Unit 2:
Forms of Matter: Gases

Nov 28-4:08 PM

Chapter 3: Properties of Gases

Lesson 1: Gases and Kinetic Molecular Theory

Lesson 2: Gases and Pressure

Lesson 3: Gases and Temperature

Nov 28-4:41 PM

Lesson 1: Gases and Kinetic Molecular Theory

In this Lesson we will be learning:

1 - How to describe and compare the behaviour of real and ideal gases in terms of kinetic molecular theory.

Nov 29-9:43 AM

Many technologies such as hot-air balloons, SCUBA tanks, dental drills, and nail guns are based on the properties of gases.

The following properties distinguish gases from other states of matter:
- compressible – can be compacted into a smaller space.
- expand with an increase in temperature
- low viscosity – easy to pour
- low density – not much of it in a space.
- miscible – mix evenly and completely.

Properties of temperature, pressure, miscibility, viscosity, and density are **macroscopic**.
- They can be directly observed using your senses or a measuring instrument

Nov 29-9:45 AM

Kinetic molecular theory of gases is a **model** that explains the macroscopic properties of gases based on the behaviour of individual particles (atoms or molecules).

Scientists use a **hypothetical** substance called an **ideal gas**.

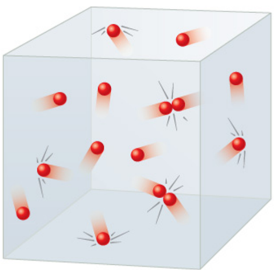
- No gas is ever ideal; however, the theory quite accurately describes the behaviour of **real gases** at ordinary temperature and pressures

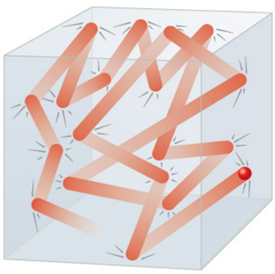
Nov 29-9:50 AM

An **ideal gas** is defined by the following:

Molecules:

- are in constant, random motion
- travel until they collide with other gas particles or walls of the container
- are **point masses (**Particles that take up no space; they have no volume
- collide with walls of a container and each other with **elastic** collisions (Kinetic energy is conserved during **elastic** collisions)





Nov 29-9:51 AM

Let's Recap!

1 - I can describe and compare the behaviour of real and ideal gases in terms of kinetic molecular theory.

Nov 29-9:43 AM

Lesson 2: Gases and Pressure

In this Lesson we will be learning:

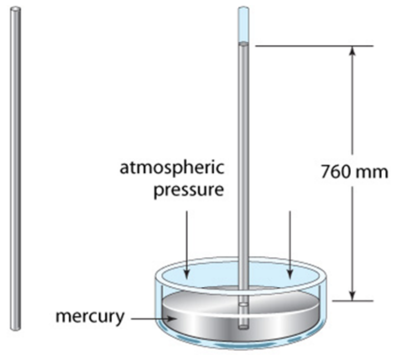
5 - How to express pressure in a variety of ways, including units of kilopascals, atmospheres, and millimetres of mercury.

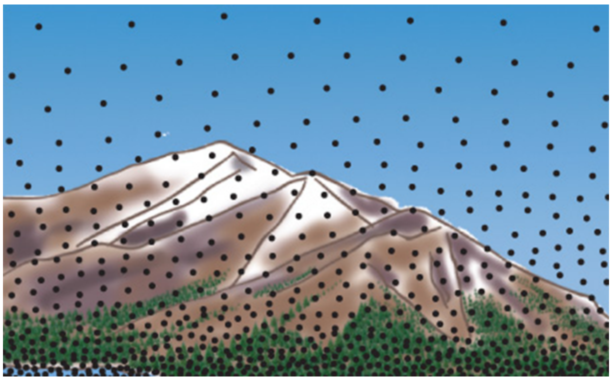
6 - How to perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

Nov 29-9:43 AM

Atmospheric pressure **decreases** as altitude increases.

Torricelli proposed the existence of atmospheric pressure and designed the **mercury barometer** to demonstrate it.





