10 17 2017

OBJ: SWBAT summarize their knowledge of Redox reactions and calculate, P,V,n,and T using the gas laws.

C5: The Gas Laws

Pressure

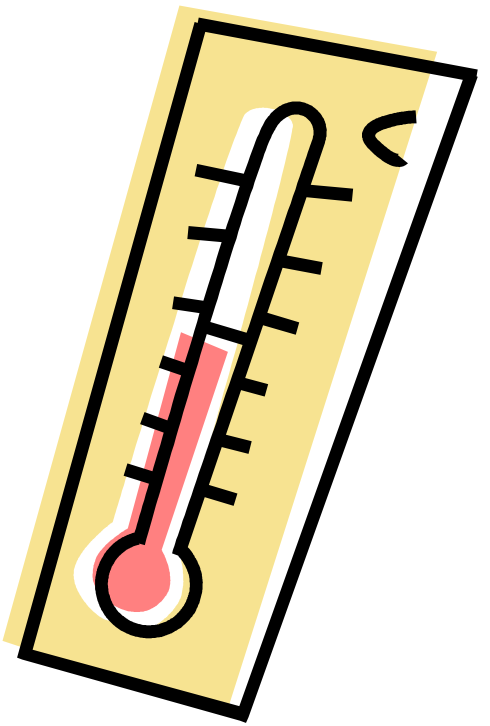
- Pressure is the result of a force distributed over an area.
- Collisions between particles of a gas and the walls of the container cause the pressure in a closed container of gas.
- The SI unit for pressure, the pascal (Pa), is shorthand for newtons per square meter.

Factors that Affect Gas Pressure:

Temperature

Volume

Number of particles



Temperature

- Raising the temperature of a gas will increase its pressure if the volume of the gas and the number of particles are constant.
  - As the temperature rises, the average kinetic energy of the particles in the air increases.
  - With increased kinetic energy, the particles move faster and collide more often with the inner walls of the tires.
  - Faster-moving particles hit the walls with greater force.
  - More collisions and increased force cause the pressure of the air in the tires to rise.

Volume

- Reducing the volume of a gas increases its pressure if the temperature of the gas and the number of particles are constant.
  - Twist the cap onto a plastic bottle and then squeeze it.   What happens?
    - The volume of the plastic bottle begins to decrease.
    - As the volume decreases, the particles of trapped air collide more often with the walls of the bottle.
    - The pressure in the bottle increases.

Number of Particles

- Increasing the number of particles will increase the pressure of a gas if the temperature and the volume are constant.
- The more particles there are in the same volume, the greater the number of collisions and the greater the pressure.

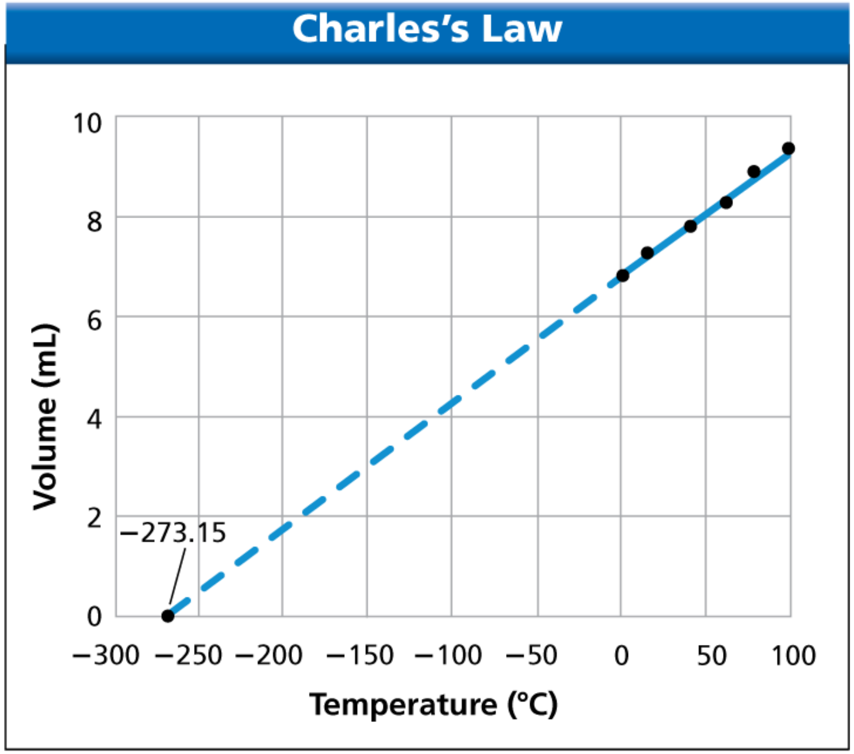
The Ideal Gas Law is the MOST important gas law because it explains all the other laws. A quick review of the other laws will be followed by the Ideal Gas Law.

