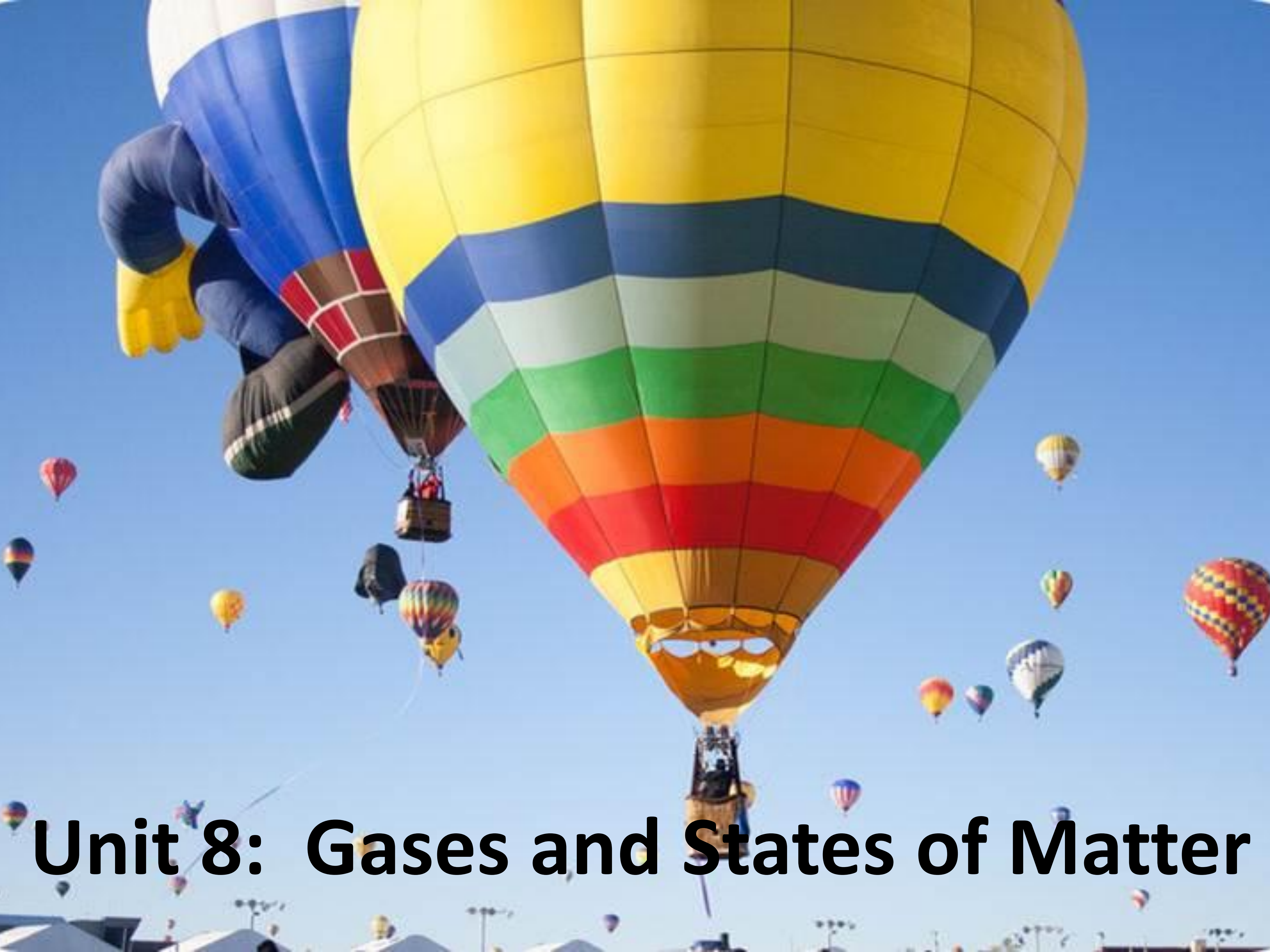


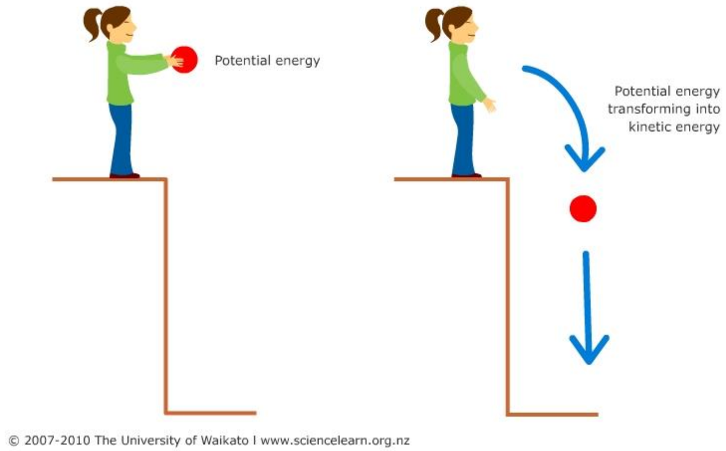
Unit 8: Gases and States of Matter

Gases

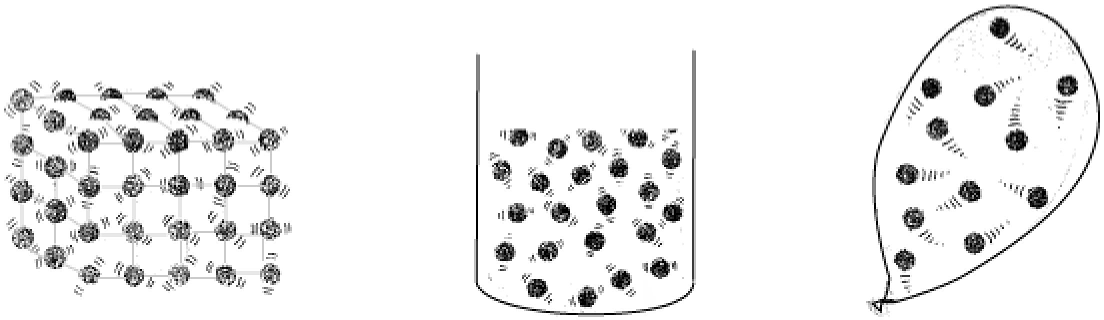
- Particles that have no definite shape or volume.
- They adapt to the shape and volume of their container.
- Ideal gases are imaginary gases that comply with all the rules of the Kinetic Molecular Theory. (KMT)
- Gas laws attempt to explain the behavior of gases under certain conditions.