Nov 30-3:40 PM

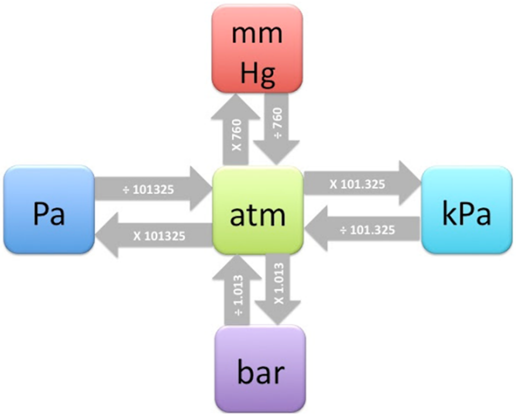
There are many units used to express pressure:

atmospheres (atm)
millimetres of mercury (mmHg)
Pascals (Pa)
kiloPascals (kPa)
bar (bar)

Standard atmospheric pressure is the pressure in dry air at 0 degrees Celsius at sea level.

1 atm = 760 mmHg = 101325 Pa = 101.325 kPa = 1.01325 bar

*Dimensional analysis can help you to convert between units! :)



Nov 30-3:49 PM

Standard Temperature and Pressure (STP) refers to a temperature of 0 degrees Celsius and a pressure of 1 atm (101.325 kPa).

Standard Ambient Temperature and Pressure (SATP) refers to a temperature of 25 degrees Celsius and a pressure of 100 kPa.

Nov 30-4:12 PM

Practice! Grab a Mini Whiteboard.

1. How many atm is 355 kPa?

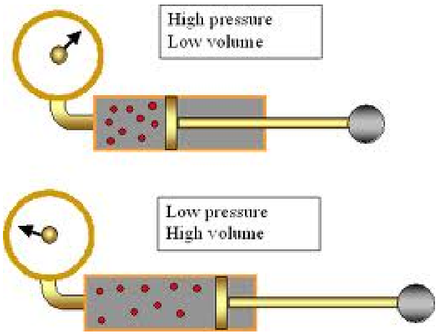
2. How many mmHg is 25 atm?

3. How many Pascals is 15 bar?

Nov 30-4:12 PM

Boyle demonstrated that the volume of a given amount of gas is **inversely proportional** to the external pressure exerted on it when the **temperature is constant**.

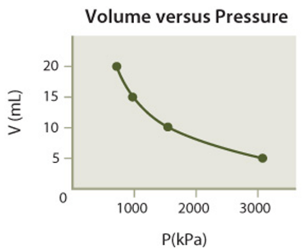
As the external pressure on a gas increases, the volume begins to decrease. As the volume decreases, the molecules become closer together causing the collision frequency to increase, increasing the pressure.

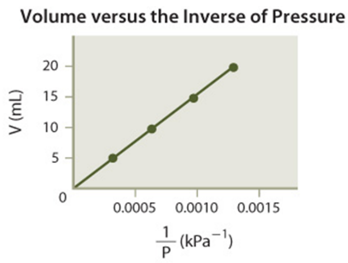


Nov 30-3:41 PM

Boyle's Law:

$$P_1V_1 = P_2V_2$$





Rearrange to solve for:

P_1

V_1

P_2

V_2

Nov 30-3:44 PM

Example Calculation:

A weather balloon with a volume of **2000L** at a pressure of **96.3 kPa** rises to a height of 1000m, where the atmospheric pressure is measured to be **60.8 kPa**.
Assuming there is no change in temperature, what is the **final volume** of the weather balloon?

$P_1 =$

$V_1 =$

$P_2 =$

$V_2 =$

Nov 30-4:05 PM

Practice: Grab a Mini White Board!

Page 110, Questions 1-6

Nov 30-4:04 PM

Let's Recap!

5 - I can express pressure in a variety of ways, including units of kilopascals, atmospheres, and millimetres of mercury.

6 - I can perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

Nov 29-9:43 AM

Lesson 3: Gasses and Temperature

In this lesson we will learn:

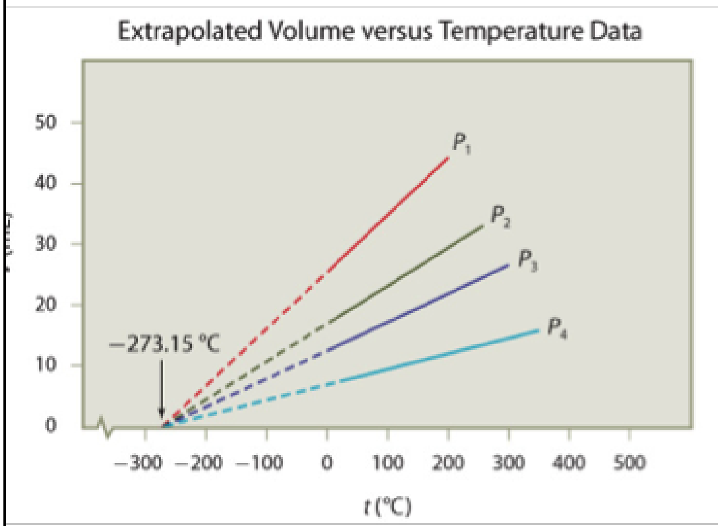
2 - How to convert between the Celsius and Kelvin temperature scales

4 - How to illustrate how Boyle's and Charles's laws, individually and combined, are related to the ideal gas law (PV = nRT)

6 - How to perform calculations, based onthe gas laws, under STP, SATP, and othedefined conditions.

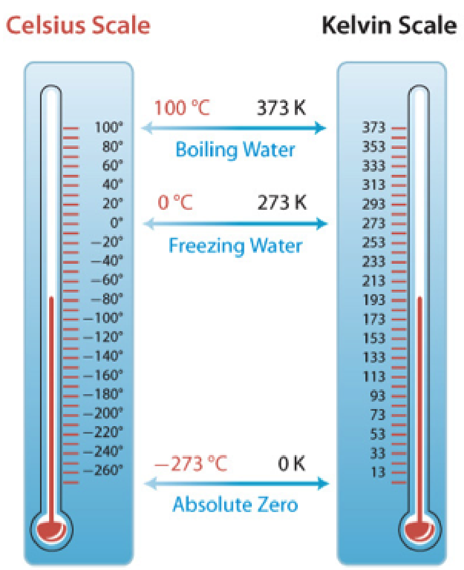
Nov 29-9:43 AM

The introduction of hot-air balloons piqued the interest of Charles and Gay-Lussac, and they began to study the relationship between the temperature and volume of gases.



Plots of volume versus temperature of a gas always extrapolate to −273.15 °C.

Dec 2-8:30 PM



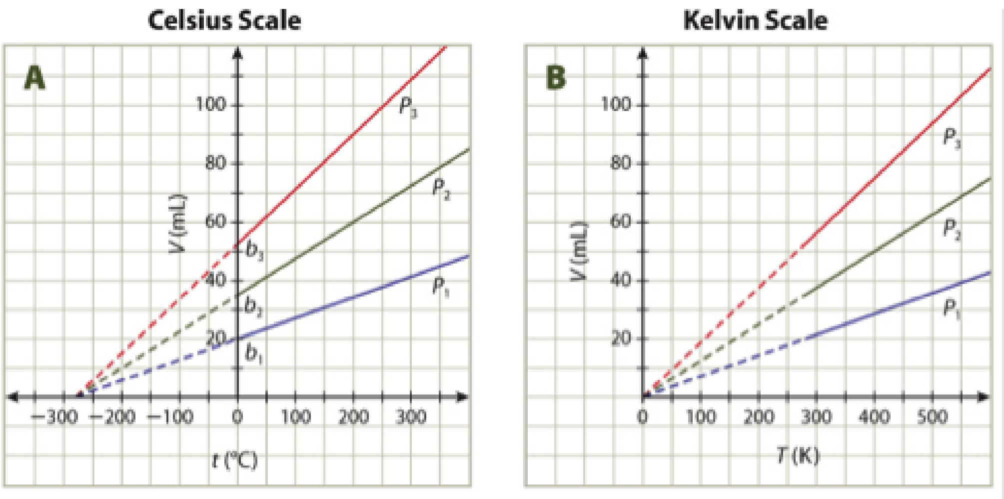
Lord Kelvin proposed that −273.15 °C was the theoretically lowest possible temperature. It is now called **absolute zero**.

The Kelvin temperature scale is based on a temperature of 0 K at absolute zero.

The size of a kelvin (unit of temperature) is the same as the size of a degree on the Celsius scale.

Dec 2-8:34 PM

The symbol *T* is used for temperature on the Kelvin scale, and *t* is used on the Celsius scale. **T = t + 273.15** and **t = T − 273.15**



Dec 2-8:45 PM

Practice! (Grab a Mini Whiteboard)

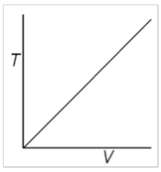
1. Convert 37*C to the Kelvin temperature.

