Tuesday, October 21, 2025 AP Chemistry

Ch. 10 Gases

(Partial Pressures of Gases packet — do along with PSet — due M 10/27)

Quiz W 10/29 online, AP Classroom

Q1 Test F 10/31 Practice test — completion grade worth 1/3 quiz grade due BEFORE Q1 test

Demos

- Magdeburg Hemispheres — P is real
- Cartesian Diver — $PV = k$
- Upside-down Flasks — $PV = k$

(As intro)

- Hand Boiler (in context) — $V = kT$
- Can crush (in context) — $V = kn$
- Boyle's Law with data (in lieu of lab) $PV = k$

10.1 Characteristics of Gases

Air is 78% N_2 21% O_2 1% Ar

noble gases He Ne Ar Kr Xe Rn

All gases have the same physical behavior

We describe that behavior with four variables.

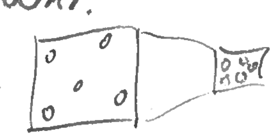
- V volume
- T temperature
- P pressure
- n number of moles

} Measurements which can vary and in doing so affect one another.

Gas Behaviors

1. Gases fill containers completely. Vol of container = vol. of gas.
2. Gases are mostly empty space — the vol. of atoms takes up 0.0001% of the vol. of a gas. The nearest molecule is 10 times the molecule's radius away.

As a result, gases are highly compressible.



SOLIDS AND LIQUIDS CAN'T BE COMPRESSED B/C ATOMS ARE IN CONTACT AND SPACES IN BTWN. ARE TOO SMALL TO FIT MORE ATOMS.

(3) GASES ALWAYS FORM A HOMOGENEOUS MIXTURE (EVENTUALLY).

10.2 PRESSURE

PRESSURE IS FORCE PER UNIT AREA $P = \frac{F}{A} \frac{(N)}{(m^2)}$ Pa

$1 N/m^2 = 1 Pa$

ATMOSPHERIC PRESSURE AT SEA LEVEL IS ABOUT 1×10^5 Pa

A STANDARD ATMOSPHERE IS

$101,325 Pa \cong 1 \times 10^5 Pa = 1 bar = 100 kPa$

OUR MOST COMMON UNIT: THE ATMOSPHERE (atm)

1 atm = 760 mm Hg = 29.92 in Hg
MILLIMETERS OF MERCURY

$760 mm \cdot \frac{1 in}{25.4 mm} =$

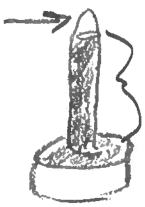
1 mm Hg = 1 torr (ALESSANDRO TORRICELLI – Hg BAROMETER INVENTOR)

1 atm = 760 torr

WHAT IS PRESSURE? IT IS THE TENDENCY OF A COLLECTION OF PARTICLES TO FLY APART DUE TO THEIR OWN CONSTANT MOTION.

WHEN WE MEASURE IT WE ARE MEASURING THE AVERAGE FORCE OVER TIME OF UNCOUNTABLY MANY MOLECULAR COLLISIONS.

THE MERCURY BAROMETER IS A GLASS TUBE FULL OF Hg AND CLOSED AT ONE END TURNED SO THE OPEN END IS IN A POOL OF Hg.



A COLUMN OF Hg 760 mm HIGH HAS A PRESSURE OF 1 atm. ATMOSPHERIC PRESSURE WILL HOLD UP JUST THAT HIGH.

SHAPE AND WIDTH DON'T MATTER, JUST HEIGHT AND DENSITY OF THE LIQUID: $P = Dhg$

$D = kg/m^3$
$h = m$
$g = m/s^2$ $(9.8\ m/s^2)$

$P = 1 atm = 101,325 Pa$

Hg: $h = \frac{P}{D \cdot g} = \frac{101,325}{(13,600)(9.8)} = 0.76\ m$

$D_{Hg} = 13,600\ kg/m^3$

H_2O: $\frac{P}{D \cdot g} = \frac{101,325}{(1000)(9.8)} = 10.3\ m$ (!)

