Note Title 12/1/2016

EXAM Preparation

① Any class or homework exercises is fair game for Qs.

② Any lectured material, same.

③ Bring your PhZ Project (PRF)
- Excel prep work (e.g. Gamma / Soreide)
- PhZ "prediction" .phz
- PhZ "Light Regression" .phz (p_s, ρ_o ± 3-5%)

④ Be prepared to discuss "your" PVT problem (if there's time)

TOPICS:

① Basic PhZ Regression Variable "usage"

② Isothermal Chemical / Gravity Equilibrium ("Compositional Grading" | SEGREGATION)

③ Miscibility (minimum "conditions" to achieve miscibility of an oil by a gas: MMP, MME) – Mechanisms of developed miscibility

(4) Black-Oil (Nasty parts of BOPUT)

(5) Wax precipitation
(6) Asphaltene precipitation

((7) Aqueos-HC phase behavior) Ch. 9

Regression Issues:

①

User-Defined Emphasis (w_i)

z_i → $\boxed{\text{Tuned EOS}}$ → PVT (EOS) "Experimental" Data d_{ci}

Default EOS (PhZ, PVTsim, ...) SRK PR → Tuned EOS

Knobs (Variables)

Laboratory Experimental Data d_{mi}

min / {RMS / SSQ}

① EOS Property Adjustment

② Composition Adjustment

May vary field-to-field | Disciple-to-Disciplin

✓ (A) EOS Model Tuning (Without Viscosities)

- (All) key PVT data ±1-3% : target

✓ (B) Viscosity Model Tuning (Only Viscosities (μ_g, μ_o))

- Should not change EOS model at all.

- EOS model provides input to viscosity model

- ± 5-10 (15%) : target

(A) & (B) usually developed with a relatively detailed component description

EOSxx → EOSxx & Visc

10-11 "Light-Int" pure compounds

H_2S N_2 CO_2 C_1 C_2 C_3 iC_4 nC_4 iC_5 nC_5 | (C_6)

not BTEX

+ 5 - 11 - 30-ish C_{7+} fractions

PVTsim

Default PR Trim : 22
Phz : 40-ish (SCN 6–30) 31+
6–35 36+

(c) Lumping (Pseudoization) ⇒ "EOSx"
↑
<10

SPE 170912

≃ ±0–2% key data

EOSxx

EOS Variables – "Pool of Variables"

1 EOS Model Parameters (e.g. N = 22)

(a) Table 1 – Component Properties

$\boxed{110}$ 5x22 M T_c p_c ω (T_b) s

(b) Table 2 – BIPs

484
− 22 ($k_{ii}=0$)
462/2 = $\boxed{231}$

k_{ij}

$\boxed{341}$ Eliminate "don't use" variables

(a) Reduction: DON'T change pure compound EOS properties (ca. 10 compounds)
– 50 don't-use variables (~290)

Most Programs (b) Reduction: DON'T change C_{6+} s_i values (always use s_i calculated from γ_i where γ_i of C_{7+} are "fixed" (known or correlated)
– 10 (≈ 280)

Maybe Soreide factor
0.29 ± +1

(c) Reduction: DON'T change C_{6+} MWs | Maybe only M_{N+}

−10 (~270) | +1

(d) Reduction: (Ph2 only) DON'T change C_{6+} T_b's (ω's), perhaps ONLY $\boxed{C_{N+}}$