Kinetic Theory (motion)

Energy an object has because of its motion

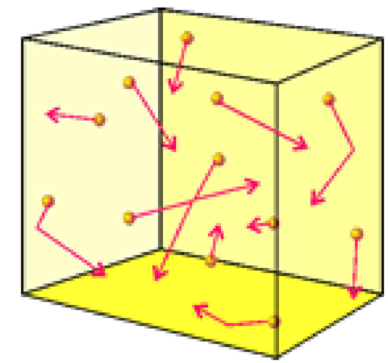


All matter consists of tiny particles that are in constant motion.



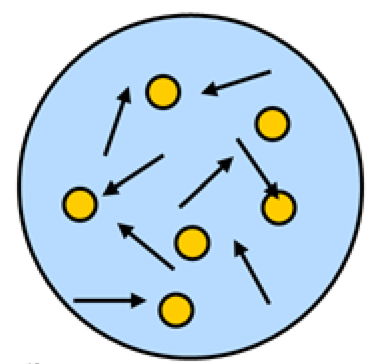
Kinetic Molecular Theory

Particles in an **ideal** (hypothetical) gas (fit all assumptions of KMT)…



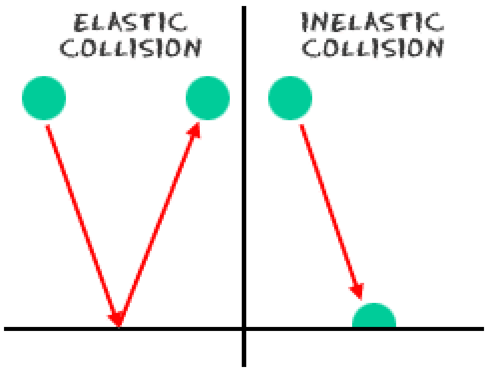
1. Gases are made up of very small molecules or atoms..

2. Gas molecules are spread apart from each other (most of the volume is empty space.)



KMT

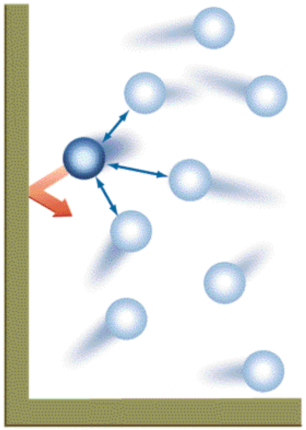
3. Gas molecules don't have any forces of attraction or repulsion between them. When gas molecules collide, energy is transferred between the particles but none is lost. These collisions are called elastic collisions.



KMT

4. Gas molecules are always moving.

5. Temperature determines the kinetic energy of gas molecules. Gases at higher temperatures have higher kinetic energies.



Gas behavior is most ideal…

- at low pressures
- at high temperatures
- in nonpolar atoms/molecules

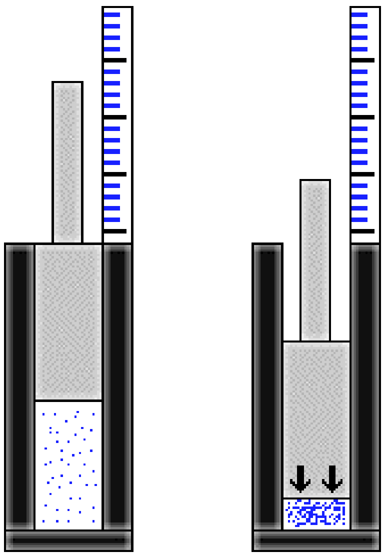
Characteristics of Gases

1. **Expansion:** Gases expand to fill any container.
2. **Fluidity**: Gases have the ability to “flow” and be poured as liquids are. That’s why gases and liquids are said to be fluid.

Characteristics of Gases

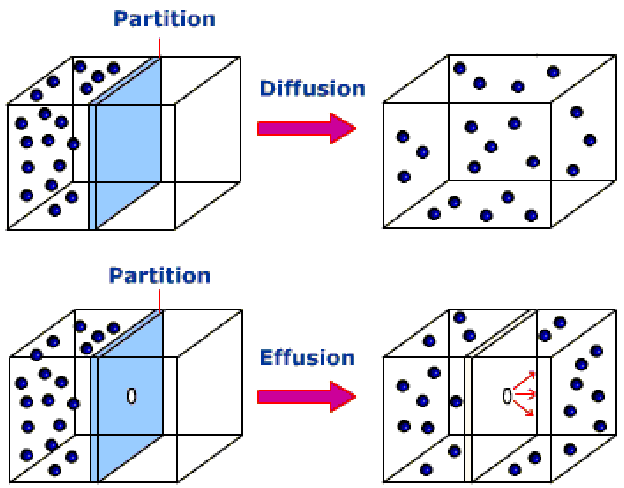
3. **Low density:** Gases have low density because the particles are spread far apart.