2. Convert 77 K to the Celsius temperature.

Dec 3-7:28 AM

Charles's law states that the volume of a fixed amount of gas at a constant pressure is directly proportional to the absolute (Kelvin) temperature of the gas.

Charles's law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$



Rearrange to solve for:

V_1 =

V_2 =

T_1 =

T_2 =

Dec 2-8:46 PM

Example:

A baloon inflated with air in a room at 22.00 *C has a volume of 650 mL. The balloon is put into the freezer of a refrigerator at 0.00*C and left long enough for the air in the balloon to reach the same temperature. Predict the volume of the balloon at the end of two hours, assuming that air pressure in the room and freezer are the same.

T_1 -

T_2 -

V_1 -

V_2 -

Dec 3-7:30 AM

Practice Questions:
(Grab a mini whiteboard)

Page 122 Questions 5 - 11 (omit 10)

Dec 2-8:52 PM

Let's Recap!

2 - I can convert between the Celsius and Kelvin temperature scales

4 - I can illustrate how Boyle's and Charles's laws, individually and combined, are related to the ideal gas law (PV = nRT)

6 - I can perform calculations, based onthe gas laws, under STP, SATP, and othedefined conditions.

Nov 29-9:43 AM

Homework:

Page 119, Questions 7-10

120, Questions 11-14

Dec 3-7:34 AM

Chapter 3 Quiz Tomorrow! :)

Questions for Review:

Page 751 # 26-36
Answers: Page 742

Dec 2-8:53 PM

Chapter 4: Exploring Gas Laws

Lesson 1: The Combined Gas Law

Lesson 2: The Law of Combining Volumes and Avogadro's Law

Lesson 3: The Ideal Gas Law

Lesson 4: Dalton's Law of Partial Pressures

Nov 28-4:41 PM

Lesson 1: The Combined Gas Law

In this Lesson we will be learning:

2 - How to convert between the Celsius and Kelvin temperature scales

5 - How to express pressure in a variety of ways, including units of kilopascals, atmospheres, and millimetres of mercury.

6 - How to perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

Nov 29-9:43 AM

We have learned from Boyle that **Pressure** and **Volume** are inversely proportional.

We have learned from Charles that **Volume** and **Temperature** are directly proportional.

Thus, we can conclude that Pressure and Temperature are also directly proportional in the **Combined Gas Law**.

Combined gas law: $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Dec 9-8:15 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Let's practice rearranging:

P_1 =

Dec 9-8:19 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Let's practice rearranging:

$V_1 = \frac{P_2V_2T_1}{T_2P_1}$

$$P_1V_1 = \frac{P_2V_2T_1}{T_2}$$

$$V_1 = \frac{P_2V_2T_1}{T_2P_1}$$

Dec 9-8:19 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Let's practice rearranging:

$T_1 =$

$$T_2P_1V_1 = \frac{P_2V_2T_1}{T_2}$$

$$\frac{T_2P_1V_1}{P_2V_2} = T_1$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{T_1}{P_1V_1} = \frac{T_2P_1V_1}{P_2V_2}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$P_1 = \frac{P_2V_2T_1}{T_2V_1}$$

Dec 9-8:19 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Let's practice rearranging:

P_2 =

Dec 9-8:19 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Let's practice rearranging:

V_2 =

Dec 9-8:19 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Let's practice rearranging:

T_2 =

Dec 9-8:19 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Example 1: A small balloon contains 275 mL of helium gas at a temperature of 25.0*C and a pressure of 350.0 kPa. What volume would this gas occupy at 10*C and 101 kPa?

$V_1 = 275 mL$

$T_1 = 25.0°C + 273.15 = 298.15 K$

$P_1 = 350.0 kPa$

$V_2 = ?$

$T_2 = 10°C + 273.15 = 283.15 K$

$P_2 = 101 kPa$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(350.0 kPa)(275 mL)}{(298.15 K)} = \frac{(101 kPa) V_2}{(283.15 K)}$$

$$\frac{322.82 \frac{kPa \cdot mL}{K}}{0.357 \frac{kPa}{K}} = \frac{0.357 \frac{kPa}{K} (V_2)}{0.357 \frac{kPa}{K}}$$

$904.25 mL = V_2$

Dec 9-8:19 AM

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Example 2: A volume of 25mL of gas is produced in a laboratory experiment at a temperature of -15*C and a pressure of 760mmHg. Predict the Celsius temperature of the gas when its volume is reduced to 20 mL and the pressure is increased to 820 mmHg.

