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Physical chemistry

Lecture 2

Ideal Gases

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Properties of ideal gases

An **ideal gas** is a theoretical gas composed of many randomly moving point particles that do not interact except when they collide elastically.

The ideal gas concept is useful because:

1. it obeys the ideal gas law, a simplified equation of state.
2. One mole of an ideal gas has a volume of 22.414 L at STP

- **At normal conditions** such as standard temperature and pressure, most real gases behave qualitatively like an ideal gas.
- Many gases such as nitrogen, oxygen, hydrogen, noble gases, and some heavier gases like carbon dioxide can be treated like ideal gases within reasonable tolerances.

Generally, a gas behaves more like an ideal gas at higher temperature and lower pressure.as the work which is against intermolecular forces becomes less significant compared with the particles' kinetic energy, and the size of the molecules becomes less significant compared to the empty space between them.

- **The ideal gas** model tends to fail at lower temperatures or higher pressures, when intermolecular forces and molecular size become important. It also fails for most heavy gases, such as many cooling system. At high pressures, the volume of a real gas is often considerably greater than that of an ideal gas. At low temperatures, the pressure of a real gas is often considerably less.

The ideal gas model has been explored in both the Newtonian dynamics (as in "kinetic theory") and in quantum mechanics (as a "gas in a box").The ideal gas model has also been used to model the behavior of electrons in a metal (in the Drude model and the free electron model), and it is one of the most important models in statistical mechanics.

Types of ideal gas

There are three basic classes of ideal gas:

1-The classical or Maxwell–Boltzmann ideal gas.

2-The ideal quantum Bose gas, composed of bosons.

3-The ideal quantum Fermi gas, composed of fermions.

1. The classical ideal gas can be separated into two types:

- The classical thermodynamic ideal gas.
- the ideal quantum Boltzmann gas.

2. quantum Bose gas [An ideal **Bose gas** is a quantum-mechanical version of a classical ideal gas. It is composed of bosons, which have an integer value of spin, and obey Bose–Einstein statistics.

3- Quantum Fermi gas in the limit of high temperature to specify these additive constants. These statistics determine the energy distribution of fermions in a Fermi gas in thermal equilibrium, and is characterized by their number density, temperature, and the set of available energy states.

Classical Thermodynamic Ideal Gas

- **The ideal gas law** is an extension of experimentally discovered gas laws. Real fluids at low density and high temperature approximate the behavior of a classical ideal gas.
- However, at lower temperatures or a higher density, a real fluid deviates strongly from the behavior of an ideal gas, particularly as it condenses from a gas into a liquid or as it deposits from a gas into a solid. This deviation is expressed as a compressibility factor.

The classical thermodynamic properties of an ideal gas can be described by two equations of state:-

1. One of them is the well known ideal gas law

This equation is derived from

Boyle's law: coV=K/P (at constant T and n); Charles's law: V=bT (at constant P and n); and Avogadro's law: (at constant T and P). By combining the three laws, it would demonstrate that which would mean that.

Under ideal conditions, ; that is**, PV=nRT** .

2-The other equation of state of an ideal gas must express Joule's law, that the internal energy of a fixed mass of ideal gas is a function only of its temperature.

$$U = Cv\ nRT$$

Where:

P is the pressure, **V** is the volume,

n is the amount of substance of the gas (in moles)

R is the gas constant (8.314 J·K^{-1}mol^{-1}, **T** is the absolute temperature

K is a constant used in Boyle's law, **b** is a proportionality constant; equal to V/T

a is a proportionality constant; equal to V/n, **U** is the internal energy

Cv is the dimensionless specific heat capacity at constant volume, ≈ 3/2 for monatomic gas, 5/2 for diatomic gas and 3 for more complex molecules.

Microscopic model of ideal gas

In order to switch from macroscopic quantities (left hand side of the following equation) to microscopic ones (right hand side), we use **$nR=NK_B$**

Where:

N is the number of gas particles

K_B is the Boltzmann constant (1.381×10^{-23} J·K^{-1}).

The probability distribution of particles by velocity or energy is given by the Maxwell speed distribution

The ideal gas model depends on the following assumptions:

1) The molecules of the gas are small hard spheres
2) All collisions are elastic and all motion is frictionless (no energy loss in motion or collision).
3) Newton's laws apply.
4) The average distance between molecules is much larger than the size of the molecules.
5) The molecules are constantly moving in random directions with a distribution of speeds.
6) There are no attractive or repulsive forces between the molecules apart from those that determine their point-like collisions.
7) The only forces between the gas molecules and the surroundings are those that determine the point-like collisions of the molecules with the walls.
8) In the simplest case, there are no long-range forces between the molecules of the gas and the surroundings.


Thank you