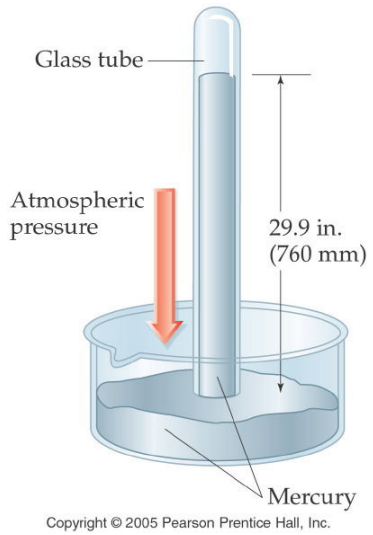
Properties of Gases

1. **Gases have an indefinite shape:** A gas takes on the shape of its container and fills it uniformly. If the shape of the container changes, so does the shape of the gas.
2. **Gases can expand:** A gas continuously expands and distributes itself throughout a sealed container. This means that the volume of gas increase when we enlarge the volume of the container.
3. **Gases can compress:** The volume of a gas in a sealed container decreases when we reduce the volume. If we reduce the volume sufficiently, the gas will eventually liquefy.
4. **Gases have low densities:** The density of air is about 0.001 g/mL. Air is about 1000 times less dense than water.
5. **Gases mix completely with other gases in the same container:** Air is a common example of a gaseous mixture.

Gas pressure is the result of constantly moving molecules striking the inside surface of their container. The pressure a gas exerts depends on how *often* and how *hard* these molecules strike the walls of the container.



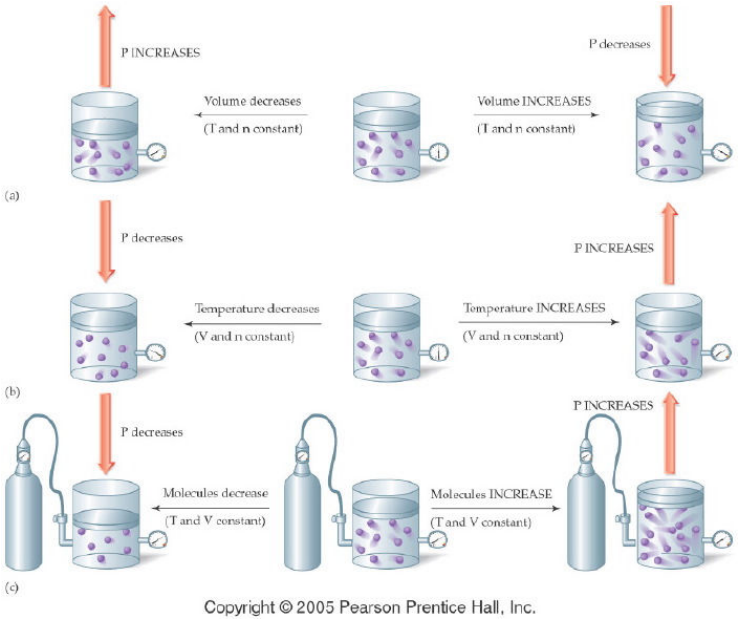
1 atm = 760 torr
760 mm Hg = 1 atm

$$P = \frac{\text{Force}}{\text{Area}}$$

Torricelli's Mercury Barometer

A sealed glass tube is filled with liquid mercury, inverted, and placed into a dish of mercury. (No bubbles)
The pressure of the atmosphere at sea level supports a column of Hg 760 mm high.

Variables Affecting Gas Pressure

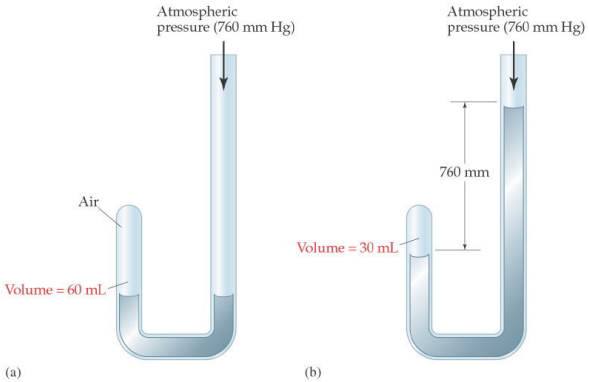


Boyle's Law

Investigated the quantitative relationship between pressure and volume of a fixed amount of gas at constant temperature.

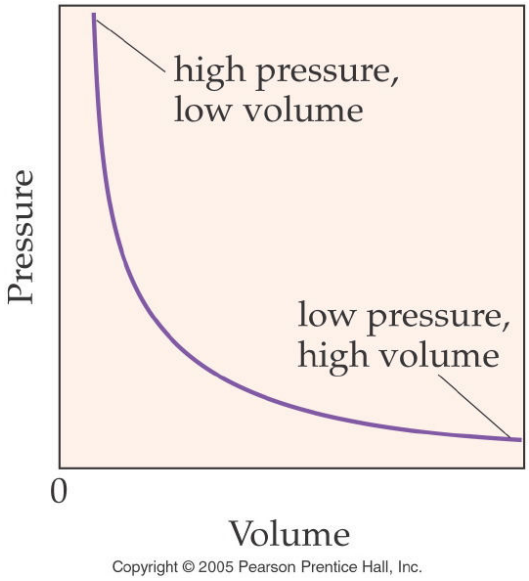
Pressure is *inversely* proportional to volume.

As P *increases*, V *decreases*



After adding Hg, the volume of gas is 30 mL (b).

