AL-Mustaqbal university college
Pharmacy department

Physical pharmacy I

lec2

Ghada Ali PhD candidate
ghada.ali@mustaqbal-college.edu.iq

States of matter

Part 2

Learning objectives

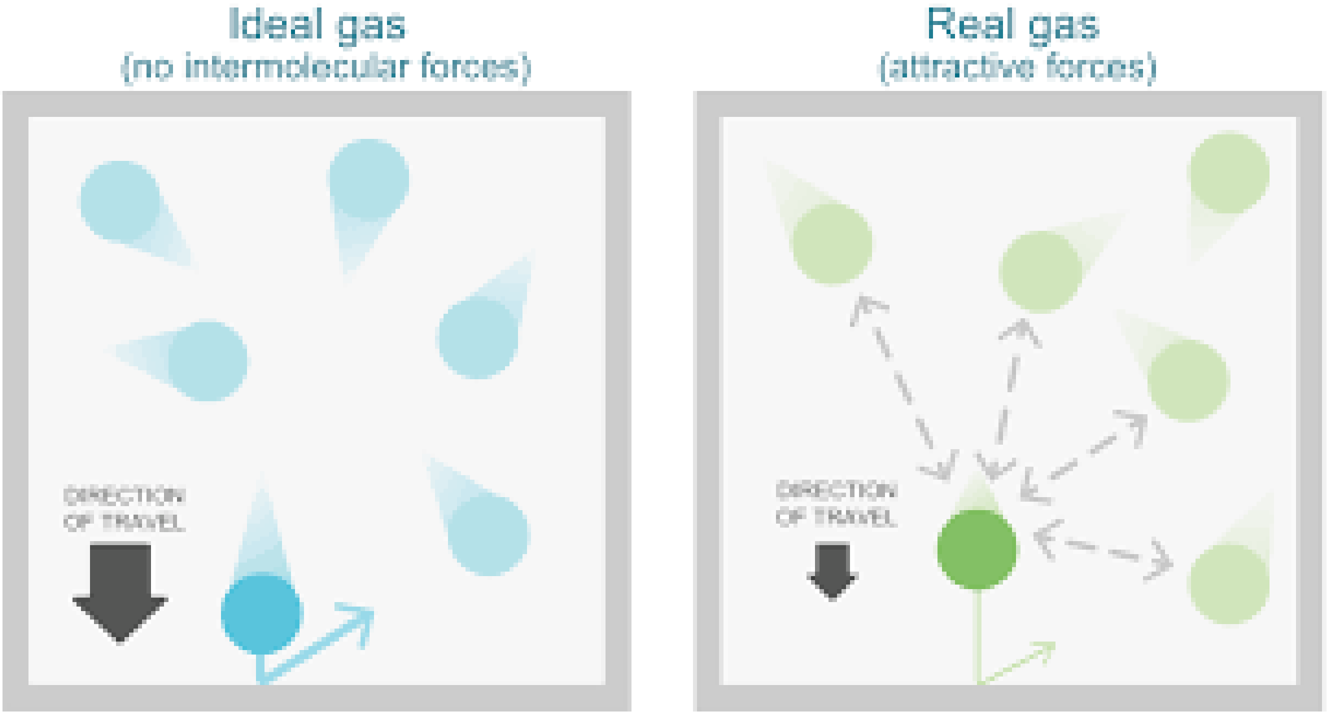
- ✓ Perform calculations involving the ideal gas law and molecular weights.
- ✓ Understand the properties of the gaseous state

