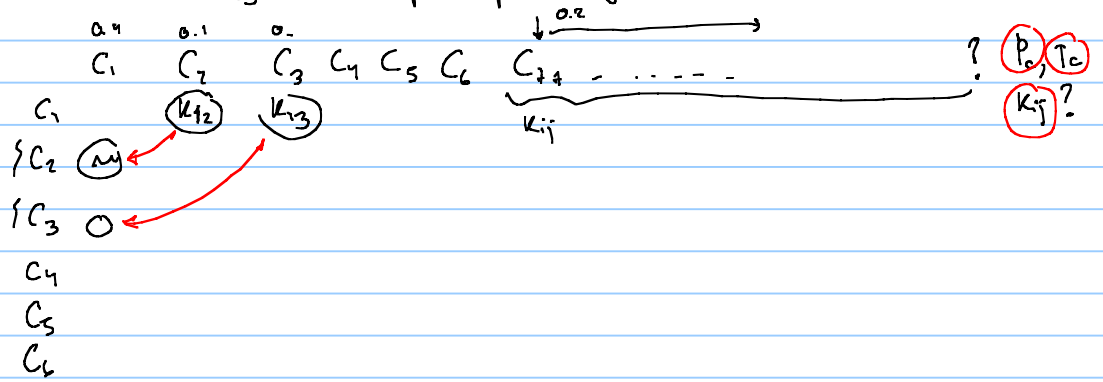
Class 4. EOS are ~~not~~ very predictive "out-of-the-box" ± 10% ± 20%

$k_{ij}$ = BIPS i can modify BIPS to improve predictability



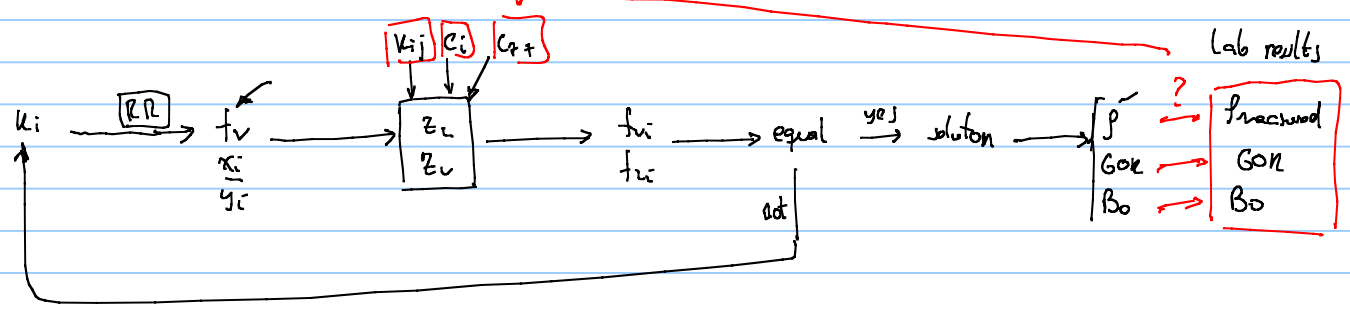

$$v_L = v_L^{EOS} - \sum_{i=1}^{N} x_i c_i$$

volume shift for heavy (pseudo components).

$$\text{and } v_v = v_v^{EOS} - \sum_{i=1}^{N} y_i c_i,$$

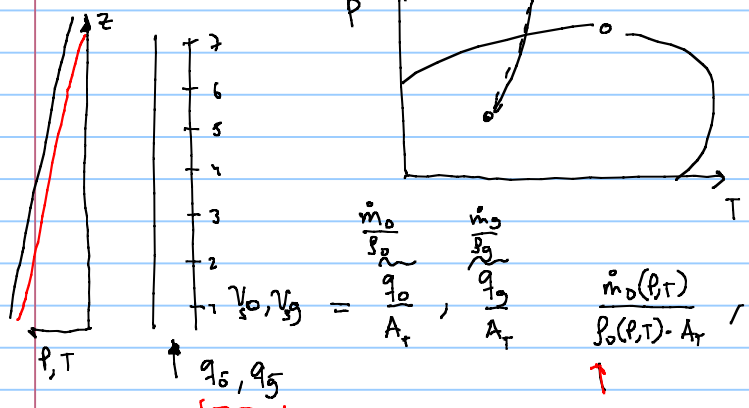
to improve predictability of EOS: - change slightly properties of pseudo components
- change BIPS
- change volume shift

to match measured/lab data!