Volume decreases under pressure

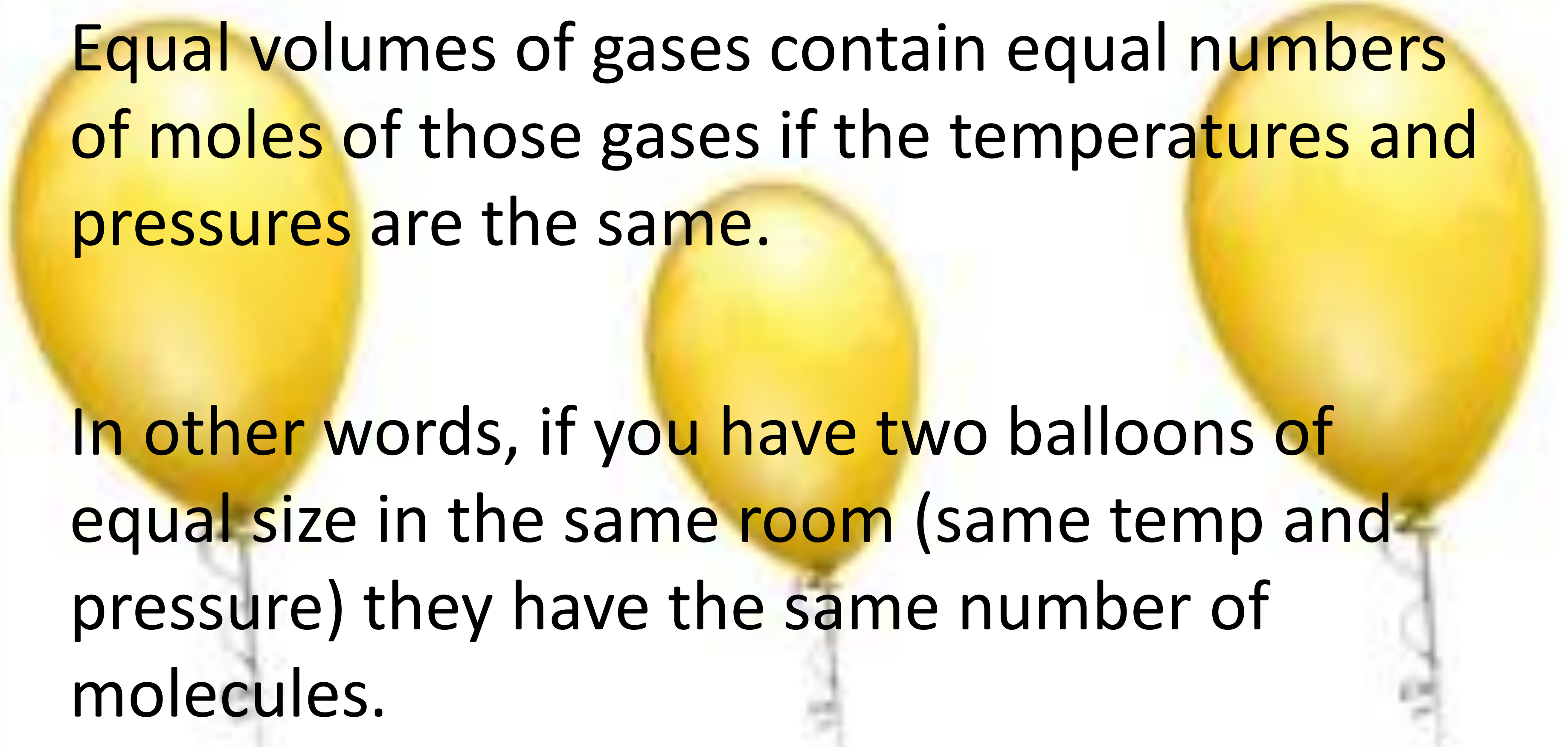


4. **Compressibility**: Gas particles can be made to occupy a smaller space by decreasing the volume of the container.

5. **Diffusion**: Gases spread out and mix with each other without agitation.



Avogadro's Principle



Equal volumes of gases contain equal numbers of moles of those gases if the temperatures and pressures are the same.

In other words, if you have two balloons of equal size in the same room (same temp and pressure) they have the same number of molecules.

REMEMBER: 1 mole of a substance has a mass equal to its molecular weight.
Ex: one mole of O_2 has a mass of 32 g

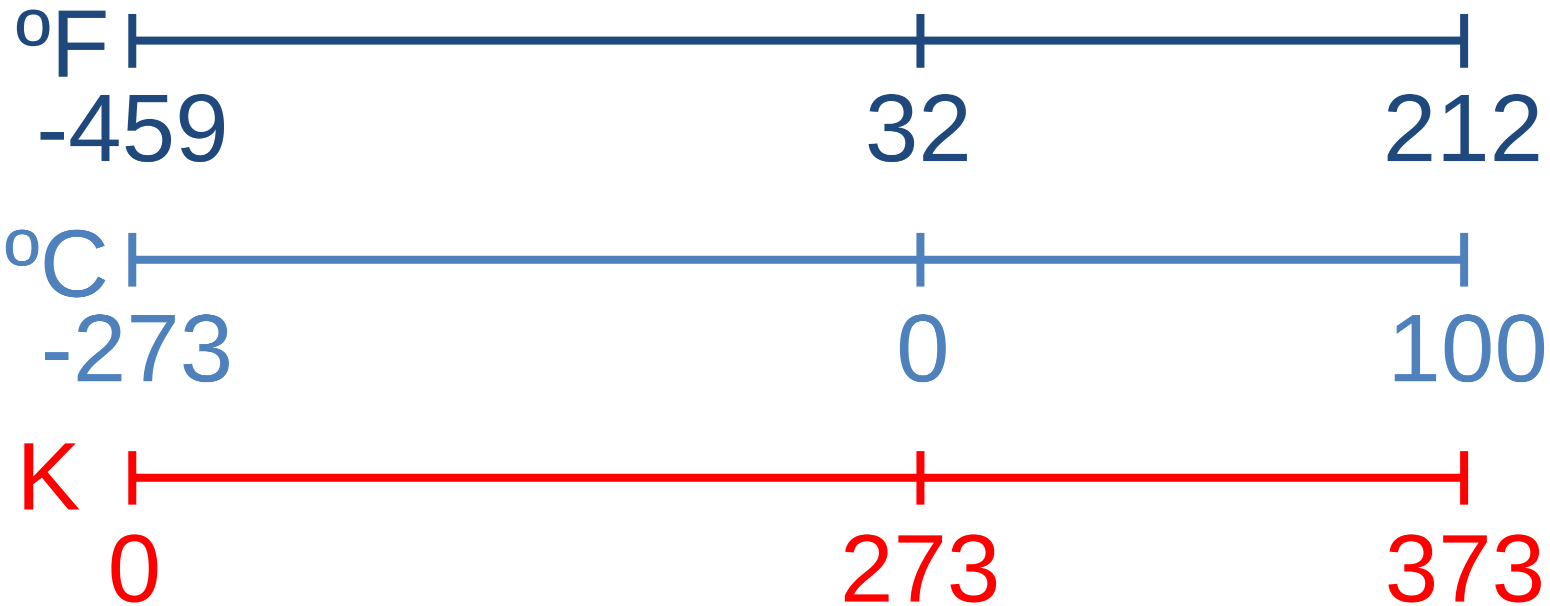
The volume occupied by a mole of any gas is 22.4 Liters at standard temperature and pressure (STP).

This is called the molar volume.

STP is 0° C and 1 atmosphere (atm) of pressure.