The gaseous state

Gas general properties

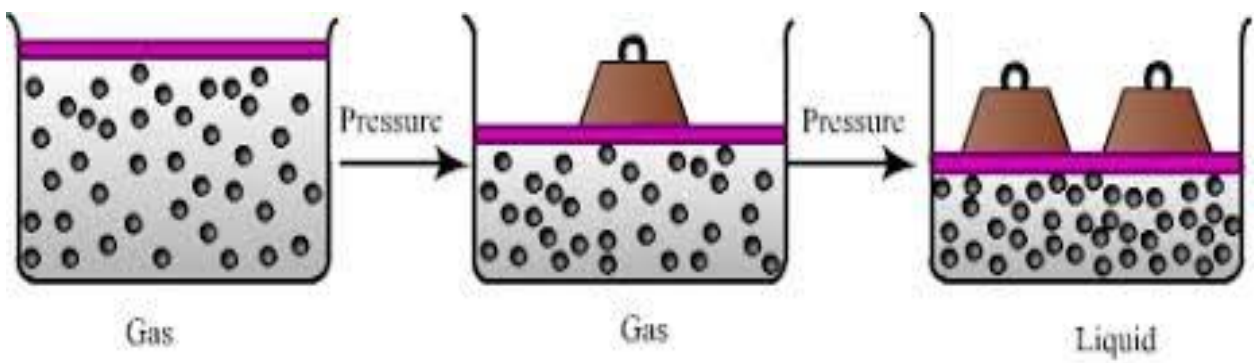
Ideal gas

Real gas



Gas general properties

- Gases can be expanded infinitively ,therefore gases can fill containers and take their volume and shape.
- Gases diffuse and mix evenly and rapidly.
- Gases have much lower densities than liquids and solids(There is a lot of free space in a gas, therefore; It is the most compressible state of matter).



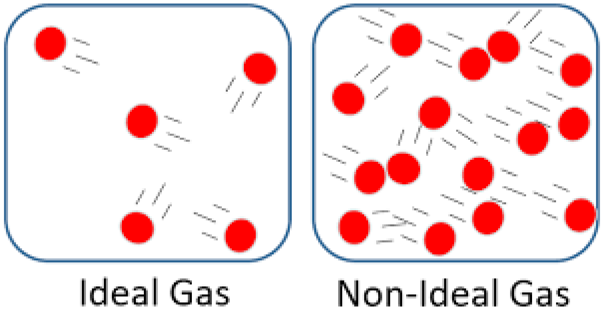
Gas molecules travel in random paths and collide with one an other and with the walls of the container in which they are kept .A gas exerts a pressure (a force per unit area)expressed in dynes/cm^2,

- **Pressure** is also recorded in atmospheres or in millimeters of mercury because of the use of the barometer in pressure measurement
- **atmospheres** or in mmHg(1atm=760mmHg=760Torr).
- Gases have **volumes** that is expressed in liters or **cubic centimeters**(1cm^3=1mL).
- The **temperature** involved in the gas equations is expressed by the absolute or **Kelvin scale** (0°C=273.15K(Kelvin)).

Ideal gas

Ideal gas is a gas where **no intermolecular interactions** exist and collisions are **perfectly elastic** , and thus no energy is exchanged during collision.

The properties of the ideal gas can be described by the general **ideal gas law** ,which are derived from Boyle ,Charles and Gay-Lussac laws