an EOS is: - Equation being used → PR / SRK
- $k_{ij}$
- $c_i$ (volume shift)
- properties of pseudo components

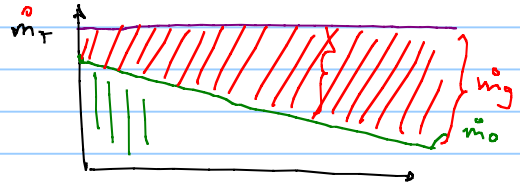
Class exercise




$$\frac{\dot{m}_o}{\rho_o} = \frac{q_o}{A_T}, \quad \frac{\dot{m}_g}{\rho_g} = \frac{q_g}{A_T}$$

$$\frac{\dot{m}_o(p,T)}{\rho_o(p,T)\cdot A_T} \Big/ \frac{\dot{m}_g(p,T)}{\rho_g(p,T)\cdot A_T}$$

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



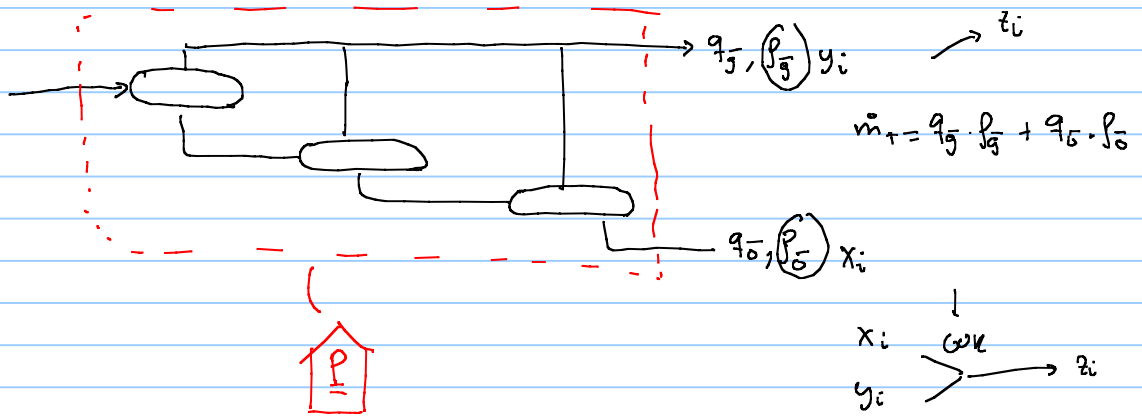

$F_v$ = molar basis

$$f_v = \frac{\dot{n}_g}{\dot{n}_g + \dot{n}_o}$$

vapor mass fraction $x_v$

$\dot{m}_g = \dot{m}_T \cdot x_v$

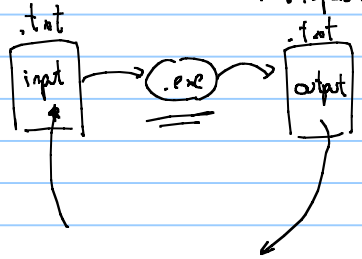
$\dot{m}_o = \dot{m}_T \cdot (1 - x_v)$




| ID | [m] | 0.127 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | [m^2] | 0.012668 | | | | | | | | | |
| mt | [kg/s] | 12 | | | | | | | | | |
| | | | | | ↓ | ↓ | ↓ | | | | |
| TVD | p | T | mo | mg | Xv | deno | Deng | qo | qg | vso | vsg |
| [m] | [bara] | [C] | kg/s | [kg/s] | [-] | [kg/m^3] | [kg/m^3] | [m^3/s] | [m^3/s] | [m/s] | [m/s] |
