Unit1Day4-LaBrake

Monday, September 09, 2013
5:09 PM

Vanden Bout/LaBrake/Crawford

CH301

Kinetic Theory of Gases

How fast do gases move?

Day 4

Important Information

LM 08 & 09– DUE Th 9AM

HW2 & LM06&07 WERE DUE THIS MORNING 9AM

QUIZ: CLICKER QUESTION 1 (points for CORRECT answer)

Given the density of a gas, one can use the ideal gas law to determine the molar mass, MM, of the gas using the following equation:

A. PV = nRT
B. P(MM) = nRT
C. P(MM)/nRT = density
D. P(MM)/RT = density
E. RT/P(MM) = m/V

CH301 Vanden Bout/LaBrake Fall 2013

QUIZ: CLICKER QUESTION 2 (points for CORRECT answer)

The numerical value of the MOLAR VOLUME of a gas is:

A. The amount of space occupied by one mole of a gas at a given T and P.
B. The number of moles of a gas occupying 1 liter of gas at a given T and P.
C. The number of moles of a gas occupying any amount of liters of a gas at any T or P.

CH301 Vanden Bout/LaBrake Fall 2013

POLL: CLICKER QUESTION 3

After reading through the question on an in-class learning activity, I typically…

A) Wait for the answer to be given then write down the correct answer.
B) Start by thinking about the chemistry principles that apply then begin working on a solution.
C) Begin by looking through my notes for the right formula that applies then plugging in the numbers to get an answer.
D) Google the topic to find a similar problem then use that as a guide for solving this problem.

CH 301 Vanden Bout/LaBrake Fall 2012

CH 301 Vanden Bout/LaBrake Fall 2013

What are we going to learn today?

Understand the Kinetic Molecular Theory

- Explain the relationship between T and KE
- Explain how mass and temperature affect the velocity of gas particles
- Recognize that in a sample of gas, particles have a distribution of velocities
- Explain the tenets of Kinetic Molecular theory and how they lead to the ideal gas law
- Apply differences in gas velocity to applications such as diffusion and effusion

CH302 Vanden Bout/LaBrake Fall 2012

POLL: CLICKER QUESTION 3

Think About Gases Microscopically

What affects the average kinetic energy of a gas?

A. Temperature
B. Pressure
C. Volume
D. Temperature and Pressure
E. Volume and Pressure

http://ch301.cm.utexas.edu/simulations/gas-laws/GasLawSimulator.swf

CH302 Vanden Bout/LaBrake Fall 2012

POLL: CLICKER QUESTION 4

In a mixture of two different gases, particles with different masses will have

POLL: CLICKER QUESTION 4

In a mixture of two different gases, particles with different masses will have

A. The same KE and the same rms velocities
B. The same KE but different rms velocities
C. Different KE but the same rms velocities
D. Different KE and different rms velocities

http://ch301.cm.utexas.edu/simulations/gas-laws/GasLawSimulator.swf

$KE \propto T$

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

CH302 Vanden Bout/LaBrake Fall 2012

DEMONSTRATION

TWO VOLUNTEERS WILL SPRITZ

CH302 Vanden Bout/LaBrake Fall 2012

POLL: CLICKER QUESTION 5

What can we say about the velocities of the N_2 gas molecules in this room?

A. All the molecules are moving with the same absolute velocity in the same direction.

B. All the molecules are moving with the same absolute velocity in random directions.

C. The molecules are moving at a distribution of speeds all in the same direction

D. The molecules are moving at a distribution of speeds in random directions.

CH302 Vanden Bout/LaBrake Fall 2012

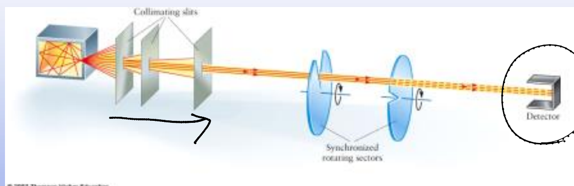
DEMONSTRATION

HCl in one end of the tube.
NH_3 in the other end of the tube.