−10 (~260) +1

heaviest

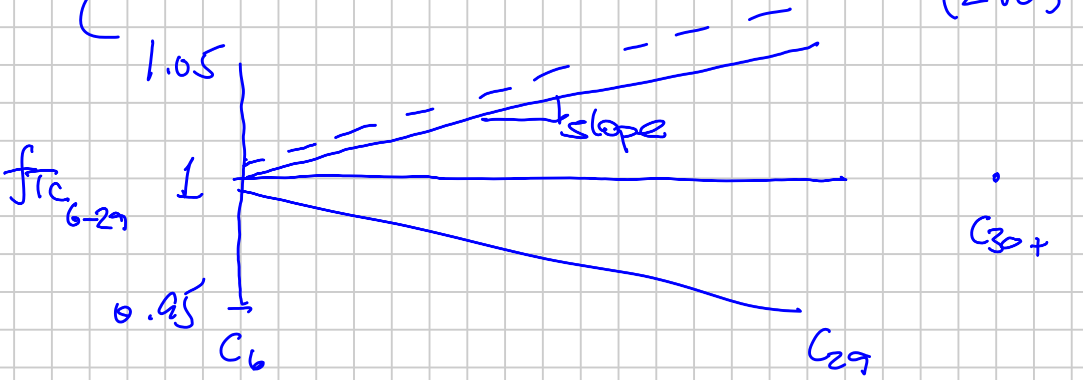
SCN Bounding Tbs are "known" (n-Paraffin values) $(\bar{T}_b)_{SCN_i} = \frac{1}{2}(T_{bL_{i-1}} + T_{bL_i})$

(e) Reduction: Instead of SCN (individual fraction) T_{ci} P_{ci}, $i = C_6, C_7, \ldots C_{N+}$

use single $\left[f_{Tc_{C6-C_{N-1}}},\ f_{Pc_{C6-C_{N-1}}} \right]$ −22

$f_{Tc_{CN+}},\ f_{Pc,CN+}$ +4

(240)



BIPS: Reduction

(a) Only use $\left\{ \begin{array}{l} C_1 - C_{7+} \\ HC-HC \end{array} \right\}$ with single variable

− single value (+1)

− "slope" & "int" (+2)

− Chueh × mult (+1)

−231

+1

−230 (~10 total Variables)

(b) Separate BIP Variable $HC-C_{N+}$ (C_1) (+1)

(c) More BIP. : BE CAREFUL!
Variables

- Use Groups of BIPs – difficult

... Uses 3–8 Regression Variables for EOS Tables

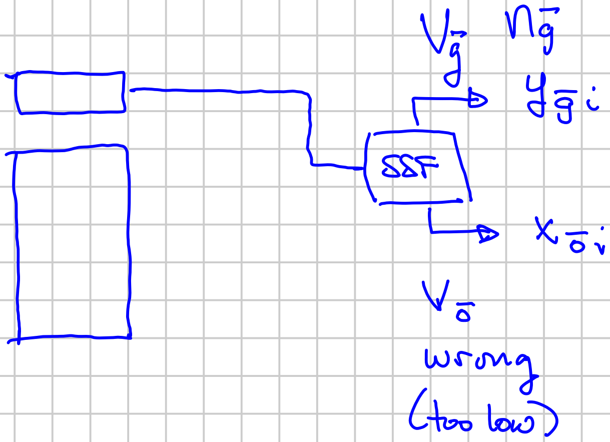
(2) COMPOSITION VARIABLES (each sample individually)

✓ (a) M_{7+} mass → moles

(b) Recombination GOR ("f_g" $= \dfrac{n_{\bar{g}}}{n_{\bar{g}} + n_{\bar{o}}}$)

(c) z_{N+}

$3 \times N_{\text{Samples}}$ more variables



$$\boxed{(M_{7+})_g} = \frac{\left[n_{\bar g} \, (y_{7+})_{\bar g} \, \overset{\sim 105}{(M_{7+})_{\bar g}} \right] + \left[\overset{\text{wrong}}{n_{\bar o}} \, \overset{\checkmark}{(x_{7+})} \, \overset{140+ \, \checkmark}{(M_{7+})_{\bar o}} \right]}{n_{\bar g} (y_{7+})_{\bar g} + \underset{\text{wrong}}{n_{\bar o}} (x_{7+})_{\bar o}}$$

$$(y_i)_{gcvd} = \frac{\overset{\checkmark}{n_{\bar g}} \, \overset{\checkmark}{(y_i)_{\bar g}} + \overset{\times}{n_{\bar o}} \, \overset{\checkmark}{(x_i)_{\bar o}}}{\underset{\checkmark}{n_{\bar g}} + \underset{\times}{n_{\bar o}}}$$

