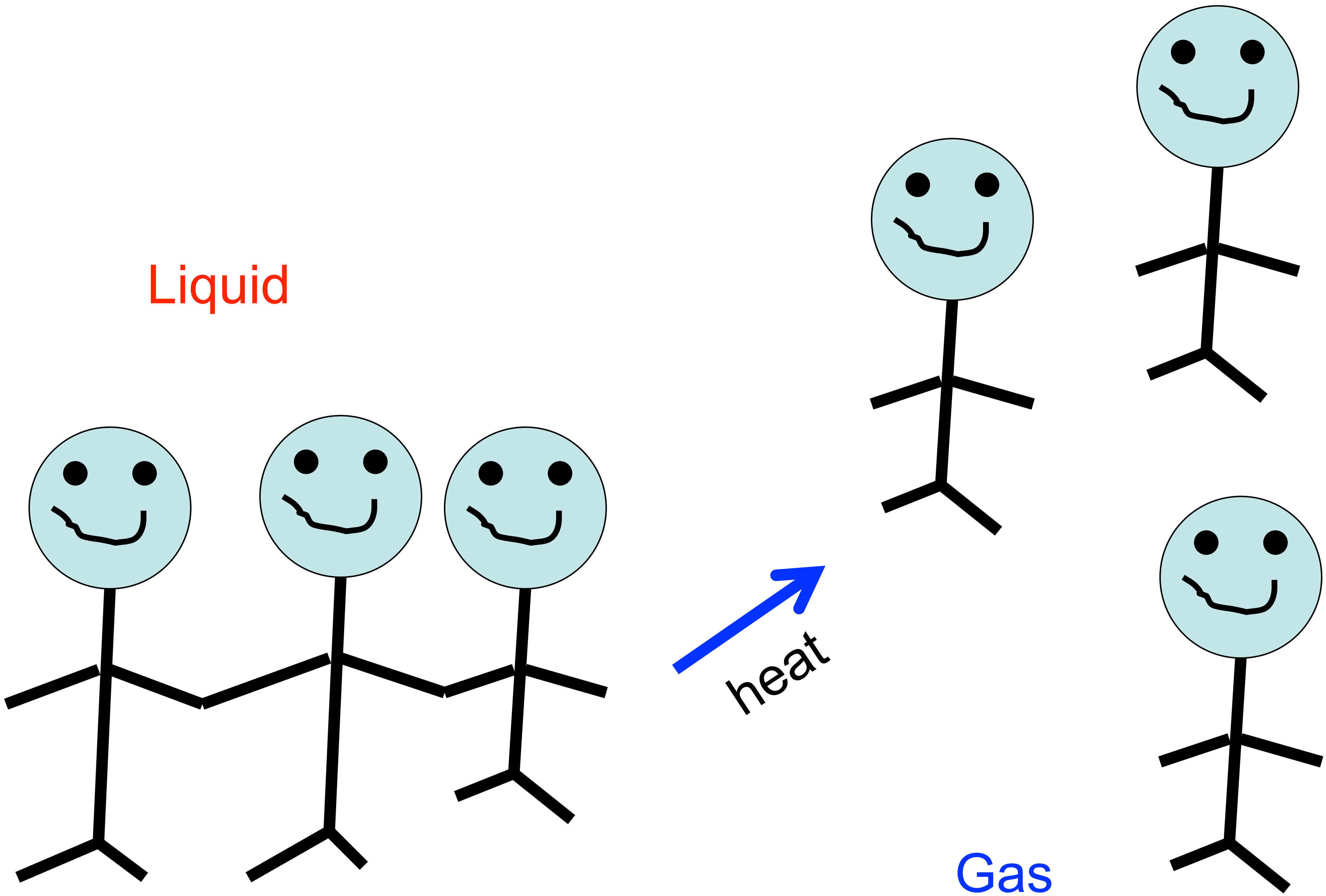
Objective 13

States of Matter – Gases
Relate kinetic theory of gases to gas variables
(P, V, T, and n)
Apply ideal gas law

IM Forces Determine a Substance's State of Matter

How is one state of matter distinguished from another?

