

Kinetic Molecular Theory

1. What are the postulates of the kinetic molecular theory?

- *1. *Particles are assumed to have a volume = 0*
2. *Particles are in constant motion.*
- *3. *Particles do not interact (attraction)*
4. *$(KE)_{avg}$ is directly proportional to temperature.*

*These postulates are particularly problematic when it comes to extending this theory to real gases. Regardless of how small atoms/molecules are, they definitely do have a volume and take up room. Secondly, depending on the nature of a particle there can be very great interactions between particles. Polar molecules, for example, are attracted to one another.

2. From this information under what conditions would real gases behave similarly to ideal gases? Why?

High temperature and low pressure are the conditions that allow a real gas to most closely approximate ideal gas behavior.

High temperature means that the particles are moving at a faster pace. The faster they move in the container the less ability they have to interact with other particles in the container. This reduces the dissimilarity caused by postulate 3.

To visualize this - picture yourself taking a slow stroll through a hall where people you know are located. You will most likely stop and interact. Now consider turning up the heat a bit – you are now traveling through the same hall. This time you are late to a midterm – no time to interact – only time to run!

Low pressure helps in 2 ways. Consider that to have a low pressure case, the number of moles (relative to the size of the container) is quite low. This means fewer particles to interact (again countering postulate 3).

This also means that the volume that the moles of gas takes up is insignificant relative to the volume of the container – diminishing the issues brought up by the first postulate.

3. What is the equation for Average Kinetic Energy?

$$(KE)_{avg} = \frac{3}{2} RT$$

$$R = 8.3145 \text{ J mol K}$$

This R is still the universal gas constant. It simply has different units.

- a. What does kinetic energy describe?

The energy of motion.

- b. How does temperature effect kinetic energy?

The higher the temperature the higher the kinetic energy.

4. What is the equation for the root mean square velocity?

$$u_{rms} = \sqrt{\frac{3RT}{M}}$$

M = Molar Mass in kg

Don't worry too much about what "root mean square" means. Due the spread of velocities the individual molecules are traveling at, there are a few characteristic velocities including most probable, average and root mean square that are used to describe the motion.

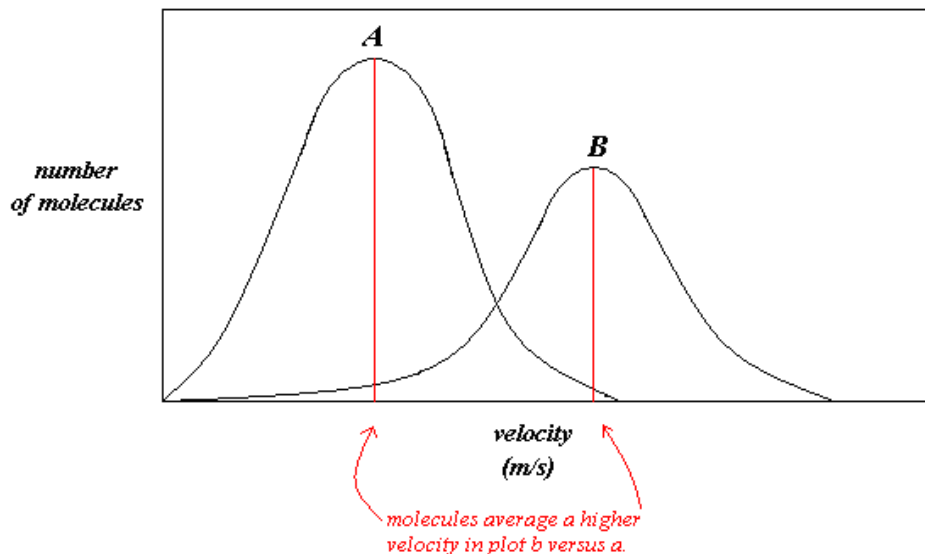
- a. How does mass affect the velocity?

The greater the mass – the slower moving the particle.

- b. How does temperature affect the velocity?

An increase in temperature results in an increase in velocity.

5. Consider:



- a. If the plot represents the velocity distribution of 1.0 L of H_2 (g) versus 1.0 L of Ar (g) at STP, which plot corresponds to each gas?

As indicated in the graph – be careful to read the axes carefully – the higher peak does not correspond to increased velocity.

Plot A represents Ar (g)

Plot B represents H_2 (g)

Ar (relative to H_2) is a heavier, and therefore, slower moving gas.

