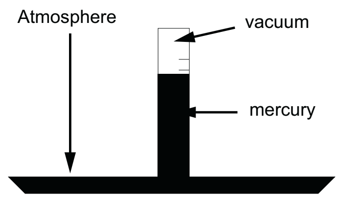
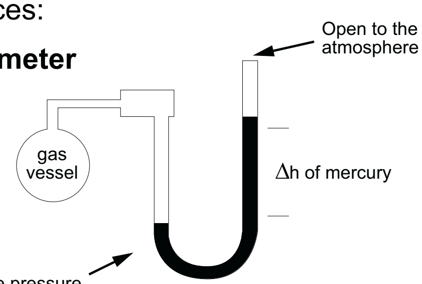
Gases and Stoichiometry: Ideal Gas Law: Student Review Notes

Pressure: Gas pressure is the force per unit area that the gas exerts on a surface. Atmospheric pressure is the weight of the atmosphere, which is about 10 miles high. You should understand two simple pressure measuring devices:

Barometer
The atmosphere pushes down on the Hg in the bowl and forces it up into the evacuated tube.



Manometer



This is where the pressure units mmHg come from

$P_{gas} = P_{atm} + \Delta h$ of Hg

Units for pressure are mildly annoying. You have to be good at converting because ideal gas law problems demand unit consistency. Also remember to always use absolute temperature.

Pressure units:	1 atm	1.013×10^5 Pa	760 mm Hg	760 Torr
		1 atm	1.013×10^5 Pa	760 mm Hg

Standard Temperature and Pressure, STP is defined as 273.15 K and 1 atm.
At STP 1 mole of an ideal gas has a volume of 22.4 liters.

Ideal Gas Law: You can relate Pressure (P), Volume (V), Temperature (T), and moles (n) under the following assumptions that define "Ideal" behavior:

1. **Molecules of an ideal gas don't interact with each other.**
2. **Molecules of an ideal gas have no volume.**

$$PV=nRT$$

*Always use absolute temperature
*Always choose R to be consistent with P, V, T.

$$R \text{ gas constant} = .0821\frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}} = 2.05\frac{\text{cm}^3\cdot\text{atm}}{\text{mol}\cdot\text{K}} = 8.31\times10^3\frac{\text{Pa}\cdot\text{L}}{\text{mol}\cdot\text{K}} = 8.31\frac{\text{J}}{\text{mol}\cdot\text{K}}$$

There are other forms of the ideal gas law.

$$\text{moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{m}{MM} = n \quad \text{and} \quad \text{density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V} = d$$

$$\text{So,} \quad PV = nRT = \frac{m}{MM}RT \quad \text{and} \quad P = \frac{m}{v}\cdot\frac{RT}{MM} = d\,\frac{RT}{MM}$$

You can get the molar mass of a gas given P, d and T

The ideal gas law is one big algebra problem with a bunch of potential unknowns (P, V, T, n, d, MM, m), but it's only one equation. You've either got to be given all the variables except one (single-state problems) or you'll be given information about two states that allows you to generate one equation with one unknown.

For two-state problems, group the changing variables on one side of the ideal gas law and the constant terms on the other side. Then just set:

$$(\text{Things that aren't constant})_{\text{State 1}} = (\text{Things that aren't constant})_{\text{State 2}}$$

All of the specifically named gas laws, Boyle's, Charle's, Avagadro's, etc, fall out of a two-state ideal gas law problem when specific variables are held constant. Take a look on the next page.

