Lesson 2:The gaseous State

Lesson objective :

At the end of the lesson, you will be able to :

- Describe the properties of gases using the kinetic molecular theory
- Describe the behavior of gases by using the variables V (volume), T (temperature), P (pressure) and n (number of moles)
- State Boyle’slaw.
- Perform anactivity to show changes in volume and pressure of gases to illustrates Boyle’s law.
- Apply Boyle’slaw in solving problems
- The Gaseous State
- State Charles’law
- Conduct anactivity to toshow changes in volume and temperature of gases to illustrate Charles’ law
- Apply Charles’lawinsolving problems
- UseGay-Lussac’slawinsolvingproblems
- Derive the combined gas law equation from Boyle’s law, Charles’law, and Gay-Lussac’s law
- Use the combined gaslawto calculate changes involume,pressure or temperature
- Define an ideal gas
- Derive an ideal gas equation from Boyle’slaw,Charles’law and Avogadro’s law
- Compare the nature of real gases with ideal gases olive problems related to the ideal gas equation
- Define diffusion.
- Dtate Graham’s law of diffusion
- Carryout an activity to to compare the rate of diffusion of two different gases.
- Apply Graham’slaw of diffusion.

Brainstorming Questions

Consider three water samples that are taken in containers: A, B, and C. The three water samples are kept at different temperatures: 120 ℃, 20 ℃, and -10 ℃, respectively, and under constant atmospheric pressure.
a. Which sample molecule has the highest kinetic energy?
b. Which sample has the greatest density?
c. Which sample has the most regular arrangement of molecules?

key terms/ Concepts

- Gas laws
- Ideal gas equation
- Grahams laws

- Charles Law

Gas laws are a set of fundamental principles that describe the behavior of gases under different conditions of pressure, volume, and temperature. These laws are derived from experimental observations and are crucial for understanding and predicting the properties and behavior of gases. The main gas laws include: Boyles, combined , ideal gad law……

3.4 The gaseous State

3.4. 1 The kinetic molecular theory of gases Assumption

i) Gas particles are in a state of constant, continuous, rapid, random motion and, therefore, possess kinetic energy.

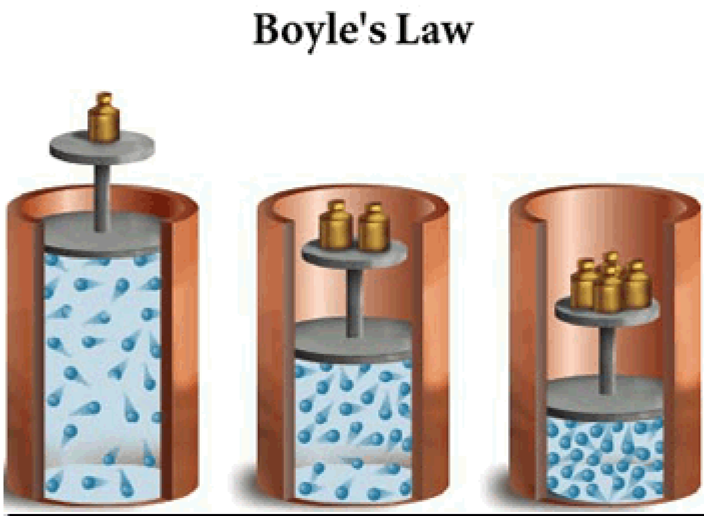
- The motion is constantly interrupted by collisions with molecules or with the container.
- The pressure of a gas is the effect of these molecular impacts.
  ii. The volume of the particles is negligible compared to the total volume of the gas.
  Gases are composed of separate, tiny invisible particles called molecules.
  Since these molecules are so far apart, the total volume of the molecules is extremely small compared with the total volume of the gas.
  Therefore, under ordinary conditions, gas consists of empty space.
  This assumption explains why gases are so easily compressed and why they can mix so readily
- III)The attractive forces between the particles are negligible.
  There are no forces of attraction or repulsion between gas particles.
  You can think of an ideal gas molecule as behaving like small billiard balls.
  When they collide, they don't stick together but immediately bounce apart.
  iv. The average kinetic energy of gas particles depends on temperature of gases.
  At any particular moment, the molecules in a gas have different velocities.
  The mathematical formula for kinetic energy is:
  K.E. = $\frac{1}{2}mv2$
  where m is mass and v is velocity of gas molecules.
  Because the molecules have different velocities, they have different kinetic energies.
  However, it is assumed that the average kinetic energy of the molecules is directly proportional to the absolute (Kelvin) temperature of the gas