State of Matter	distance between molecules	volume/ shape	density	compress ibility	motion of molecules	chemical forces
Gas	Far apart	Indefinite Fits shape of container	Low Air=1 g/L	yes	Fast, constant, random	London
Liquid	Intermedi ate	Definite/ Fits shape of container	High H_2O=1 Hg=13.5	no	2 layers sliding past each other	IM forces
Solid	Close together	Definite/ Fixed	High Li=0.53 Au=19.3	no	Vibrating in fixed position	Depends on solid type


Liquid
heat
Gas

Exception: Ice floats on water

WHY?

http://www.weather.com/news/science/why-does-ice-float-20131105

Density of H_2O (l) is __________ the density of H_2O (s)

a. greater than   b. equal to   c. less than

Other substances in which solid is less dense than its liquid: As, Bi, Ga, Si
http://cen.acs.org/articles/91/i34/Galileo-Ice.html
C&EN, 8/26/13, p. 28

IM Forces Hold the Atoms/Molecules Together in its State of Matter
Stronger IM Forces ==> Higher b.p.

1. Identify the intermolecular forces in:

A. Water
B. Acetone
C. CO_2
D. H_2S

2. a. Why does water have a higher b.p. than acetone?
b. Compare H_2O to CO_2. Why is CO_2 a gas at room temperature whereas H_2O is a liquid?
c. Compare H_2O to H_2S. Why is H_2O a liquid at room temperature whereas H_2S is a gas?

Crude Oil: Mixture of 50 to 95% Hydrocarbons by Weight

Hydrocarbons: ***London forces α size***

http://chemed.chem.purdue.edu/genchem/topicreview/bp/1organic/coal.html

Petroleum Fraction	# of C atoms	b.p. range, °C
Natural gas	1 to 4	< 20
Petroleum ether	5 to 6	20-60
Gasoline	5 to 12 (mostly 6 - 8)	40-200
Kerosene	12 to 13	150-260
Fuel oils	>14	> 260
Lubricants	>20	> 400
Asphalt or coke	Polycyclic	residue

More than ***500 different hydrocarbons*** have been identified in the gasoline fraction.

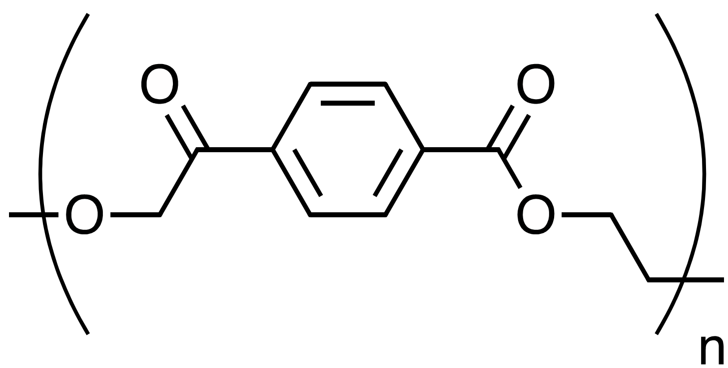
Light, Sweet Crude contains < 0.5% sulfur (as H_2S). Higher proportion of gasoline, kerosene, and fuel oil fractions.

Heavy, Sour Crude costs less than light, sweet crude.

As hydrocarbon size increases, what happens to boiling point?

1. a. Explain why water has a higher boiling point than ethanol.
b. Explain why motor oil has a higher boiling point than water.
c. Explain why motor oil has a higher viscosity than water.

2. a. What is PET used for?
b. Circle the functional group(s) in PET. Write the name of the functional group next to your circle.



1. Which statement is <u>not</u> true about gases?

a) Gas molecules move very fast.
b) Strong chemical forces exist between gas molecules.
c) Gas molecules are far apart.

