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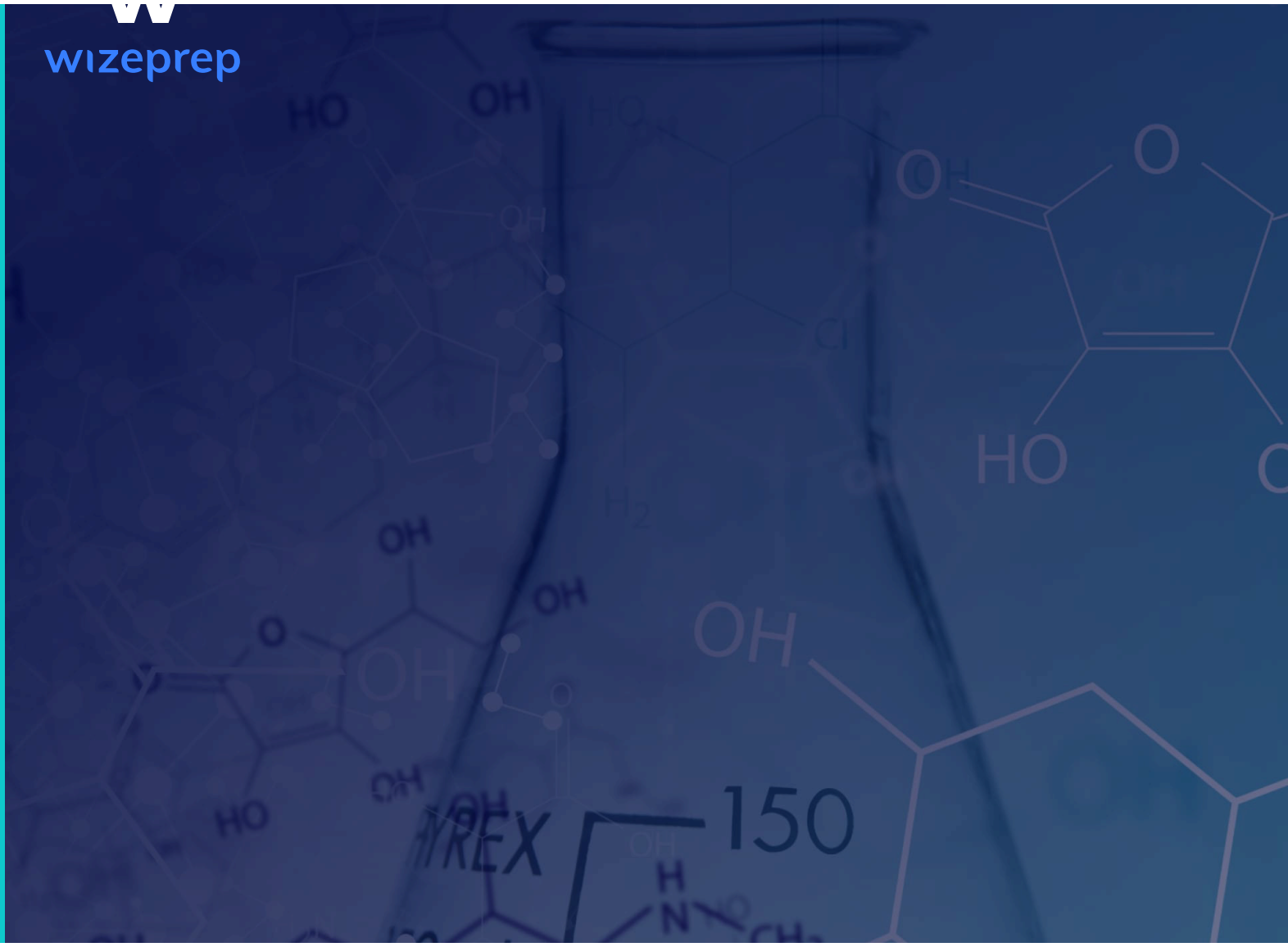

Ontario High School
Grade 11 Chemistry

Summer 2024, Chapter 9 Notes

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Dana 4.4/5 ⭐
MSc

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9. Gas Laws

9.1 Introduction to Gas Laws

9.1.1

Measurable Properties of Gases

Volume

- Gases completely fill the container they are placed in; as such when we talk about the volume of a gas we refer to the volume of the container the gas is found in



