

Properties of Reservoir Fluids (PGE 362)

Gasses

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Non-HC Component effect on Z-factor

N₂, CO₂, and H₂S

HC

- Sour (1 gm of H₂S/100 ft³)
- Sweet

Both sour and sweet gases contain CO₂, N₂ or both.

No significant effect for concentration < 5%

10% error for higher concentration.

Pseudocritical properties need adjustment

1. Wichert-Aziz correction method
2. Carr-Kobayashi-Burrows (CKB) correction method

Non-HC Component effect on Z-factor

1. Whichert-Aziz correction method

- Why we need correction?
- $T_{pc}' = T_{pc} - \varepsilon$
- $P_{pc}' = \frac{P_{pc}T_{pc}'}{T_{pc} + B(1-B)\varepsilon}$
- B = mole fraction of H₂S
- ε = pseudocritical temperature adjustment factor
 - $\varepsilon = 120 \times (A^{0.9} - A^{1.6}) + 15 \times (B^{0.5} - B^4)$
 - A = sum of CO₂ and H₂S mole fraction

Non-HC Component on Z-factor

2. Carr-Kobayashi-Burrows (CKB) correction method

1. Used when composition is not available
2. Calculate pseudo-critical pressure and temperature
 1. $T_{pc} = 168 + 325\gamma_g - 12.5\gamma_g^2$
 2. $P_{pc} = 677 + 15\gamma_g - 37.5\gamma_g^2$
3. Adjust the pseudo-critical pressure and temperature
 1. $T_{pc}' = T_{pc} - 80y_{CO_2} + 130y_{H_2S} - 250y_{N_2}$
 2. $P_{pc}' = P_{pc} + 440y_{CO_2} + 600y_{H_2S} - 170y_{N_2}$
4. Calc. pseudo-reduced temp. and press.
5. Obtain Z factor from the chart

Non-HC Component on Z-factor

Example:

A sour gas (sp. gr. **0.7**) contains **5%** CO₂ and **10%** H₂S.

Calculate the density of the gas at (3500 psia and 160 °F)

Solution:

Whichert-Aziz correction method:

$$T_{pc} = 168 + 325(\mathbf{0.7}) - 12.5(\mathbf{0.7})^2 = 389.38 \text{ }^{\circ}\text{R}$$

$$P_{pc} = 677 + 15(\mathbf{0.7}) - 37.5(\mathbf{0.7})^2 = 669.1 \text{ psia}$$

$$\varepsilon = 120 \times (0.15^{0.9} - 0.15^{1.6}) + 15 \times (0.1^{0.5} - 0.1^4) = 20.735 \text{ }^{\circ}\text{R}$$

$$T_{pc}' = 389.38 - 20.735 = 368.64 \text{ }^{\circ}\text{R}$$

$$P_{pc}' = \frac{(669.1)(368.64)}{(389.38 + 0.1(1 - 0.1)(20.735))} = 630.44 \text{ psia}$$

Non-HC Component on Z-factor

Example:

A sour gas (sp. gr. **0.7**) contains **5%** CO₂ and **10%** H₂S.

Calculate the density of the gas at (3500 psia and 160 °F)

Solution:

Whichert-Aziz correction method:

$$P_{pr} = \frac{3500}{630.44} = 5.55$$

$$T_{pr} = \frac{(160+460)}{368.64} = 1.68$$

$$Z = 0.89$$

$$Ma = (28.96)(0.7) = 20.27$$

$$\rho_g = \frac{(3500)(20.27)}{(0.89)(10.73)(620)} = 11.98 \text{ lb/ft}^3$$

Non-HC Component on Z-factor

Example:

A sour gas (sp. gr. **0.7**) contains 5% CO₂ and 10% H₂S.

