Gasses
(CH-3)

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Non-HC Component effect on Z-factor

N_2, CO_2, and H_2S

HC

- Sour (1 gm of $H_2S/100\ ft^3$)
- Sweet

Both sour and sweet gases contain CO_2, N_2 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 correction method

Non-HC Component 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 H_2S
   - ε = pseudocritical temperature adjustment factor
     - $\varepsilon = 120 \times (A^{0.9} - A^{1.6}) + 15 \times (B^{0.5} - B^{4})$
     - A = sum of CO_2 and H_2S mole fraction

Non-HC Component on Z-factor

2. Carr-Kobayashi-Burrows correction method
   1. Used when composition is not available

   2. Calculate pseudocritical 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 pseudocritical 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% CO_2 and 10% H_2S.

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

Solution:

$T_{pc} = 168 + 325(0.7) - 12.5(0.7)^2$ = 389.38 °R

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

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

$T_{pc}{}' = 389.38 - 20.735$ = 368.64 °R

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

Non-HC Component on Z-factor

Example:

A sour gas (sp. gr. 0.7) contains 5% CO_2 and 10% H_2S.

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

Solution cont.:

$P_{pr} = \frac{3500}{630.44}$ = 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 lb/ft^3

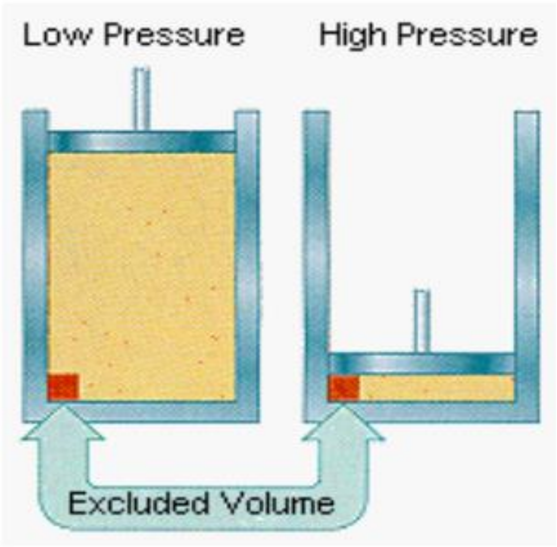
Van der Waals' equation

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:

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

Gas	a (atm liters2)	b (liters)
CH_4	2.253	0.04278
C_2H_6	5.489	0.0638
C_2H_4	4.471	0.05714
C_2H_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
	$(J \cdot m^3/mole^2)$	$(m^3/mole)$	(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_2O)	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_2F_2)	1.078	$9.98x10^{-5}$	4.12	385 K