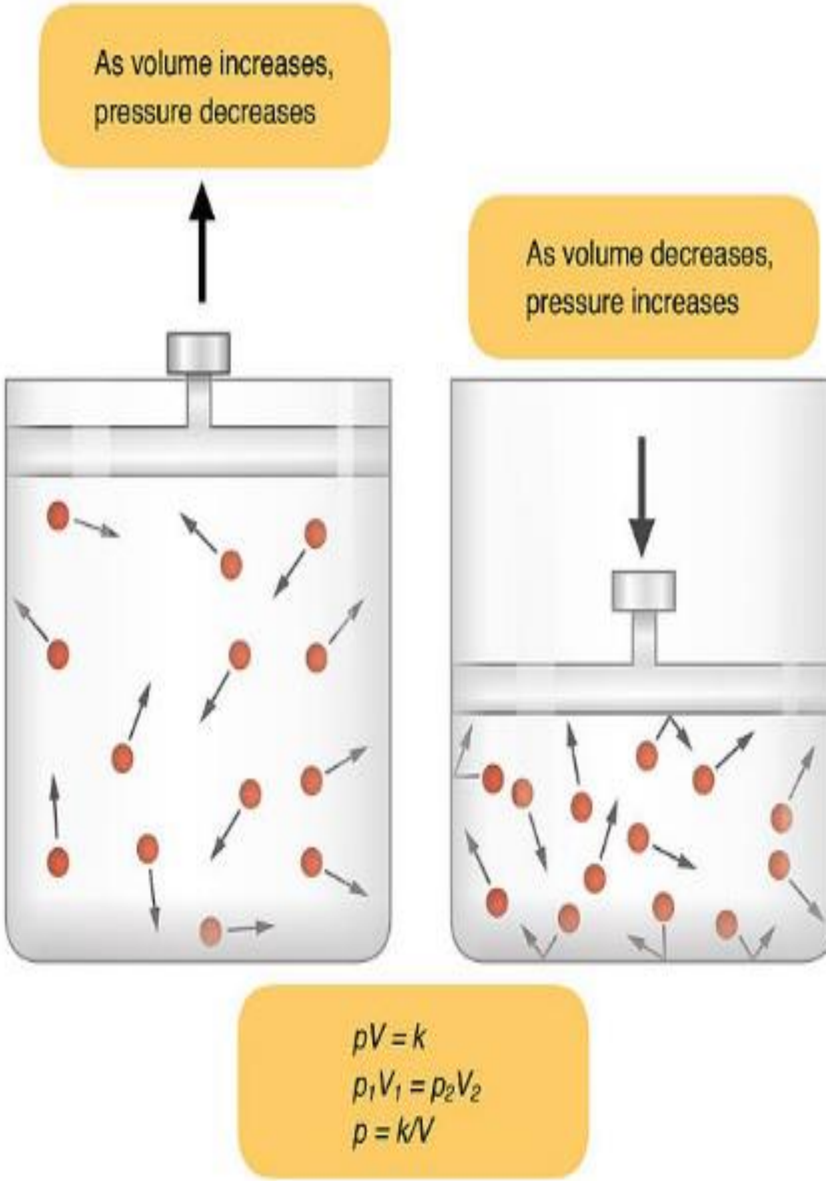
Boyle's law

Boyle's law states that the volume and pressure of a given mass of gas is inversely proportional (i.e. when the pressure of a gas increases ,its volume decreases).

