

① What is the difference between a **GAS RESERVOIR** and an **OIL RESERVOIR**?

② Why does it matter? Does it matter?

What is common between **GR** & **OR**?

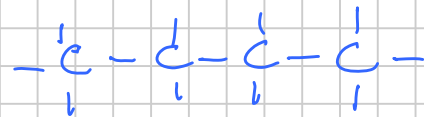
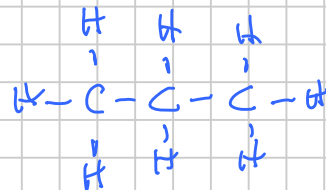
Mobile **Hydrocarbon** - Bearing Pores in a Rock (with connate Water (Brine))

(N₂ CO₂ H₂S) at Initial (P, T, D)
 H₂O
 (ii)

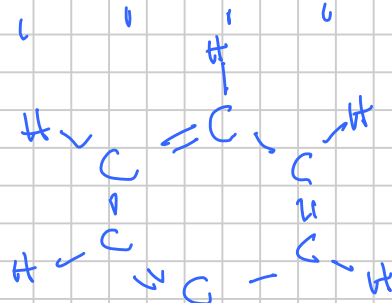
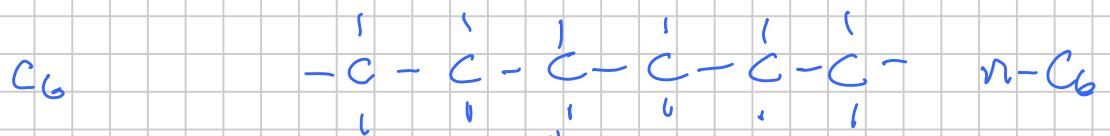
Amounts
 (I)
 Z_i = $\frac{C_i}{\sum C_i}$
 W_i = $\frac{S_i}{\sum S_i}$

Which Compounds

C₁ CH₄
 C₂ C₂H₆
 C₃ C₃H₈
 C₄ n-C₄



C₅



Benzene
 C₆H₆

Reservoir "Gas" or "oil" ?

$$\left\{ \underline{z}_i \in (p_{Ri}, T_R) \right\}$$

Measured
or
Calculated

Saturation Pressure @ T_R
&
Type (Bubblepoint, BP, p_b
Dewpoint, DP, p_d)

Oil Reservoir if $p_b(T_R) \leq p_{Ri}$

Gas Reservoir if $p_d(T_R) \leq p_{Ri}$ or $T_R > T_{critical}^*$

(No gas-oil split at any pressure)

Gas+Oil Reservoir if $p_s(T_R) > p_{Ri}$

(A) z_i splits into gas & oil at T_R, p_{Ri}

(B) or Gravitational segregation of individual components leads to z_i (D) "Equilibrium"

(C) or Reservoir mixture z_i has not yet (and may never) reach "Equilibrium" (Chemical-Gravity-Non-Equilibrium Thermal-...)

Why R_G vs R_O might be important

- μ_g vs μ_o :
 $0.01 - 0.1 \text{ cp}$ vs $0.1 - 10^6 \text{ cp}$
 mPa·s

$\Delta P_{R,P} \uparrow$ Costs \uparrow

Number of Wells

Size (diameter) of Pipes

Reservoir Recovery

Development Plans

- ρ_g vs ρ_o

$1 - 300 \frac{\text{kg}}{\text{m}^3}$

$300 - 1000 \frac{\text{kg}}{\text{m}^3}$

$g \uparrow$

Costs \uparrow

- Gas Expansion
 $50 - 500$

vs Oil Shrinkage
 $0.95 - 0.3$

Gas

vs

Oil

ρ_{og}

<

ρ_{oo}

Value

↔
 $\$/\text{STB}$

- Middle East :

Surface oil from R_{Gas} : State owns

Surface oil from R_{Oil} : Production Sharing

Value to
 / State
 / Company

- USA :

Oklahoma, Texas

R_G : $R_P = \frac{V_g}{V_o}$ > $(R_P^*)_{\text{State}} = 10000 \frac{\text{scf}}{\text{STB}}$ → R_G
 R_O (GOR) → R_O