- SI unit for volume is **meter cubed**

$$\boxed{1m^3 = 1000L}$$

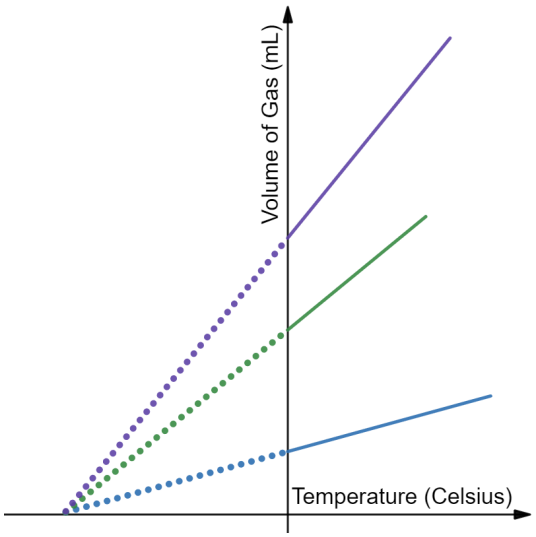
Temperature

- SI unit for temperature is **Kelvin**

$$\boxed{T\,(K) = \ T\,(^{\circ}C) + 273.15}$$

Absolute Zero

- **Absolute zero** is the temperature at which the volume of a gas is zero.
- All gases if cooled sufficiently will start to liquify
- The volume of different gases were measured while changing temperature, but keeping pressure constant.
- When those data points were plotted and the lines extrapolated, it was found that they all intercept the temperature axis at the same point



Pressure

- **Pressure** is a force that acts on a 2-D sheet, typically through the collision of atoms against that surface.

$$\boxed{P = \frac{F}{A}}$$

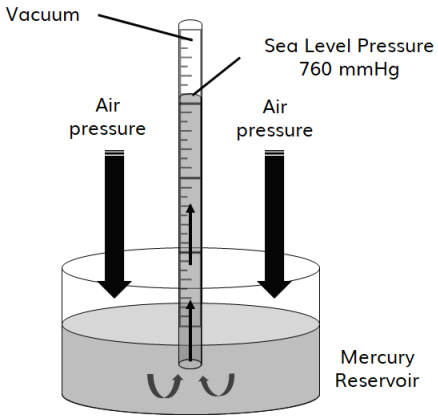
- SI unit of pressure is **the pascal**

$$\boxed{1 \ \frac{N}{m^2} = 1 \ Pa}$$

Atmospheric Pressure

- Gas particles in Earth's atmosphere exert a pressure on Earth's surface; this is known as **atmospheric pressure**
- Atmospheric pressure can be measured using a barometer
- The atmospheric pressure measured at sea level is **760mmHg** (millimeters mercury) or **1atm** (atmosphere)
- To convert between units of pressure:

$$\boxed{1\text{atm} = 760\text{mmHg} = 760\text{Torr} = 101325\text{Pa}}$$



STP and SATP Conditions

- STP = Standard Temperature and Pressure
  - T= 0°C
  - P = 101.325kPa
- SATP = Standard Ambient Temperature and Pressure
  - T= 25°C
  - P = 100kPa

Watch the video tutorial for this lesson (08:18)

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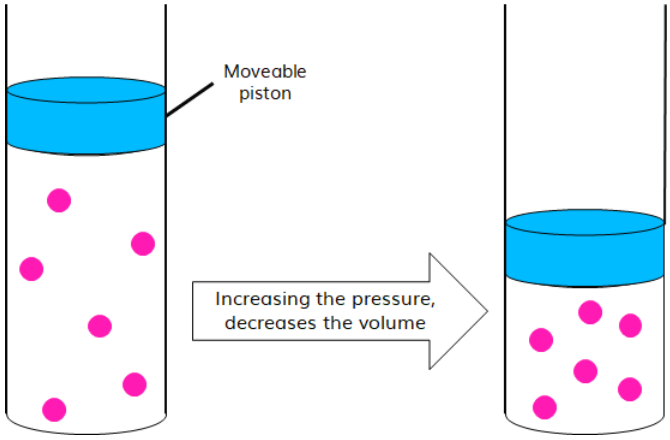
9.1.2

Gas Laws

Boyle's Law

- At constant temperature for a fixed amount of gas, the volume is inversely proportional to the pressure $\left(P \propto \frac{1}{V}\right)$

