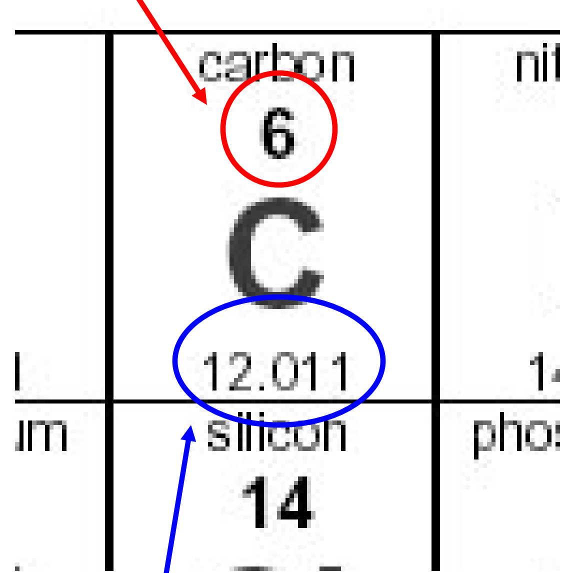
Gas Laws

AP Physics B

The Periodic Table

Atomic # - # of protons OR electrons

All of the elements on the periodic table are referred to in terms of their atomic mass. The symbol ***u*** is denoted as an atomic mass unit.

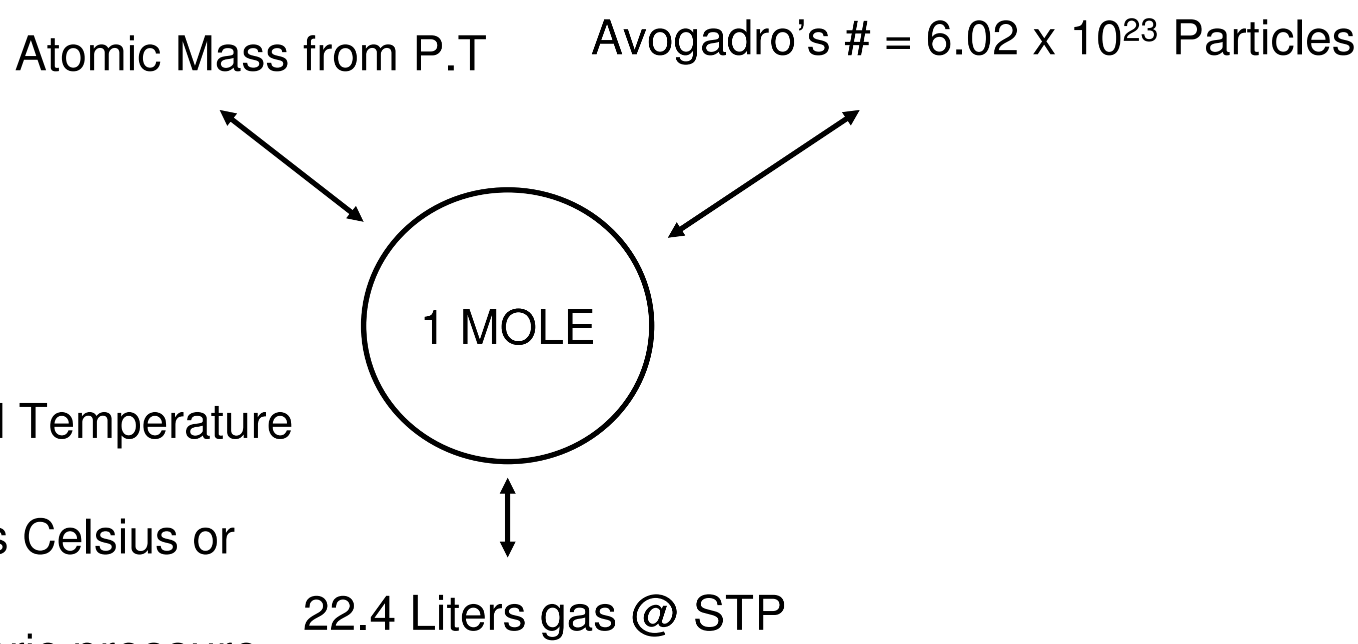


1 amu = 1.66×10^{-27} kg

Atomic Mass - # of protons + Neutrons

The Mole

The word “mole” is derived from Latin to mean “heap” or “pile”. It is basically a chemical counting unit. Below, what we have is called the Mole Road Map and it summarizes what a mole equals.