Static column

$$\frac{dp}{dh} = \rho g \qquad v_{Darcy,h} = \frac{k}{\mu} \cdot \frac{d\phi}{dh} = 0$$

$$\underbrace{\qquad\qquad}$$

$$\frac{d\phi}{dh} = 0 \qquad \phi = p + \rho g (h - h_{ref})$$

Gibbs $(\nabla T = 0 = dT/dh)$

Static colum of a Mixture where

(1) $\frac{d\phi}{dh} = 0$ $\quad v_h = 0$ $\quad$ bulk flow $\Rightarrow p(h)$

(2) $v_{ih} = 0 = \frac{d\phi_i}{dh}$ $\quad$ component flow

Molecular Diffusion

Total potential (energy)

$$v_{ih} = D_i \left(\frac{d\phi_i}{dh}\right)$$

$$= 0 \text{ only if } \frac{d\phi_i}{dh} = 0$$

$$\phi_i = \mu_i + M_i g (h - h_{ref})$$

N eq. $\quad \phi_i(h) = \mu_i(\overset{\checkmark}{T}, \underset{1}{\underline{p(h)}}, \underset{+\;N}{\underline{z_i(h)}}) + \underbrace{\overset{\checkmark}{M_i} \overset{\checkmark}{g} (h - \overset{\checkmark}{h_{ref}})}$

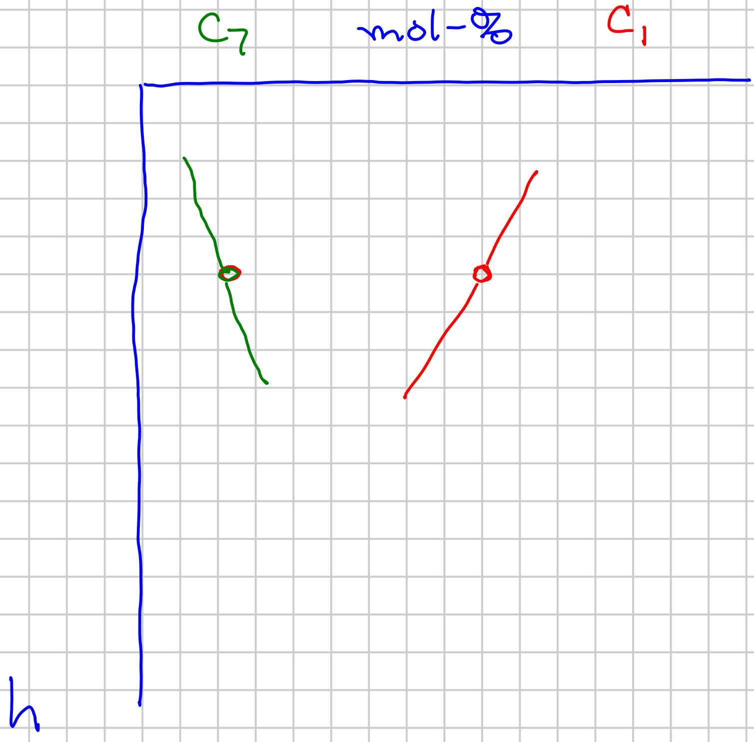
Know: $z_i(T, p(h_{ref}), z_i(h_{ref})) \Rightarrow$

Know: $\phi_i(h_{ref}) = \mu_i(T, p_{ref}, z_{ref\,i})$

$$= \phi_i(h)$$

1 eq. $\quad \sum z_i(h) = \underline{1}$

$\Rightarrow \quad z_i(h)$ & $p(h)$



Muskat (193x): Simple Liquid EOS

$$\mu_i$$

$$\nabla z_i = \frac{dz_i}{dh} \sim 0$$

Sage-Lacey (194x): More rigorous (Valid) EOS

$$\nabla z_i \neq 0$$

∴ few field case histories ∇R_s, ∇p_b

Schulte (1980) Cubic EOS
Birba (Oman)
Brent (NS)
} found significant ∇z_i computationally & for field cases

magnitud ∇z_i was strongly dependent on % of C_{7+} fractions with aromatics

SCN $\bar{C}_7$ $\left\{ \begin{array}{c} Bz \\ \vdots \\ n\text{-}C_7 \end{array} \right\}$ ⊛