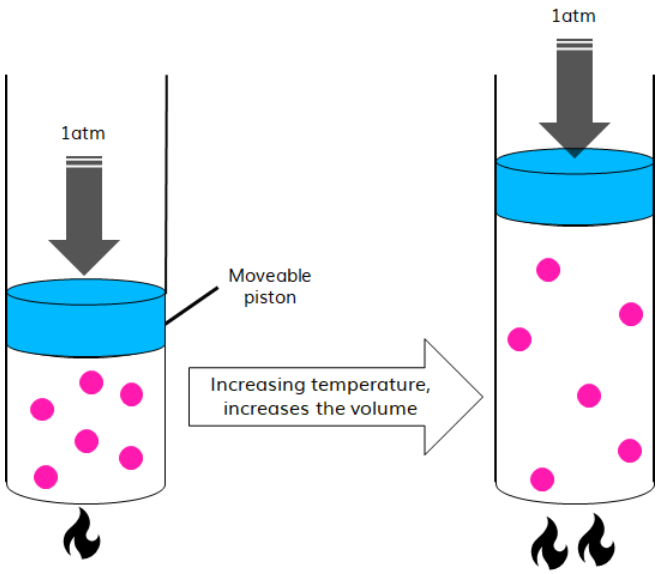
$$\boxed{P_1V_1 = P_2V_2}$$



Charles' Law

- At constant pressure for a fixed amount of gas, the volume increases with increasing temperature $(V \propto T)$

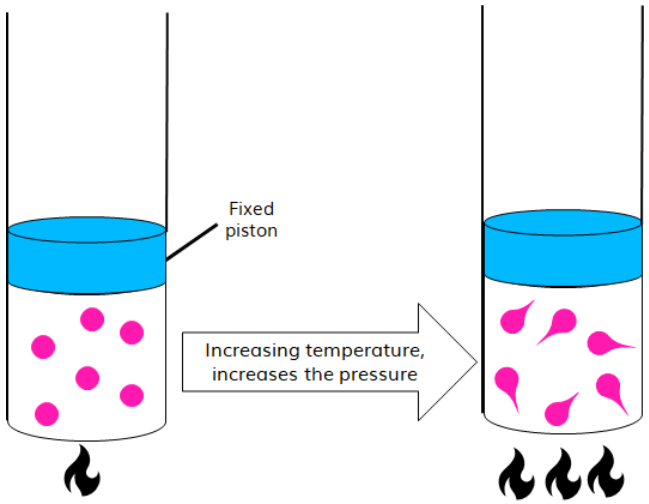
$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$



Gay-Lussac's Law

- At constant volume for a fixed amount of gas, the pressure is proportional to the absolute temperature $(P \propto T)$

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



The Combined Gas Law

- For a fixed amount of gas, the ratio $\frac{PV}{T}$ is constant:

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

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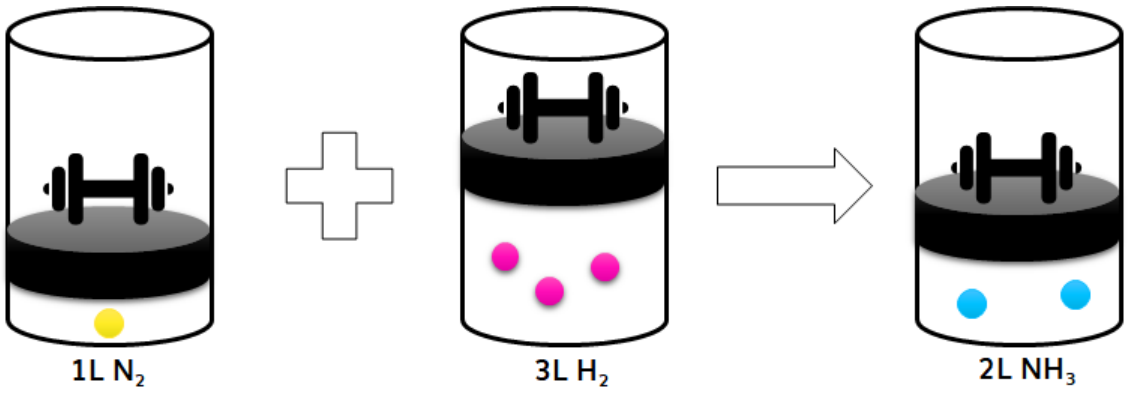
9.1.3

