Degrees of freedom

A degree of freedom of a physical system is an independent parameter that is necessary to characterize the state of a physical system.

Translational degree of freedom

Each individual gas molecule can translate in any spatial direction along the three axes. Thus all gas molecules have three translational degrees of freedom.

Rotational degree of freedom

A diatomic molecule can rotate about three axes.Multi-atomic gas molecules may undergo rotational motions associated with the structure of the molecule. A monatomic molecule has zero rotational degrees of freedom.

Vibrational degrees of freedom

There may be intermolecular vibrational motion between nearby gas particles, and vibrational motion arising from intermolecular forces between atoms that form the molecules. A monoatomic molecule has zero vibrational degrees of freedom. A diatomic molecule has one vibrational degree of freedom.

Monatomic gas

Monatomic gas has three translational degrees of freedom

Diatomic gas

There are 3 translational, 2 rotational, and 1 vibrational degree of freedom for a diatomic molecule.

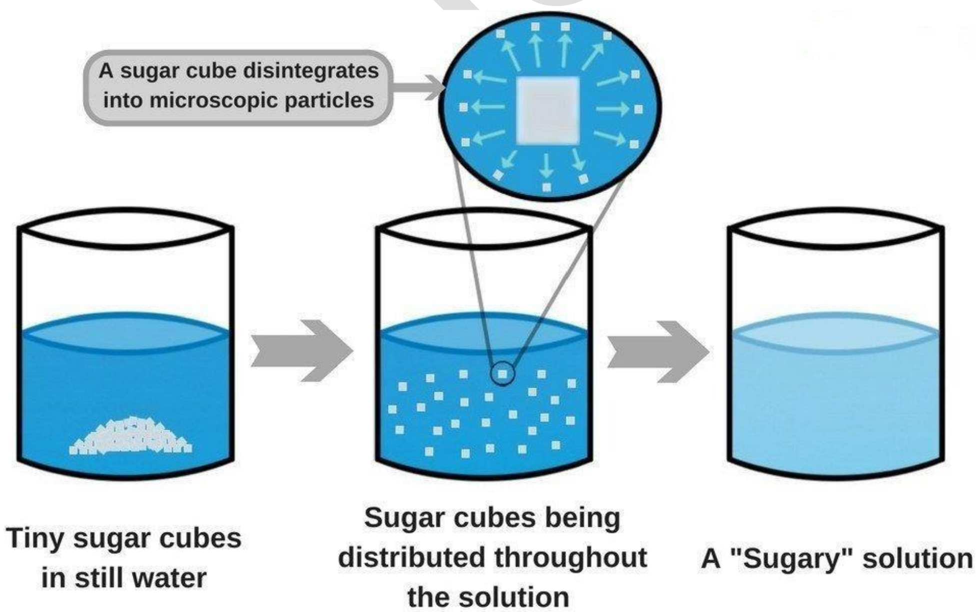
Polyatomic gases

There are 3 translational, 2 rotational, and 3N-5 vibrational, a total of 3N degree of freedom for a polyatomic molecule, where N is the number of atoms.

Existence of Motion of Molecules in a Substance

For Motion of Gas Particles :
If you open a bottle of perfume in one corner of a room, the fragrance gradually spreads and the whole room is filled with its smell.

Existence of Motion of Molecules in a Substance



For Motion of Solid Particles :

Put some quantity of sugar in a small quantity of water taken in a beaker. After some time, the sugar particles disappear as the sugar gradually gets dissolved into water.

Existence of Motion of Molecules in a Substance

For Motion of Liquid Particles :

Take water in beaker. Place it on a table. Now with the help of a dropper, put a drop of ink in water. Observe it carefully. You will notice that the ink particles gradually move into the entire quantity of water and get mixed with its particles because of which water turns blue.

Assumptions for motion of molecules in a matter

1. Molecules are in a state of continuous motion and accordingly, molecules possess kinetic energy.
2. The kinetic energy of molecules increases with an increase in temperature and decreases with decrease in temperature.
3. The molecules of matter always attract each other.
4. Molecules of matter have space between them. The space between any two consecutive molecules is called intermolecular space.
5. If the intermolecular space between the molecules decreases, the intermolecular force of attraction increases.

Intermolecular Force of Attraction

The force of attraction between the molecules (either cohesive or adhesive) is called the intermolecular force of attraction.
They include :

Hydrogen bonding
Dipole-dipole attraction
London dispersion forces

Basic Arrangement of Molecules in Solids

In solid, particles are held together (closely packed), hence are difficult to break apart. They vibrate but do not move from place to place as particles in liquids and gases do. Thats why they have a fixed shape and fixed volume.

Basic Arrangement of molecules in liquids

In liquid, particles are held close together with no regular arrangement. They can vibrate or move freely. As a result, they dont have fixed shape but have a fixed volume.

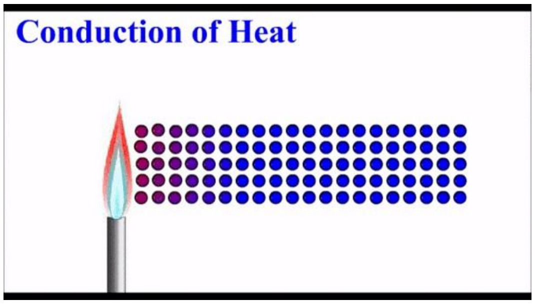
Arrangement of molecules in liquids

1. Molecules are less tightly packed in liquids.
2. The molecules in liquids attract each other with a lesser force as the intermolecular space is larger as compared to solids.
3. As the intermolecular force of attraction is less, the molecules do not stay at the same position and they move from one place to another.
4. Due to less force of attraction between the molecules of the liquids, the liquids do not have any particular shape. They acquire the shape of vessel in which they are kept.

