The Ideal Gas Law

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Recall: Characteristics of Gases

- Gases do not have a fixed volume nor a fixed shape.
- Gases are described in terms of four macroscopic observables:
  - Pressure
  - Temperature
  - Volume
  - Moles of gas

Recall: Characteristics of Gases

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- The early gas laws described these macroscopic observables or characteristics relative to each other, but none of them put all of the “observables” together in one equation.
  - Boyle’s law related the pressure and volume of a gas at fixed T and n.
  - Charles’s law related the temperature and volume of a gas at a fixed P and n.
  - Avogadro’s law says one mole of any gas at STP (0°C and 1 atm) will take up a volume of 22.4 L.

*Ideal-Gas Law

So, let's continue developing the reasoning for the Ideal Gas Law! ☺

Boyle's Law says the pressure of a gas is *inversely* related to its volume.

($V \propto 1/P$)

Charles's Law determined that the temperature of a gas and its volume or directly proportional.

($V \propto T$)

Avogadro's Law demonstrated that the volume of a gas is directly proportional to the number of moles of the gas. ($V \propto n$)

*Ideal-Gas Law

Combining all three laws, we get

$$V \propto \frac{nT}{P}$$

But, we need a "*proportionality constant*" to be able to use our relationship for calculating V, n, P, or T!

*Ideal-Gas Law

The gas constant, R, represents this proportionality.

$$\mathbf{R = 0.08206\ \frac{L\ atm}{mol\ K}}$$

**For the gas laws, we will only use this one.

Be sure to convert V, T, and P into these units!**

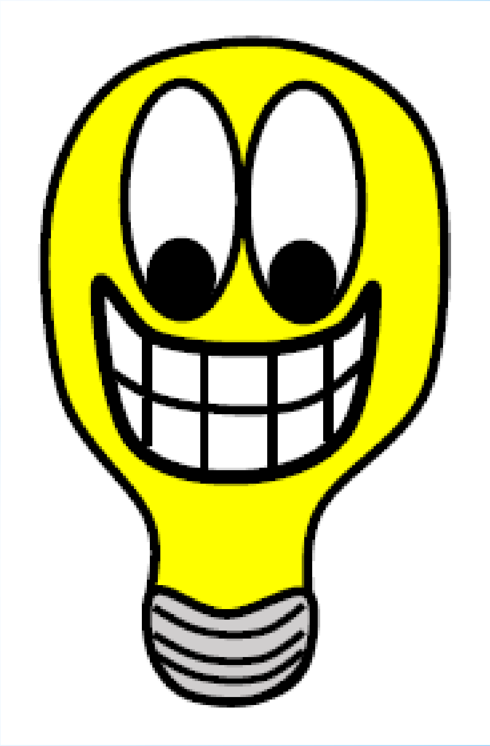
*Ideal-Gas Law

- Using R, we now have

$$V = R\frac{nT}{P}$$ Or………………

PV = nRT

Aka "PiV-NeRT"



NOTE: You do not need to be able to derive the IG equation.

*Example: The Ideal-Gas Law

When solid calcium carbonate ($CaCO_3$is heated, it decomposes into solid calcium oxide (CaO) and carbon dioxide gas (CO_2) according to the reaction given below. A small sample of $CaCO_3$ is heated, and the carbon dioxide that evolves is collected in a 125-mL flask. The gas collected in the flask has a pressure of 1.95 atm at a temperature of 45 °C. How many moles of CO_2 gas were produced?

$$\mathbf{CaCO_3(s) \rightarrow CaO\ (s)\ + CO_2(g)}$$

* Example: The Ideal-Gas Law (Solution)

When solid calcium carbonate ($CaCO_3$is heated, it decomposes into solid calcium oxide (CaO) and carbon dioxide gas (CO_2). A small sample of $CaCO_3$ is heated, and the carbon dioxide that evolves is collected in a **125-mL** flask. The gas collected in the flask has a pressure of **1.95 atm** at a temperature of **45 °C**. How many moles of CO_2 gas were produced?

First, let's look at what we are given in the problem: V = 125 mL, P = 1.95 atm, T = 45 °C

What are we looking for? The moles (n) of gas.

We need an equation that relates P, V, n, and T.

Use the Ideal Gas Law for this problem!

* Example: The Ideal-Gas Law (Solution)

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Let's convert all of our "givens" into the correct units for the Ideal Gas Law:

T needs to be in K: 45 + 273 = 318 K

V needs to be in L: $125\,mL\left(\frac{1\,L}{1000\,mL}\right) = 0.125\,L$

P should be in atm (and it already is).

* Example: The Ideal-Gas Law (Solution)

Calcium carbonate, $CaCO_3(s)$, the principal compound in limestone, decomposes upon heating to $CaO(s)$ and $CO_2(g)$. A sample of $CaCO_3$ is decomposed, and the carbon dioxide is collected in a 250-mL flask. After decomposition is complete, the gas has a pressure of 1.3 atm at a temperature of 31 °C. How many moles of CO_2 gas were generated?

Use PV = nRT

Rearrange the equation to solve for moles (n) of gas. Then plug everything into the equation.

$$\mathbf{PV = nRT}$$

$$\mathbf{n = \frac{PV}{RT} = \frac{(1.95\ atm)(0.125\ L)}{\left(0.08206\,\frac{L\ atm}{mol\ K}\right)(318\ K)}}$$

Example: The Ideal-Gas Law (Solution)

Calcium carbonate, $CaCO_3(s)$, the principal compound in limestone, decomposes upon heating to $CaO(s)$ and $CO_2(g)$. A sample of $CaCO_3$ is decomposed, and the carbon dioxide is collected in a 250-mL flask. After decomposition is complete, the gas has a pressure of 1.3 atm at a temperature of 31 °C. How many moles of CO_2 gas were generated?

Cancel the units to make sure that we get moles, then calculate.

$$\mathbf{PV = nRT}$$

$$\mathbf{n = \frac{PV}{RT} = \frac{(1.95\ \cancel{atm})(0.125\ \cancel{L})}{\left(0.08206\frac{\cancel{L}\ \cancel{atm}}{mol\ \cancel{K}}\right)(318\ \cancel{K})} = 0.0093\ moles\ CO_2\ gas}$$