Charles' Law

- French physicist Jacques Charles collected data on the relationship between the temperature and volume of gases.
- The graph of the data showed a direct relationship between the volume of a gas and the temperature of the gas.

Charles' Law

- Charles extended the graph beyond the measured data to find the temperature that would produce a volume of 0 L.
- The temperature at the point where the line crossed the *x*-axis was –273.15°C.
- This temperature is equal to 0 K on the Kelvin temperature scale.
- A temperature of 0 K is called **absolute zero.**



Charles' Law

Charles's law states that the volume of a gas is directly proportional to its temperature in kelvins if the pressure and the number of particles of the gas are constant.

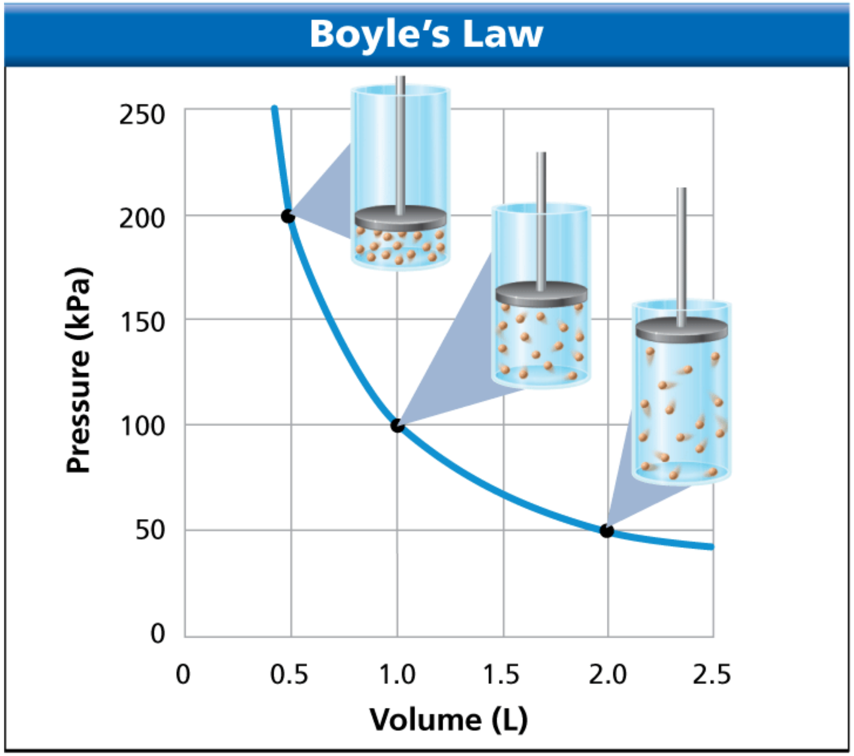
Charles's Law

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

$$V = \underbrace{\frac{nR}{P}}_{\text{A constant, K}} \times T$$

Boyle's Law

- Robert Boyle described the relationship between the pressure and volume of a gas.
- The graph shows an inverse relationship between the volume of a gas and the pressure of the gas.



Boyle's Law

Boyle's law states that the volume of a gas is inversely proportional to its pressure if the temperature and the number of particles are constant.

Boyle's Law

$$P_1V_1 = P_2V_2 \quad = K$$

$$P = \underbrace{(nRT)}_{\text{A constant, K}} \frac{1}{V}$$

The Combined Gas Law

- The combined gas law describes the relationship among the temperature, volume, and pressure of a gas when the number of particles is constant.