| 0 | 80 | 70 | 5.891 | 6.109 | 0.509 | 630.312 | 54.682 | 0.009 | 0.112 | 0.738 | 8.819 |
| 200 | 90 | 73 | | | | | | | | | |
| 400 | 100 | 76 | | | | | | | | | |
| 600 | 110 | 79 | | | | | | | | | |
| 800 | 120 | 82 | | | | | | | | | |
| 1000 | 130 | 85 | | | | | | | | | |
| 1200 | 140 | 88 | | | | | | | | | |
| 1400 | 150 | 91 | | | | | | | | | |
| 1600 | 160 | 94 | | | | | | | | | |
| 1800 | 170 | 97 | | | | | | | | | |
| 2000 | 180 | 100 | | | | | | | | | |
| 2200 | 190 | 103 | | | | | | | | | |

home excuse retrieve properties from EOS automatically to populate excel table
- HYSYS in VBA
- to install HYSYS on another .exe utility

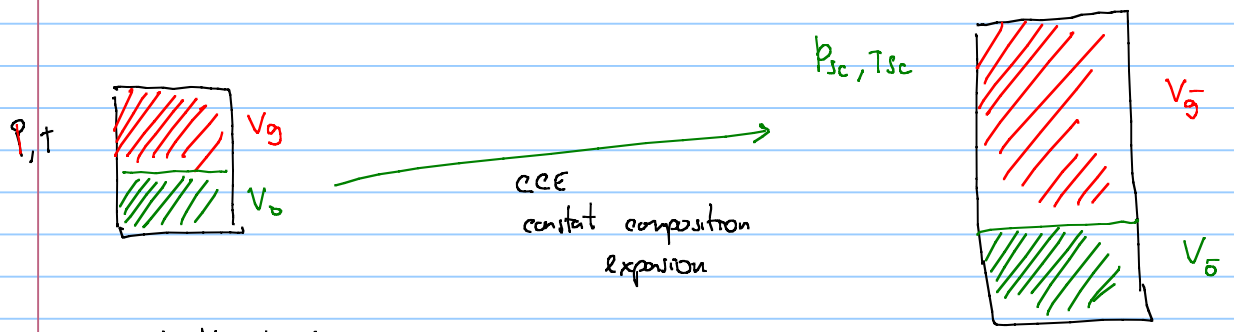
Flash-pack




Black oil approach $B_o$, $R_s$, $B_g$, $r_s$ ($R_v$)

traditional BO: regular crudes (low GOR), dry gas

extended BO: volatile oil (↑ API, ↑ GOR)
↳ condensation of oil from gas




traditional BO

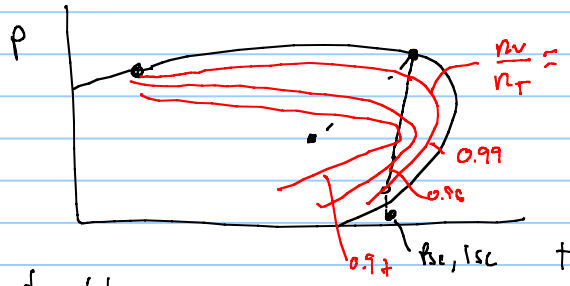
oil volume factor $B_o = \frac{V_o(P,T)}{V_{\bar{o}}} \sim 1.1 \rightarrow 1.8$ (dead oil → volatile oil)

if $P_z = P_R$, $T = T_R$ "formation volume factor"