Temperature

Always use absolute temperature (Kelvin) when working with gases.



$$^{o}C = \frac{5}{9}\left(^{o}F - 32\right)$$

$$K = {}^{o}C + 273$$

Absolute zero is 0 K, so -273 ° C

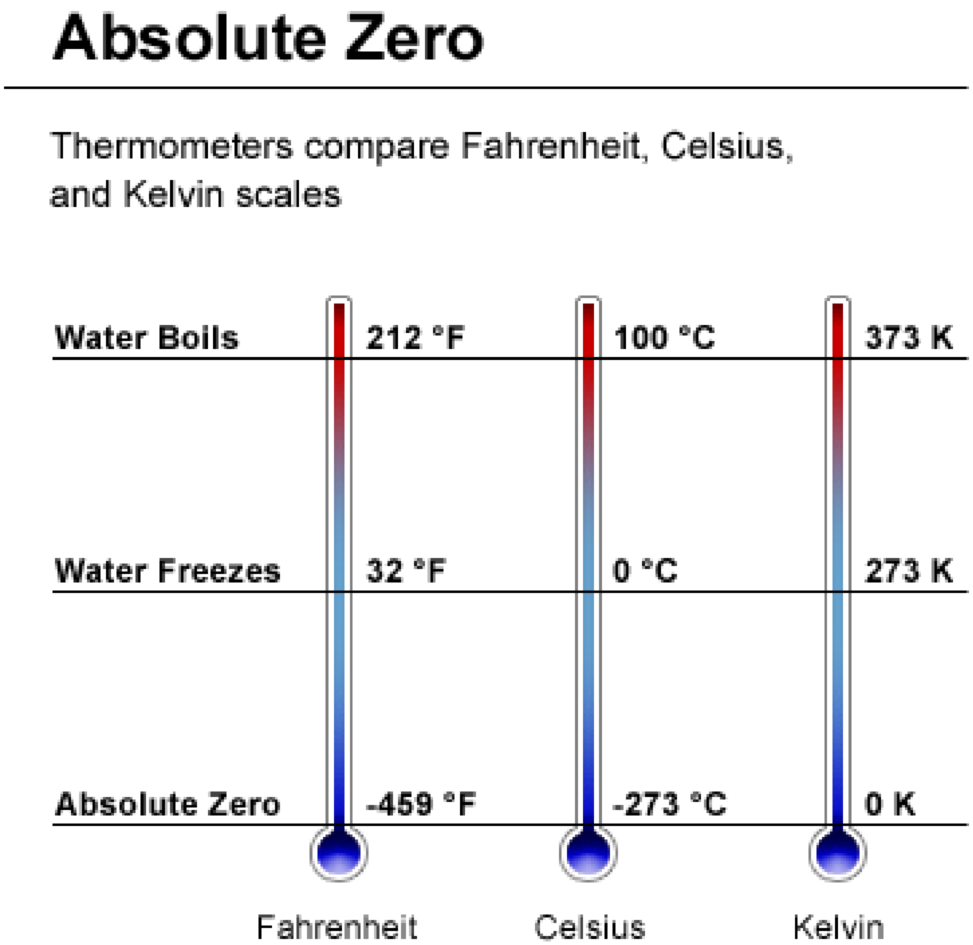
At absolute zero, matter stops moving.

Atoms/molecules in a solid, which usually vibrate, come to a complete stop.

Convert 25 ° C to K:

Convert 100 K to °C:

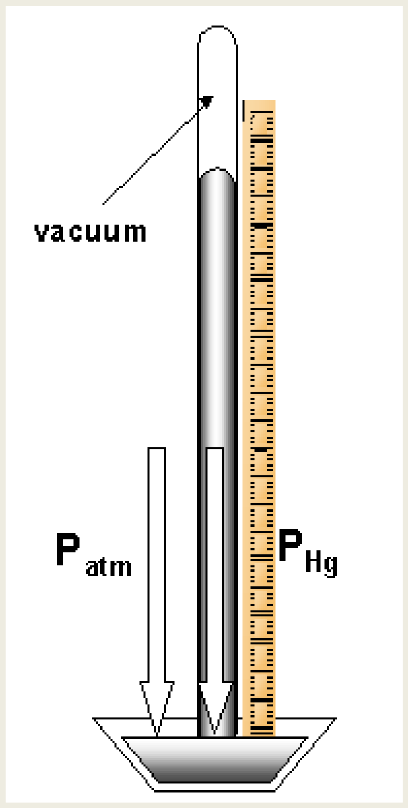
Convert -20 C to K:



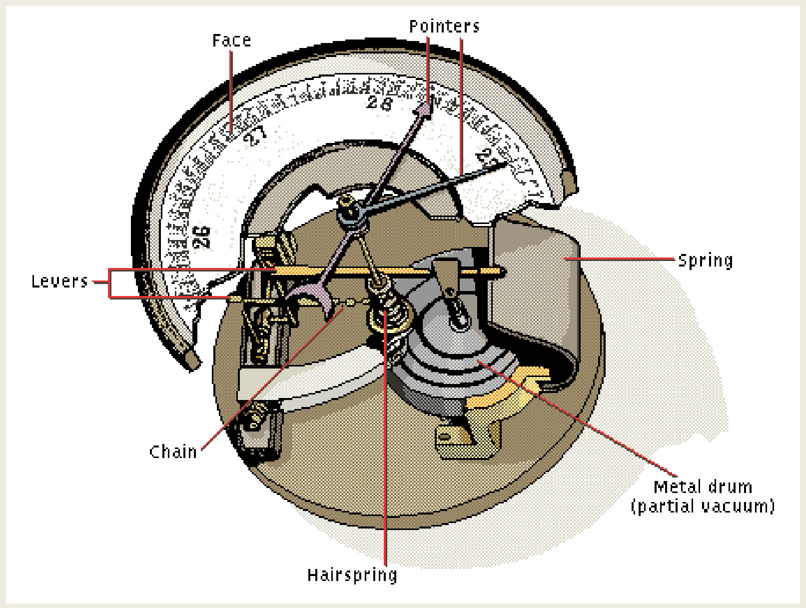
Pressure

Barometer

– Atmospheric pressure varies from day to day and is measured with a barometer



Mercury Barometer

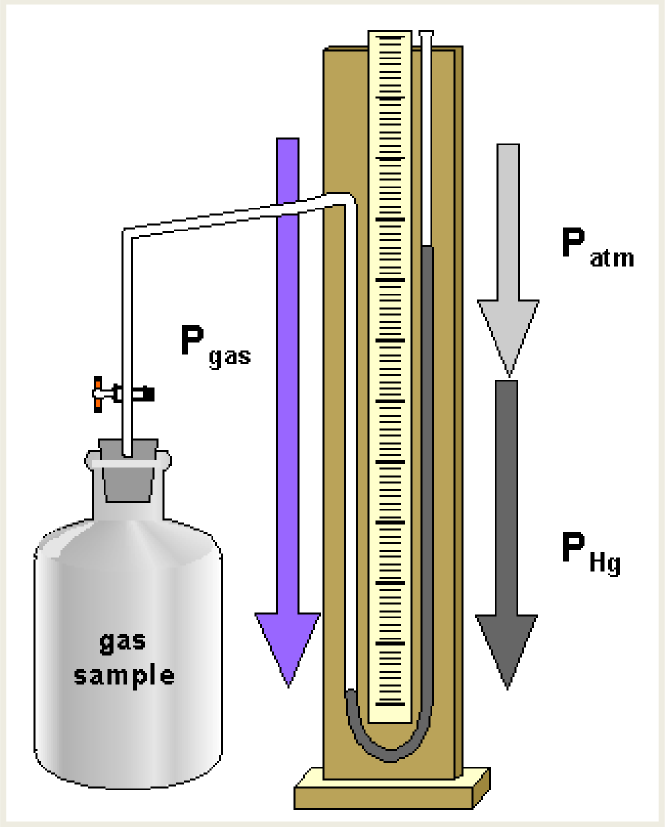


Aneroid Barometer

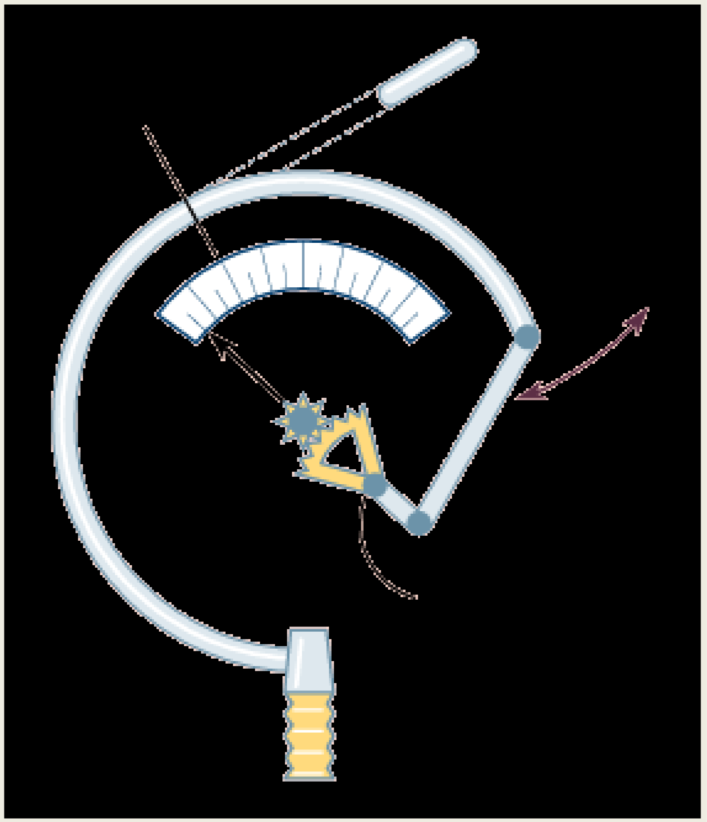
Pressure

Manometer

– measures gas pressure in a closed container



U-tube Manometer



Bourdon-tube gauge

KEY UNITS AT SEA LEVEL

1 atm *is equal to*:

101.325 kPa (kilopascal)

14.7 psi

760 mm Hg

760 torr

Standard Temperature & Pressure

0°C	-OR-	273 K
1 atm		101.3 kPa

Practice

1. Convert 1.09 atm to kPa:

2. Convert 765 torr to atm:

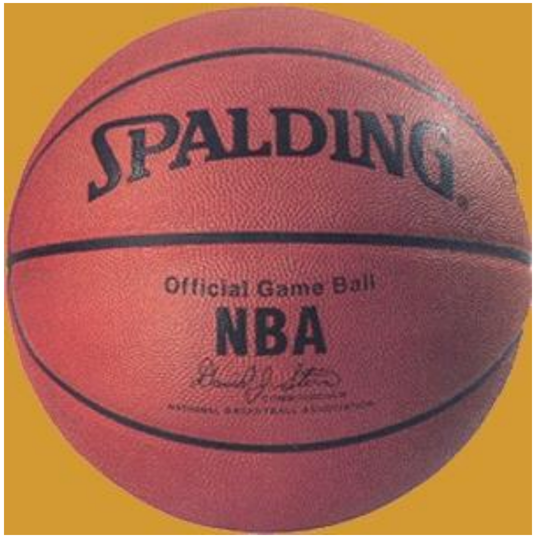
3. Convert 95 kPa to mm Hg:

4. Convert 800. mm Hg to atm:

Pressure

Pressure depends on:

- Number of molecules
- Volume of container
- Average kinetic energy (temperature)



Pressure and Temperature

- At lower temperatures, gas molecules move slower and exert less pressure.
- At higher temperatures, gas molecules move faster and exert greater pressure.

Pressure

Pressure (the force of a gas acting on the walls of its container) is measured in several different units.

– Atm = atmospheres

– mm Hg = millimeters of mercury

– Torr = torr

– Pa = pascals

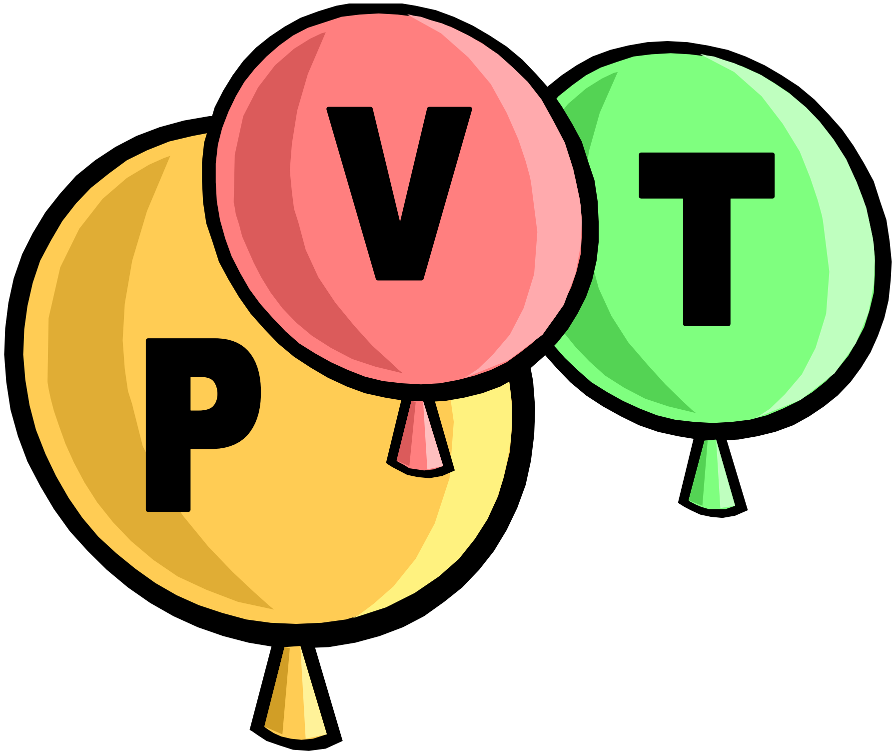
– kPa = kilopascals

Density of gases

The higher the molar mass of a gas, the more dense the gas will be. This equation relates these variables:

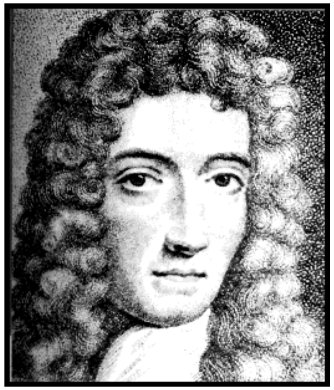
$$MM = dRT/P$$

If a density of a gas is 1.2 g/L at 745 torr and 20.°C, what is its molar mass?

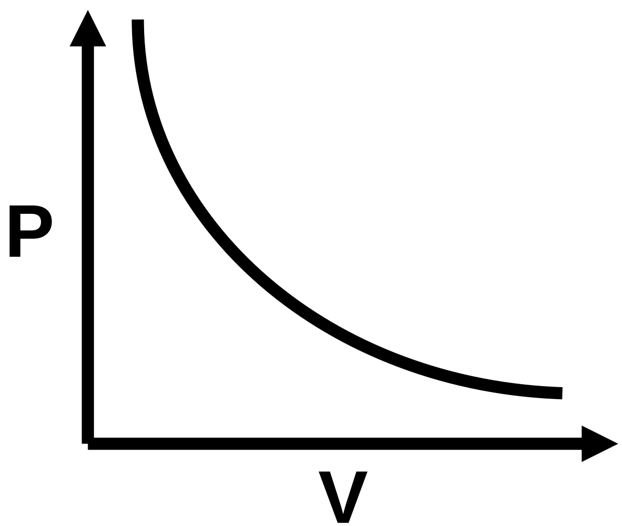


The Gas Laws

Boyle's Law

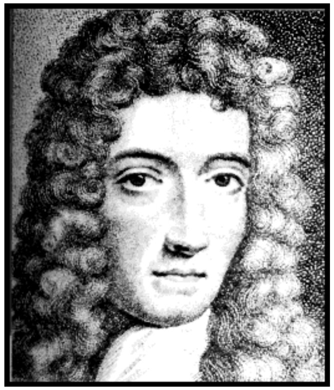


The volume of a gas varies inversely (indirectly) with the pressure of the gas, if the temperature is held constant.

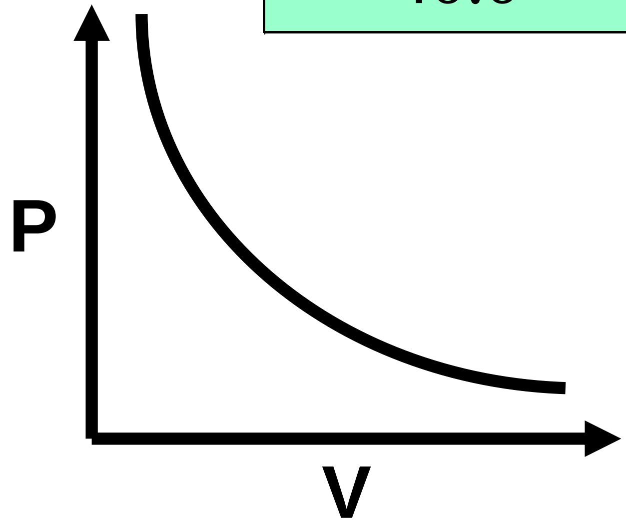


$$P_1V_1 = P_2V_2$$

Boyle's Law



Volume (mL)	Pressure (torr)	P·V (mL·torr)
10.0	760.0	7.60×10^3
20.0	379.6	7.59×10^3
30.0	253.2	7.60×10^3
40.0	191.0	7.64×10^3



$$P_1V_1 = P_2V_2$$

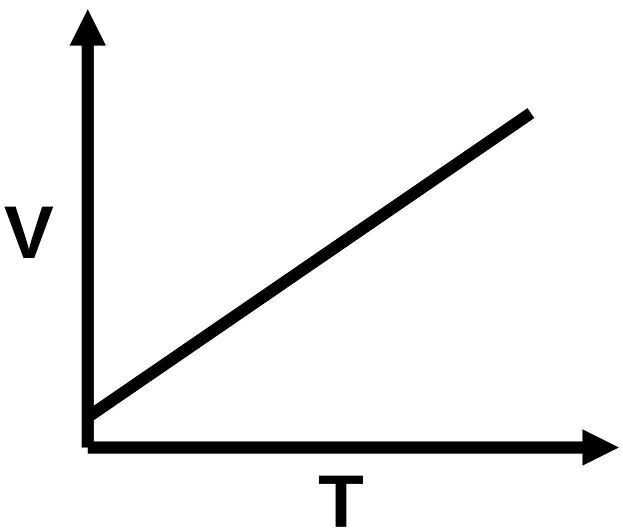
Boyle's Law

1. A balloon is filled with helium on a day when atmospheric pressure is 780 mm Hg. A storm comes through and the pressure drops to 715 mm Hg. If the initial volume of helium was 1500. mL, what is its new volume?

2. A syringe has 10.0 mL of gas inside and the pressure is 1.00 atm. If pressure is applied and the volume decreases to 4.8 mL, what is the final pressure of the gas inside?