Shell C_{7+} characterization method: (Pre 200x) PVTsim

5-7 fractions < P, A

F1P

F1A

F2P

F2A

⋮

* F6A
* F7A

] – often leads to LLV equilibrium

REAL / FALSE

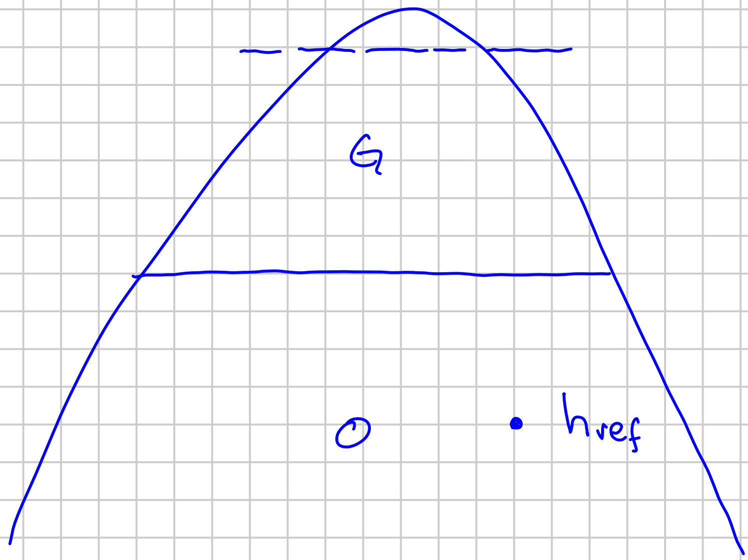
1990 SPE 28000

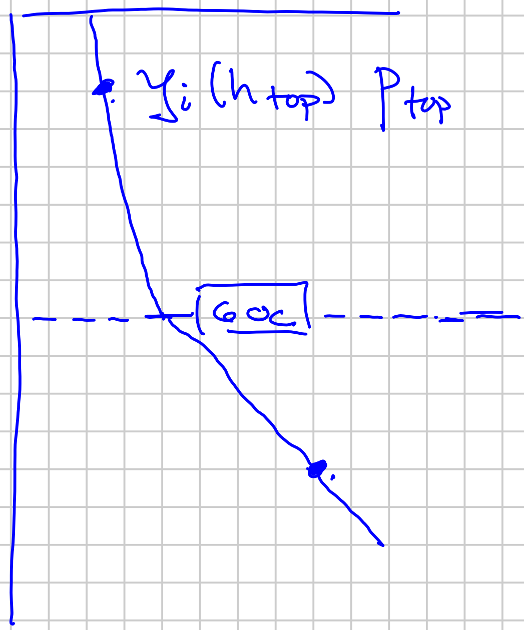
$\boxed{z_i}$ $\nabla T \neq 0$ Non-Isothermal

3-4 churches

Field ∇z_i

198x → Now





MISCIBILITY

Developed Miscibility

90+%

Through multiple contacts of the gas injectant with the oil (immiscible) and derivative gases & oils from that mixing where a (developed moving gas) contacts an (altered oil) that are miscible, or very-nearly miscible – i.e. near critical mixture (at the miscible front).

Upstream & downstream to the miscible front, either an Immiscible 2-phase gas-oil or a single phase oil (~ original oil).

