

CHM 112 (General Chemistry II)

The Kinetic Theory of Gases Exercise

The reasons for why gases behave the way they do (have volume and pressure) was explained more than a century ago using a model called the **kinetic-molecular theory**. The theory is based on the following assumptions:

- I. Gases are composed of a large number of particles that behave like hard, spherical objects in a state of constant, random motion.
- II. These particles move in a straight line until they collide with another particle or the walls of the container.
- III. These particles are much smaller than the distance between particles. Most of the volume of a gas is therefore empty space.
- IV. There is no force of attraction between gas particles or between the particles and the walls of the container.
- V. Collisions between gas particles or collisions with the walls of the container are perfectly elastic. None of the energy of a gas particle is lost when it collides with another particle or with the walls of the container.
- VI. The average kinetic energy of a collection of gas particles depends on the temperature of the gas and nothing else.

1. What is momentum?

Any object in motion has a **kinetic energy** that is defined as one-half of the product of its mass times its velocity squared.

$$KE = \frac{1}{2} mv^2$$

The momentum of a molecule is very important when gas molecules collide.

2. What would you expect to happen to the pressure of a gas as the momentum of the molecules increases?
3. Recall Boyle's Law. What was the relationship between the pressure and volume of a constant number of moles at a constant temperature?

The **kinetic-molecular theory** utilizes the idea of the **root mean velocity (RMV or**

v_{RMV}). The RMV can mathematically be described as follows: $v_{RMV} = [v_x^2 + v_y^2 + v_z^2]^{1/2}$.

The RMV takes into account the fact that a gas molecule can move in the x, y or z directions.

Combining the RMV idea with the previously discussed momentum discussion leads to the following equation: $PV = \frac{1}{3}nMv_{RMV}^2$. Where n is the number of moles and M is the molecular mass of the gas. This equation relates the PV of a gas to the **root mean velocity (RMV or v_{RMV})**.

Molecular Speeds

- Using the Ideal Gas Law, and the equation above to find a mathematical relationship for v_{RMV} . How is the v_{RMV} of gas molecules related to temperature and to molecular mass?
- Using the expression obtained in the previous question to calculate the RMV of carbon dioxide at 20 °C. Remember that a Joule = 1 kg m²s⁻².
- Calculate the RMV of diatomic nitrogen at 20 °C.
- Compare the RMV of carbon dioxide and diatomic nitrogen. Are the values similar?
- Compare the results from questions 6 and 7 to the RMV of the speed of sound at sea level (340 ms⁻¹). Are the values similar, different? WHY?
- In a mole of gas, are all the molecules moving at the same speed? Why or Why not?

The expression below describes the temperature dependence of the fraction of gas molecules.

$$f = 4\pi \left(\frac{M}{2\pi RT} \right)^{3/2} v^2 e^{-Mv^2/2RT}$$

where f is the fraction of molecules and v is the velocity of the molecules and M is the molecular mass (Kg/mol)



"Dr. Prushan, may I be excused, by brain is full!"

10. Using Excel, calculate the f of N_2 , H_2 and Cl_2 at **300 K** for a range of v (velocities). Start at 25 m/s and in steps of 25 m/s go to 300,000 m/sec. Graph (x-y scatter plot, lines only).
11. What happens to the curves as the gas changes? This is really an effect of what parameter?
12. Record the width of the peaks at their base. The peak width is a measure of what?
13. Using Excel, calculate the f of N_2 at **25, 100, 300 K** for a range of v (velocities). Start at 25 m/s and in steps of 25 m/s go to 300,000 m/sec. Graph (x-y scatter plot, lines only).
14. What happens to the curves as the temperature changes?
15. Record the width of the peaks at their base.
16. What effect does composition (molecular weight) have on the speed distribution (f)?
17. What effect does temperature have on the speed distribution (f)?
18. How does the kinetic theory of gases explain the gas laws? Use what you have learned in this exercise to answer this question.