$$P \alpha \frac{1}{V} \quad or \quad PV = k$$

$$P_1V_1 = P_2V_2$$

P:pressure,
K:constant,
V:volume



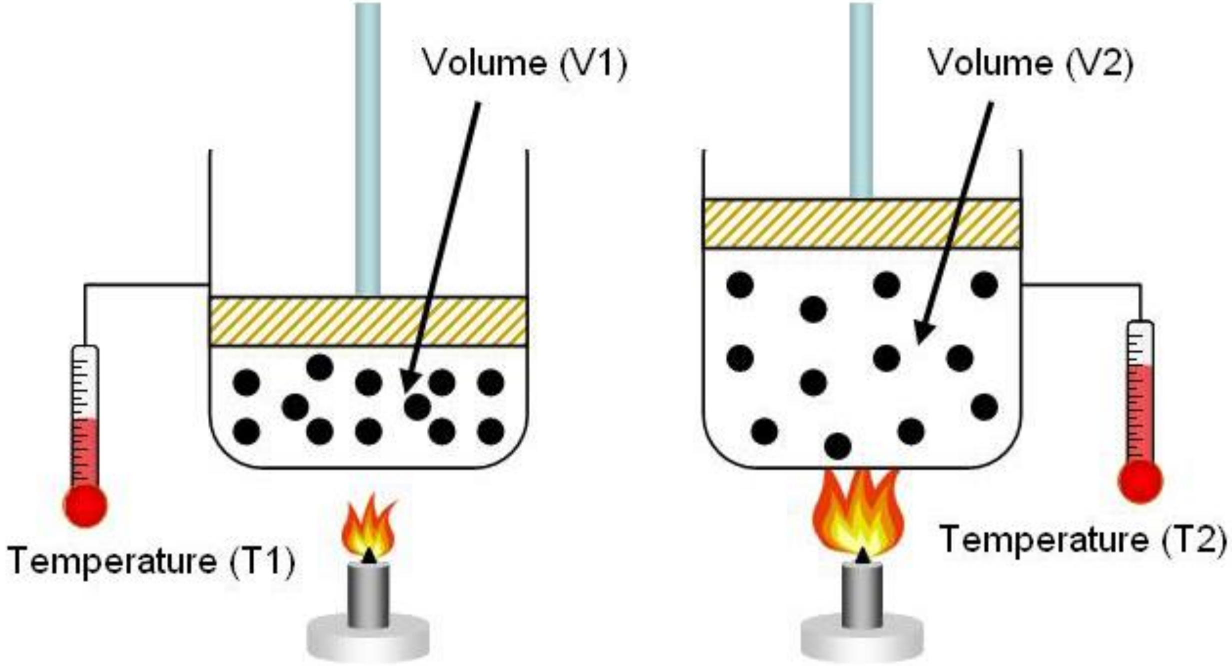
Charles law

Charles law states that the volume and absolute temperature of a given mass of gas **at constant pressure** are directly proportional (i.e when the temperature of a gas increases ,its volume increases as well).

VαT *or* **V=kT**

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

T: temperature in Kelvin

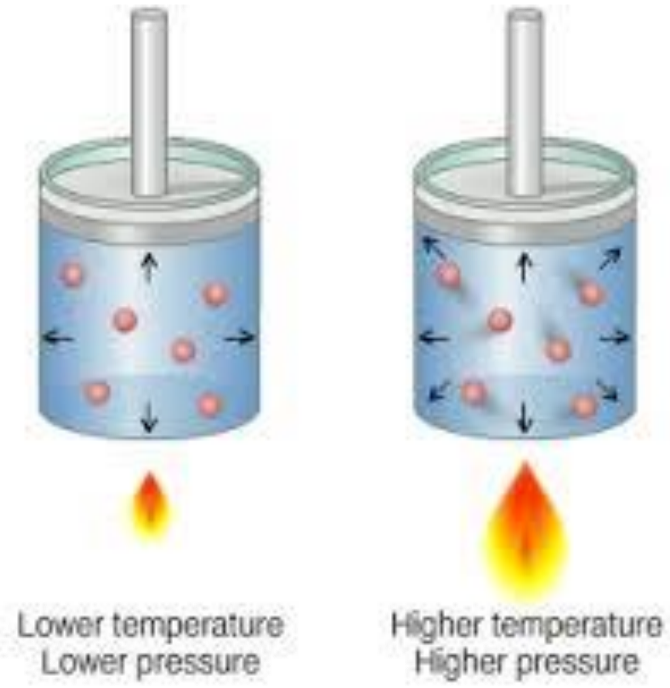


Gay-Lussac law

The law of Gay-Lussac states that the pressure and absolute temperature of a given mass of gas at **constant volume** are directly proportional(i.e when the temperature of a gas increases ,its pressure increases as well).