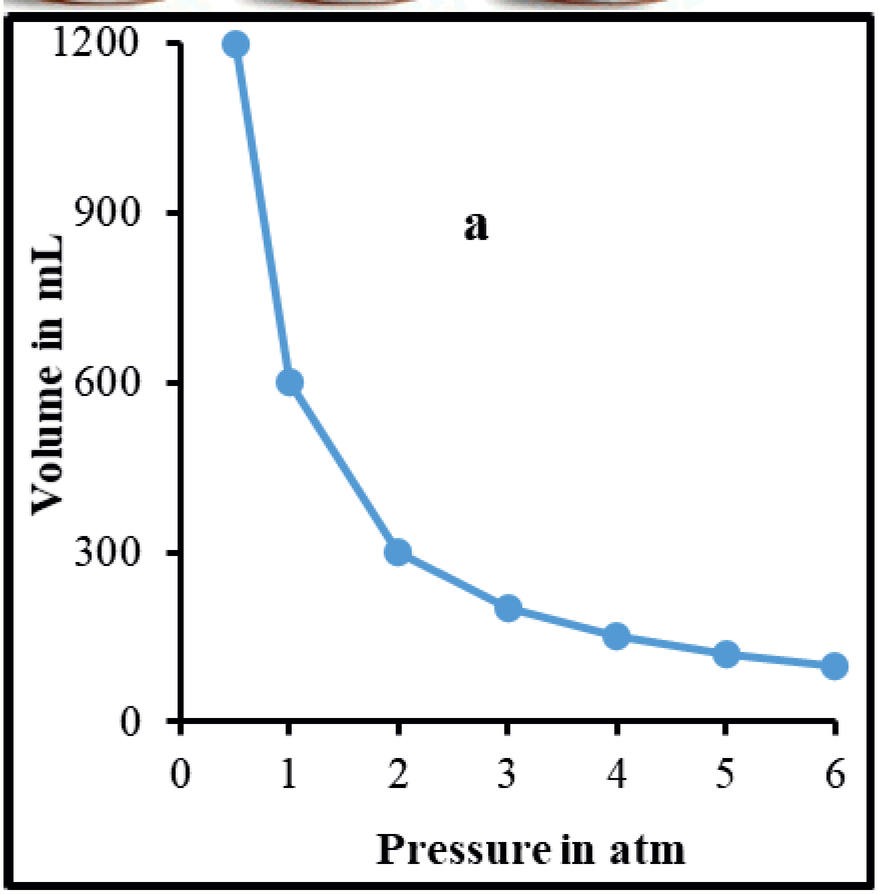
3.4.2 The Gas Laws

- The gas laws are the products of many experiments on the physical properties of gases, which were carried out over hundreds of years ago.
  Simple mathematical equations can be derived that relate a gas's volume, pressure and temperature.
  $PV = nRT$ Ideal Gas Equation

These equations are called state equations because they describe mathematical relationships between the volume, temperature, pressure, and quantity of a gas (number of moles.
1.Boyles law

- Boyle’s law states that the volume of a fixed mass of gas is inversely proportional to the pressure at a constant temperature.
  Mathematically given as:
  If P1 and V1 represent the initial conditions; and P2 and V2 represent the new or final conditions, Boyle’s law can be written as:
  P1V1 = P2V





Example 1
An inflated balloon has a volume of 0.55 L at sea level (1.0 atm) and is allowed to rise to a height of 6.5 km, where the pressure is about 0.40 atm.
Assuming that the temperature remains constant, what is the final volume of the balloon?
Solution:
Givens: Initial conditions Final conditions
P_1 = 1.0 atm P_2 = 0.40 atm

$V_1 = 0.55$ L $V_2 = ?$ $V_2 = P_1V_1/P_2$
$V_2 = 0.55$Lx $1/0.4 = 1.4$L
2. Charles Law

The French physicist, Jacques Charles (1746-1823), was the first person to fill a balloon with hydrogen gas and made the first solo balloon flight.
Charles investigated quantitative relationship between the volume and temperature of a fixed quantity of gas which is held at constant pressure.
He stated that the volume of a fixed mass of gas at constant pressure varies directly with the Kelvin temperature.
In 1848, Lord Kelvin realized that a temperature of -273.15oC is considered as absolute zero. It is theoretically the lowest attainable temperature.
Then he set up an absolute temperature scale, or the Kelvin temperature scale, with absolute zero as the starting point on the Kelvin scale.
For example,
Doubling the Kelvin temperature causes the volume of a gas to double, and
Reducing the Kelvin temperature by half causes the volume of a gas to decrease by half.
This relationship between Kelvin temperature and the volume of a gas is known as Charles' law

