WHAT WE ALREADY KNOW
MOVEMENT OF PARTICLES

Matter can be found in 3 states, namely solid, liquid and gas. The kinetic theory of Matter explains the properties of matter in each of the states.

1. All matter consists of small particles.
2. These particles are in constant motion. This motion is described as Brownian Motion (random movement).
3. There are empty spaces between the particles.
4. There are attractive and repulsive forces between the particles.
5. The particles collide elastically with each other and with the sides of the container.
6. Average kinetic energy of all the particles is constant even though at any given time, the speed and energy of each particle differs.

Remember – Gases can be compressed and can undergo diffusion.
ENERGY AND TEMPERATURE

\[ T \propto \text{average } E_K \]

\[ T \propto \frac{1}{2}mv^2 \]

Heat gas – temperature increases – kinetic energy of molecules increase – speed of individual particles increase - more intense collisions – increase in reaction rate of particles.
THREE MEASURABLE VARIABLES OF GASES

• Temperature (T)- A measure of average kinetic energy.

• Volume (V)- The space occupied by the gas in the container.

• Pressure (p)- The outward force per unit area applied by gas when the gas particles collide with the container walls.
THE IDEAL GAS MODEL

Ideal gases are theoretical gases that obey the gas laws under all conditions of temperature and pressure.

Properties of an ideal gas:
- The particles of a gas are all identical and in constant motion.
- The volume of the gas is due to the motion of the particles as the particles have no volume themselves.
- The intermolecular forces between gas particles are negligible.
- All collisions are perfectly elastic.
Real gases do not actually have these properties. Real gases deviate from ideal gases at:

- Low temperature
- High Pressure

AT LOW TEMPERATURE:

- Gas particles move much slower, decreasing the number of collisions between the particles and the container walls. Pressure of the gas is lower than expected.

- Attractive forces are stronger due to the particles being closer together and moving slower. The gas is more likely to become a liquid and the volume is greater than expected.

TB pg. 94 & 95
Ideal Gas model

Real gases do not actually have these properties. Real gases deviate from ideal gases at:

- Low temperature
- High Pressure

AT HIGH PRESSURE:
- The volume of the gas particles become significant in relation to the container.
- Increases in the intermolecular forces between the particles due to proximity, gas will liquefy and the volume is larger than expected.

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Ideal Gas model

So... when do real gases behave like ideal gases?

At:

- High temperatures
- Low Pressures

A funny gas?

He He He
Homework

Exercise 8
Understanding the relationship between gas volume and pressure

Pressure can be defined as the force that is applied per unit of area.

\[ P = \frac{F}{A} = \frac{N}{m^2} = Pa \]

The pressure that the gas exerts on the walls of the container is caused by gas particles colliding with the wall.

- Increasing container size (by increasing the volume) \( \rightarrow \) gas particles have more room to do their thing without hitting the walls as often \( \rightarrow \) decreases the pressure.

- Decrease container size \( \rightarrow \) gas particles will run into the walls more often \( \rightarrow \) increasing the pressure.

Don’t forget STP

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Standard Pressure</td>
<td>101.3 kPa</td>
<td>kilopascal</td>
</tr>
<tr>
<td></td>
<td>1 atm</td>
<td>atmosphere</td>
</tr>
<tr>
<td>Standard Temperature</td>
<td>273 K</td>
<td>kelvin</td>
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<tr>
<td></td>
<td>0°C</td>
<td>degree Celsius</td>
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TB pg. 99
The Ideal Gas Laws

- Boyle’s law
- Charles’s law
- Gay-lussac’s law
- Ideal gas equation

Robert Boyle

Jacques Charles
Boyle’s Law

The volume of an enclosed gas is inversely proportional to the pressure of the gas if the temperature remains constant.

\[ P_1 V_1 = P_2 V_2 \quad V \propto \frac{1}{P} \quad \text{(constant } T) \]

The temperature remains constant, therefore the average \( E_k \) of the particles remains the same. If the volume decreases, more collisions would take place and the pressure would increase.
Graphs that represent Boyle’s Law

The volume of an enclosed gas is inversely proportional to the pressure of the gas if the temperature remains constant.

\[ V \propto \frac{1}{p} \]

\[ TV \]
Examples of Calculations

A balloon has a volume of 1000 cm³ at a pressure of 60 kPa. If the pressure on the balloon changes to 100 kPa, calculate the new volume of the balloon.

\[ p_1V_1 = p_2V_2 \]

\[ (60)(1000) = (100)V_2 \]

\[ V_2 = 600cm^3 \]
Mercury barometer. Measures atmospheric pressure.

