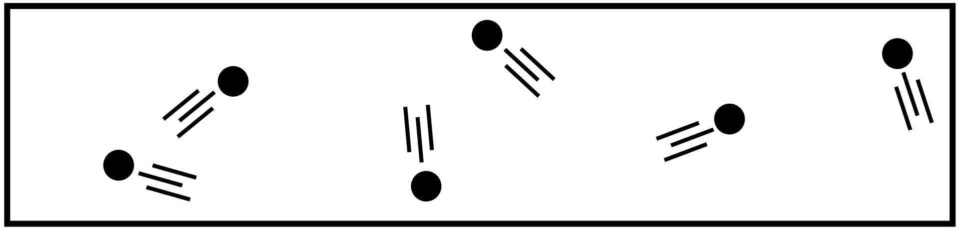
Outline

- Properties of Gases
- Gas Pressure
- Gas Laws
- Gas Mixtures
- Real Gases

Properties of Gases

Particles (atoms / molecules) of a gas move in a random, independent manner…



Gases…

expand indefinitely and uniformly to fill a space...

…have indefinite shape and volume

can be highly compressed…

…have low density

Kinetic-molecular theory explains behavior and properties of gases…

1. gases composed of tiny particles

2. distance between particles extremely large

3. particles in constant motion, with constant collisions

4. particles do not lose energy in collisions

5. particles are not attracted to one another

6. energy of the particles proportional to temperature (K)

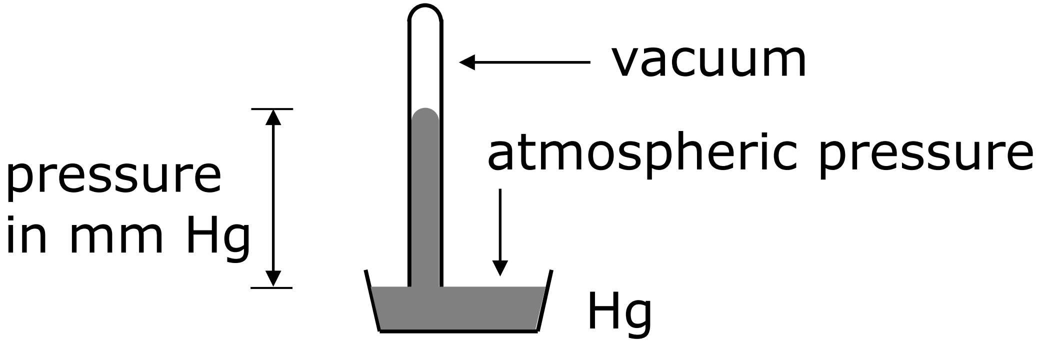
Gases that conform to these assumptions are ideal gases

Gas Pressure

Pressure is force applied per unit area…

Gas pressure results from collisions of particles with walls of a container

Atmospheric pressure is measured with a <u>barometer</u>



Pressure of atmosphere can support a 760 mm column of Hg

Pressure of atmosphere can support a column of water 34 ft high!

Pressure measured in different units…

mm Hg	
atmospheres	(1 atm = 760 mm Hg)
torr	(1 atm = 760 torr)
lbs per in^2	(1 atm = 14.68 psi)
pascal	(1 atm = 101325 Pa)

How many atm in 225 mm Hg?

$$225\,\text{mm Hg} \times \frac{1\,\text{atm}}{760\,\text{mm Hg}} = \underline{0.296\,\text{atm}}$$

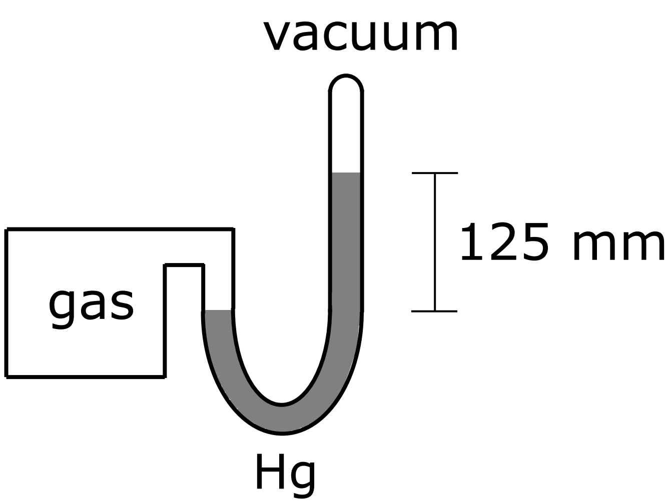
How many kPa?