$$HCl_{(g)} + NH_{3(g)} \rightarrow NH_4Cl_{(s)}$$

Distribution of Velocities

The particles have a distribution of velocities



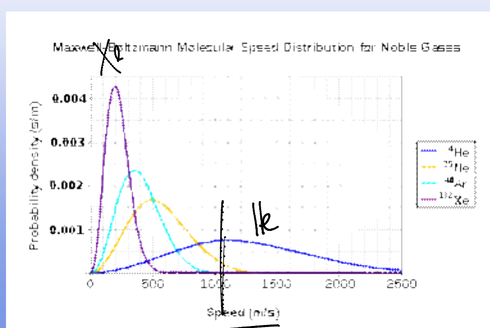
Set the T

Pick molecules all going in the same direction

Pick molecules all going a particular velocity

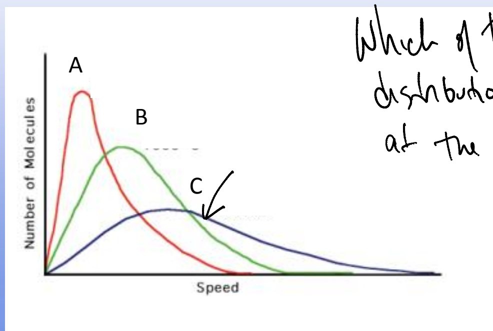
Distribution of Velocities

What does the distribution look like for different molecules at the same temperature?



POLL: CLICKER QUESTION 6

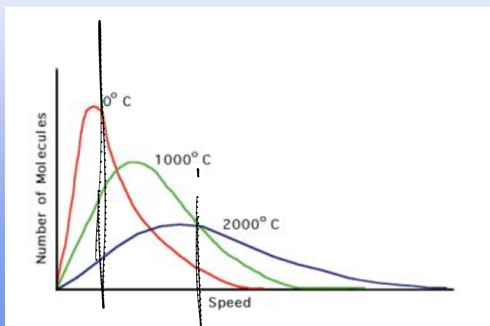
What does the distribution look like for the same molecule at different temperatures?



Which of these distributions is at the highest T?

Distribution of Velocities

What does the distribution look like for the same molecule at different temperatures?



Remember the Simulator!

http://ch301.cm.utexas.edu/simulations/gas-laws/GasLawSimulator.swf

Temperature changes average K.E.
K.E. is proportional to Temperature
Proportionality constant is the Gas Constant R!

$$K.E. \propto T$$

$$K.E. = \frac{3}{2}RT$$

gas constant

temperature

What is Kinetic Energy?

K.E. energy is related to mass and velocity

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

What is Kinetic Energy?

K.E. energy is related to mass and velocity

$$K.E. = \frac{1}{2}mv^2 \qquad K.E. = \frac{3}{2}RT$$

$$v^2 = \frac{3RT}{m}$$

Who cares about velocity squared?

We think in velocity units

Who cares about velocity squared?

Who cares about velocity squared?

We think in velocity units

$$v^2 = \frac{3RT}{m}$$

$$v_{\mathrm{rms}} = \sqrt{\frac{3RT}{m}}$$

"root mean square" = square root of the average of the square

POLL: CLICKER QUESTION 7

Rank the following from fastest to slowest in terms of rms velocity

A. H_2 at 300 K
B. H_2 at 600 K
C. O_2 at 300 K
D. O_2 at 600 K

$$v_{\mathrm{rms}} = \sqrt{\frac{3RT}{m}}$$

Use the alphanumeric response to enter the four letters in the correct order

B A D C

POLL: CLICKER QUESTION 8

Check on demo

Let's think about our demo. What is the ratio of the speeds of the two molecules in our demo? NH_3 : HCl

Numerical Question: Give an answer to one decimal place

$$\frac{V_{rms\,NH_3}}{V_{rms\,HCl}} = \frac{\sqrt{\frac{3RT}{MM_{NH_3}}}}{\sqrt{\frac{3RT}{MM_{HCl}}}} = \frac{\sqrt{\frac{1}{MM_{NH_3}}}}{\sqrt{\frac{1}{MM_{HCl}}}} = \sqrt{\frac{MM_{HCl}}{MM_{NH_3}}} = \sqrt{\frac{36}{17}} = \sqrt{2.14} \approx 1.5$$

1 decimal point

Kinetic Molecular Theory

Now we know the particles are moving at distribution of velocities

And we know what the velocities are.