gas volume factor $B_g = \frac{V_g(P,T)}{V_{\bar{g}}} \sim 0.01$ 1E-2 – 1-E-03

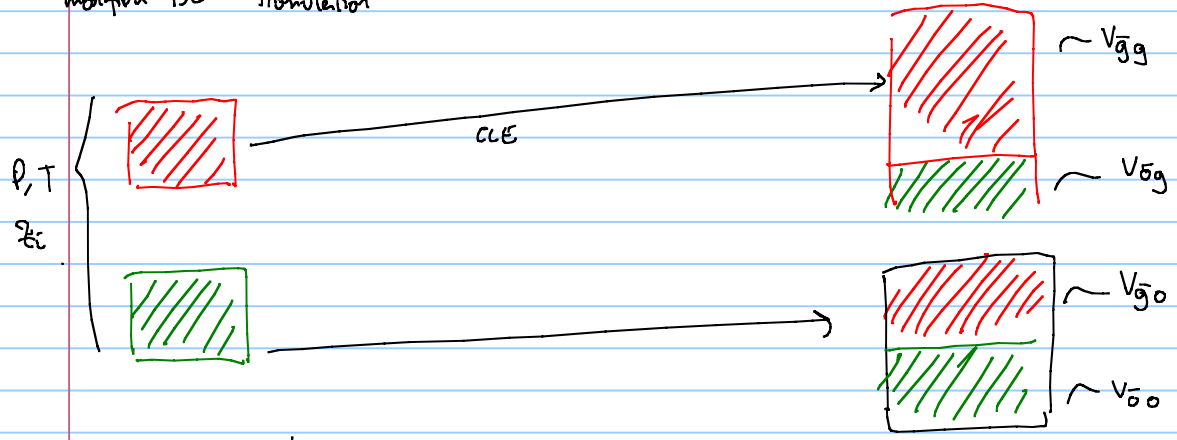
Solution gas/oil ratio $R_s = \frac{V_{\bar{g}}}{V_{\bar{o}}} \sim \frac{Sm^3}{Sm^3}$ (dead oil: 20 → volatile/gas condensate: 2000)

gas @ $p^*, T^*$




t $p_{sc}, T_{sc}$

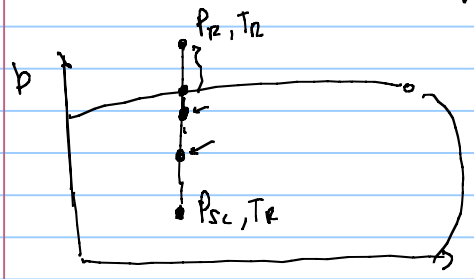
modified BO formulation



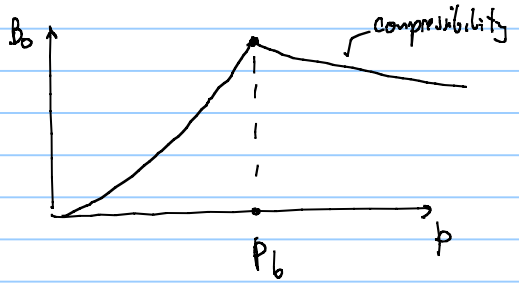

BO parameters

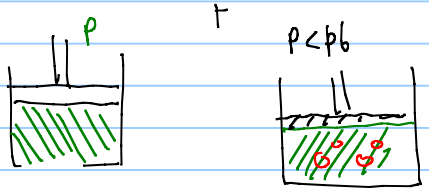
$$B_o(p,T) = \frac{V_o}{V_{\bar{o}o}} \qquad R_s = \frac{V_{\bar{o}o}}{V_{\bar{o}o}}$$

$$B_g(p,T) = \frac{V_g}{V_{\bar{g}g}} \qquad r_s = \frac{V_{\bar{o}g}}{V_{\bar{g}g}}$$