PαT *or* **P=kT**

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



Example

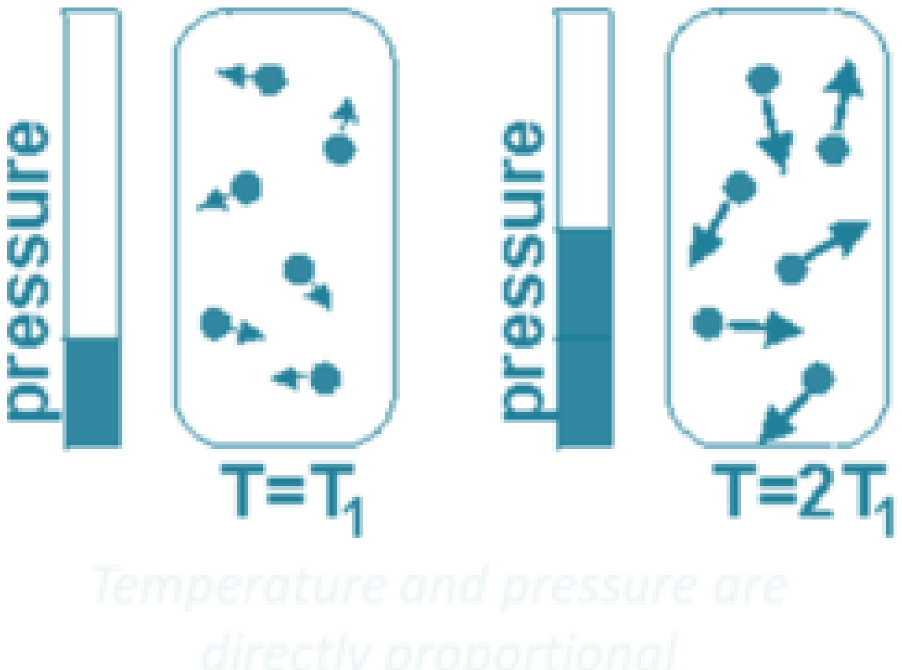
Suppose you have a gas at 30.0 atm pressure and 100°C and the temperature is changed to 400°C .What is the new pressure of the gas?

$T_1 = 100\ °C + 273 = 373\ K$

$T_2 = 400\ °C + 273 = 673\ K$

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

$$\frac{30}{373} = \frac{P_2}{673} \Rightarrow P_2 = 54.1\ atm$$



Combined gas law

Boyle ,Gay-Lussac and Charles law can be combined to obtain the familiar relationship:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Example 1

A sample of methane CH_4 has a volume of 7.0 dm^3 at a temperature of 4°C and a pressure of 0.848 atm .Calculate the volume of methane at a temperature of 11°C and a pressure of 1.52 atm.

dm^3=1L

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = 4\ dm^3$$

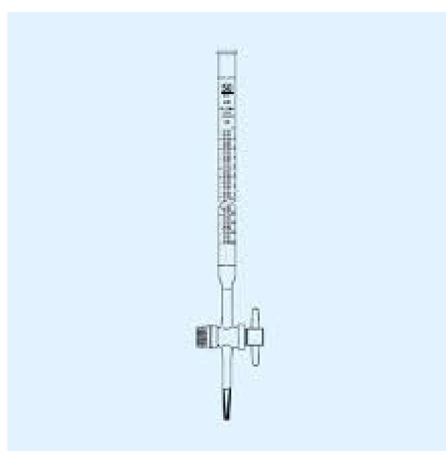
Example2

The Effect of Pressure Changes on the Volume of an Ideal Gas

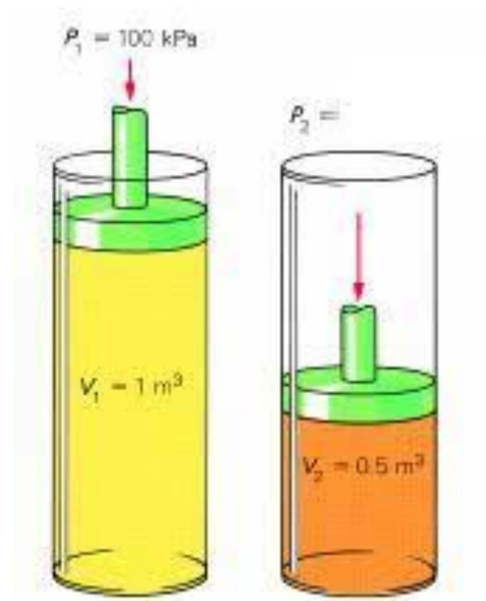
In the assay of ethyl nitrite spirit, the nitric oxide gas that is liberated from a definite quantity of spirit and collected in a gas burette occupies a volume of 30.0 mL at a temperature of 20◦C and a pressure of 740 mm Hg. Assuming the gas is ideal, what is the volume at 0◦C and 760 mm Hg? Write