$V_1 = 25mL$ $V_2 = 20mL$

$T_1 = -15°C + 273.15 = 258.15K$ $T_2 = ?$

$P_1 = 760mmHg$ $P_2 = 820mmHg$

$$T_2 = \frac{T_1 P_2 V_2}{P_1 V_1} = \frac{(258.15K)(820\,mmHg)(20\,mL)}{((760\,mmHg)(25\,mL))}$$

$T_2 = 222.82\ K - 273.15$

$T_2 = -50.33°C$

Dec 9-8:19 AM

Practice:

Page 130 Questions 1-6
Answers: page 730

~~Homework check tomorrow :)~~

Dec 9-9:55 AM

Let's Recap!

2 - I can convert between the Celsius and Kelvin temperature scales

5 - I can express pressure in a variety of ways, including units of kilopascals, atmospheres, and millimetres of mercury.

6 - I can perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

Nov 29-9:43 AM

Lesson 2: The Law of Combining Volumes and Avogadro's Law

In this Lesson we will be learning:

3 - How to explain the law of combining volumes.

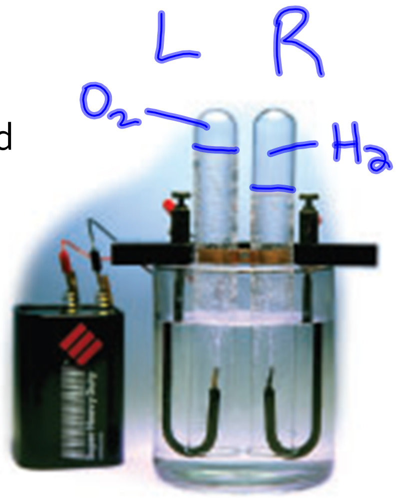
6 - I can perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

Nov 29-9:43 AM

The Law of Combining Volumes states:

When measured at the same temperature and pressure, volumes of gaseous reactants and products of chemical reactions are always in simple ratios of whole numbers

A simple example of this is the decomposition of liquid water, in which the volumes of hydrogen and oxygen gas are always produced in a 2:1 ratio



Which side is Hydrogen?

$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$

Dec 10-7:26 AM

Example 1 **Reaction between hydrogen gas and oxygen gas**

$2H_2 + O_2 \rightarrow 2H_2O$

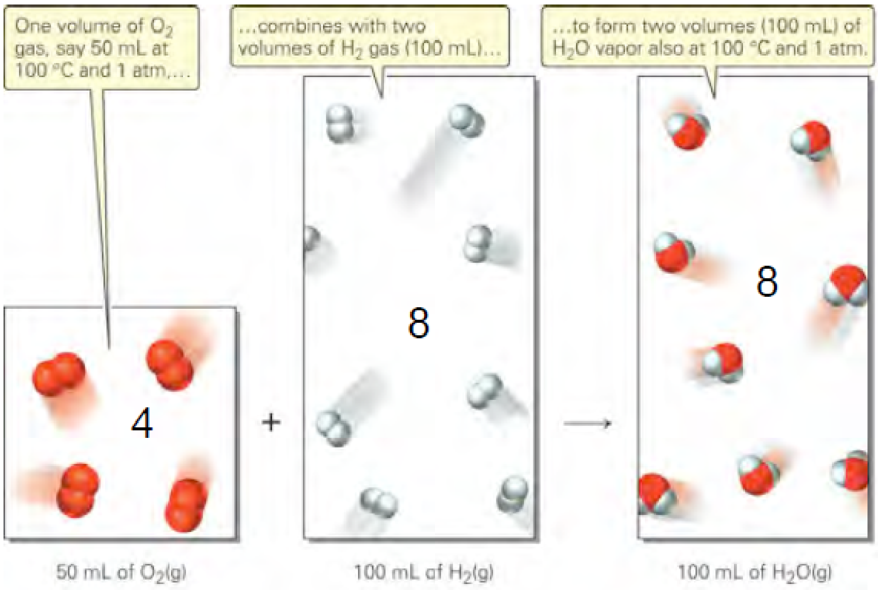
hydrogen gas + oxygen gas → water vapour				
100 mL	+	50 mL	→	100 mL
50 mL	+	25 mL	→	50 mL
8 mL	+	4 mL	→	8 mL