Basic arrangement of molecules in gases

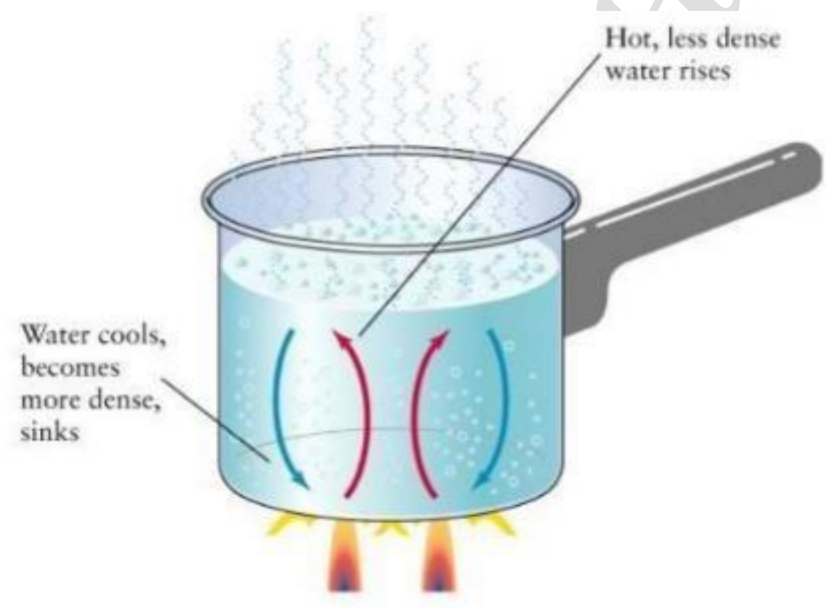
In gas, particles are separated with no regular arrangement.They moves freely and have empty spaces that is why they can be compressed.They have neither definite shape nor definite volume.

Heat conduction on kinetic model of matter



Conduction is the process of heat transmission in which heat energy is transferred from one atom or molecule to another. Heat generally tranfers in the direction of higher to lower temperature without the actual movement of the atoms or molecules from their mean positions. In the transfer of heat due to conduction, particles (atoms or molecules) of the medium do take part in the process as they vibrate about their mean positions, but there is no net displacement in them.

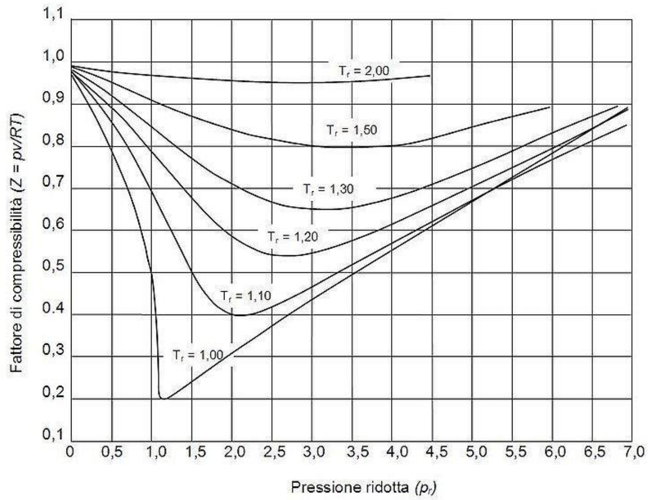
Heat convection on kinetic model of matter



The property due to which particles of a medium actually move and carry heat energy from one place to another is known as convection. On the basis of kinetic theory, we can explain it as follows:

When a substance is heated, its molecules come in direct contact with the source of heat, they absorb heat energy and expand. On expansion they become lighter than the rest of the molecules of the substance and so they rise upwards taking the heat energy along with them. This results in the generation of convectional currents taking the warmer molecules up while sinking the colder molecules down.

compressibility factor vs pressure graph



Boyle's Law

The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system.

P∝1V

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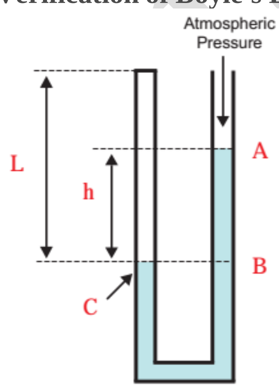
Verification of Boyle's Law



Experiment: By using a simple U-tube apparatus, Boyles Law can be verified as shown in the figure. The U tube is a glass tube closed on one end (left side) and left open to the atmosphere on the other side. It is filled with mercury in such a way that some air or any other gas used for the experiment is trapped in the closed end of the U tube. The height of the mercury column AB (height h in the the figure) along with the atmospheric pressure PA gives the pressure of the trapped gas in mm of mercury.

Charle's law

When the pressure on a sample of a dry gas is held constant, the Kelvin temperature and the volume will be directly related.
$V \propto T$

Assumptions in kinetic theory of gases

Assumptions of Kinetic Theory of Gases:

All gases are made of molecules moving randomly in all directions.
The size of a molecules is much smaller than the average separation between the molecules.
The molecules exert no force on each other or on the walls of the container except during collision.
All collisions between two molecules or between a molecule and a wall are perfectly elastic. Also, the time spent during a collision is negligibly small.
The molecules obey Newton's laws of motion.
When a large number of molecules of a gas is left for sufficient time, it comes to a steady state. The densities and distribution of the molecules with different velocities are independent of position, direction and time.

Root mean square velocity

Root-mean-square speed is the measure of the speed of particles in a gas, defined as the **square root** of the average **velocity**-squared of the molecules in a gas.