Combined Gas Law

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

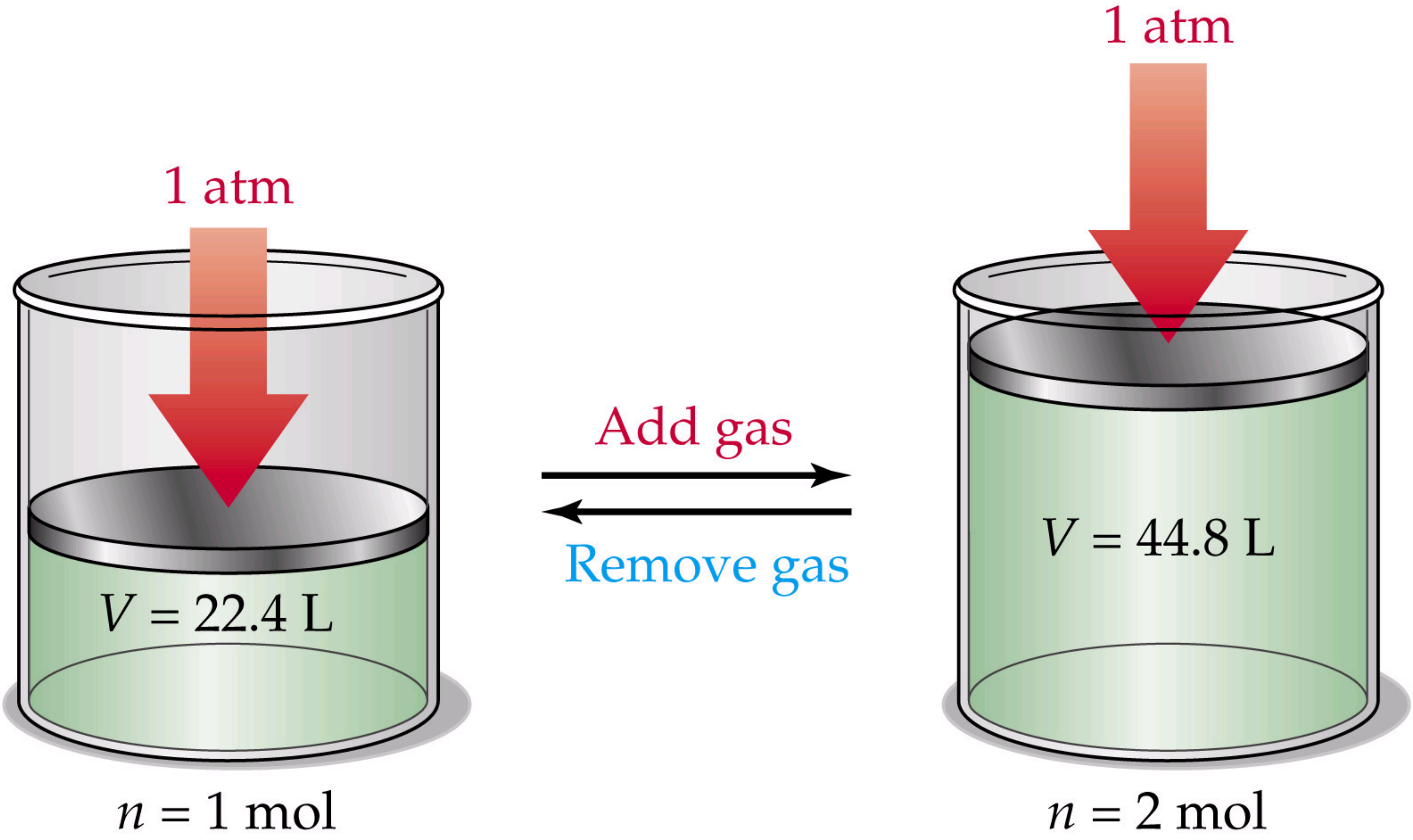
K, a constant, = n R

Avogadro's Law

Amedeo Avogadro
Physicist
Turin, Italy
August 9, 1776 – July 9, 1856

- At **constant temperature and pressure**, the **volume** of a gas is **directly related to the number of moles**.
- $V = K n$
- $V_1 / n_1 = V_2 / n_2$

Avogadro's Law: $V_1/n_1=V_2/n_2$



Gay-Lussac Law

- At **constant volume**, **pressure** and **absolute temperature** are **directly related**.
- $\mathbf{P = k\,T}$
- $\mathbf{P_1 / T_1 = P_2 / T_2}$