STP = Standard Temperature and Pressure

- ST = 0 degrees Celsius or 273 Kelvin
- SP = atmospheric pressure

Example

A flexible container of Oxygen(O_2) has a volume of 10.0 m^3 at STP. Find the # moles and molecules that exist in the container

$$10m^3\left(\frac{1L}{1x10^{-3}m^3}\right)\left(\frac{1mole}{22.4L}\right)$$

446.43 moles

$$446.43moles\left(\frac{6.02x10^{23}\ particles}{1mole}\right) =$$

$2.68x10^{26}$ particles

Factors that effect a GAS

1. The **quantity** of a gas, ***n***, in moles
2. The **temperature** of a gas, ***T***, in Kelvin (Celsius degrees + 273)
3. The **pressure** of a gas, ***P***, in pascals
4. The **volume** of a gas, ***V***, in cubic meters

Gas Law #1 – Boyles' Law (complete TREE MAP)

"The pressure of a gas is inverse related to the volume"

- *Moles and Temperature are constant*

$$P \alpha \frac{1}{V} \rightarrow P = \frac{k}{V}$$

$$k = \text{constant of proportionality}$$

$$P_o V_o = k$$

$$PV = k$$

$$\boxed{P_o V_o = PV}$$

Gas Law #2 – Charles' Law

"The volume of a gas is directly related to the temperature"

- *Pressure and Moles are constant*

$$V_o \alpha T_o \rightarrow V_o = kT_o$$

$$k = \frac{V_o}{T_o}$$

$$k = \frac{V}{T}$$

$$\boxed{\frac{V_o}{T_o} = \frac{V}{T}}$$

Gas Law #3 – Gay-Lussac's Law

"The pressure of a gas is directly related to the temperature"

- *Moles and Volume are constant*

$$P_o \alpha T_o \rightarrow P_o = kT_o$$

$$k = \frac{P_o}{T_o}$$

$$k = \frac{P}{T}$$

$$\boxed{\frac{P_o}{T_o} = \frac{P}{T}}$$

Gas Law #4 – Avogadro's Law

"The volume of a gas is directly related to the # of moles of a gas"

- *Pressure and Temperature are constant*

$$V_o \alpha\, n_o \rightarrow V_o = k n_o$$

$$k = \frac{V_o}{n_o}$$

$$k = \frac{V}{n}$$

$$\boxed{\frac{V_o}{n_o} = \frac{V}{n}}$$

Gas Law #5 – The Combined Gas Law

You basically take Boyle's Charles' and Gay-Lussac's Law and combine them together.

- *Moles are constant*

$$P_oV_o \alpha T_o \rightarrow P_oV_o = kT_o$$

$$k = \frac{P_oV_o}{T_o}$$

$$k = \frac{PV}{T}$$

$$\boxed{\frac{P_oV_o}{T_o} = \frac{PV}{T}}$$

Example

Pure helium gas is admitted into a leak proof cylinder containing a movable piston. The initial volume, pressure, and temperature of the gas are 15 L, 2.0 atm, and 300 K. If the volume is decreased to 12 L and the pressure increased to 3.5 atm, find the final temperature of the gas.

$$\frac{P_o V_o}{T_o} = \frac{PV}{T} \rightarrow T = \frac{T_o PV}{P_o V_o}$$

$$T = \frac{(12)(3.5)(300)}{(15)(2)} =$$ 420 K

Gas Law #6 – The IDEAL Gas Law

All factors contribute! In the previous examples, the constant, k, represented a specific factor(s) that were constant. That is NOT the case here, so we need a NEW constant. This is called, R, the universal gas constant.

$$PV \; \alpha \; nT$$

$$R = \text{constant of proportionality}$$

$$\text{R} = \text{Universal Gas Constant} = 8.31 \frac{\text{J}}{\text{mol} \bullet \text{K}}$$

$$PV = nRT$$

Example

A helium party balloon, assumed to be a perfect sphere, has a radius of 18.0 cm. At room temperature, (20 C), its internal pressure is 1.05 atm. Find the number of moles of helium in the balloon and the mass of helium needed to inflate the balloon to these values.

$$V_{sphere} = \frac{4}{3}\pi r^3 \rightarrow \frac{4}{3}\pi(0.18)^3 =$$ **0.0244 m^3**

$$T = 20 + 273 =$$ **293 K**

$$P = 1.05 atm =$$ **1.05x10^5 Pa**

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

$$n = \frac{(1.05x10^5)(0.0244)}{(8.31)(293)} =$$ **1.052 moles**