C/VM

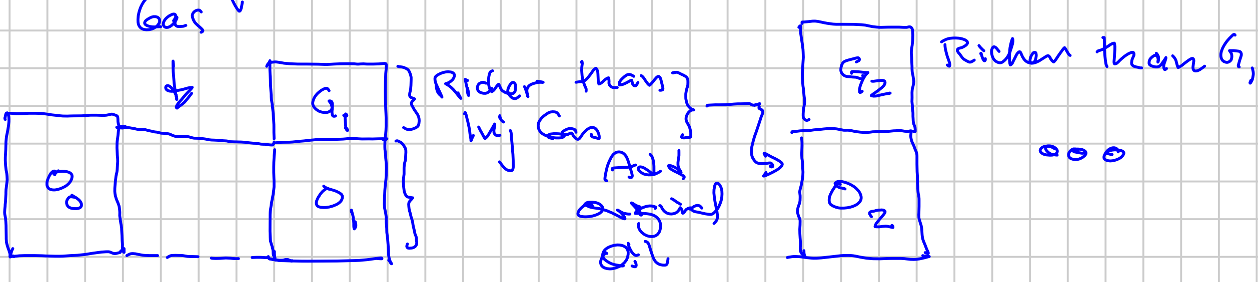
L Condensing/Vaporizing Drive Mechanism — Aaron Zick (1985-86)

10-%

VGD — Developed gas becomes miscible with the original oil.

L Vaporizing Gas Drive

Inj (C_1, C_2) Gas

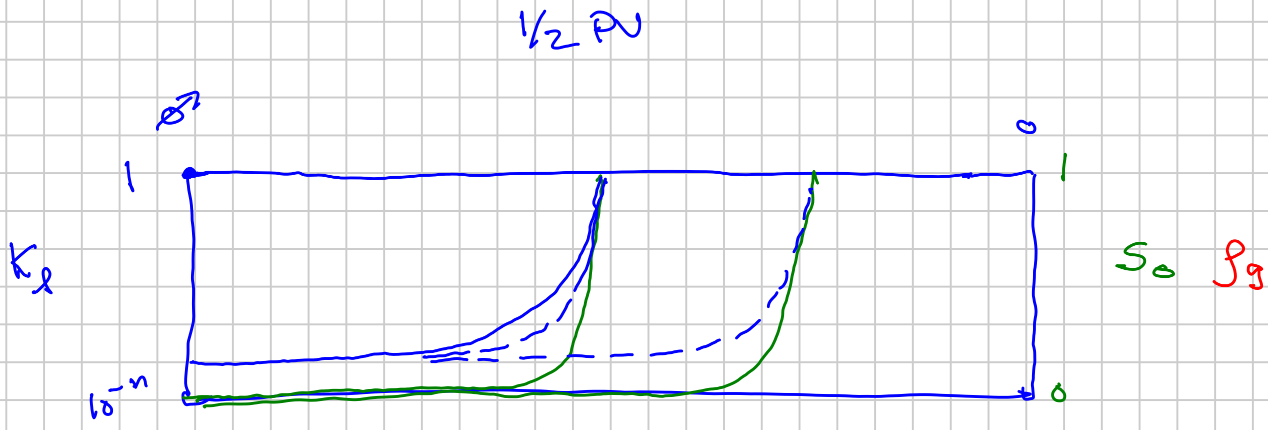


5000 psia

$$K_\ell(T, p, \underline{\underline{z_i}}) = \frac{y_\ell}{x_\ell} \qquad \uparrow K_\ell$$

C_6
C_7
.
C_{N+}

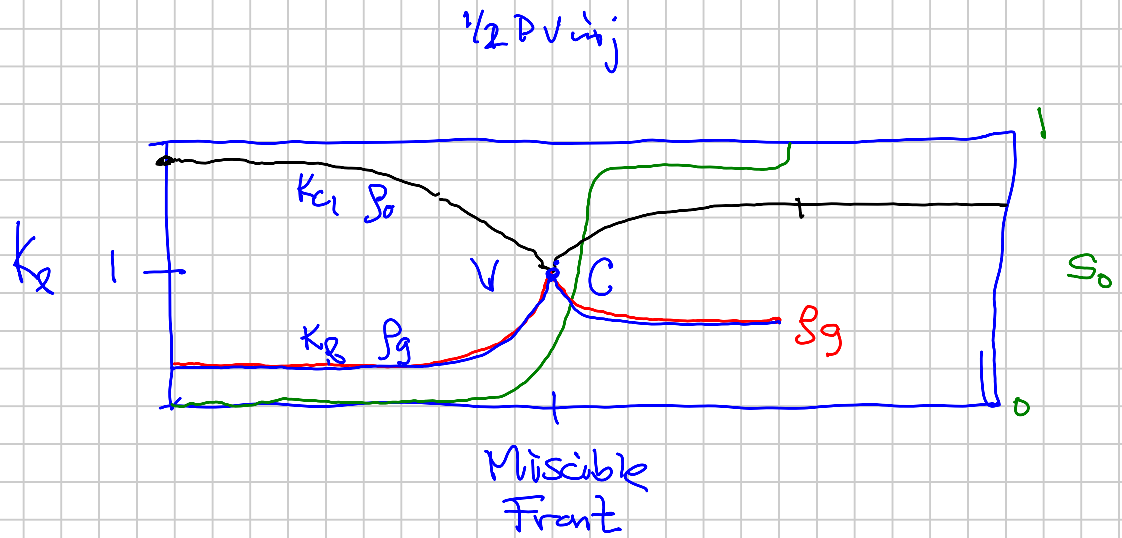
Gas becomes "first contact" miscible w/ Original Oil directly