2. Gases behave ideally under:

a) High T and High P
b) High T and Low P
c) Low T and High P
d) Low T and Low P

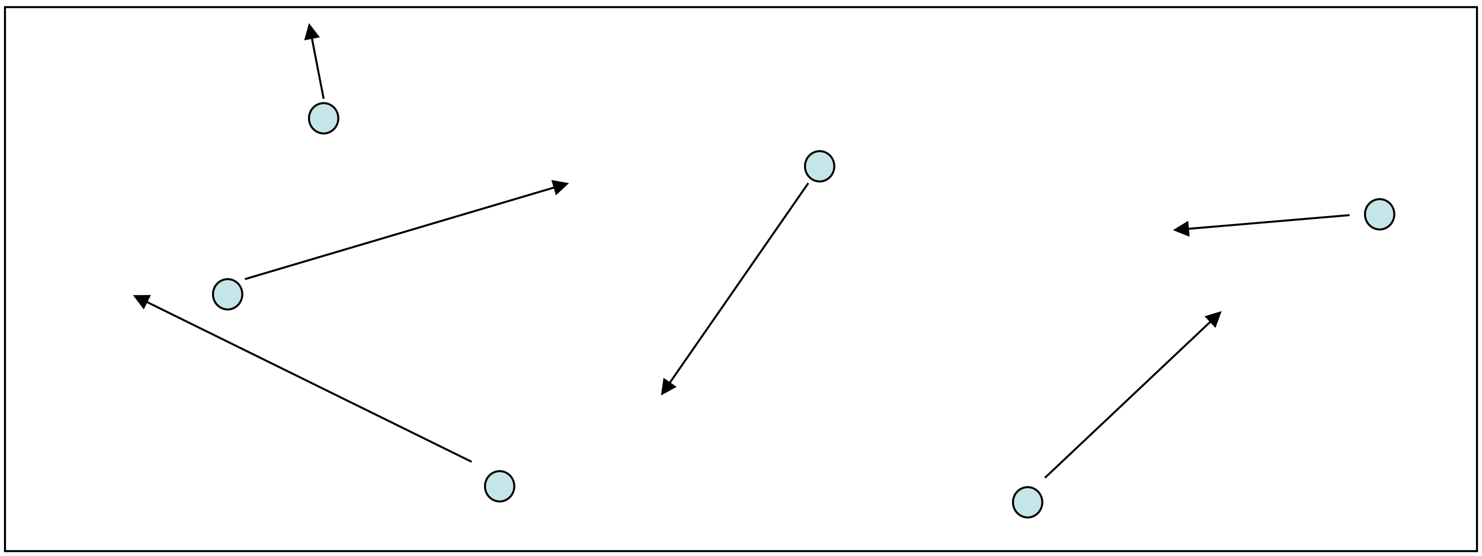
3. As the temperature of a gas increases,

a) The pressure increases
b) The volume decreases
c) The gas condenses

Gases are Described with the Kinetic Molecular Theory

<u>Assumptions</u>:

1. Gas molecules move very fast, in constant random motion.
2. Gas molecules are "point-sized." (Gas molecules are far apart compared to size of gas molecule.)
3. No attractive or repulsive forces between gas molecules.



As the Temperature increases, gas molecules move ______.
As the Pressure increases, gas molecules move ______.

Ideal Gas: Gases Behave "Ideally" Under Certain Temperature and Pressure Conditions

Assumptions (kinetic molecular theory):

1. Gas molecules move very fast, in constant random motion.
2. Gas molecules are "point-sized." (Gas molecules are far apart compared to size of gas molecule.)
3. No attractive or repulsive forces between gas molecules.

Under what temperature conditions are these assumptions valid? (Hint: see Assumption 1)

Under what pressure conditions are these assumptions valid? (Hint: see Assumption 2)

a) High T and High P
b) **High T and Low P**
c) Low T and High P
d) Low T and Low P

Ideal Gases are Ideal

Does methane behave like an ideal gas?

YES NO

Give reasons.

Compare steam to CO_2. Which gas behaves like an ideal gas?

H_2O (g) CO_2

Give reasons.

Kinetic Theory of Gases:
Gases move very fast in constant, random motion

But do different gases move at the same speed?

$$KE = 0.5\ mv^2$$

Temperature = measure of average KE of a substance

$$v = \left[\frac{2\ KE}{m}\right]^{1/2}$$

Ideal Gases are Ideal

Based on the kinetic theory of gases, is it possible for an ideal gas to condense? Give reasons.