$D_{H_2O} = 1000\ kg/m^3$

RELEVANCE TO DIVING

P = 1atm (SURFACE)
10m P = 2atm
10m P = 3atm
20m

GAS LAWS

① PRESSURE - VOLUME LAW $\quad P \cdot V = \text{CONSTANT } (k)$
OR
BOYLE'S LAW (17TH CENT.)

② TEMPERATURE - VOLUME LAW $\quad \frac{V}{T} = k$
OR
CHARLES'S LAW / GAY-LUSSAC'S LAW (19TH CENT)

③ MOLES - VOLUME LAW $\quad \frac{V}{n} = k$
OR
AVOGADRO'S LAW (19TH CENT.)

PRESSURE - VOLUME LAW

P AND V ARE INVERSELY PROPORTIONAL
WHEN T AND n ARE HELD CONSTANT
(ALSO, T CAN'T BE TOO LOW OR ELSE A GAS CONDENSES)

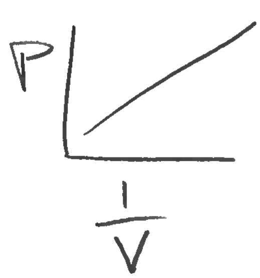
$\boxed{P \propto \frac{1}{V}}$ $\quad P = k\frac{1}{V}$ OR $PV = k$

(SEE THE CARTESIAN DIVER - FRED THE SQUID)

$\propto$ MEANS "IS PROPORTIONAL TO"
K IS THE "CONSTANT OF THE PROPORTION"

LOOK AT VERNIER PROBE DATA FOR P VS. V

$PV = k$



$P = k\frac{1}{V}$

Solving Problems

Constant T and amount of gas

$$\left.\begin{array}{l} P_1V_1 = k \\ P_2V_2 = k \end{array}\right\} P_1V_1 = P_2V_2$$

Solve this proportion concerning changes in P & V (make sure units match)

Temperature-Volume Law

Demo: Hand Boiler

V and T are directly proportional when n and P are held constant

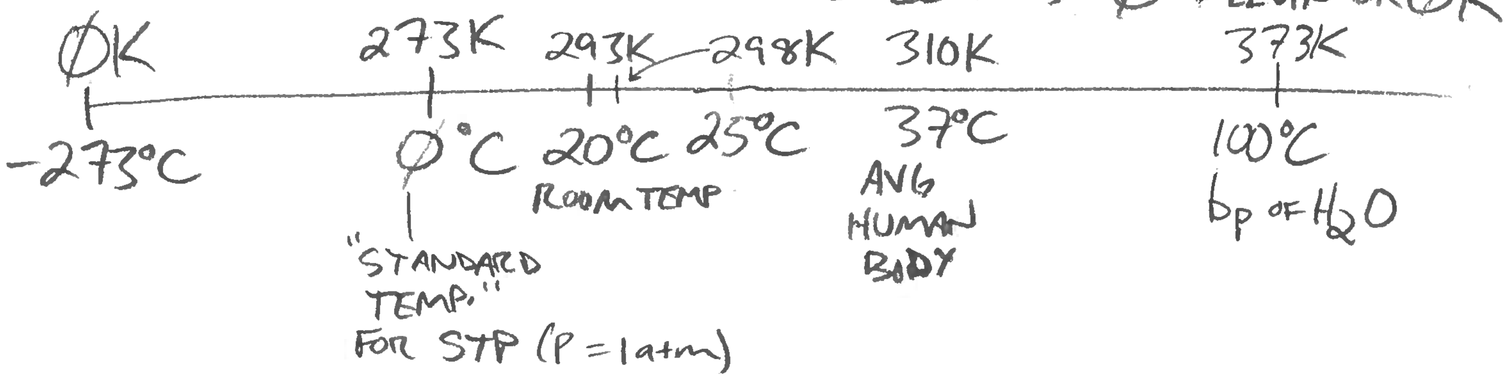
→ constant means open to air

$$\boxed{V \propto T} \qquad V = kT \text{ or } \frac{V}{T} = k$$

Solving problems

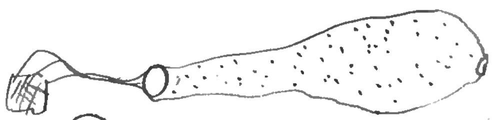
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