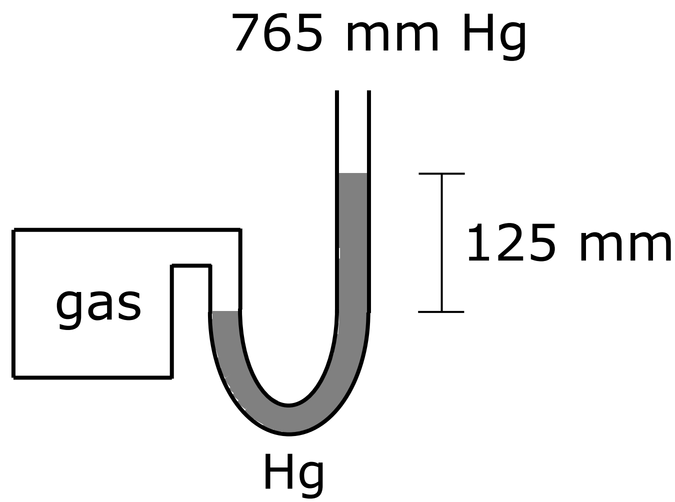
$$0.296\,\text{atm} \times \frac{101325\,\text{Pa}}{1\,\text{atm}} \times \frac{1\,\text{kPa}}{1000\,\text{Pa}} = \underline{30.0\,\text{kPa}}$$

How many psi?

$$0.296\,\text{atm} \times \frac{14.68\,\text{psi}}{1\,\text{atm}} = \underline{4.35\,\text{psi}}$$

Gas pressure is measured with a manometer





P = 125 mm Hg

P = 890. mm Hg

Gas Laws

Boyle's Law

The volume of a gas is inversely proportional to its pressure... for constant temperature and amount

$$V \propto \frac{1}{P} \quad \Rightarrow \quad V = k \times \frac{1}{P} \quad \Rightarrow \quad PV = k$$

If P is...	Then V is...
doubled	halved
halved	doubled
quadrupled	quartered

Boyle's Law:

$$\Rightarrow \qquad P_1V_1 = P_2V_2$$

A sample of gas has V = 125 mL at 1.5 atm. What's V at 2.9 atm?

$$P_1V_1 = P_2V_2 \qquad \Rightarrow \qquad V_2 = \frac{P_1V_1}{P_2} = \frac{(1.5\ \text{atm})(125\ \text{mL})}{(2.9\ \text{atm})} = \underline{65\ \text{mL}}$$

A sample of gas has V = 5.71 L at 56 torr. What's P if V = 1.35 L?

$$P_1V_1 = P_2V_2 \qquad \Rightarrow \qquad P_2 = \frac{P_1V_1}{V_2} = \frac{(56\ \text{torr})(5.71\ \text{L})}{(1.35\ \text{L})} = \underline{240\ \text{torr}}$$

Charles' Law

The volume of a gas is directly proportional to its temperature (in K)… for constant pressure and amount

$$V \propto T \quad \Rightarrow \quad V = k \text{ x } T \quad \Rightarrow \quad \frac{V}{T} = k$$

If T is…	Then V is…
doubled	doubled
halved	halved
quadrupled	quadrupled

Charles' Law:

$$\Rightarrow \qquad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

A sample of gas has V = 36 mL at 274 K. What's V at 371 K?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad \Rightarrow \qquad V_2 = \frac{T_2 V_1}{T_1} = \frac{(371\,\text{K})(36\,\text{mL})}{(274\,\text{K})} = \underline{49\,\text{mL}}$$

A sample of gas has V = 2.89 L at 358 K. What's T if V = 5.68 L?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad \Rightarrow \qquad T_2 = \frac{V_2 T_1}{V_1} = \frac{(5.68\,\text{L})(358\,\text{K})}{(2.89\,\text{L})} = \underline{704\,\text{K}}$$

Pressure results from collisions between particles and walls of container…

Pressure increases with increasing collision frequency…

1. Boyle's Law:

   decrease volume → increased collisions → pressure increase

2. Charles' Law:

   increase temp → increase speed (collisions) → volume increase

More Gas Laws…

"Char-Boyled" Law:

Combination of Charles' Law and Boyle's Law

$$V \propto \frac{T}{P} \quad \Rightarrow \quad V = k \text{ x } \frac{T}{P} \quad \Rightarrow \quad \frac{VP}{T} = k \quad \Rightarrow \quad \frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$$

A sample of gas has V = 1.23 L and P = 755 torr at 0.0 ^{o}C. What is V if P = 735 torr at 50.0 ^{o}C.