The pressure doubled, 760 mmHg + 760 mmHg = 1520 mmHg.



$$V \propto \frac{1}{P}$$

"Volume is proportional to the reciprocal pressure"

$$P_1V_1 = P_2V_2$$

Example:

A sample of gas occupies 5.18 liters at 776 torr.
Find the volume of the gas if the pressure is changed to 827 torr.

Example:

A sample of gas occupies 2.25 L at 758 torr.
Find the final volume if the pressure is decreased to 698 torr.

Example:

A sample of gas occupies 3.91 L at 0.988 atm.
Find the volume of the gas if the pressure is changed to 901 torr.

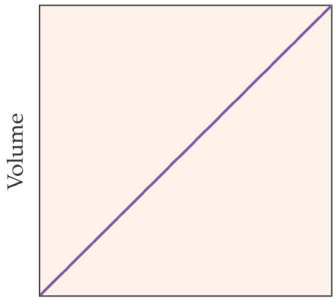
Charles's Law

The volume of a fixed quantity of gas at constant pressure is *directly* proportional to absolute temperature.

Temperature *must* be in kelvin!!!!!

$$V \propto T$$

"Volume is proportional to temperature"



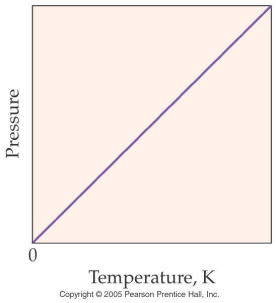
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Example: A gas with initial volume of 1.67 L, measured at 32°C, is heated to 55°C at constant pressure. What is the new volume of the gas.

Example: A gas initial temperature at 26 °C and volume of 2.25L is expanded to 3.16 L. What is the new temperature in K?

Gay-Lussac's Law

The pressure of a gas is *directly* proportional to the Kelvin temperature at constant volume.



Temperature *must* be in kelvin!!!!!

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Example:
A steel container filled with nitrous oxide at 15.0 atm is cooled from 25°C to -40°C. Calculate the final pressure (in atm).

Example:
A container filled with oxygen gas at 792 torr at 32°C is compressed to 689 torr. Calculate the new temperature (in K).

Combined Gas Law

Boyle's Law: $PV = a$ $\quad P_1V_1 = P_2V_2$

Charles's Law: $\frac{V}{T} = b$ $\quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$

Gay-Lussac's Law: $\frac{P}{T} = c$ $\quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$

Combined Gas Law: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

STP = standard temperature and pressure = 1 atm and 0°C

Example:

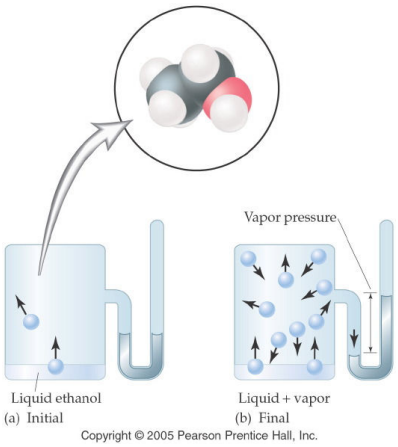
A nitrogen gas sample occupies 50.5 mL at -80°C and 1250 torr. What is the volume at STP?

Example:
If a sample of gas occupies 2.50 L at -25°C and 650 torr, what is the new pressure if it is compressed to 1.25 L and the temperature is increased to 3.2°C?

Example:
A sample of krypton gas has a volume of 500.0 mL at 225 torr and -125°C. Calculate the new temperature if the gas occupies 250.0 mL at 440 torr.

Vapor Pressure

Vapor pressure is the pressure exerted by the gaseous molecules above the liquid molecules when *the rate of evaporation and condensation are equal.*



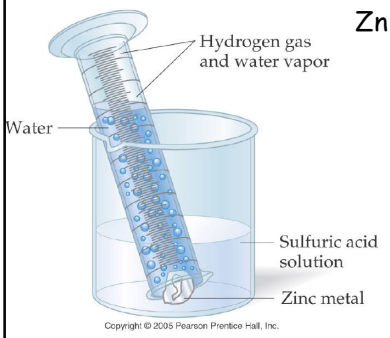
Vapor Pressure is dependent on temperature.

As T ↑ , P_{vapor} ↑

Dalton's Law of Partial Pressures

The total pressure of a gaseous mixture is equal to the sum of the individual pressures of each gas.

$$P_{total} = P_1 + P_2 + P_3 + P_4 + \ldots$$



$$Zn\,(s) + H_2SO_4\,(aq) \longrightarrow ZnSO_4\,(aq) + H_2\,(g)$$

$$P_{atm} = P_{H_2} + P_{H_2O}$$

Rearrange the expression

$$P_{H_2} = Patm - P_{H_2O}$$

$$Zn\,(s) + H_2SO_4\,(aq) \longrightarrow ZnSO_4\,(aq) + H_2\,(g)$$

When the hydrogen gas is collected over water at 20°C and 766 torr, what is the partial pressure of the hydrogen gas? (P_{H_2O} @ 20°C = 17.5 torr)

Ideal Gas Behavior

Kinetic Theory of Gases

1. Gases are made up of very tiny molecules.
2. Gas molecules demonstrate rapid motion, move in straight lines, and travel in random directions.
3. Gas molecules have no attraction for one another.
4. Gas molecules undergo elastic collisions (they do not lose KE after colliding).

Ideal Gas Law

$$PV = nRT$$

R = ideal gas constant = 0.0821 $\frac{\text{atm L}}{\text{mol K}}$

How many moles of hydrogen gas occupy a volume of 2.00 L at STP?

What volume of hydrogen gas does 1.00 mole occupy at STP?