✱ For calculations you <u>must</u> use absolute temperature, which has no negative values. Temp. is a measure of the energy of molecular motion and you can't have less than no motion. Absolute zero is the temp. at which all molecular motion ceases. We use the Kelvin scale where absolute zero is Ø Kelvin or ØK



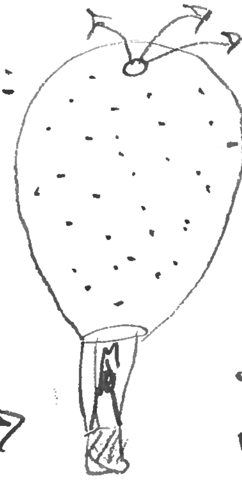
We use K b/c 20°C is not twice as hot as 10°C!
How much hotter is 20°C compared to 0°C?

HOW HOT AIR BALLOONS WORK:



1. FILL WITH COLD AIR USING A FAN
2. HEAT THE AIR INSIDE USING FIRE!

→



SAME VOL OF BALLOON BUT THE HOTTER AIR TAKES UP A BIGGER VOL. AND ESCAPES THE BALLOON

BECAUSE OF LOWER DENSITY HOTTER AIR INSIDE THE BALLOON IT CAN FLOAT IN THE COLDER HIGHER-DENSITY AIR.

MOLES - VOLUME LAW

V AND n ARE DIRECTLY PROPORTIONAL WHEN T AND P ARE HELD CONSTANT

$$\boxed{V \propto n} \quad V = kn \text{ or } \frac{V}{n} = k \quad \Big\| \quad \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

CAN CRUSH DEMO - THE CAN CRUSHES B/C THE CONSTANT ATMOSPHERIC PRESSURE PROVIDES THE FORCE WHICH DECREASES THE VOLUME WHEN THE STEAM INSIDE THE CAN CONDENSES, REDUCING THE NUMBER OF MOLES OF GAS.

(DO DEMO)

STOPPED HERE GROUP Y TU 2025-10-21

10.4 The Ideal Gas Law

$PV = k_1$

$\frac{V}{T} = k_2$

$\frac{V}{n} = k_3$

$\frac{PV}{nT}$ = ONE CONSTANT TO RULE THEM ALL

$\frac{PV}{nT} = R$ — THE UNIVERSAL GAS CONSTANT

$$R = 0.08206 \frac{L \cdot atm}{K \cdot mol}$$

Standard Temp Pressure

$T_{STD} = 273K$ (0°C)

$P_{STD} = 1\ atm$

For 1 mol of gas $V_{STD} = 22.41\ L$

$$R = \frac{(1\,atm)(22.41\,L)}{(1\,mol)(273\,K)} = 0.08206 \frac{L\,atm}{K\,mol}$$

$$PV = nRT$$

MEMORIZE

$P = \frac{nRT}{V}$ $V = \frac{nRT}{P}$ $T = \frac{PV}{nR}$ $n = \frac{PV}{RT}$

(1) Do algebra
(2) Plug in numbers with units

For situations where variables change

$R = \frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ n is usually constant so: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

10.5 Applications of the Ideal Gas Law

Gas Density

Gas Stoichiometry

Density of Gases

$\frac{g}{L}$ (not $\frac{g}{mL}$)   D for density   (ρ = rho)

$\mathcal{M}$ = molar mass ($\frac{g}{mol}$)

m = mass (g)

n = no. of mol

You don't need to be able to...

