5.4 - The Ideal Gas Equation

In the mole theory and stoichiometry unit we briefly, and unknowingly, talked about the third simple gas law.

In that unit, we found that any gas at a given temperature and pressure will have the same number of atoms or molecules within a given volume (no matter what the gas is).

For example, 5 L of O_2 and 5 L of Br_2 at the same temperature and pressure contain the same number of molecules.

In 1811, Amedeo Avagadro proposed a law that used this observation.

Avagadro's law states that if the temperature and pressure of a gas is fixed, the volume of a gas is directly proportional to the amount of gas.

Ex) Describe what happens to the amount of gas if the volume is cut in half.

Now, with all of the other simple gas laws we broke the proportionality statement into a mathematical equation involving a constant:

The use of this equation comes in stoichiometry when we converted a number of moles of gas to a volume. We usually used the mole reference guide.

Recall that at STP our constant would be 22.4 L/mol and at SATP our constant is 24.8 L/mol.

Because we have done this extensively in the past we will skip the calculations.

The Ideal Gas Law

Each of the three simple gas laws describes the effect on the gas volume when changes happen in one variable while two others are kept constant:

Boyle's Law - describes the effect of pressure: $V \alpha \frac{1}{P}$
Charles's Law - describes the effect of temperature: $V \alpha T$
Avagadro's Law - describe the effect of the amount of gas: $V \alpha n$

The combination of the three gas laws shows the combination of the relationships between pressure and the other variables:

Each of these laws involved a constant (either a, b, or k). If we combine all of these constants into one we get the ideal gas equation:

We will put the ideal gas equation into the more mathematically friendly version below:

We have one problem. The ideal gas equation works for any situation when you are dealing with a gas… but we do not know what our constant is equal to.

Ex) Calculate the gas constant if you have 1.00 mol of a gas at STP.

One problem is that sometimes we are given a question involving atmospheres. If we are, then our constant changes a bit. We can use the constant to be :

Ex) What is the volume occupied by 13.7 g of Cl_2 at 45.0°C and 105 kPa?

Ex) What is the temperature, in degrees Celsius, of a 1.00×10^{20} molecules of N_2 in a 305 mL flask if the pressure exerted is 0.0200 atm?