Environmental Engineering Systems

Sample Problem: Ideal Gas Calculation

Problem:

Calculate the volume of 44 g of carbon dioxide (CO_2) at 27 °C and 2.96 atm.

Solution:

Start with ideal gas law:

$$P\,V = n\,R\,T$$

(Ideal gas law should be an equation that you know completely! It applies to GASES not liquids or solids. It is your path to a gas density - mass or molar density (n/V = RT/P. Ideality is valid for high T and low P. Ambient T and P easily satisfy these criteria. I would STRONGLY discourage you from using or remembering the "22.4 L per mol" style information as it is rare that one also remembers what T and P this is valid at thus it introduces unnecessary risk.)

Rearrange to isolate volume.

$$V = \frac{n\,R\,T}{P}$$

First determine the number of moles of carbon dioxide.

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

$$n = \frac{44\ g_{CO2}}{44\ \frac{g_{CO2}}{mol_{CO2}}} = 1.0\ mol_{CO2}$$

Enter the value of each parameter into the equation complete with its units.

$$V = \left(\frac{1.0\ mol_{CO2} * 8.314\ Pa\ m^3/(mol\ K) * (273.15 + 27)K}{2.96\ atm * 101325\ Pa/atm}\right)$$

(There are lots of different "R values" depending on the units. I find it easier to just remember one R with its units. I find 8.314 Pa m^3/(mol K) the best to remember as it is SI. It also works in energy terms too as a Pa.m^3 is also a Joule leading to 8.314 J/(mol K). Some individuals use a value of R in mass units rather than molar units. This requires a different value for R for each compound. These different R-values in mass units are just different due to the different molar mass values for each compound. It is just easier to work with R in molar units and use molar mass for the role of converting between mass and moles.)

Calculate and reconcile units.

$$V = 0.00832\ m^3_{CO2}$$

Judgment check – ambient air has a density of about 1.2 kg/m^3. We have about 1/30^{th} of 1.2 kg and 3 times the pressure; thus we should expect about 1/90^{th} of 1.0 m^3. This provides or confirms the calculated value is approximately correct.

Therefore, the volume of 44 g of carbon dioxide at 27 °C and 2.96 atm is 0.0083 m^3 assuming ideal gas behaviour prevails.