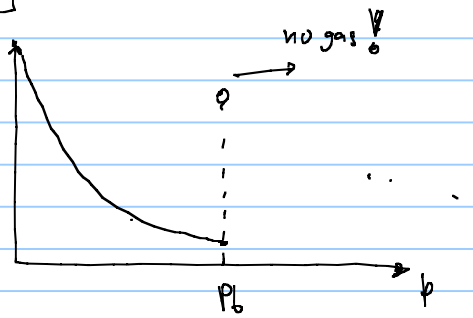


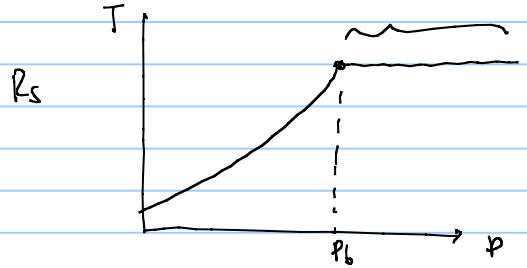

T

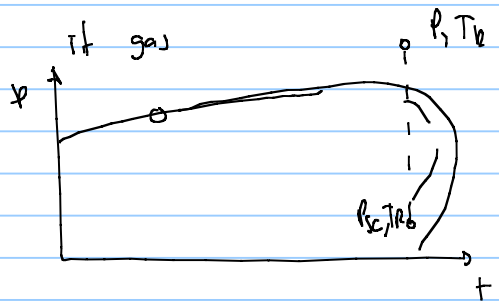


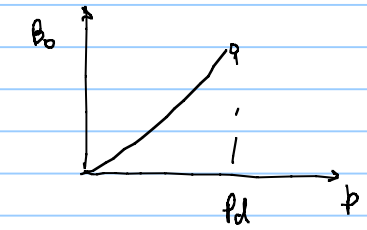



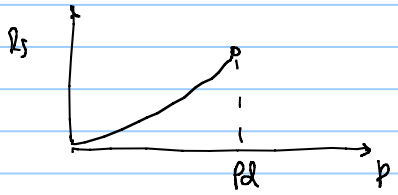

$$B_g = \frac{V_g(p,T)}{V_{\bar{g}g}}$$

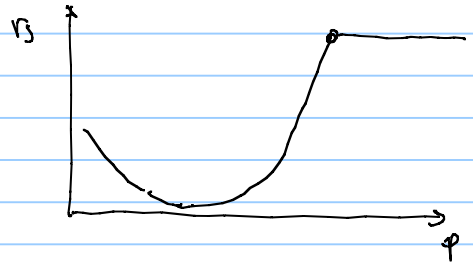


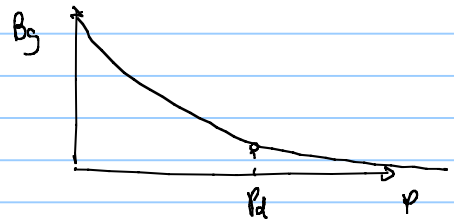




$$q_{\bar{o}} = q_{\bar{o}o} + q_{\bar{o}g} = \frac{q_o}{B_o} + r_s \, q_{\bar{g}g} \qquad \frac{q_g}{q_{\bar{g}g}} = B_g$$

$$q_{\bar{o}} = \frac{q_o}{B_o(p_i)} + r_s(p_i)\frac{q_g}{B_g(p,T)}$$

$$q_{\bar{g}} = q_{\bar{g}o} + q_{\bar{g}g} = R_s \cdot q_{\bar{o}o} + \frac{q_g}{B_g} \qquad \frac{q_o}{q_{\bar{o}o}} = B_o$$

$$q_{\bar{o}o} = \frac{q_o}{B_o}$$

$$q_{\bar{g}} = \frac{R_s}{B_o} q_o + \frac{q_g}{B_g}$$

$$\begin{Bmatrix} q_{\bar{o}} \\ q_{\bar{g}} \end{Bmatrix} = \begin{Bmatrix} \frac{1}{B_o} & \frac{r_s}{B_g} \\ \frac{R_s}{B_o} & \frac{1}{B_g} \end{Bmatrix} \cdot \begin{Bmatrix} q_o \\ q_g \end{Bmatrix}_{(p,T)}$$

$$\begin{Bmatrix} q_o \\ q_s \end{Bmatrix} = \begin{Bmatrix} q_{\bar{o}} \\ q_{\bar{s}} \end{Bmatrix}$$

$$\begin{bmatrix} q_g \\ q_o \\ q_w \end{bmatrix} = \begin{bmatrix} \frac{B_g}{1-R_s \cdot r_s} & \frac{-B_g \cdot R_s}{1-R_s \cdot r_s} & 0 \\ \frac{-B_o \cdot r_s}{1-R_s \cdot r_s} & \frac{B_o}{1-R_s \cdot r_s} & 0 \\ 0 & 0 & B_w \end{bmatrix}_{(p,T)} \cdot \begin{bmatrix} q_{\bar{g}} \\ q_{\bar{o}} \\ q_{\bar{w}} \end{bmatrix}$$

