Applications of the Ideal Gas Law

There are three common applications of the ideal gas law that are

- Calculation of Molar Volume
- Calculation of Density
- Calculation of Molar Mass (weight of one mole)

Calculation of Molar Volume

If you examine the ideal gas law, PV = nRT, it is evident that the volume of the gas depends the number of moles of gas at a particular pressure and temperature. If the pressure and temperature are standard pressure and temperature, one mole of gas has the volume of 22.4 L. This is known as the molar volume. This definition is useful in comparing the volumes occupied by gases at STP.

Example

Assuming the ideal behavior, arrange the following gases in order of increasing volume at STP.

(a) 10 g of H_2 (b) 10 g O_2 (c) 10 g of N_2 (d) 10 g of CO_2 (e) 10 g of SO_2

Answer

Find the number of moles of each gas.

mol H_2 = 10 g/ 2.0 g/ mol = 5 mol H_2
mol O_2 = 10 g / 16.0 g/mol = 0.625 mol O_2
mol N_2 = 10 g / 28.0 g/mol = 0.357 mol N_2
mol CO_2 = 10 g / 44 g/mol = 0.227 mol CO_2
mol SO_2 = 10 g/ 64.0 g/mol = 0.156 mol SO_2

Since the volume is directly proportional to number moles of gas, arrange these gases from smaller number of moles to greater number of moles.

$SO_2 < CO_2 < N_2 < O_2 < H_2$

$\longrightarrow$

volume increases

Molar Mass

The most useful application of the ideal gas law is to determine the molar mass (mass of one mole of gas) of an unknown gas in combination with mass measurements. Consider the following example.

Example

A sample of gas with a mass of 0.450 g occupies the volume of 345 ml at 65^0 C and at the pressure of 776 mm Hg. What is the molar mass of the gas?

Answer

There are two steps involved in the calculation.

Step 1: calculate n (number of moles) using the ideal gas law.

$$n = \frac{PV}{RT}$$

Step 2: calculate the molar mass using the following definition.

molar mass = mass (g) / moles (n)

First convert the volume to liters,

V = 345 ml /1000 ml/L = 0.345 L

Next convert Celsius temperature to Kelvin,

T = 65 + 273.15 = 338.15 K

Next convert pressure from mm Hg to atm,

P = 776 mm Hg / 760 mm Hg/atm = 1.02 atm

Substitute these values in the equation, n = PV/RT, to determine the number of moles (n). Hence,

$$n = \frac{PV}{RT} = \frac{(1.02\,\text{atm})(0.345\,\text{L})}{(0.082\,\frac{\text{L x atm}}{\text{mol x K}})(338.15\,\text{K})} = 1.269\text{x}10^{-2}\,\text{mol}$$

Now divide the mass by this number of moles to get the molar mass. Thus

$$\text{molar mass} = \frac{0.450\,\text{g}}{1.269\text{x}10^{-2}\,\text{mol}} = 35.46\,\frac{\text{g}}{\text{mol}}$$

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Hands on Practice to Calculate Molar Mass