$$T_1 = 0.0 + 273.15 = 273.\underline{1}5\text{ K} \qquad T_2 = 50.0 + 273.15 = 323.\underline{1}5\text{ K}$$

$$\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2} \quad \Rightarrow \quad V_2 = \frac{V_1P_1T_2}{P_2T_1}$$

$$V_2 = \frac{(1.23\text{ L})(755\text{ torr})(323.\underline{1}5\text{ K})}{(735\text{ torr})(273.\underline{1}5\text{ K})} = \underline{1.49\text{ L}}$$

Gas volumes can be compared if at same temperature and pressure

Standard temperature and pressure (STP) is 0 ^{o}C (273.15 K) and 1 atm

A sample of gas at STP has V = 2.50 L. What is T if P = 0.25 atm and V = 5.00 L.

$$\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2} \quad \Rightarrow \quad T_2 = \frac{V_2P_2T_1}{V_1P_1}$$

$$T_2 = \frac{(5.00\,\text{L})(0.25\,\text{atm})(273.15\,\text{K})}{(2.50\,\text{L})(1\,\text{atm})} = \underline{140\,\text{K}}$$

Avogadro's Law

For same temperature and pressure, equal volumes of gas contain equal numbers of particles

The volume of a gas is directly proportional to the mole amount… for constant temperature and pressure

$$V \propto n \quad \Rightarrow \quad V = k \text{ x } n \quad \Rightarrow \quad \frac{V}{n} = k$$

If n is…	Then V is…
doubled	doubled
quartered	quartered

Volume of 1 mol of gas at STP is 22.41 L (standard molar volume)

molar volume provides relationship between density and molar mass

What's molar mass of a gas with density of 1.2 g/L at STP?

$$\frac{1.2\ \text{g}}{\text{L}} \times \frac{22.41\ \text{L}}{1\ \text{mol}} = 2\underline{6}.8\ \text{g/mol} = \underline{27\ \text{g/mol}}$$

What's density of a gas with molar mass of 121 g/mol?

$$\frac{121\ \text{g}}{1\ \text{mol}} \times \frac{1\ \text{mol}}{22.41\ \text{L}} = 5.3\underline{9}9\ \text{g/L} = \underline{5.40\ \text{g/L}}$$

Ideal Gas Law is the combination of all gas laws…

Boyle's… $V = k \text{ x } \frac{1}{P}$

Charles'… $V = k \text{ x } T$

Avogadro's… $V = k \text{ x } n$

Combined… $V = k \text{ x } \frac{nT}{P}$ or $\underline{PV = nRT}$

R is the universal gas constant…

$$R = \frac{PV}{nT} = \left(\frac{P}{T}\right)\left(\frac{V}{n}\right) = \left(\frac{1\text{ atm}}{273.15\text{ K}}\right)\left(\frac{22.414\text{ L}}{1\text{ mol}}\right) = \underline{0.08206\text{ L atm / mol K}}$$

What's the volume of 1.52 mol of CO at 0.992 atm and 65 ^{o}C?

$$T = 65 + 273.15 = 33\underline{8}.1\ \mathrm{K}$$

$$V = \frac{nRT}{P} = \frac{(1.52\ \mathrm{mol})(0.08206\ \mathrm{L\ atm\ /\ mol\ K})(33\underline{8}.1\ \mathrm{K})}{0.992\ \mathrm{atm}} = \underline{42.5\ \mathrm{L}}$$

What's the temperature of 67.4 g of N_2O at 5.00 atm in a 7.00-L container?

$$67.4\ \mathrm{g\ N_2O} \times \frac{1\ \mathrm{mol}}{44.02\ \mathrm{g}} = 1.5\underline{3}1\ \mathrm{mol\ N_2O}$$

$$T = \frac{PV}{nR} = \frac{(5.00\ \mathrm{atm})(7.00\ \mathrm{L})}{(1.5\underline{3}1\ \mathrm{mol})(0.08206\ \mathrm{L\ atm\ /\ mol\ K})} = \underline{279\ \mathrm{K}} \qquad (\approx 6\ ^{o}\mathrm{C})$$

Gas Mixtures

Gas laws apply to mixtures of gases… that don't react with each other

Partial Pressure is the pressure exerted by a single gas in a mixture of gases

The total pressure of a gas mixture equals the sum of the partial pressures (Dalton's law)

$$P_{total} = P_a + P_b + P_c + \ldots$$

Real Gases

Real gases deviate from ideality because...

1. molecules take up space… reducing volume available to gas

2. molecules attract each other… reducing gas pressure

Real gases obey ideal gas law at low pressures and high temperatures

1. low pressures…

    large separation of particles lowers attractive forces

2. high temperatures…

    high speed overcomes attractive forces more easily