (pseudo) components are not the same

⇓

Ternary diagram can be very misleading if used Quantitatively.

(Concept of Developed Miscibility)

1986 Aaron Zick

High near 100% recovery of Oil by an Injection Gas

Pressure-Composition Diagram "(p-x or p-z)"

Used in understanding gas injection effect on oil recovery (Enhanced Oil Recovery, EOR)

RO — Inject some gas — IG

$z_i = x_i$

⇒ N_2

⇒ CO_2

C_1 $(+ C_2-C_4)$

⇒ Lean HC gas

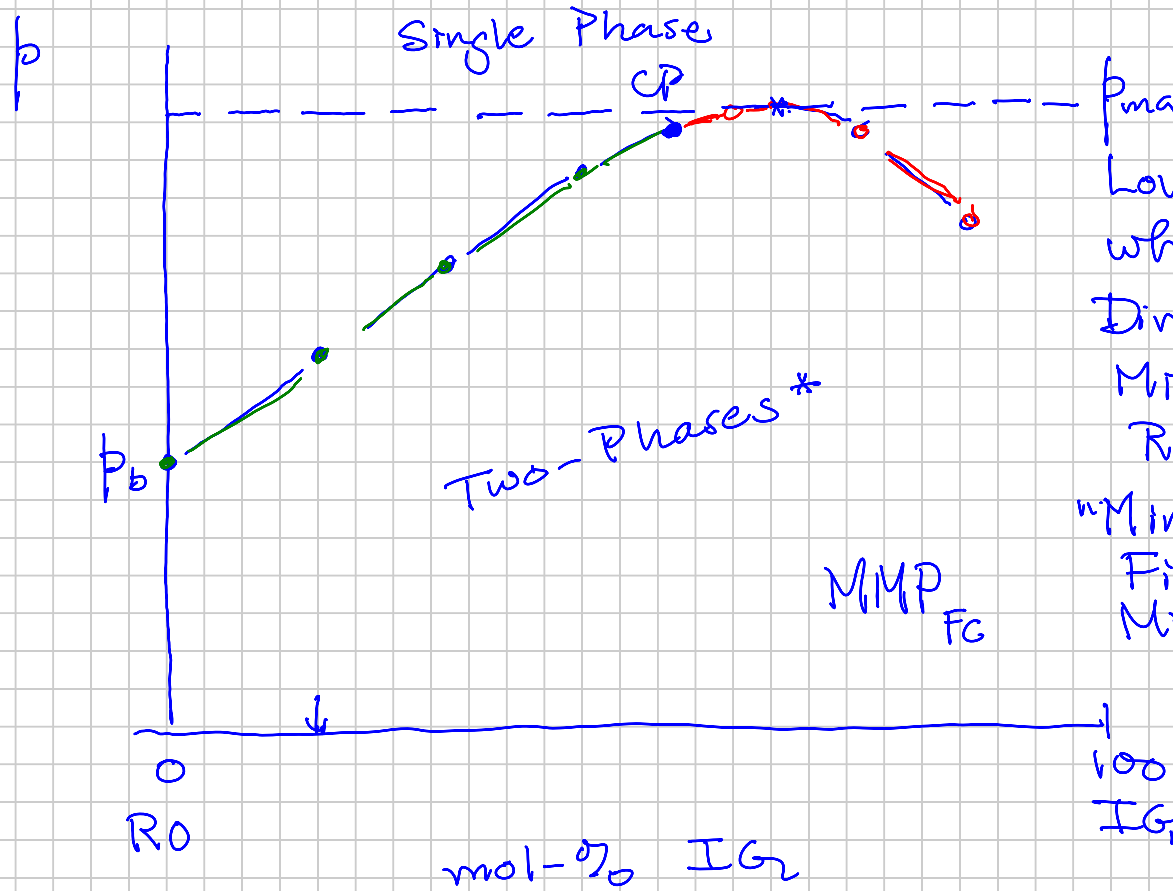
C_1 $(+ C_2-C_5)$

⇒ Separator Gas

add (C_2-C_4)

⇒ Enriched Gas

T_R = const

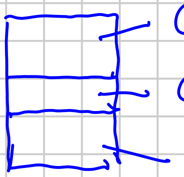


p_{max} = Lowest pressure where IG is Directly (First Contact) Miscible with RO

"Minimum First Contact Miscibility Pressure"

* Some "local" regions with 3 phases:

e.g.