Example 2 **Decomposition of ammonia gas**

$2NH_3 \rightarrow 3H_2 + N_2$

ammonia gas → hydrogen gas + nitrogen gas				
150 mL	→	225 mL	+	75 mL
50 mL	→	75 mL	+	25 mL
8 mL	→	12 mL	+	4 mL

Dec 10-7:29 AM



Dec 10-6:50 PM

Example problem:

What volume of nitrogen forms when 300 mL of ammonia decomposes?

$$2NH_3 \rightarrow 3H_2 + N_2$$

300 mL ... ?

$$?\,N_2 = 300\,mL\,NH_3 \times \frac{1\,mL\,N_2}{2\,mL\,NH_3} = 150\,mL\,N_2$$

$$?\,H_2 = 300\,mL\,NH_3 \times \frac{3\,mL\,H_2}{2\,mL\,NH_3} = 450\,mL\,H_2$$

Dec 10-7:29 AM

Practice (On a mini whiteboard)

Page 133 Questions 7-9

Answers on page 730

Dec 10-7:31 AM

Avogadro's Law:

Two years after The Law of Combining Volumes, Avogadro proposed a new explanation in terms of numbers of molecules:

"equal volumes of gases at the same temperature and pressure contain equal numbers of molecules"

V = volume

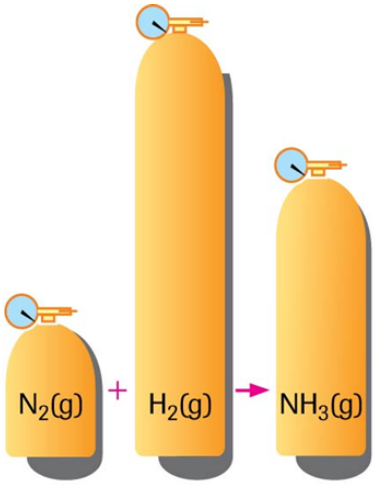
$$\frac{n_1}{V_1} = \frac{n_2}{V_2}$$

n = # of molecules in moles

This means the mole ratios provided by a balanced equation are also the volume ratios. aka: $2H_2O \rightarrow 2H_2 + 1O_2$

Note: This equivalence between the chemical amounts (coefficients) and the volumes only works for gases, and only if they are at the same temperature and pressure.

Dec 10-7:34 AM



Coefficients:	1	3	2
Chemical Amounts:	1 mol	3 mol	2mol
Volumes:	1 L	3 L	2 L
Example:	2 mL	6 mL	4 mL

$N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g)$

Dec 10-7:37 AM

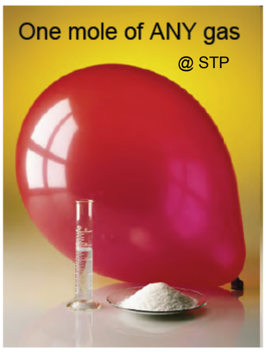
Molar Volume:

The volume that one mole of a gas occupies. The units are L/mol.

molar volume (v) = $\frac{\text{volume (V)}}{\text{moles (n)}}$

The molar volume will vary with different temperatures and pressures.

Conditions	Pressure	Celsius temperature	Kelvin temperature	Molar volume
STP	101.325 kPa	0 °C	273.15 K	22.4 L/mol
SATP	100.0 kPa	25 °C	298.15 K	24.8 L/mol



Dec 10-7:38 AM

Example:

An empty, sealed vacuum container with a volume of 0.652 L is found to have a mass of 2.50g. When filled with nitrogen gas, the container has a mass of 3.23 g. The pressure of the nitrogen in the container is measured and found to be 97.5 kPa when the temperature is 21.0*C.
Calculate the molar volume of nitrogen gas at STP.

Dec 10-8:02 AM

Let's Recap!

3 - I can explain the law of combining volumes.

6 - I can perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

Nov 29-9:43 AM

Lesson 3: The Ideal Gas Law

In this Lesson we will be learning:

4 - How Boyle's and Charles's Laws, individually and combined, are related to the Ideal Gas Law (PV=nRT).