Bourdon gauge. Measures gas pressure.

Altimeter. Measures height above sea level.
Homework

Exercise 9

TB pg. 104-106
Temperature time!

KELVIN TEMPERATURE SCALE

Converting from one form to another?

\[ T = t + 273 \]

\[ t = T - 273 \]

\( T \) is Kelvin.

\( T \) is Celsius.
Charles’s Law

The volume of an enclosed gas is directly proportional to the temperature (in Kelvin) of the gas provided the pressure remains constant.

\[
\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad V \propto T \quad \text{(constant P)}
\]

There is a linear relationship between temperature and volume.

If you extrapolate the graph to 0 volume, the graph will cut the x axis (temp) at -273°C.
A certain sample of gas has a volume of 125 cm$^3$ at standard temperature and pressure. If the pressure of the gas remains constant but the temperature of the gas increases to 25 °C, calculate the new volume of the gas.

\[
\frac{V_1}{T_1} = \frac{V_2}{T_2}
\]

\[
\frac{125}{273} = \frac{V_2}{298}
\]

\[
V_2 = 136.45\text{cm}^3
\]
Gay-Lussac’s Law

The pressure of an enclosed mass of gas is directly proportional to the absolute temperature if the volume of the gas remains constant.

\[ \frac{p_1}{T_1} = \frac{p_2}{T_2} \quad P \propto T \quad \text{(constant V)} \]

A decrease in temperature indicates a decrease in kinetic energy. As kinetic energy decreases, so does the outward force during collisions between particles and container.
Explaining the Graphs

The graph does not cut at the origin. It cuts at -273°C.

Because the absolute zero is -273°C, a temperature scale was created where the absolute temperature is the zero point.

At 0K, no motion of molecules takes place. Temperatures lower than 0K are not possible.

Absolute zero is the lowest possible temperature that any substance can ever reach.
Examples of Calculations

Calculate the pressure of a gas at 25 °C, if originally the gas had a pressure of 200 Pa at a temperature of 100 °C.

\[
\frac{p_1}{T_1} = \frac{p_2}{T_2}
\]

\[
\frac{200}{373} = \frac{p_2}{298}
\]

\[
p_2 = \frac{200 \times 298}{373} = 159.79 \text{ Pa}
\]

\[
T_2 = 25 + 273 = 298 \text{ K}
\]
Homework

Exercise 10
Relationship between pressure, volume and temperature of a gas.

\[ \frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \]
Examples of Calculations

An air bubble at the bottom of the sea has a volume of $1.75\, cm^3$. The temperature of the water on the bottom is $5^\circ C$. The air bubbles move upwards. The temperature of the water on the surface is $12^\circ C$ and the pressure is standard atmospheric pressure. The volume of the bubbles increases to $4.2\, cm^3$ when it reaches the surface. Calculate the pressure at the bottom of the sea.

\[
\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}
\]
Homework

Exercise 11
The Ideal gas equation

By combining the gas laws and gas formulae we get the following formula:

\[ pV = nRT \]

- **pressure** \((\text{Pa})\)
- **volume** \((\text{m}^3)\)
- **mol**
- **universal gas constant** \(8.31 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}\)
- **temperature** \((\text{K})\)
Close textbooks
Derive \( pV = nRT \)

Using the above equation, derive the unit of \( R \).
Translation:

- cm$^3$ \(\div 1\,000\) \(\div 10^{-6}\)
- dm$^3$ \(\div 1\,000\)
- m$^3$

Quick facts:

- Pa \(\rightarrow\) kPa $\times 1\,000$

\[
n = \frac{m}{M}
\]

- mass (g)\(\rightarrow\) molar mass (g·mol$^{-1}$)
Examples of Calculations

Example:

Calculate the pressure exerted by 0.5 moles of helium in a container of volume 2.5 dm$^3$ at a temperature of 27°C.

$$pV = nRT$$

$$p (2.5 \times 10^{-3}) = 0.5 \times 8.31 \times 300$$

$$p = \frac{0.5 \times 8.31 \times 300}{2.5 \times 10^{-3}}$$

$$p = 498600 \text{ Pa}$$

$$p = 498.6 \text{ kPa}$$
Homework

Exercise 12