$V \propto T$ *at constant* P *and* n:

$$V = kT, \quad \text{or} \quad \frac{V}{T} = k$$

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

Example
A sample of gas at 15 °C and 1 atm has a volume of 2.58 L. Whatvolume will this gas occupy at 38 °C and 1 atm?
Solution:
Given:Initialconditions:T_1=15°C=15+273=288K,V_1=2.58L
FinalConditions:T_2=38°C=311K,V_2=?
ByrearrangingCharles'equation(Equation3.9),V_2canbecalculatedas:
V=V_1T_2 = 2.58L×311K
=2.78L
T_1 288K
A sample of gas has a volume of 2.80L at an unknown temperature. When the sample is submerged in ice water at 0 °C, its volume decreases to 2.57 L. What was its initial temperature (in Kelvin's and in Celsius)? Solution:

Given:Initial conditions:T_1?,V_1=2.80L
Finalconditions:T_2=0°C=273K,V_2=2.57L
Ans T_1 = 277.43K or 24°C

3. Combined Gas Law

- Expresses the relationship between pressure,volume,and temperature of a fixed amount of gas.
- A sample of a gas often undergoes changes in temperature ,pressure,andvolume.When thishappens, the three variables must be dea lt with at the same time.

Derivation of the combined gas law:

Boyle'slaw:V α1/P and Charles'law:

then VαTThen,V T/P (combined)

- V = kT/P (where k is a constant)Itfollows,
- P_1V_1/T_1=kand P_2V_2/T_2=K

the combined gas law equation is given as follows:

$P_1V_1/T_1=P_2V_2/T_2=$
eg. If 50cm3 of gas sample of gas exert a pressure of 60kpa at 35 degree celicieswhat is the volume at STP?

Solution:
GivenV_1=50cm3, P_1=60kpa, T_1=35OC=308K V_2=?
atSTP, P_2=1atm =101325pa=101.325kpa,T_2= 0oc=273K
$P_1V_1=P_2V_2$
V_2=26.243cm3
4.Avogadro'slaw:

states that the volume of the gas is directly proportional to the number of mole of gas,when the tempreture and pressure are held constant.

Mathematically,Vαn;whereVis thevolumeand n isnumber ofmoles.

Commonexampleofavogadro'slawisthedeflationofautomobiletires.

5 The Ideal Gas Equation

- Hypothetical gas that obeys the gaslaws.Realgasesonlyobeytheidealgaslaws closelyat high temperature and low pressure.Theideal gaslawis acombinationof
- Boyle'slaw,
- Charles'lawand

- Avogadro’slaw.
  VαnT
  V = k1/p
  PV =nRT

  6. Grahams Law

Mathematically it can be expressed as: $r \propto \sqrt{\frac{1}{d}}$ or $r \propto \sqrt{\frac{1}{M}}$

Rearranging these relationships gives the following expression $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$ *or* $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$:

Summary

Certainly! Here’s a brief summary of the gaseous state and t

Gaseous State:

1. Gases are one of the three classical states of matter (alongside solids and liquids). Gases have:
- No fixed shape or volume; they expand to fill the container they are in Particles that are far apart and move rapidly in random directions.
- Low density compared to solids and liquids.
1. **Behavior**: Gases are highly compressible and can be easily expanded or compressed by changes in pressure and temperature. They also exhibit fluidity, meaning they can flow and diffuse to mix uniformly with other gases.
2. **Ideal Gas Assumption**: The behavior of ideal gases is governed by ideal gas laws under specific conditions:
- Low pressure (compared to atmospheric pressure).
- High temperature (compared to the boiling point of the substance).
- Negligible intermolecular forces between gas particles.

Gas Laws

Boyle’s Law
- At constant temperature, the volume of a given amount of gas is inversely proportional to its pressure ,(P1 V1 = P2 V2)
- **Implication**: As pressure increases, volume decreases proportionally, and vice versa.

Charles’s Law

At constant pressure, the volume of a given amount of gas is directly proportional to its absolute temperature , V1T2=V2T

Gay Lussac’s Law

- **Statement**: The pressure of a given amount of gas at constant volume is directly proportional to its absolute temperature, P1T2= T1P2
- **Implication**: As temperature increases, pressure increases proportionally, and vice versa.

Combined Gas Law
Combination of Boyle’s , Charles , Lussac law

Ideal Gas law

- Describes the behavior of an ideal gas under all conditions of temperature, pressure, and volume.
- Mathematical expression ($PV = nRT$)
  - (P): Pressure of the gas
  - (V): Volume of the gas
  - (n): Number of moles of gas
  - (R): Ideal gas constant
  - (T): Temperature of the gas in Kelvin
- **Implication**: Ideal gases follow this equation under all conditions, while real gases may deviate under certain circumstances (high pressure or low temperature).

Applications:

- Gas laws are foundational in chemistry, physics, engineering, and meteorology.
- They are used to predict and understand the behavior of gases in various systems and processes.
- Gas laws are applied in designing gas storage and transport systems, studying atmospheric dynamics, and developing technologies such as refrigeration and air conditioning.