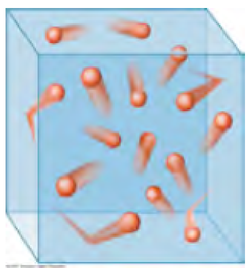
6 - I can perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

5 - How to express pressure in a variety of ways including kilopascals, atmospheres, and millimetres of mercury.

Nov 29-9:43 AM

Avogadro's observations provide the last piece of data we need to create a link between pressure, temperature, volume, and number of gas molecules.

To create a link between the macroscopic (what we see), and particulate (what the particles are doing) worlds of gases!



Particulate model

Macroscopic behavior

Dec 10-6:49 PM

The ***Ideal Gas Law*** comes from combining the individual gas laws:

Boyle's Law $V \propto \frac{1}{P}$

Avogadro's Law $V \propto n$

Charles's Law $V \propto T$

$$V \propto \frac{1}{P} \times n \times T$$

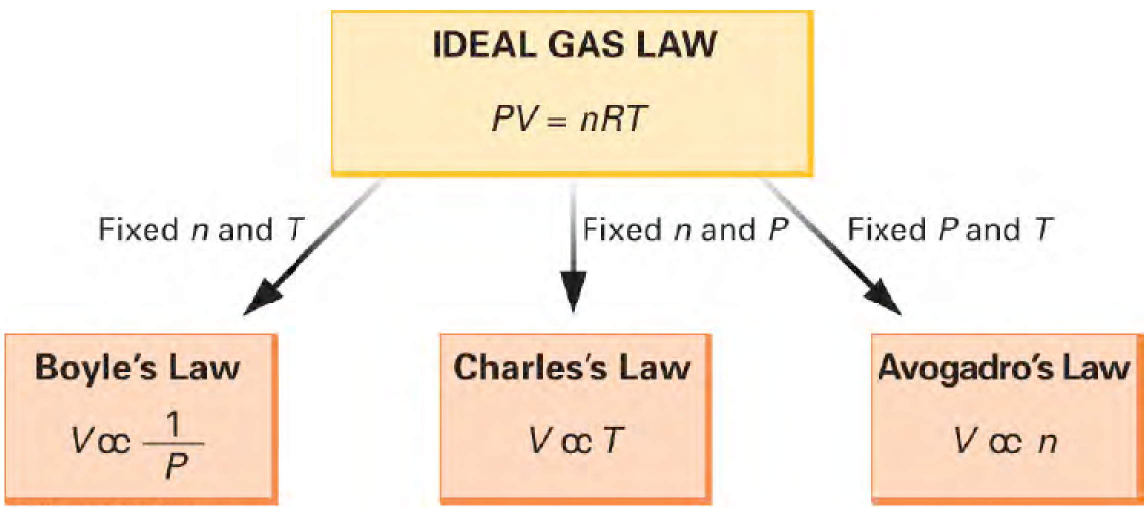
$$V = R \times \frac{1}{P} \times n \times T$$

$$PV = nRT$$

R is the universal gas constant
n is the number of moles of particles

Dec 10-6:52 PM

The other laws can be seen as simplifications of the Ideal Gas Law under specific conditions:



Dec 10-6:55 PM

We LOVE Rearranging!! :)

Rearrange PV=nRT for:

P

Dec 10-7:00 PM

We LOVE Rearranging!! :)

Rearrange PV=nRT for:

V

Dec 10-7:00 PM

We LOVE Rearranging!! :)

Rearrange PV=nRT for:

n

Dec 10-7:00 PM

We LOVE Rearranging!! :)

Rearrange PV=nRT for:

R

Dec 10-7:00 PM

We LOVE Rearranging!! :)

Rearrange PV=nRT for:

T

Dec 10-7:00 PM

The universal gas constant

- A 0.1000-mole sample of helium is placed in a piston and heated to 25.00°C (298.15 K). The volume is adjusted to 4.600 L, and the resulting pressure is measured as 0.5319 atm. Use these data to determine the value of the universal gas constant

PV = nRT

Dec 10-6:55 PM

Example: What is the pressure (atm) in a helium-filled 0.77-L balloon if it contains 1.0 g of gas at 22°C?

Dec 10-7:03 PM

Example 2:

The pressure exerted by 6.04 mol of nitrogen monoxide at 18 ºC is 17.2 atm. What is the volume of the gas in liters?

