In-Class Exercise: Application of the Ideal Gas Law to Natural Gas Extraction

Volumes of natural gas in formation are measured in cubic feet or millions of cubic feet (Mcf). The volume of gas extracted from the reservoir is dependent upon temperature and pressure at depth, according to the Idea Gas Law:

$$PV = nRT$$

where *P* is the pressure of the gas, *V* is the volume of the gas, *n* is the amount of substance of gas (measured in moles), *R* is the ideal, or universal, gas constant, and *T* is the temperature of the gas.

P = pressure in atm
V = Volume in liters
n = mass in moles
T = temperature in degree Kelvin
R = 0.0821 liter-atm/°K-mole

When natural gas is extracted from the reservoir at depths of thousands of feet, and delivered to the surface of the Earth, the temperature and pressure changes will result in volume change during the process. Volume-temperature-pressure are important as they will dictate how much the natural gas sells per cubic foot on the market. Let's explore the effects of these relationships in a hypothetical scenario described below:

Our goal is to extract 10 moles of methane (CH_4) from a gas well located in a reservoir at a depth of 7000 ft below the surface. The following information is available related to the conditions:

Drill Hole Depth = 7000 ft
Mass = 10 moles of methane
Surface Pressure = 1 bar
Surface Temperature = 25 °C
Bottom Hole Temperature = 125 °C
Bottom Hole Pressure = 2700 psi

Task 1. Using the periodic chart, determine the mass of 10 moles of CH_4 in grams.

160.43g

Task 2. Calculate the volume of methane occupied by 10 moles at the bottom of the hole, vs. the volume of methane occupied by the same 10 moles at the top of the hole (surface).

Vol @ Bottom = 1.78L
vol @ top = 247.13L

Task 3. Determine the percent change in volume from subsurface to surface. SHOW ALL OF YOUR MATH WORK AND UNIT ALGEBRA.

13,783.71% change

Conversion factors and constants that may be helpful:

R = 0.0821 liter-atm/°K-mole
°K = 273 + °C
1 atm = 1013 mb
1 bar = 1000 mb
1 bar = 100,000 Pa = 14.5 lb/in^2

$$(PV = nRT)$$

- Well info: Temp – (Surface) 25°C + 273 = 298 K
  – (Bottom) 125°C + 273 = 398 K

  Pressure – (Surface) $1\text{ bar} \times \frac{1000\text{ mb}}{1\text{ bar}} \times \frac{1\text{ atm}}{1013\text{ mb}} = 0.99\text{ atm}$

  (Bottom) $\frac{2700\text{ psi}}{} \times \frac{1\text{ bar}}{14.5\text{ psi}} \times \frac{1000\text{ mb}}{1\text{ bar}} \times \frac{1\text{ atm}}{1013\text{ mb}} = 183.82\text{ atm}$

#1 Mass = 10 moles CH_4 = 16.043g × 10 mole = (160.43g/mole)
C = 12.011g, H = 1.008g × 4 = 4.032g

#2 Vol at Bottom – $\frac{PV}{P} = \frac{nRT}{P}$ $\left(V = \frac{nRT}{P}\right)$

$$V = \frac{(10\text{ moles})\left(\frac{0.0821\text{ L-atm}}{\text{K-moles}}\right)(398\text{ K})}{183.82\text{ atm}} = 1.78\text{ L}$$

Vol at Surface –

$$V = \frac{(10\text{ moles})\left(\frac{0.0821\text{ L-atm}}{\text{K-moles}}\right)(298\text{ K})}{0.99\text{ atm}} = 247.13\text{ L}$$

#3 Vol @ Bottom = 1.78L
Vol @ Surface = 247.13L

$\left(\frac{V2 - V1}{V_1} \times 100\% = \text{Change in }\%\right)$

$$\frac{247.13\text{ L} - 1.78\text{ L}}{1.78\text{ L}} \times 100\% = (13{,}783.71\%\text{ Change})$$