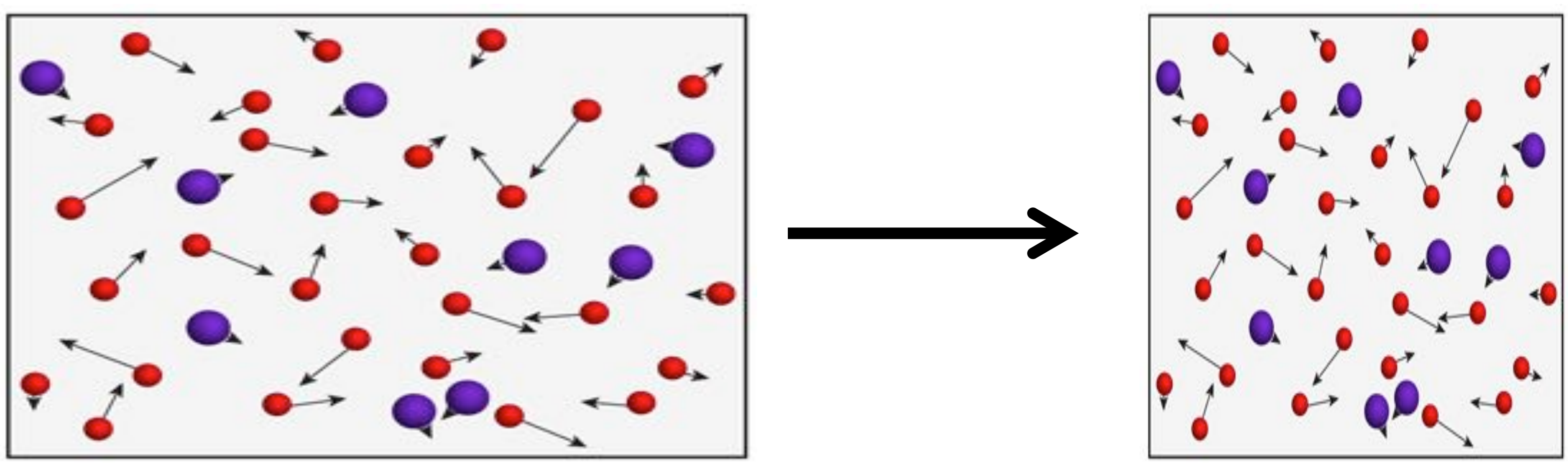
<u>Assumptions</u> (kinetic molecular theory):

1. Gas molecules move very fast, in constant random motion.
2. Gas molecules are "point-sized." (Gas molecules are far apart compared to size of gas molecule.)
3. No attractive or repulsive forces between gas molecules.

Ideal Gases are Ideal

A gas that is subjected to high enough pressure will condense to a liquid.
Which assumption(s) in the kinetic molecular theory are no longer valid at high pressure? Give reasons.

<u>Assumptions</u> (kinetic molecular theory):
1. Gas molecules move very fast, in constant random motion.
2. Gas molecules are "point-sized." (Gas molecules are far apart compared to size of gas molecule.)
3. No attractive or repulsive forces between gas molecules.



Ideal Gases are Ideal

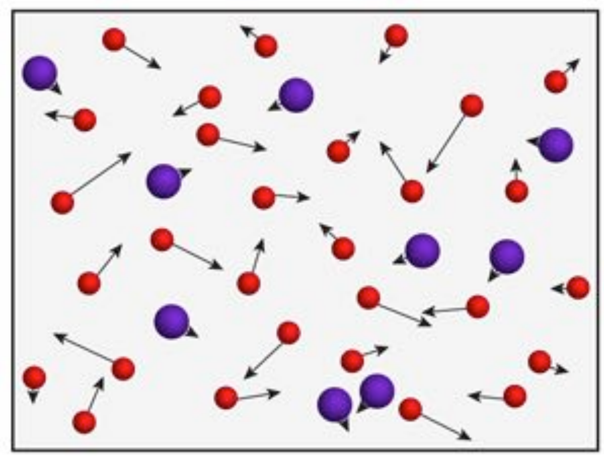
A gas that is subjected to a low enough temperature will condense to a liquid.
Which assumption(s) in the kinetic molecular theory are no longer valid at low temperature? Give reasons.