Charles's Law

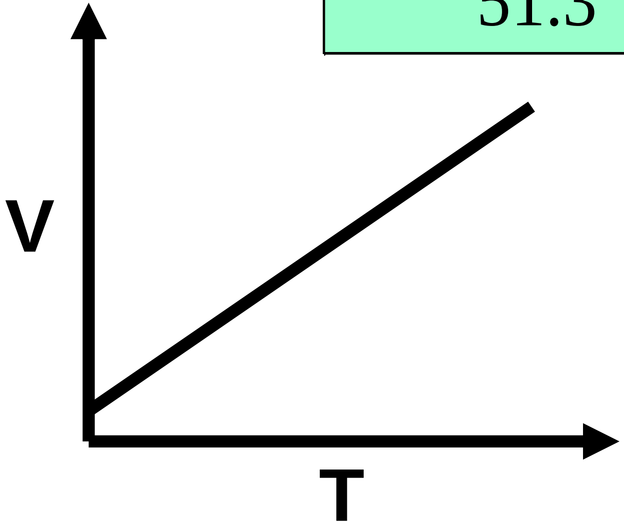
The volume of a gas varies directly with the Kelvin temperature of the gas if the pressure is held constant.



$$V_1/T_1 = V_2/T_2$$

Charles's Law

Volume (mL)	Temperature (K)	V/T (mL/K)
40.0	273.2	0.146
44.0	298.2	0.148
47.7	323.2	0.148
51.3	348.2	0.147



$$V_1/T_1 = V_2/T_2$$

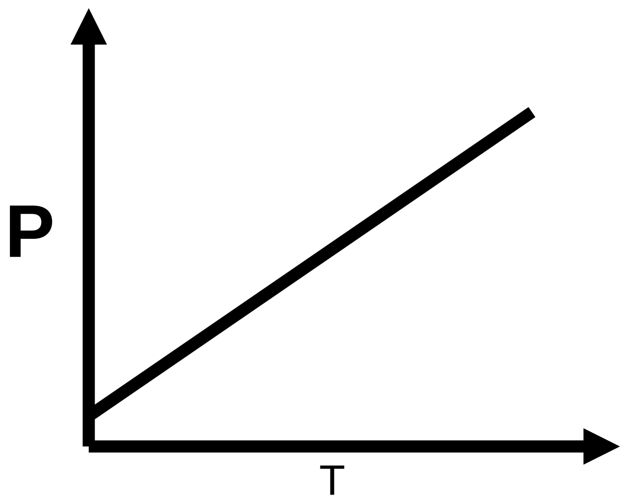
Charles's Law

1. A balloon is filled to 2.18 L on a day when the temperature is 23°C. Assuming no change in pressure, what is the volume of the balloon on a day when the temperature is 17°C? (*gas laws temperature always needs to be in Kelvin!*)

2. To what Kelvin temperature must 7.98 cm^3 of oxygen be cooled, to reduce its volume to 5.00 cm^3 if it is initially at STP and pressure does not change?

Gay-Lussac's Law

The pressure of a gas varies directly with temperature if the volume is held constant.



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

Gay-Lussac's law

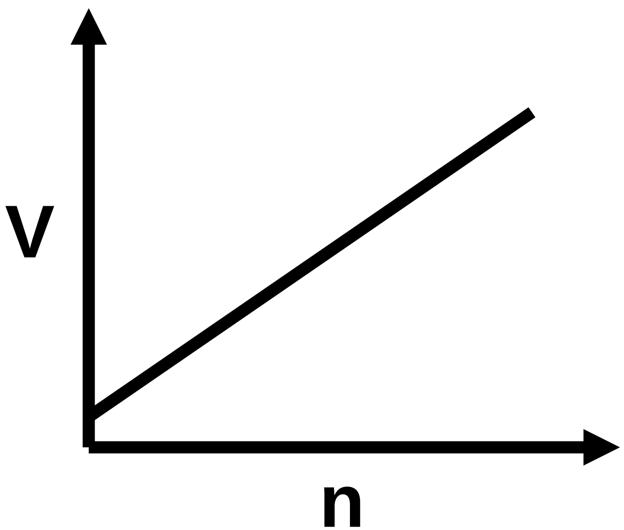
1. If you cap a 2 L coke bottle containing air, and the temperature changes from 25°C to 35°C, what is the pressure on the inside wall of the bottle? Assume the initial atmospheric pressure when you capped the bottle was 728 mm Hg.

Avogadro’s Principle

Equal volumes of gases contain equal numbers of moles

- at constant temp & pressure
- true for any gas

At STP 1 mol of any gas occupies a volume of 22.4L



$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Avogadro's Principle

1. Sulfur dioxide (SO_2) is a gas produced by burning coal. It is an air pollutant and one of the causes of acid rain. Determine the volume, in liters, of 0.60 mol SO_2 gas at STP.

Combined Gas Law

The three gas laws can be combined into one law that can always be used. This equation helps figure out the new pressure, temperature, or volume of a gas if the initial conditions are known.

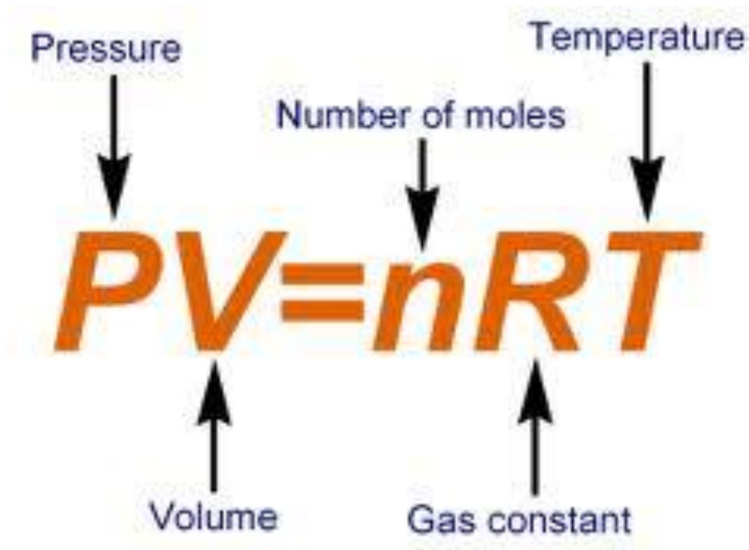
$$\frac{\mathbf{P_1V_1}}{T_1} = \frac{\mathbf{P_2V_2}}{V_2}$$

1. A weather balloon is filled with 5040 L of helium on a day when the temperature is 18°C and the pressure is 767 mm Hg. It rises in the atmosphere to where the temperature is -7°C and the pressure is only 458 mm Hg. What is the new volume of the balloon?

2. How much pressure must be applied to 68 L of a gas at STP to reduce its volume by half if the temperature is raised to 20.°C?

Ideal Gas Law

Ideal Gas Law



UNIVERSAL GAS CONSTANT

$R = 0.0821\ L \cdot atm/mol \cdot K$

$R = 8.315\ dm^3 \cdot kPa/mol \cdot K$

You don’t need to memorize these values!