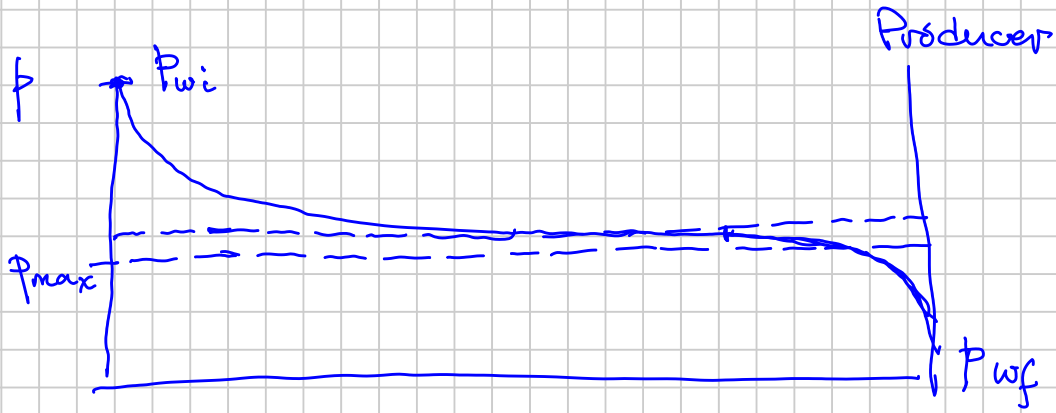


CO_2-rich Gas → V

CO_2-rich Liquid → L_2

HC-rich Liquid → L_1

$L_1 L_2 V$



99+% $p > p_{max}$

Why (how) does nature decide if z_i @ p, T is single phase or two (more) phases?

① Nature always tries to minimize the system energy.

Chemical energy (Gibbs) $\mu_i(z, p, T, v)$

Single Phase: $\mu_{t1} = \sum n_i \mu_i = n \sum z_i \mu_i(z)$

Two Phases: $\mu_{t2} = \underline{\underline{n_V}} \cdot \sum \underline{\underline{y_i}} \mu_{iV}(y) + \underline{\underline{n_L}} \cdot \sum \underline{\underline{x_i}} \mu_{iL}(x)$

$\left.\begin{array}{ll} \mu_{iV} = \mu_{iL} & ✓ \\ n = n_V + n_L & ✓ \end{array}\right\}$

Problem: so many combinations n_V, n_L y_i x_i

$\mu_{t1} < \mu_{t2} \Rightarrow$ Single Phase

$\mu_{t2} < \mu_{t1} \Rightarrow$ Two (more) Phases

Gibbs: Simplified method only to identify if single phase or 2(+) phases

$\{u_i = \text{composition}\}$

$$\mu_t^* = \epsilon \cdot \sum u_i \cdot \mu_i(u) + (1-\epsilon) \sum z_i \cdot \mu_i(z)$$

$$\mu_t^*(u) < \mu_t(z) \Rightarrow 2(+) \text{ phases}$$

$$\mu_i(u) \propto \mu_i(z)$$

$$\frac{\mu_i(u)}{\mu_i(z)} = \text{constant} \quad \text{all } i$$

Challenge to look in a large composition space for u_i

Ch. 3 Calculation of Saturation Pressure (BP, DP)

Calculation of Two-Phase Equilibrium

z_i @ P, T = n_v n_L y_i x_i

All

$\boxed{3.6}$: K-values

only

$\boxed{4.3.1}$: Two-Phase Flash

4.5 : Saturation Pressure

$\boxed{\text{Eqs. 4.74-4.75 Only}}$