BO properties are generated → laboratory tests (not very common, unless reservoir $T_R$)

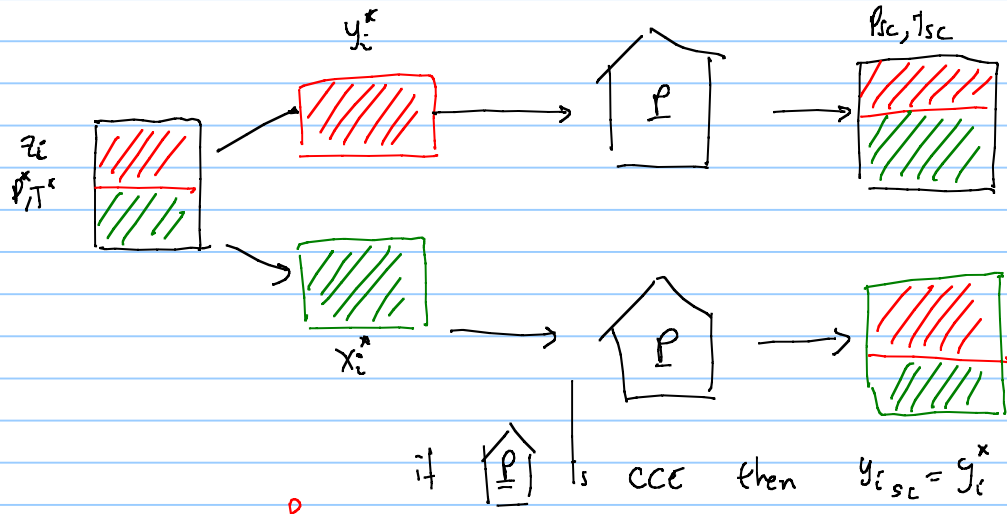
→ correlations (Standing, Beggs, Vasquez as a function of GOR → $r_s$; $p_o \simeq x_i$; $p_g \simeq y_i$ → $z_i$)