1. How many grams of oxygen are in a 5.0 L tank that has a pressure of 65 atm and a temperature of 22 °C?

2. At what temperature would 0.0828 moles of hydrogen have a pressure of 1.00 atm and a volume of 55.0 L?

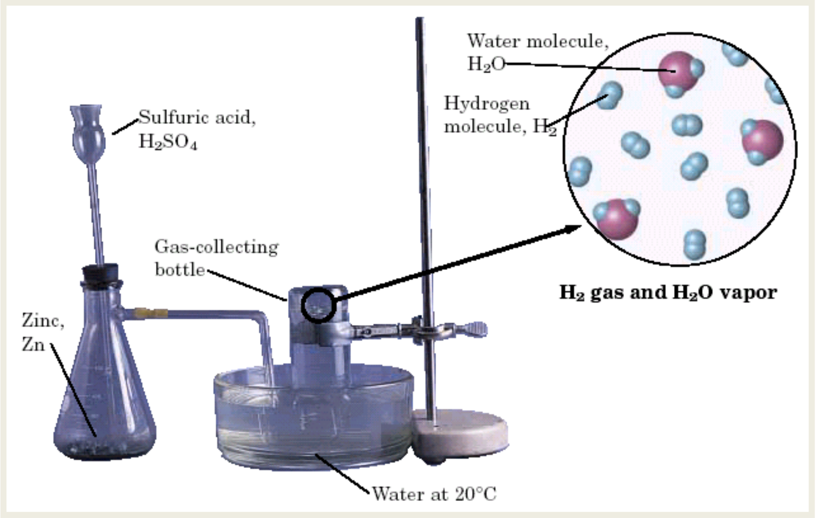
Two More Laws

Gases

Dalton's Law

The total pressure of a mixture of gases equals the sum of the partial pressures of the individual gases.

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



When H_2 gas is collected by water displacement, the gas in the collection bottle is actually a mixture of H_2 and water vapor.

Gases Collect Over Water

Water Vapor Pressure Table

Temperature (°C)	Pressure (mmHg)	Temperature (°C)	Pressure (mmHg)	Temperature (°C)	Pressure (mmHg)
0.0	4.6	19.5	17.0	27.0	26.7
5.0	6.5	20.0	17.5	28.0	28.3
10.0	9.2	20.5	18.1	29.0	30.0
12.5	10.9	21.0	18.6	30.0	31.8
15.0	12.8	21.5	19.2	35.0	42.2
15.5	13.2	22.0	19.8	40.0	55.3
16.0	13.6	22.5	20.4	50.0	92.5
16.5	14.1	23.0	21.1	60.0	149.4
17.0	14.5	23.5	21.7	70.0	233.7
17.5	15.0	24.0	22.4	80.0	355.1
18.0	15.5	24.5	23.1	90.0	525.8
18.5	16.0	25.0	23.8	95.0	633.9
19.9	16.5	26.0	25.2	100.0	760.0

Dalton's Law

Hydrogen gas is collected over water at 22.5°C. Find the pressure of the dry gas if the atmospheric pressure is 94.4 kPa.

The total pressure in the collection bottle is equal to atmospheric pressure and is a mixture of H_2 and water vapor.

GIVEN:	WORK:
$P_{H2} = ?$	$P_{total} = P_{H2} + P_{H2O}$
$P_{total} = 94.4$ kPa	$94.4 \text{ kPa} = P_{H2} + 2.72 \text{ kPa}$
$P_{H2O} = 2.72$ kPa	$P_{H2} = 91.7$ kPa

Look up water-vapor pressure on p.899 for 22.5°C.

Sig Figs: Round to least number of decimal places.

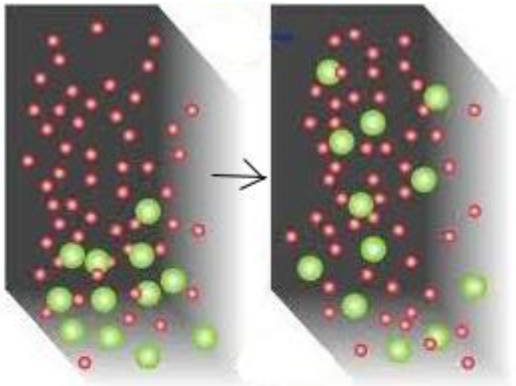
1. A mixture of gas contains oxygen, carbon dioxide, and nitrogen. The total pressure of the gases is 400 torr. The pressure of the oxygen gas is 320 torr, and the pressure of the nitrogen is 33 torr. What is the pressure of the carbon dioxide?

2. A student collects 89 mL of oxygen gas by bubbling it through water. The pressure reading that day is 103.2 kPa and the temperature is 20. °C. Determine the number of moles of gas collected.

Graham's Law

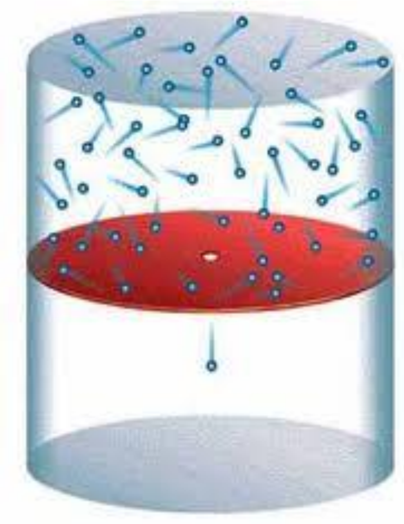
Diffusion

– Spreading of gas molecules throughout a container until evenly distributed.



Effusion

– Passing of gas molecules through a tiny opening in a container



Graham's Law

Speed of diffusion/effusion

- Kinetic energy is determined by the temperature of the gas.
- At the same temp & KE, heavier molecules move more slowly.
  - Larger $\boldsymbol{m} \Rightarrow$ smaller $\boldsymbol{v}$

Molar Volume at STP

1 mol of a gas = 22.4 L
at STP

Standard **T**emperature & **P**ressure
0°C and 1 atm

1. Hydrogen and oxygen combine to form water. What volume of oxygen is needed to make 20.0 g of H_2O?

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$

2. How many grams of $KClO_3$ are required to produce 9.00 L of O_2 at STP?

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

3. How many liters of oxygen will be produced when 16.8 g of $KClO_3$ decompose?

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

Which volume is bigger?

4. 10 grams of oxygen or 10 grams of argon