Molar Volume

Law of Combining Volumes

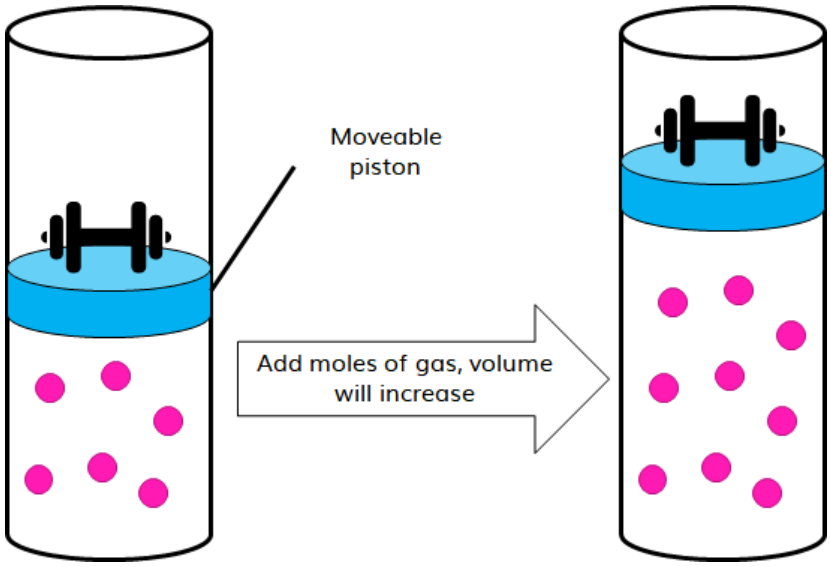
- Volumes of gases react in whole number ratios only, when reactions are carried under conditions of constant temperature and pressure.



Avogadro's Law

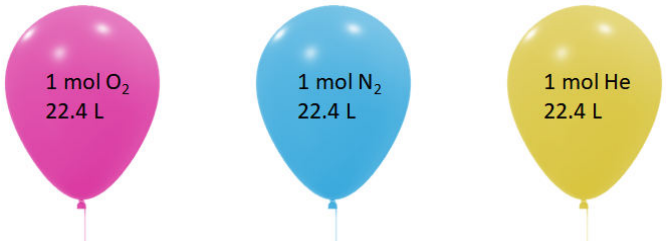
- At a given pressure and constant temperature, equal volumes of gas contain the same number of molecules ($V \propto n$)

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



Molar Volume

- **Molar volume** is the volume occupied by 1mol of any gas at a specified temperature and pressure
  - Under STP conditions, one mole of any gas occupies 22.4L



  - Under SATP conditions, one mole of any gas occupies 24.8L

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9.1.4

Example: Pressure Conversions

The atmospheric pressure at an altitude of 15000m above sea level is 429mmHg. What is this pressure in atm? What about kPa?

Solution available online

Watch the video tutorial for this lesson (02:54)

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9.1.5

Example: Gas Laws

Suppose we have a gas in a flexible container that can expand or contract. How will the volume of the container be affected by the following changes? Assume the amount of gas is kept constant.

1. Pressure is doubled at constant temperature
2. Temperature is doubled at constant pressure

Solution available online

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9.1.6

Example: Molar Volume

You have two vessels, one containing 0.5mol of He and the other containing 0.5mol of Xe. Both gases are at a temperature of 93.8K and under a pressure of 132kPa. Answer the following questions:

1. Which vessels contains more atoms of gas?

Solution available online

2. Which gas has the greater volume?

Solution available online

3. Which gas has the greater mass?

Solution available online

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Practice: Gas Laws

Boyle's law states that the product of the volume and pressure of a gas is constant if which of the following variables is constant?

- number of moles, mass of the gas
- the gas constant, the molecular weight
- the number of moles, the temperature
- all of the above

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9.1.8

Practice: Stoichiometry and Molar Volumes

Suppose that 12.0L of hydrogen gas reacts with excess nitrogen gas to make ammonia gas, all at the same temperature and pressure. What volume of ammonia is expected from this reaction? Give your answer to one decimal point; do not include units

Answer

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9.1.9

Which of the following relationships is/are CORRECT for gases?

- [ ] The amount of a gas (in moles) is inversely proportional to its volume (at constant temperature and pressure).
- [ ] The volume of a gas is directly proportional to its temperature in kelvin (at constant pressure and moles).
- [ ] The pressure of a gas is inversely proportional to its temperature in kelvin (at constant volume and moles).

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9.1.10

Practice: Combined Gas Law

A 5.0L sample of gas is collected at 400mmHg and 727°C. What is the volume if the temperature were cooled to 77°C and the pressure increased to 700mmHg?

- 2.5L
- 250mL
- 2.0L
- 50L
- 1.0L

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9.1.11

Practice: Gases and Limiting Reagents

What volume, in L, of hydrogen gas at STP will be produced when 50g of aluminium is added to 1.00L of 1.5mol/L sulfuric acid? Round your answer to the nearest integer; do not include units in your answer.