Joseph-Louis Gay-Lussac

Experimentalist

Limoges, France

December 6, 1778 – May 9, 1850

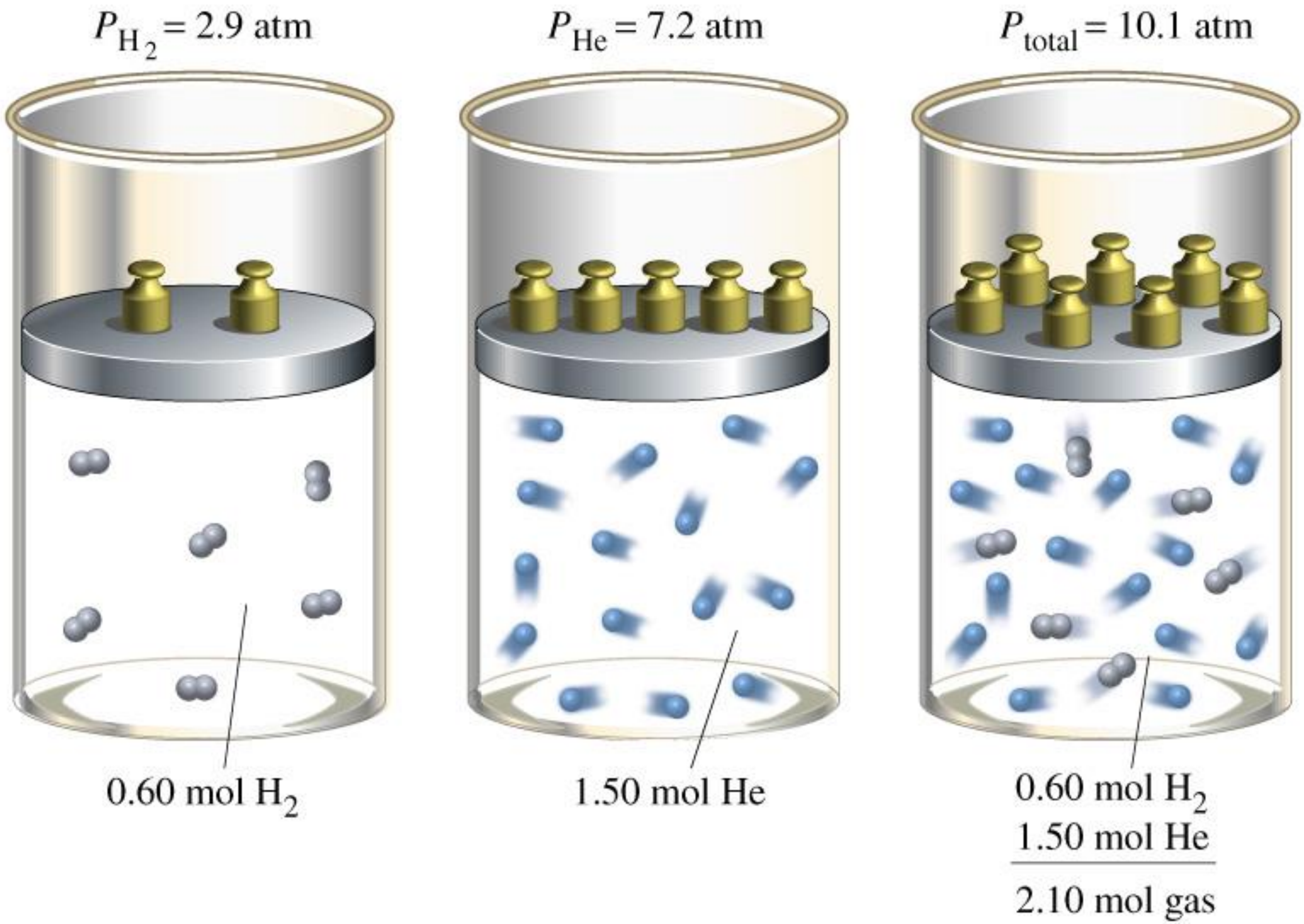
Dalton's Law

- The **total pressure** in a container is the **sum of the pressure each gas** would exert if it were alone in the container.
- The total pressure is the sum of the partial pressures.
- $P_{Total} = P_1 + P_2 + P_3 + P_4 + P_5 \ldots$

(For each gas $P = nRT/V$)

John Dalton
Chemist & Physicist
Eaglesfield, Cumberland, England
September 6, 1766 – July 27, 1844

Dalton's Law



(a) 5.0 L at 20 °C **(b)** 5.0 L at 20 °C **(c)** 5.0 L at 20 °C

Vapor Pressure

- ***Water evaporates!***
- When that water evaporates, the **vapor has a pressure**.
- Gases are often collected over water so the **vapor pressure of water** must be **subtracted from the total pressure**.