Calculate the density of the gas at (3500 psia and 160 °F)

Solution:

Carr-Kobayashi-Burrows correction method:

$$T_{pc} = 168 + 325(\mathbf{0.7}) - 12.5(\mathbf{0.7})^2 = 389.38 \text{ }^{\circ}\text{R}$$

$$P_{pc} = 677 + 15(\mathbf{0.7}) - 37.5(\mathbf{0.7})^2 = 669.1 \text{ psia}$$

$$T_{pc}' = 389.38 - 80(\mathbf{0.05}) + 130(\mathbf{0.1}) - 250(\mathbf{0}) = 398.38 \text{ }^{\circ}\text{R}$$

$$P_{pc}' = 669.1 + 440(\mathbf{0.05}) + 600(\mathbf{0.1}) - 170(\mathbf{0}) = 757.1 \text{ psia}$$

Non-HC Component on Z-factor

Example:

A sour gas (sp. gr. 0.7) contains 5% CO₂ and 10% H₂S.

Calculate the density of the gas at (3500 psia and 160 °F)

Solution cont.:

$$P_{pr} = \frac{3500}{757.1} = 4.62$$

$$T_{pr} = \frac{(160+460)}{398.38} = 1.66$$
$$Z = 0.86$$

$$Ma = (28.96)(0.7) = 20.27$$

$$\rho_g = \frac{(3500)(20.27)}{(0.86)(10.73)(620)} = 12.40 \text{ lb/ft}^3$$

Van der Waals' equation

One mole of single pure gas (not applicable for gas mixture)

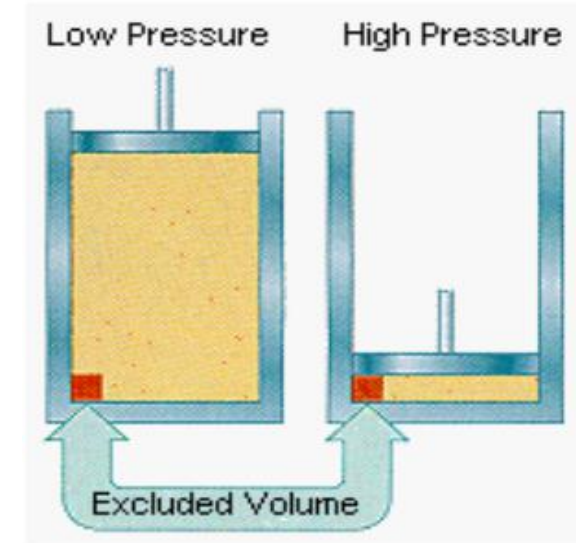
- $\left(P + \frac{a}{V^2}\right)(V - b) = RT$

For n moles

- $\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$
- a and b constant (different for each gas)
- $\frac{a}{V^2}$ accounts for the attraction forces between molecules
- b represents the volume of the molecules

- At low pressure and high temperature the volume V is large and the above equation can be reduced to the general gas law (perfect gas behavior)

- $PV = nRT$



Van der Waals' equation

For the units P (atm.), V (liters), T (°K), and R (0.08205) a and b are as follows:

or, from critical data:

- $a = 3P_c V_c^2$
- $b = \frac{V_c}{3}$
- V_c : critical volume
- P_c : critical pressure

Gas	a (atm liters ²)	b (liters)
CH ₄	2.253	0.04278
C ₂ H ₆	5.489	0.0638
C ₂ H ₄	4.471	0.05714
C ₂ H ₂	4.39	0.05136
CO ₂	3.592	0.04267

Van der Waals' equation



Which gas has the lowest

value of **a**? why?

Which gas has the largest

value of **b**? why?

Substance	a	b	P _c	T _c
	(J·m ³ /mole ²)	(m ³ /mole)	(MPa)	(K)
Air	0.1358	3.64x10 ⁻⁵	3.77	133 K
Carbon Dioxide (CO ₂)	0.3643	4.27x10 ⁻⁵	7.39	304.2 K
Nitrogen (N ₂)	0.1361	3.85x10 ⁻⁵	3.39	126.2 K
Hydrogen (H ₂)	0.0247	2.65x10 ⁻⁵	1.3	33.2 K
Water (H ₂ O)	0.5507	3.04x10 ⁻⁵	22.09	647.3 K
Ammonia (NH ₃)	0.4233	3.73x10 ⁻⁵	11.28	406 K
Helium (He)	0.00341	2.34x10 ⁻⁵	0.23	5.2 K
Freon (CCl ₂ F ₂)	1.078	9.98x10 ⁻⁵	4.12	385 K