Answer

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9.2 Ideal Gases

9.2.1

Ideal Gases and the Ideal Gas Law

Ideal Gas Law

- Combining Boyle's Law, Charles' Law and Avogadro's Law gives us the ideal gas law

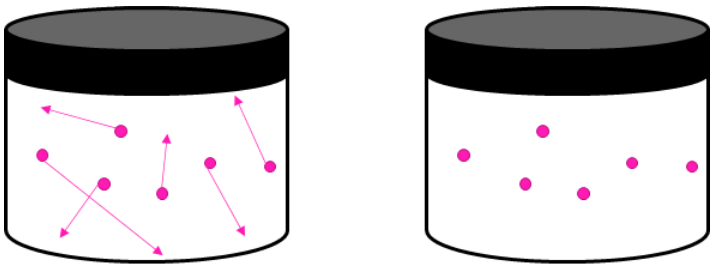
$$\boxed{PV = nRT}$$

P is **pressure** measured in **kPa**
V is **volume** measured in **L**
n is **number of moles** of the gas in **mol**
R is the **ideal gas constant** with a value of **8.314 L kPa mol^{-1} K^{-1}**
T is **temperature** measured in **K**

- There are other values of R involving other units, such as 0.08206 L atm mol^{-1} K^{-1}

Ideal Gases Assumptions

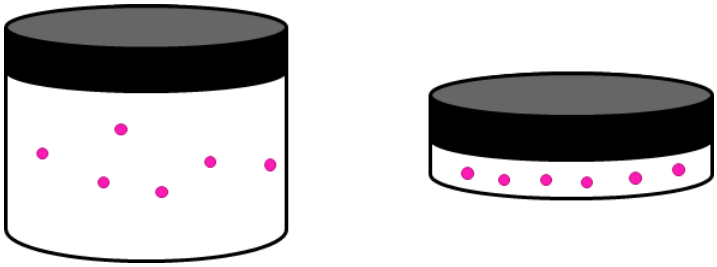
- Ideal gas particles are in constant, random, straight motion
- Ideal gas particles occupy a negligible portion of the total volume of the container - their individual contribution may be ignored



- Ideal gas particles collide elastically with themselves and the walls of the container; there is no loss of kinetic energy
- Ideal gas particles do not attract, nor repel each other

Deviations from Ideal Gas Behavior

- In reality, no gas behaves ideally.
- Gases behave most ideally at:
  - High temperatures: collisions between particles are elastic
  - Low pressures: particle size is negligible compared to the space between particles
- Ideal gas behavior breaks at:
  - Low temperatures: low molecular speed, collisions are no longer elastic
  - High pressures: volume of the individual gas particles no longer negligible



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9.2.2

Example: Using the Ideal Gas Law

1.1moles of Argon are stored in a 2.0L container kept at 10°C. What is the pressure of this gas in kPa?

Solution available online

Watch the video tutorial for this lesson (03:32)

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9.2.3

Example: Gas Stoichiometry

The first recorded observation of hydrogen gas was made by the famous alchemist Paracelsus when he added iron to sulfuric acid. Calculate the volume of hydrogen gas at STP produced by adding 10.0g of iron to an excess of sulfuric acid.

$$2Fe(s) + 3H_2SO_4(aq) \rightarrow 3H_2(g) + Fe_2(SO_4)_3(aq)$$

Solution available online

2.

3.

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9.2.4

Practice: Ideal vs Real Gases

Real gas behaviour deviates from ideal gas behaviour because real gas particles have:

- no volume and no attraction for each other
- no volume but some attraction for each other
- volume, but no attraction for each other
- volume and some attraction for each other

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9.2.5

Answer the following two questions based on the Ideal Gas Law:

Part 1

What is the volume of 2.5mol of Ne at 298K and 101.325kPa?

Enter your answer to one decimal point and make sure to include units.

Answer

Answer the following two questions based on the Ideal Gas Law:

Part 2

What is the new volume after 4.5mol of Ne are added?

Enter your answer to one decimal point and make sure to include units.

Answer

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9.2.6

Practice: Using the Ideal Gas Law

A 0.483g sample of gas occupies a volume of 0.530 L at 130°C and 109kPa. What is the molar mass of this gas? Give your answer rounded to one decimal point; do not include units.