<u>VGD</u>: (1) Lean Gas (C_1 | N_2)
(2) High Pressures > 5000 psia
(3) Lighter Oil (API > 35)

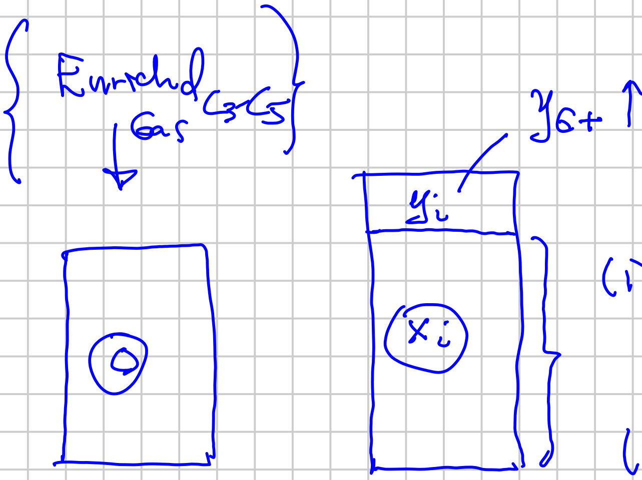
<u>CVD</u>:

<u>Ch. 8</u>



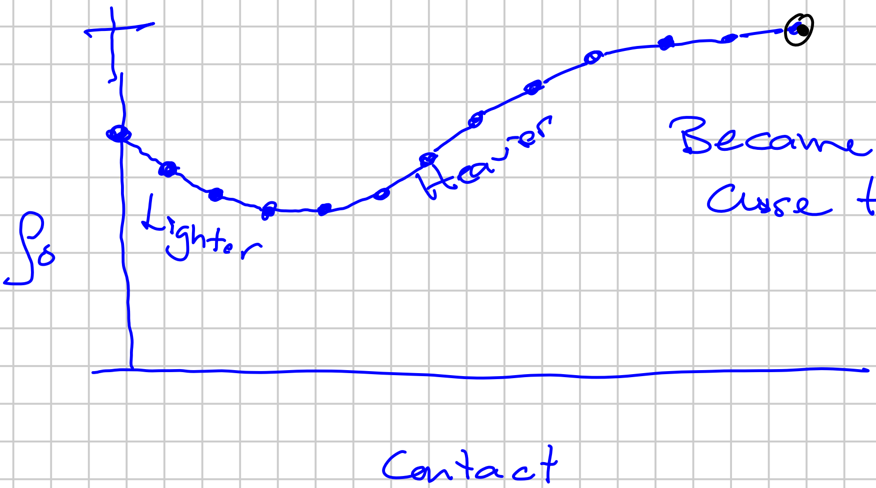
C/V M   Result of Fluid Mixing & Phase Equilibria
(Arbitrary)
Independent of Relative Permeability of Rock

$y^{IG}_{C_{6+}} = 0$



(1) Enriched by Solvent in the gas through "condensation"

(2) Vaporized of C6+ components



Became No Where Close to Miscible