- b. If the plots correspond to the velocity distribution of 1.0 L of O_2 (g) at 273K and 1273K, which plot corresponds to each temperature?

Plot A represents movement at 273K

Plot B represents movement at 1273 K

Remember there is a direct relationship between velocity and temperature. As the temperature increase, so does the velocity.

- c. Under which temperature condition would the $O_2(g)$ behave most ideally?

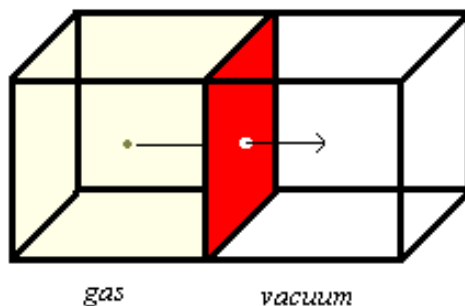
The higher temperature – 1273 K.

6. What is diffusion?

Diffusion is the movement of a substance from higher concentration to lower concentration.

7. What is effusion?

Effusion is the passage of a gas through a tiny hole into an evacuated chamber.



8. What is Graham's Law?

Compares the rate of effusion of 2 gases.

$$\frac{\text{Rate of effusion gas}_1}{\text{Rate of effusion gas}_2} = \frac{\sqrt{M_2}}{\sqrt{M_1}}$$

9. It took 5.3 minutes for 1.0 L of helium to effuse through a porous barrier. How long will it take for 1.0L of chlorine gas to effuse under identical conditions?

$$\frac{0.19 \text{ L min}}{\text{Rate of effusion Cl}_2} = \frac{\sqrt{70.90 \times 10^{-3} \text{ kg}}}{\sqrt{4.003 \times 10^{-3} \text{ kg}}} = 0.045 \text{ L min}$$

Remember that this question asked for the length of time for 1.0L to diffuse – not for the rate of effusion. So...

$$1.0 \text{ L Cl}_2 \frac{\text{min}}{0.045 \text{ L}} = \boxed{22.2 \text{ min}}$$

10. Consider the following equations

Number of collisions with container wall

$$Z_A = \frac{N}{V} A \sqrt{\frac{RT}{2\pi M}}$$

N = # of molecules

Intermolecular collisions

$$Z = 4 \frac{N}{V} d^2 \sqrt{\frac{\pi RT}{M}}$$

A = area of wall

d = diameter of molecule

Mean Free Path

$$\lambda = \frac{1}{\sqrt{2} (N/V) \pi d^2}$$

How would the following affect number of collisions and length of mean free path?

a. Increase in mass?

A larger mass would result in fewer collisions as the velocity would decrease.

There is no direct effect on the mean free path.

b. Increase in diameter of particle?

An increase in the number of intermolecular collisions and a smaller mean free path.

c. Increase concentration of gas?

Remember concentration = particles/volume (N/V)

Thus increasing the concentration increases the rate of collision and decreases the mean free path.

11. What is the Van Der Waal's Equation?

$$\left[\underset{\text{corrected pressure}}{P_{\text{observed}} + a\left(\frac{n}{V}\right)^2} \right] \underset{\text{corrected volume}}{(V - nb)} = nRT$$

a and b are substance dependent constants.

a. What is it correcting for?

Pressure is corrected because particles do interact with each other

$$P_{\text{observed}} < P_{\text{ideal}}$$

greater the density, the greater the difference between them

Volume corrected because the actual volume is smaller than ideal volume. In reality the volume of the container is not the same as the volume available to the gas particles as they do occupy some of the space. The greater the density, the greater the effect.

b. What does the variable "a" have to do with?

I always remember this variable by thinking "a" is for **a**tttraction. The greater the attraction between particles the greater the value of "a".

c. What does the variable "b" have to do with?

I always remember this variable by thinking "b" is for **b**ig.

The larger the particles the greater the value of "b".

12. Would $\text{He}_{(g)}$ or $\text{H}_2\text{O}_{(g)}$ have a greater value of "a"?

He is a noble gas and H_2O is a polar water molecule. Being polar, H_2O would have a greater attraction to other water molecules than He molecules would have to each other. Therefore, H_2O would have a larger value of "a".

13. Would $\text{He}_{(g)}$ or $\text{Xe}_{(g)}$ have a smaller value of "b"?

Because He is much smaller than Xe, it would have a smaller value of "b".