Derive the Density of a Gas Equation

$PV = nRT$ and $m = n \cdot \mathcal{M}$ $g = mol \cdot g/mol$

① $(PV = nRT)\mathcal{M}$

② $PV \cdot \mathcal{M} = (n \cdot \mathcal{M})RT$

③ $\frac{PV \cdot \mathcal{M}}{V} = \frac{mRT}{V}$

④ $P \cdot \mathcal{M} = DRT$ $\left(\frac{m}{V} = D\right)$

⑤ $\boxed{D = \frac{P \cdot \mathcal{M}}{RT}}$ — directly proportional to pressure and molar mass

— inversely proportional to temperature

Demo: Density of CO_2 with vapor ramp & candle

Another: Prep and Properties of H_2 (another day)

GAS STOICHIOMETRY

STOICH. CALC. REQUIRE (mol)

CH. 3 $\_\_\,g \cdot \frac{1\,mol}{g} = \quad mol$

CH 4 $\_\_\,L \cdot \frac{mol}{1\,L} = \quad mol$

CH. 10 $n = \frac{PV}{RT}$

CALC. mol FIRST IF A PROBLEM INVOLVES A CHEM. RXN.

A USEFUL SHORTCUT IS TO USE VOL. OF GAS INSTEAD OF mol. FOR CONSTANT P AND T, VOL. IS DIR. PROP. TO mol.

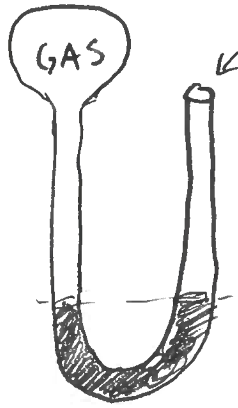
$3H_2 + N_2 \rightarrow 2NH_3$

3 mol	1 mol	2 mol	
3 L	1 L	2 L	AT CONSTANT P & T
3 atm	1 atm	2 atm	AT CONSTANT V & T

PARTIAL PRESSURES CAN ALSO BE USED IN STOICH. CALC. (PARTIAL PRESSURE IS THE PRESSURE DUE TO JUST ONE COMPONENT OF A MIXTURE).

MANOMETERS – A TOOL FOR MEASURING PRESSURE BY DIFFERENCE

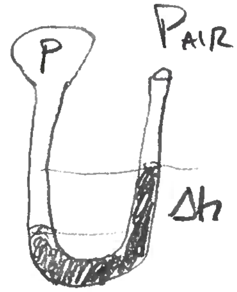
(NOT MAHNA MAHNA)



OPEN TO AIR

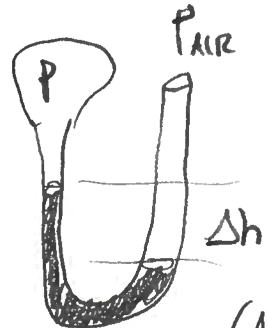
IF Hg IS THE SAME HEIGHT ON BOTH SIDES, THE $P_{INSIDE} = P_{OUTSIDE}$

PARTIALLY FILLED WITH Hg



$P > P_{AIR}$

$P = P_{AIR} + \Delta h$



Δh = OUTER – INNER

$P < P_{AIR}$

$P = P_{AIR} + \Delta h$

(Δh IS NEGATIVE)

10.6 GAS MIXTURES AND PARTIAL PRESSURES

PARTIAL PRESSURE OF A GAS IS THE PRESSURE DUE TO JUST ONE GAS ALONE WITHIN A MIXTURE.

THE TOTAL PRESSURE FOR A MIXTURE OF GASES IS THE SUM OF THE PARTIAL PRESSURES OF THE GASES IN THE MIXTURE.

$$P_{tot} = P_1 + P_2 + \ldots + P_n$$

THIS IS REALLY THE SAME AS SAYING THE TOTAL NUMBER OF MOLES EQUALS THE SUM OF MOLES OF EACH COMPONENT.

$$n_{tot} = n_1 + n_2 + \cdots n_n$$

$$P_1 = \frac{n_1 RT}{V} \quad \text{AND} \quad P_{tot} = \frac{n_{tot} RT}{V}$$

FOR ANY COMPONENT

SEE SAMP. EX. 10.10 pg 416

MOLE FRACTION

A UNIT OF CONCENTRATION EXPRESSED AS MOLES OF A COMPONENT DIVIDED BY THE SUM OF MOLES OF ALL COMPONENTS.