$$\frac{740 \times 30.0}{273 + 20} = \frac{760 \times V_2}{273}$$

$$V_2 = 27.2\ \text{mL}$$



burette



General ideal gas law

General ideal gas law (also called equation of state) relates the specific conditions ,that is , the **pressure** ,**volume** ,and **temperature** of a given mass of gas.

$$\frac{PV}{T} = R$$

or

$$PV = RT$$

in which R is the constant value for the PV/T ratio of an ideal gas. This equation is correct only for 1 mole (i.e., 1 g molecular weight) of gas; for n moles it becomes

$$PV = nRT$$

R = 0.08205 liter atm/mole K

If 1 mole of an ideal gas is chosen, its volume under standard conditions of temperature and pressure (i.e., at 0◦C and 760 mm Hg)

Example

Calculation of Volume Using the Ideal Gas Law

What is the volume of 2 moles of an ideal gas at 25◦C and 780 mm Hg?

$$PV = nRT$$

780mmHg/760mmHg=1.0263atm

25°C+273=298K

$$(780\ \text{mm}/760\ \text{mm atm}^{-1}) \times V$$
$$= 2\ \text{moles} \times (0.08205\ \text{liter atm/mole deg}) \times 298\ \text{K}$$
$$V = 47.65\ \text{liters}$$

Molecular weight

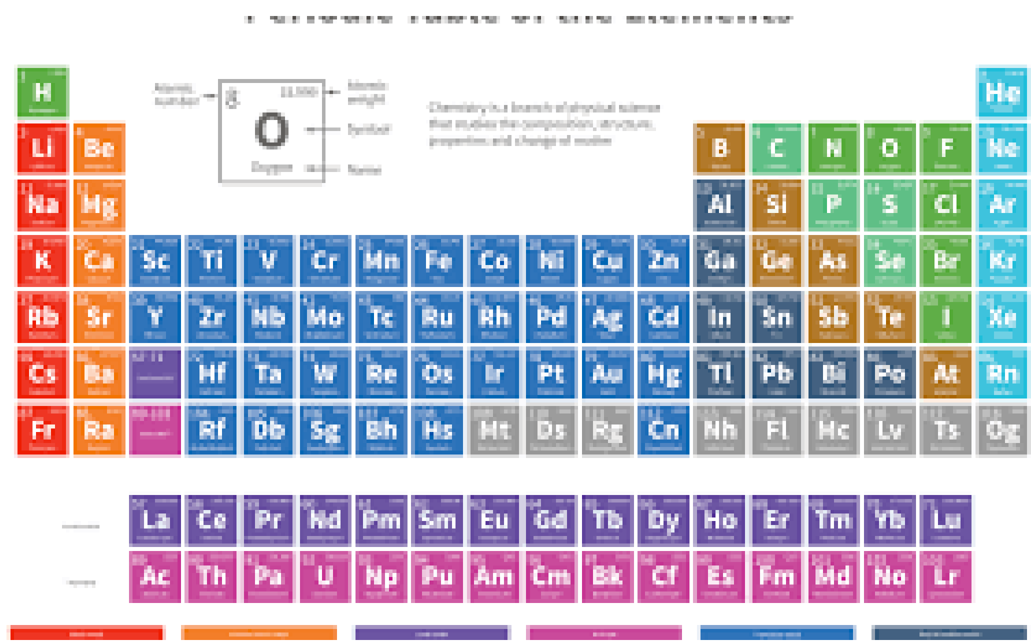
The approximate molecular weight of agas can be determined by use of the ideal gas law:

$$PV = nRT \qquad \text{since } \mathbf{n = g/M}$$

Then

$$PV = \frac{g}{M} RT$$

$$M = \frac{gRT}{PV}$$



Example

If 0.30g of ethyl alcohol in the vapor state occupies 200mL at a pressure of 1 atm and a temperature of 100°C,what is the molecular weight of ethyl alcohol?