Gases and Stoichiometry: Ideal Gas Law: Student Review Notes

Boyle's Law: Two-state ideal gas law problem at constant Temperature and moles of gas

$$(PV)_1 = \underbrace{nRT}_{\text{constant}} = (PV)_2$$

Charles's Law: Two-state ideal gas law problem at constant Pressure and moles of gas

$$\left(\frac{V}{T}\right)_1 = \underbrace{\frac{nR}{P}}_{\text{constant}} = \left(\frac{V}{T}\right)_2$$

Avagadro's Law: Two-state ideal gas law problem at constant Temperature and Pressure

$$\left(\frac{V}{n}\right)_1 = \underbrace{\frac{RT}{P}}_{\text{constant}} = \left(\frac{V}{n}\right)_2$$

Combined Gas Las: Two-state ideal gas law problem at constant moles of gas

$$\left(\frac{PV}{T}\right)_1 = \underbrace{nR}_{\text{constant}} = \left(\frac{PV}{T}\right)_2$$

Gases in Chemical Reactions

In any chemical reaction you're reacting moles of each species.

Look at the ideal gas law:

$$\mathbf{n = \frac{PV}{RT} = \left(\frac{P}{RT}\right) V}$$

Two things can happen:

1. If P and T are constant, you can react volumes like they are moles since n α V (α means proportional and this is Avagadro's Law).

2. Or, use the conditions of the problem and the ideal gas law to find the moles of the reactants, perform the reaction, get the moles of products formed, and then often use the ideal gas law to convert moles of products to volumes of products.

Dalton's Law of Partial Pressure & Gas Mixtures

For a mixture of ideal gases, the total pressure is just the sum of the individual pressure of each gas (the partial pressure of each gas). The partial pressure of each gase, P_A , in a mixture is just the mole fraction, X_A, of the gas times the total pressure, P_{tot}, of the mixture. So for example if you have a mixture of three gases, A, B, and C there are a bunch of ways of looking at the pressure of the system:

$$\mathbf{P_{TOT} = P_A + P_B + P_C = X_A P_{TOT} + X_B P_{TOT} + X_C P_{TOT}}$$

or

$$\mathbf{P_{TOT} = \frac{n_A RT}{V} + \frac{n_B RT}{V} + \frac{n_C RT}{V}}$$

* If you are given the vapor pressure of a pure liquid at a particular temperature that's the same as giving you the partial pressure of the vapor above the liquid. (Usually the liquid is H_2O)

Gases and Stoichiometry: Non-ideal Gases: Student Review Notes

What defines an "Ideal" Gas

1. **Molecules of an ideal gas don't interact with each other.**
2. **Molecules of an ideal gas have no volume.**

Real gases that behave ideally will have weak intermolecular forces, like the noble gases. State conditions that lead to ideal behavior would be low pressure (very few gas molecules, therefore their volume is negligible) and high temperature (the kinetic energy of the molecules is much greater than the associated intermolecular forces).

Gases that behave ideally	Gases that deviate from ideality
Noble Gases, Diatomics	Water, HF, etc. anything that hydrogen bonds
Non-polar molecules	Polar molecules
	Large molecules

Non-ideal Gases

The closer that a gas is to the liquid state, the more it will deviate from ideal behavior.

Low temperature and high pressure (gas volume is no longer negligible)

Strong intermolecular forces (intermolecular attraction is no longer negligible)

The **van der Waals equation** is an equation of state which may be used to account for deviations from ideality.

$$\underbrace{\left(P + a\frac{n^2}{V^2}\right)}_{\text{corrected pressure}}\underbrace{(V - nb)}_{\text{corrected volume}} = nRT$$

Take a look, if the van der Waals constants a and b are zero, the equation reduces to the ideal gas law.
The **van der Waals constant a** accounts for deviations caused by the attractive forces between particles.
The **van der Waals constant b** accounts for deviations caused by particle volume.

Know how to solve the van der Waals equation for pressure:

$$P = \frac{nRT}{V - nb} - a\frac{n^2}{V^2}$$

Here are some van der Waals constants for some typical gases

Gas	a $(L^2atm)/(mol^2)$	b (L/mol)
H_2	0.244	0.027
O_2	1.360	0.032
N_2	1.390	0.039
CH_4	2.253	0.043
CO_2	3.592	0.043
SO_2	6.714	0.056
Cl_2	6.493	0.056
H_2O	5.464	0.030