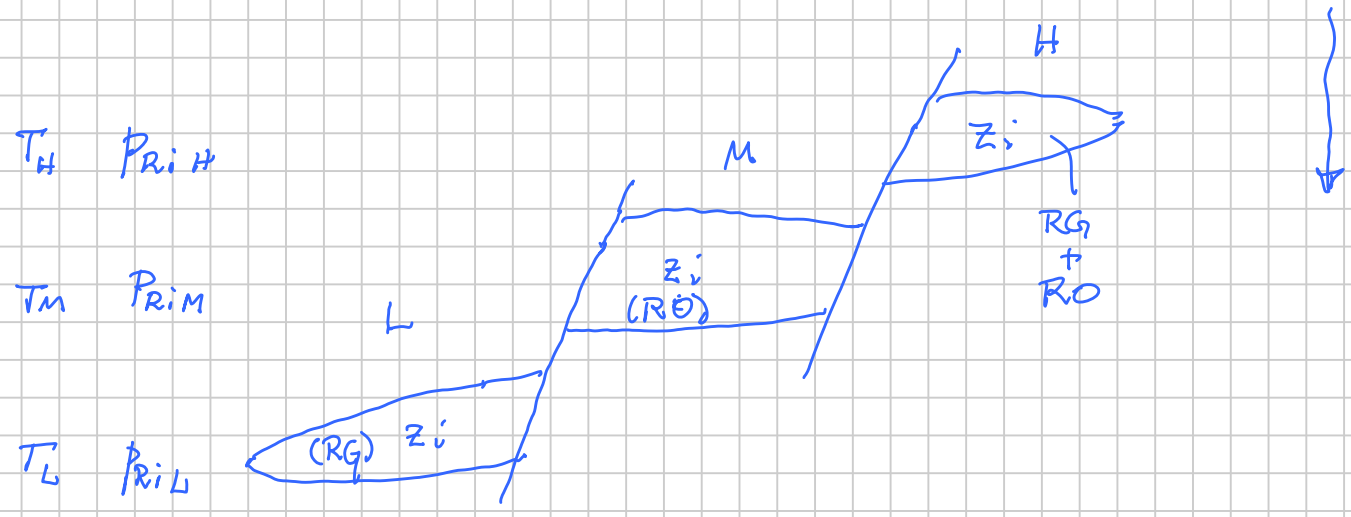
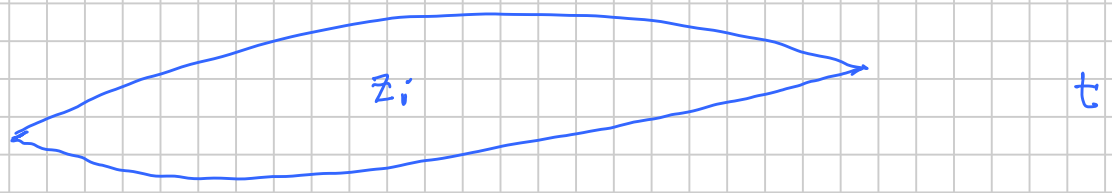
$$U = \left(\frac{\partial}{\partial M} \right) \frac{\Delta D}{L} = C \frac{\Delta D}{L}$$



Cost
Value

$$t_D = \left(\frac{\partial}{\partial M G R_w^2} \right) t$$

Well Spacing $\left\{ \begin{matrix} M \\ C \end{matrix} \right\} = f(GOR)$



$$(z_i)_L = (z_i)_M = (z_i)_H$$

RG, & RO "Reservoir Hydrocarbon" Compositions

non-HCs: N_2 CO_2 H_2S H_2O (Hg)

HCS: C_1 most amount

C_2

C_3

C_{4s} (i-C₄, n-C₄)

C_{5s} (i-C₅, n-C₅)

C_6 (alkanes only, not Benzene)

C_7 all compounds boiling between n-C₆ ... n-C₇
(includes Benzene)

C_8 (also includes Toluene)

C_9

C_{10}

⋮

C_{N+} Typically C_{25+} ... C_{36+} (varies by lab, historically)

Solids: Wax: n-C₂₀ → n-C₅₀₊
fct)

Asphaltenes: OILS

$M > 1000$

$f(p \rightarrow p_0 \downarrow)$
(Adding Gas)
 $z_i \rightarrow z_i^\uparrow$

< 1980 C_{7+}

1980s $C_{10+} - C_{24+}$

1990s $C_{15+} - C_{20+}$

> 2000 $C_{31+} - C_{36+}$

Molar compositions z_i total mixture = $\frac{n_i}{n}$
 y_i gas phase = $\frac{(n_i)_g}{n_g}$

x_i oil phase

$$= \frac{(m_i)_0}{n_0}$$

$$\sum_{i=1}^N z_i = \sum y_i = \sum x_i = 1$$

(Lab Measurement)

Mass composition

$$w_i = \frac{m_i}{m}$$

$$w_{gi} = \frac{(m_i)_g}{m_g}$$

$$w_{oi} = \frac{(m_i)_o}{m_o}$$

$$\boxed{z_i \leftrightarrow w_i}$$

$$M_i \equiv \frac{m_i}{n_i}$$

Known values for non-HCs

HCS ... C_5

$$\bar{M} = \frac{\sum m_i}{\sum n_i} = \frac{m}{n}$$

M_i for $C_6, C_7, \dots \pm 1-10\%$

$$\left. \begin{aligned} z_i &= \frac{n_i}{n} \\ w_i &= \frac{m_i}{m} \end{aligned} \right\}$$

$$\bar{M} = \frac{m}{n} = \frac{\frac{(m_i)}{w_i}}{\frac{(n_i)}{z_i}} = \frac{z_i}{w_i} \cdot \frac{m_i}{n_i} = \frac{z_i}{w_i} \cdot M_i$$

$$z_i = \frac{\bar{M}}{M_i} \cdot w_i$$

$$\frac{\bar{M}}{M_i}$$

$$w_i = z_i \frac{M_i}{\bar{M}}$$

Lab should provide (at minimum)

$$z_i, \bar{M}$$

Measure w_i
 \bar{M}

$$z_i, w_i, \bar{M}$$

Assume M_i

$$z_i, w_i, M_i, \bar{M}$$

Ch. 2: Phase Behavior $\Rightarrow (p, T)$ for a given z_i

where ① Single Phase

② Two Phases

p-T Phase Diagram

H₂O: $z_{H_2O} = 1$

(p, T) where H₂O is both L & V

