

IDEAL GAS and THE KINETIC MOLECULAR THEORY (KMT)

When the Kelvin temperature is zero, the volume of the gas seems to be zero also. Since there is no such thing as negative volume, zero Kelvins must be the lowest temperature possible = *absolute zero*.

However, a gas can not have a zero volume because the gas molecules themselves occupy a certain amount of space.

Zero volume at absolute zero (0 K = -273 °C) is a characteristic of an ideal gas. “Ideal” – is a term used to describe something that conforms perfectly to a given set of conditions.

The KMT is based on an “ideal” gas (in which molecules exert no force on each other), an ideal gas obeys the gas laws under all conditions. The ideal gas does not exist in practice: two of the major assumptions of an ideal gas are that its **particles are negligible in volume and the forces of attraction between the molecules are negligible**.

Every gas approaches such “ideal” behaviour when its pressure is Low and at High temperatures. (At high T, molecules are moving rapidly, and therefore intermolecular forces (what are we referring to?) are not significant.)

At very low pressures, molecules are widely spaced that their attractive forces are negligible. Therefore, **gases at Low pressures and High Temperatures obey the ideal gas law:**

$$PV = n RT \quad \text{(Below 1 atm, 101.3 kPa)}$$

However at **High Pressures and Low Temperatures:** the KMT no longer applies and gases behave differently (i.e. they deviate from ideal behaviour)

According to Boyle’s Law: $P \propto 1/v$, therefore at High Pressures, the molecules are much closer together, the intermolecular forces between molecules increases – because of the shorter distance – to pull the molecules together into a liquid. Real gases liquify as they cool and can not compress to zero volume because their molecules are not dimension-less points.

Therefore, at **High P and Low T, the KMT no longer applies**, gases deviate from ideal behaviour, and at Absolute Zero, the gas laws no longer apply.

The gas laws and the ideal gas equation relate only to ideal gases.

(**Note:** The ideal gas equation is modified in Van-Der-Waals’ equation:

$$(P + a/V^2) (V-b) = n RT$$

a and b are constants for a particular gas

The term $(P + a/V^2)$ takes account of the intermolecular forces in the gas and the term $(V-b)$ compensates for the volume of the particles in the gas. The forces which exist between the molecules in a gas are mostly due to Van-der-Waals’ forces; dipole-dipole, and hydrogen bonding.)

APPLICATION OF KINETIC MOLECULAR THEORY (KMT)

VELOCITIES OF MOLECULES:

Kinetic Energy, K_E , is the energy possessed by molecules as they move through space, according to the KMT, the physical properties of any gas depend on the K_E of its molecules and the K_E of molecules depends entirely on the temperature of the gas.

$$K_E = \frac{1}{2} m v^2$$

m = the mass of molecules

v = the velocity of molecules

Kinetic Energy is the energy of translation of the molecules.

See Graph: Distribution of velocities of molecules in a gas

At a particular temperature, the molecules in a gas have velocities which are distributed over a wide range of values (and a wide range of kinetic energies). However, only a small fraction of them move very quickly (see Graph of Maxwell - Boltzmann Distribution of Velocities), most have velocities which are reasonably close to a mean value (see graph: many molecules at a moderate velocity). Largest fraction of the molecules of the gas have moderate (average) K_E .

Since K_E of molecules is a function of its temperature, ie

$$K_E \propto T \quad (\text{temp} = K).$$

If the temperature increases then the average velocity increases by a constant rate.

The volume, Pressure, and the # of mols of gas DO NOT matter. Only the velocity of the gas molecules are significant.

When you heat a gas, the molecules move faster, the average velocity of the molecules increases.

The distribution is shifted to the right (see graph) to represent the increased average velocity of the molecules.

An increase in temperature causes a shift towards higher velocities and a flattening of the peak indicates that a wider range of velocities exist.

The hotter the gas, the faster the molecules move on the average and the wider the distribution of molecular velocities.

Therefore two gases (eg. $H_2 + O_2$) at the **same temperature** will have the same KE but differing molecular velocities (velocity of H_2 molecules is greater than those of O_2 molecules.)

Comparison of Average Velocity, Average Kinetic Energy and Mass

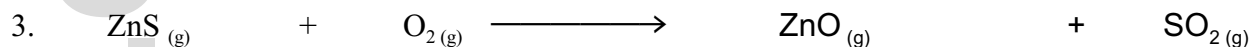
1. You have a 1.00 L flask of $\text{NH}_3(\text{g})$ and a 1.00 L flask of $\text{CO}_2(\text{g})$ both at 75.0 kPa and 22°C . Compare the two flasks using terms such as \leq , \geq , or $=$.

- A) Average Velocity
- B) Average Kinetic Energy
- C) Number of Molecules
- D) Total Mass

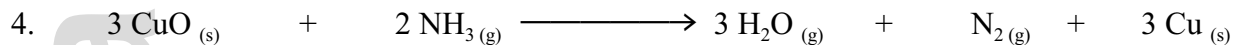
2. You have a 10.0 L flask at 15°C and 96.0 kPa filled with $\text{H}_2(\text{g})$ and a second 5.00 L flask at 15°C and 192 kPa filled with $\text{O}_2(\text{g})$.

Compare the two flasks using terms such as \leq , \geq , or $=$.

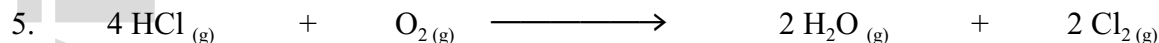
- A) Average Velocity
- B) Average Kinetic Energy
- C) Number of Molecules
- D) Total Mass



- A) Balance the above equation
- B) Identify the reactant molecules
- C) If 50.0 g of $\text{O}_2(\text{g})$ at STP react with ZnS then the:
 - i) Moles of $\text{SO}_2(\text{g})$ produced would be
 - ii) Mass of $\text{SO}_2(\text{g})$ would be
 - iii) Number of Molecules of $\text{SO}_2(\text{g})$ would be
 - iv) Volume of $\text{SO}_2(\text{g})$ at STP would be
 - v) Volume of $\text{SO}_2(\text{g})$ at 65.2 kPa and 27°C would be



Calculate the volume of $\text{N}_2(\text{g})$ at STP that can be produced from 100.0 g of CuO according to the above balanced equation.



Calculate the volume of $\text{HCl}(\text{g})$ at STP that is needed to produce 1.25×10^2 g of $\text{Cl}_2(\text{g})$.