Differences Between Ideal and Real Gases

	Ideal Gas	Real Gas
Obey PV=nRT	Always	Only at very low P and high T
Molecular volume	Zero	Small but nonzero
Molecular attractions	Zero	Small
Molecular repulsions	Zero	Small

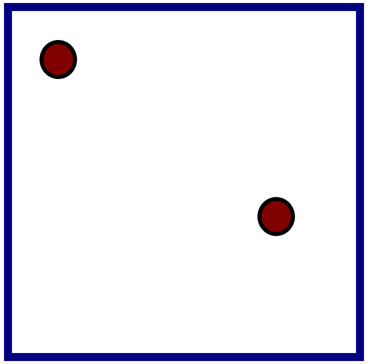
Real Gases

- **Real molecules** **do take up space** and **do interact** with each other (especially polar molecules).
- Need to **add correction factors** to the ideal gas law to account for these.

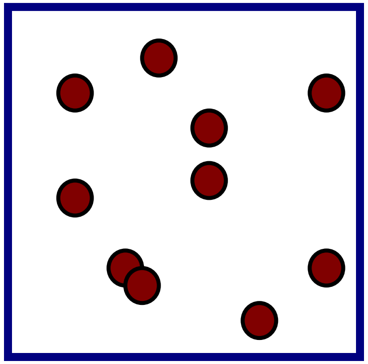
Ideally, the VOLUME of the molecules was neglected:

Ar gas, ~to scale, in a box 3nm x 3nm x3nm

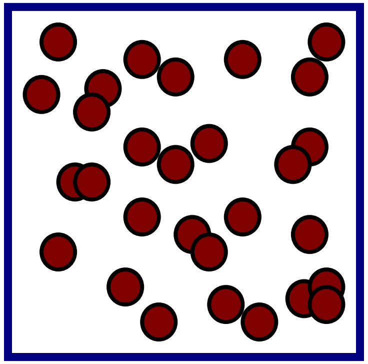
at **1** Atmosphere Pressure



at **10** Atmospheres Pressure



at **30** Atmospheres Pressure



But since real gases do have volume, we need:

Volume Correction

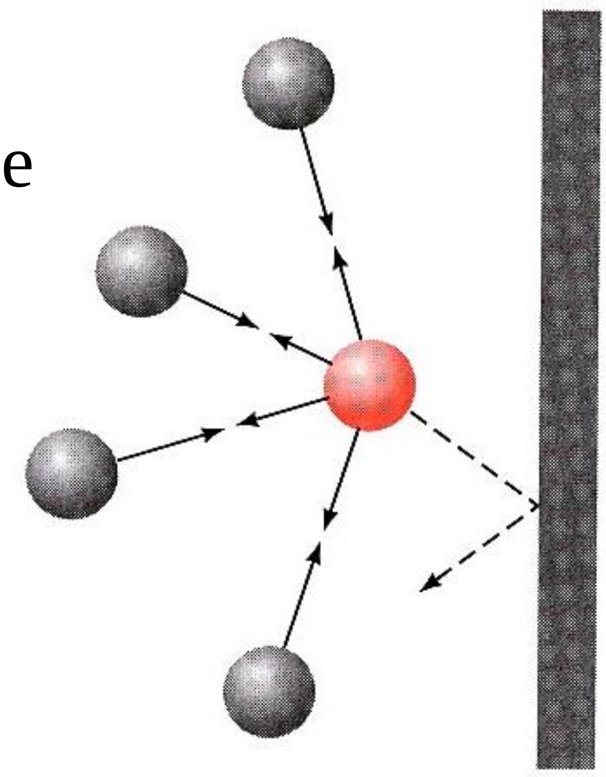
- The **actual volume** free to move in is **less** because of particle size.
- **More molecules** will have **more effect**.
- Corrected volume **$V' = V - nb$**
- "**b**" is a constant that **differs for each gas**.

Pressure Correction

- Because the **molecules are attracted** to each other, the **pressure** on the container will be **less than ideal**.

- Pressure **depends on** the **number of molecules per liter**.

- Since **two molecules interact**, the **effect must be squared**.



$$\boxed{P_{observed} = P - a\left(\frac{n}{V}\right)^2}$$

Van der Waal's equation

$$[P_{obs} + a\left(\frac{n}{V}\right)^2](V - nb) = nRT$$

Corrected Pressure **Corrected Volume**

- "**a**" and "**b**" are **determined by experiment**
- "**a**" and "**b**" are **different for each gas**
- **bigger molecules** have **larger** "**b**"
- "**a**" depends on both **size** **<u>and</u>** **polarity**

Johannes Diderik van der Waals
Mathematician & Physicist
Leyden, The Netherlands
November 23, 1837 – March 8, 1923