(χ "CHI") $\chi_1 = \frac{n_1}{n_{tot}}$ $\chi_2 = \frac{n_2}{n_{tot}}$ $n_{tot} = n_1 + n_2$

$$\chi_1 + \chi_2 = 1 \quad (100\%)$$

χ IS A "FRACTION" USUALLY WRITTEN AS A DECIMAL (LIKE 0.2) OR AS A PERCENT (LIKE 20%).
↳ MOLE PERCENT.

$\chi_1 = \frac{n_1}{n_{tot}}$ $n_1\left(\frac{RT}{V}\right) = P_1$ $n_{tot}\left(\frac{RT}{V}\right) = P_{tot}$ so $\chi_1 = \frac{P_1}{P_{tot}}$

so $\boxed{\chi_1 = \frac{n_1}{n_{tot}} = \frac{P_1}{P_{tot}}}$

IF YOU KNOW χ_1 AND n_{tot}...

$n_1 = \chi_1 n_{tot}$

$P_1 = \chi_1 P_{tot}$

SEE SAMP. EX. 10.11 pg 417

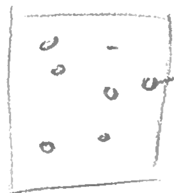
FOR THE REST, SEE MY OLD NOTES

ALSO 2022-10-25
F 2021-10-29 AP CHEM
GIVEN AS PRE-WRITTEN NOTES
ALSO 2025-10-23

10.7 KINETIC-MOLECULAR THEORY (KMT)

① GASES ARE MADE OF PARTICLES IN CONTINUOUS RANDOM MOTION.

② THE VOLUME OF PARTICLES THEMSELVES IS NEGLIGIBLE IN COMPARISON WITH CONTAINER VOLUME



$r_{ATOM} = 10^{-10} m$

$V \cong 10^{-30} m^3$ ATOMS REALLY ARE SMALL!

③ THE ATTRACTIVE AND REPULSIVE FORCES THAT EXIST BTWN. PARTICLES ARE TOO WEAK TO MATTER WHEN WE CONSIDER THE VERY HIGH SPEEDS OF PARTICLES IN A GAS.

④ COLLISIONS BTWN. PARTICLES ARE PERFECTLY ELASTIC SO NO ENERGY IS LOST TO FRICTION WHEN PARTICLES COLLIDE.

THE AVERAGE KINETIC ENERGY OF A COLLECTION OF GAS PARTICLES DEPENDS ONLY ON TEMPERATURE.

⑤ THE AVERAGE KINETIC ENERGY (KE) OF A COLLECTION OF MOLECULES IS DIRECTLY PROPORTIONAL TO THEIR ABSOLUTE TEMP. FOR AN IDEAL GAS.

$$KE_{AVG} = \frac{3}{2} RT$$

$$R = 0.08206 \frac{L \cdot atm}{K \cdot mol}$$

CONVERT L·atm TO J

UNITS OF ENERGY J (JOULE)

$$R = 8.314 \frac{J}{K \cdot mol}$$

ONLY USED FOR KINETIC-MOL. THEORY

⑫ ~~18~~ 13

NOTES NOT GIVEN IN CLASS

SEARCH FOR PhET GAS PROPERTIES AND PLAY WITH THAT SIMULATOR TO GET A SENSE OF KMT.

KMT EXPLAINS...