Dec 10-7:04 PM

Example 3:

At what temperature (ºC) will 0.810 mol of chlorine in a 15.7 L vessel exert a pressure of 2 atm ?

Dec 10-7:04 PM

Example 4:

What is the volume of one mole of gas (the molar volume) at 11°C and 1.33 atm?

Dec 10-7:04 PM

Example 5:

Find the density of helium at SATP, to two decimal places.
Note: for gases, density is usually in g/L.

Dec 10-7:04 PM

Practice / Homework:

Page 141 Questions 10-16

Answers Page 730

Dec 10-7:06 PM

Let's Recap!

4 - I can illustrate how Boyle's and Charles's Laws, individually and combined, are related to the Ideal Gas Law (PV=nRT).

6 - I can perform calculations, based on the gas laws, under STP, SATP, and other defined conditions.

5 - I can express pressure in a variety of ways including kilopascals, atmospheres, and millimetres of mercury.

Nov 29-9:43 AM

Lesson 4: Dalton's Law of Partial Pressures

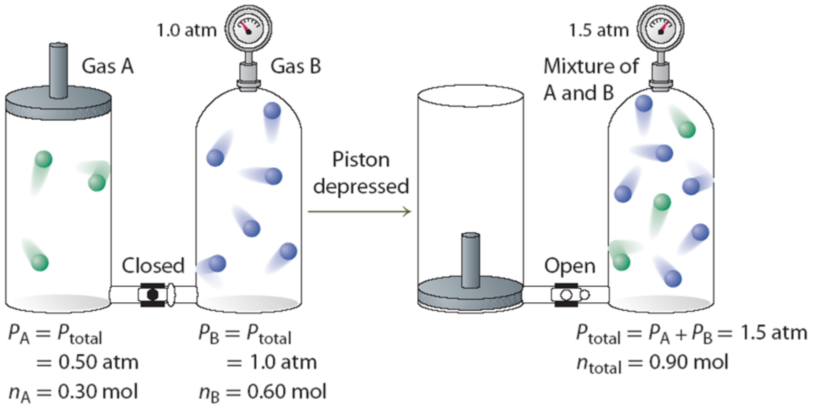
In this Lesson we will be learning:

5 - How to express pressure in a variety of ways including kilopascals, atmospheres, and millimetres of mercury.

Nov 29-9:43 AM

Dalton's Law of Partial Pressures states:

In a mixture of gases that do not react chemically, the total pressure is the sum of the partial pressures of each individual gas.

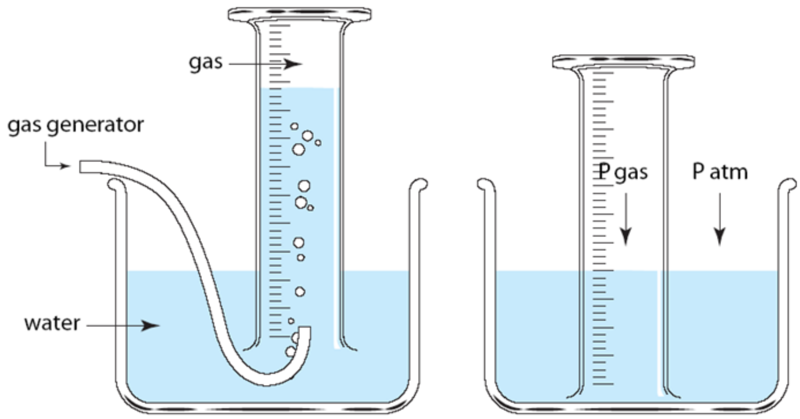


$$P_{total} = P_{gas\ A} + P_{gas\ B} + \ldots$$

Dec 10-7:18 PM

When you collect a gas by displacement of water, you must account for the partial pressure of the water vapour when determining the pressure of the collected gas by using the equation:

$P_{total} = P_{gas} + P_{water\ vapour}$



Dec 10-7:21 PM

Ideal Gases and Real Gases

Real gases behave non-ideally under the following conditions:

1. Low temperatures

Molecules don't have enough kinetic energy to overcome the attractive forces among the molecules

2. High pressure

Molecules are so close together that collisions occur frequently and cause the measured pressure to be low

Molecules are so close together that they take up a significant percentage of the volume, making volume measurements too large

Dec 10-7:22 PM