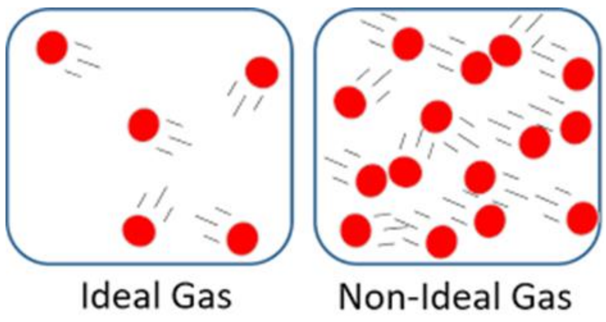
$100\ °C + 273 = 373\ K$

$200\ mL \div 1000\ mL = 0.2\ L$

$$\mathbf{M} = \frac{\mathbf{gRT}}{\mathbf{PV}} = \frac{0.3 \times 0.082 \times 373}{1 \times 0.2} = 46 \frac{g}{mole}$$

<u>Real gas</u>

- Real gases do not interact without energy exchange ,and therefore do not follow the laws of Boyle ,Charles,and Gay-Lussac.
- Real gases are **<u>not</u>** composed of infinitely small and perfectly elastic non-attracting spheres.
- They are composed of molecules of a finite volume that tend to attract one another.
- The significant molecular volume and the intermolecular attractions between gas molecules affect both the volume and the pressure of a real gas respectively.



Van der Waals Equation

The vanderWaals equation is **a modified** ideal gas equation that takes in to account the factors that affect the volume and pressure of areal gas.

For 1 mole of gas: $$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

For **n** moles of gas: $$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

The term a/V^2 accounts for the *internal pressure* per mole resulting from the intermolecular forces of attraction between the molecules;

b accounts for the *excluded volume*, which is about four times the molecular volume.

The influence of non-ideality is **greater** when the gas is compressed (At high pressure and low temperature). When the volume of a gas is **large**(At low pressure and high temperature),the molecules are well dispersed and far apart .Under these conditions ,$\mathbf{a/V_2}$ and **b** become in significant with respect to **P** and **V** ,respectively , and the vanderWaals equation for the real gas reduces to the ideal gas equation:

PV = n RT

At these conditions, real gases behave in an ideal manner.

Application of the van der Waals Equation

A 0.193-mole sample of ether was confined in a 7.35-liter vessel at 295 K. Calculate the pressure produced using

(a) the ideal gas equation and

(b) the vanderWaals equation.

The vanderWaals a value for ether is 17.38 liter^2atm/$mole^2$; the b value is 0.1344 liter/mole .To solve for pressure, the vanderWaals equation can be rearranged as follows:

$$P = \frac{nRT}{V - nb} - \frac{an^2}{V^2}$$

(*a*)

$$P = \frac{0.193 \text{ mole} \times 0.0821 \text{ liter atm/deg mole} \times 295 \text{ deg}}{7.35 \text{ liter}}$$

$$= 0.636 \text{ atm}$$

(*b*)

$$P = \frac{0.193 \text{ mole} \times 0.0821 \text{ liter atm/deg mole} \times 295 \text{ deg}}{7.35 \text{ liter} - (0.193 \text{ mole}) \times (0.1344 \text{ liter/mole})}$$

$$- \frac{17.38 \text{ liter}^2 \text{ atm/mole}^2 \, (0.193 \text{ mole})^2}{(7.35 \text{ liter})^2}$$

$$= 0.626 \text{ atm}$$


Thank You