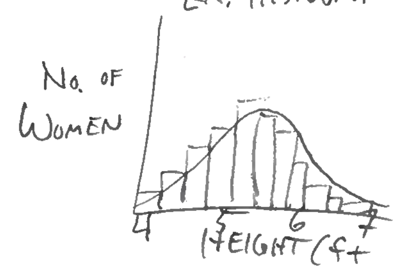
- PRESSURE, WHICH ARISES DUE TO COLLISIONS OF GAS PARTICLES WITH EACH OTHER AND THE WALLS OF A CONTAINER.
- BOYLE'S LAW: PRESSURE INCR. DUE TO AN INCR. IN THE FREQUENCY OF COLLISIONS WITH A WALL. IN A SMALLER VOL. PARTICLES HAVE A SHORTER DISTANCE TO TRAVEL SO COLLISION FREQ. INCREASES.
- CHARLES'S LAW (REPHRASED AS $P \propto T$ AT CONSTANT V): AS TEMP. INCR. PARTICLE SPEEDS INCR. SO THEY STRIKE THE WALLS HARDER AND MORE OFTEN, WHICH WE MEASURE AS AN INCR. IN P.

STOP HERE Th 2025-10-23 GROUP Y

SPEEDS OF MOLECULES

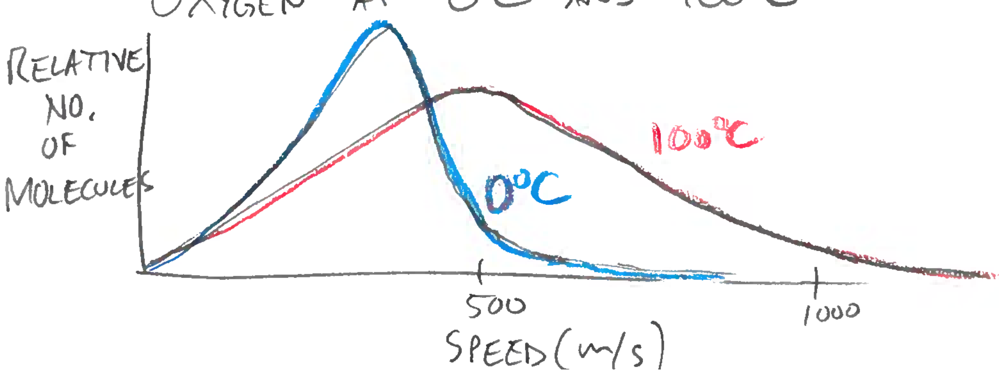
A COLLECTION OF MOLECULES DOES NOT HAVE ONE SPEED. INSTEAD THERE IS A DISTRIBUTION OF SPEEDS. A HISTOGRAM WHICH LUMPS TOGETHER MOLECULES WITH SIMILAR SPEEDS CAN GIVE US A GOOD IDEA ABOUT MOLECULAR SPEEDS.

EX. HISTOGRAM



COMPARING SPEED DISTRIBUTIONS AT DIFF. TEMP.