Answer

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9.3 Gas Mixtures

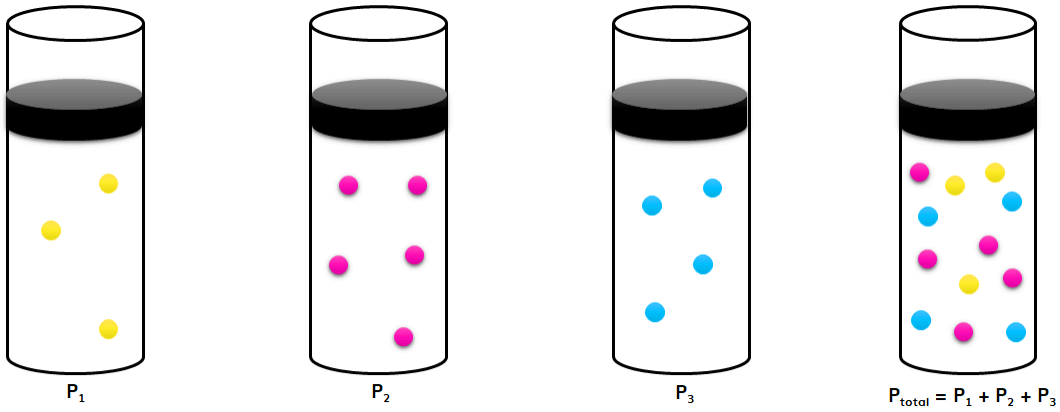
9.3.1

Dalton's Law of Partial Pressures

- Gases mix in a homogeneous manner due to their low particle density.
- If we assume ideal behavior, then the gas particles are not interacting with each other.
- The partial pressure of a gas is the pressure that the gas would exert if it were the only gas present in the mixture
- This means that each gas in the mixture will have its own contribution total pressure of the system

$$P_{tot} = P_1 + P_2 + P_3$$

- This is known as **Dalton's Law of Partial Pressures**



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9.3.2

Example: Gas Mixtures

If a gas sample is 1/3 oxygen and 2/3 argon with a total pressure of 120 kPa, what is the pressure of each gas?

Solution available online

Watch the video tutorial for this lesson (01:18)

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9.3.3

Practice: Gas Laws Definitions

Match the following terms and definitions.

A. The volume of a fixed amount of gas varies directly with the temperature at constant pressure

B. The total pressure of a mixture of gases is equal to the sum of the partial pressures of the component gases.

C. The volume of a fixed amount of gas varies inversely with the pressure at constant temperature.

D. At constant temperature and pressure, the volumes of gaseous reactants and products can be expressed as ratios of small whole numbers.

E. The relationship between pressure, volume, and temperature is expressed by this law.

F. The pressure of a fixed amount of gas varies directly with the kelvin temperature at constant volume

G. Equal volumes of gases at the same temperature and pressure contain equal amounts of gas.

Dalton's Law

Charles' Law

Gay-Lussac’s Law

Boyle’s Law

Combined Gas Law

Law of Combining Volumes

Avogadro's Law

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9.3.4

Practice: Dalton's Law of Partial Pressures

Gas samples A, B and C are contained in a system at STP. The partial pressure of sample A is 40.8kPa and the partial pressure of sample B is 25.3kPa. What is the partial pressure of sample C?

- 101.325kPa
- 33.9kPA
- 35.2kPa
- 40.8kPa

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9.3.5

Practice: Gas Mixtures

Hydrogen and helium were mixed together in a 5L vessel at 243K to create a total pressure of 942kPa. If there are two moles of hydrogen in the mixture, what is the partial pressure of helium? Give your answer in kPa rounded to the nearest whole integer; do not include units

Answer

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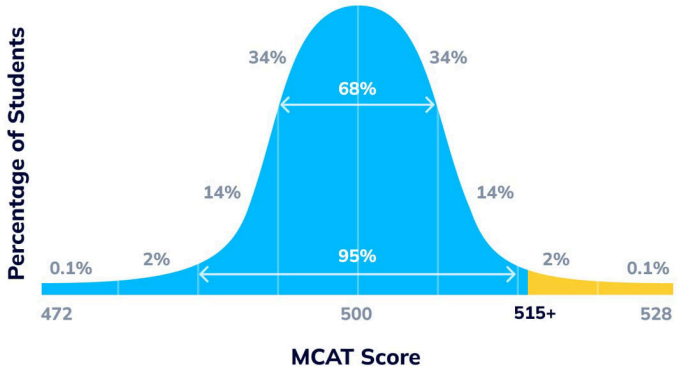

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