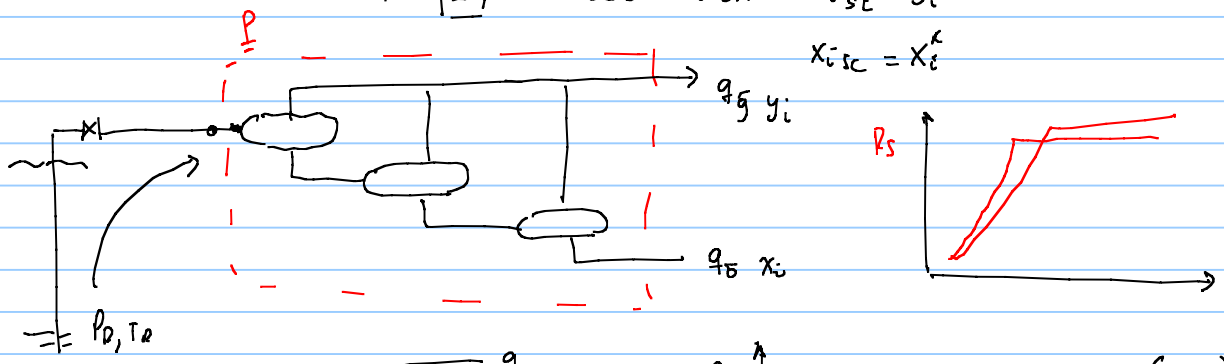
must be tuned to data

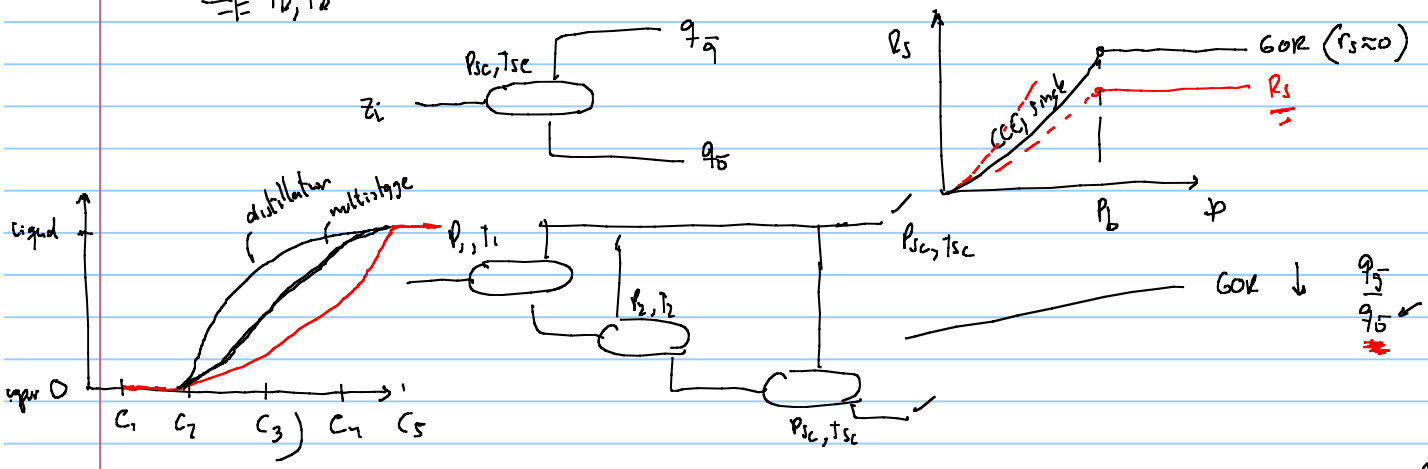
$B_o$ changing $C_1, C_3$ — p

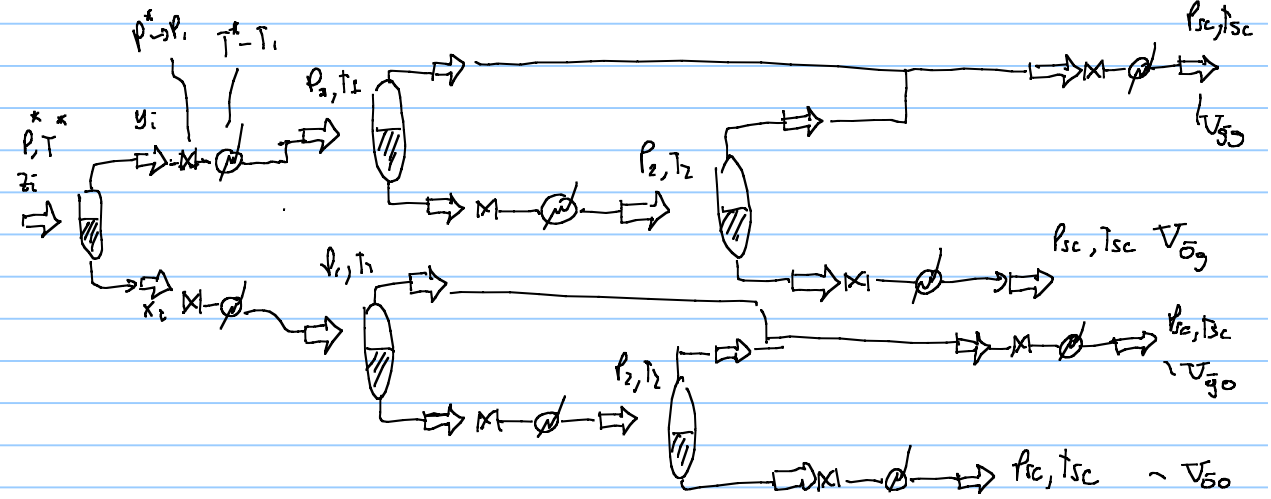
$B_g \simeq$ $pV = zRT$

→ generate from @c compositional model




homework. Generate BO properties with the utility, P, T } details to be sent later !

$z_i$

in the GOR changes ⇒ $z_i$ will change → EOS use the new $z_i$ !
→ black oil

how to estimate numerically new $z_i^{\eta}$.
$z_i(t)$

depends on the reservoir recovery process { gas injection


method commonly used recombination of separator fluids