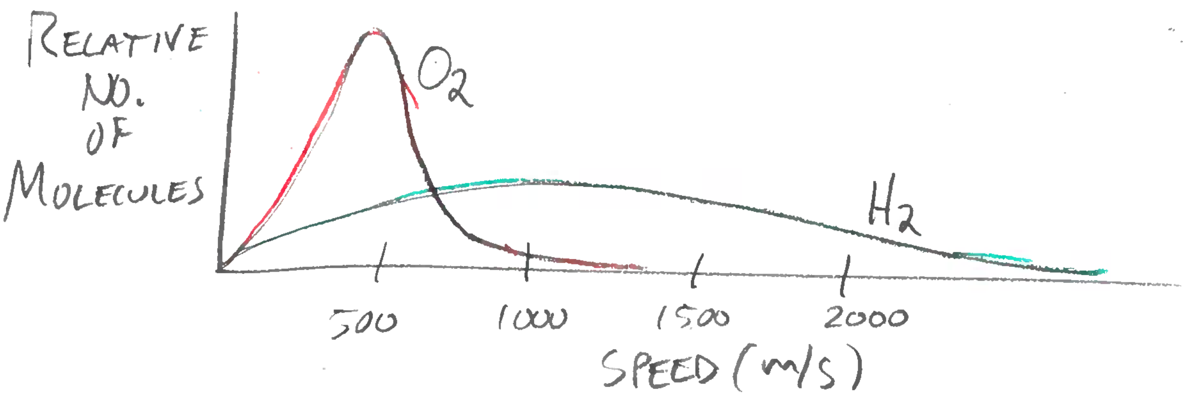
OXYGEN AT 0°C AND 100°C



F 2021-10-29 AP Chem

At higher temp. there are more available speeds and more of them are higher speeds.

Comparing Speed Distributions with diff. Molecules (at the same temp.)



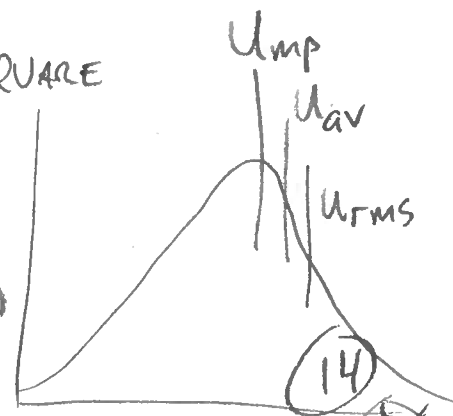
With a lower molar mass H_2 has more available speeds and more of them are higher speeds than O_2.

Speed is directly proportional to temp. ($KE_{avg} = \frac{3}{2}RT$ and $KE = \frac{1}{2}mv^2$ v = velocity) so at higher T molecules move faster on average.

Speed is inversely proportional to molar mass ($\frac{2KE}{v^2} = m$). So with a higher molar mass the average speed is lower.

Molecules move at many diff. speeds, so how do we measure an average speed?

Most probable	Weighted average	Root mean square
U_{mp}	U_{av}	U_{rms}



U instead of V for velocity (for some reason)

U_{rms} is the speed for a molecule with a KE equal to the average KE

u_{rms} IS EASY TO CALC. AND GIVES YOU A SENSE OF HOW T, SPEED, AND MOLAR MASS ARE RELATED.

$$u_{rms} = \sqrt{\frac{3RT}{M}} \qquad R = 8.314 \frac{J}{K\,mol} \qquad u_{mp} = \sqrt{\frac{2RT}{M}}$$

$KE_{AVG} = \frac{3}{2}RT$

$KE = \frac{1}{2} m u_{rms}^2$

* M = MOLAR MASS IN kg/mol NOT g/mol

EFFUSION & DIFFUSION

EFFUSION IS HOW QUICKLY A GAS ESCAPES THROUGH A SMALL HOLE. SINCE GASES WITH SMALLER MOLAR MASSES HAVE HIGHER AVG. SPEEDS THEY HAVE A HIGHER RATE OF EFFUSION THAN THOSE WITH HIGHER MOLAR MASSES.

FOR EX., LATEX He BALLOONS SHRINK DUE TO HELIUM ATOMS ESCAPING THE MICROSCOPIC HOLES IN THE LATEX.

DIFFUSION IS THE RATE AT WHICH GASES MIX. ALTHOUGH AT ROOM TEMP. GASES HAVE SPEEDS FROM 500 - 1000 m/s THEY MIX SLOWLY. THIS IS B/C THEY COLLIDE ABOUT 10^{10} TIMES A SECOND. THEY ONLY TRAVEL ABOUT 60 nm BTWN. COLLISIONS. (THEY ARE ONLY 0.1 nm IN SIZE).

FASTER PARTICLES MIX FASTER.

GRAHAM'S LAW OF EFFUSION

r = RATE

M = MOLAR MASS

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} \quad \text{B/C } r \propto u_{rms} \quad \frac{r_1 = \sqrt{3RT/M_1}}{r_2 = \sqrt{3RT/M_2}}$$