Therefore we should be able to figure out how often they hit the walls of their container and how “hard” they hit to figure out what the pressure is.

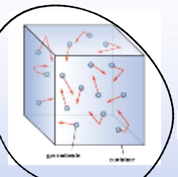
CH302 Vanden Bout/LaBrake Fall 2012

Kinetic Molecular Theory

- The particles are so small compared with the distance between them that the volume of the individual particles can be assumed to be negligible (zero)
- The particles are in constant motion. The collisions of the particles with the walls of the container are the cause of the pressure exerted by the gas. "elastic"
- The particles are assumed to exert no forces on each other; they are assumed to neither attract nor repel each other.
- The average kinetic energy of a collection of gas particles is assumed to be directly proportional to the Kelvin temperature of the gas.

CH302 Vanden Bout/LaBrake Fall 2012

And then there was a lot of math



If you are interested
it is in the chemistry wiki e-book

http://en.wikibooks.org/wiki/General_Chemistry/Gas_Laws

Here is the short version

Pressure is proportional to # of collisions per second x “impact” of the collisions

The number of collisions of the particles with the walls scales with the velocity

The impact of the of collisions of the particles with the walls scales with the momentum which is proportional to the velocity

$$P \propto \sqrt{T} \quad x \quad \sqrt{T} = T$$

CH302 Vanden Bout/LaBrake Fall 2012

What about the mass?

If the "impact" is related to momentum
Shouldn't more massive particles have a higher pressure?

POLL: CLICKER QUESTION 9

Question: In a mixture of one mole of He and one mole of Ar, the partial pressure of the Ar compared to the partial pressure of He is ?

A. The same
B. Higher
C. Lower

The mass affects the velocity too

Here is the short version

Pressure is proportional to # of collisions per second x "impact" of the collisions

More massive means fewer collisions

The momentum increases due to the mass, but only by sqrt of m since the velocity is lower as well

$$P \propto \sqrt{\frac{T}{m}} \; x \; m \times \sqrt{\frac{T}{m}} = T$$

Mass affects velocity but not pressure!

Arrive at the IGL from KMT

What about P and V?

The number of collisions scales inversely with volume (impact unchanged)

$$P \propto \frac{1}{V}$$

What about P and n?

The number of collisions scales proportionally with with n (impact unchanged)

$$P \propto n$$

Put it all together and you get

$$PV = nRT$$

When will this fail?

When our assumptions of the model fail

Worst assumption: The particles are assumed to exert no forces on each other; they are assumed to neither attract nor repel each other

CH302 Vanden Bout/LaBrake Fall 2012

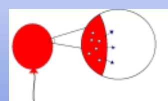
Diffusion and Effusion

Diffusion:

Spread of particles due to random motion (perfume “smell” wander across the room)

Effusion:

Loss of gas from a container through a small pore. (He balloon that deflates slowly)



Both directly related to the velocity of the gas particles

CH302 Vanden Bout/LaBrake Fall 2012

POLL: CLICKER QUESTION 10

You have two gases under identical conditions. One gas has a density that is double that of the other gas. What is the ratio of the rate of diffusion of the high density gas compared lower density gas

A. 2 times less
B. Sqrt(2) times less
C. 2 times faster
D. sqrt(2) times faster
E. they are identical

$$v_{\text{rms}} = \sqrt{\frac{3RT}{m}}$$

CH302 Vanden Bout/LaBrake Fall 2012

What did we learn today?

Ideal Gas is amazing – empirically derived and also theoretically derived.

We now know how to relate rms velocity to both temperature and mass

We can apply our knowledge of velocities to diffusion and effusion of gases

Finally, there is a distribution of velocities. This will have huge implications for future understanding of chemistry!

DAY 4 LEARNING OUTCOMES

Explain the relationship between the kinetic energy and temperature of a gas.

Explain the relationship between temperature and the velocity of a gas.

Explain the relationship between molar mass and the velocity of a gas.

Apply the ideas of kinetic molecular theory to a variety of gas phenomena.

Describe the distribution of velocities for the particles in a gas sample and what factors affect this distribution.

Explain how T, V and n affects the pressure as described by the KMT.

Explain what the breakdown of the ideal gas law tells us about the assumptions of the KMT

Explain when and why the ideal gas model fails to predict the behavior of gases observed in nature and in the laboratory.