<u>Assumptions</u> (kinetic molecular theory):
1. Gas molecules move very fast, in constant random motion.
2. Gas molecules are "point-sized." (Gas molecules are far apart compared to size of gas molecule.)
3. No attractive or repulsive forces between gas molecules.

http://cen.acs.org/articles/91/i15/Mosh-Pit-Physics-Chemistry-Bar.html

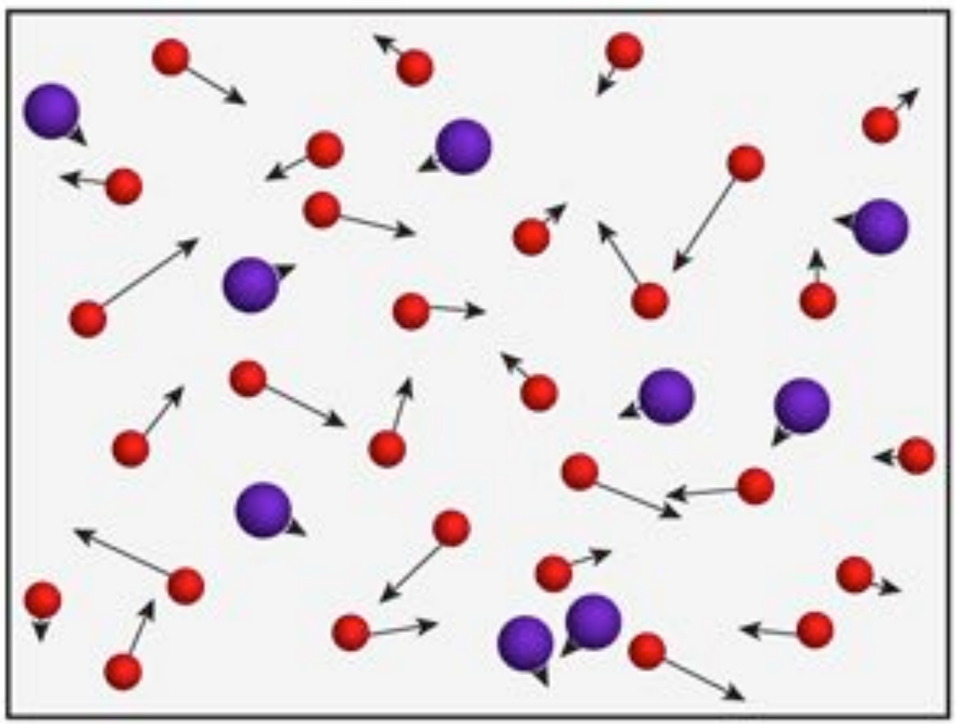
4/15/13, CEN, p. 48 How is a mosh pit like an ideal gas?

dancers collide with each other randomly and at a distribution of speeds that resembles particles in a two-dimensional gas



Gas Laws: Changing T, P, V, n Changes T, P, V, n

Temperature (T in ºK) = average KE of substance
Pressure (P in atm) = force exerted on an area
Volume (V in ℓ) = space occupied by a substance
Moles (n) = amount of substance present



http://atomsinmotion.com/book/chapter1/atoms

Explain what happens in the situations described below. Identify the variables and the specific gas law that is involved.

a. Marshmallow when heated.

http://en.wikipedia.org/wiki/Marshmallow

b. Marshmallow when placed in a closed filter flask attached to a vacuum cleaner.

http://www.coleparmer.com/buy/product/81845-kimcote-heavy-wall-filter-flask-4000ml-953760-4002.html
http://thelastpsychiatrist.com/2009/06/delaying_gratification.html

Explain what happens in the situations described below. Identify the variables and the specific gas law that is involved.

c. Tire pressure in the summer compared to the winter.

http://www.ezcreditwarehouse.com/rims/casinochrome.html

d. You have a big balloon and a small balloon. Which balloon has more air in it?

http://www.csballoon.com/balloon_finishes.htm

Explain what happens in the situations described below. Identify the variables and the specific gas law that is involved.

20 ml of air at $25^{o}C$ and 1 atm is compressed to 15 ml. What is the new pressure?

http://www.enasco.com/product/C12889N

Gas Laws: Changing T, P, V, n Changes T, P, V, n

Temperature (T in °K) = average KE of substance
Pressure (P in atm) = force exerted on an area
Volume (V in ℓ) = space occupied by a substance
Moles (n) = amount of substance present

Ideal Gas Law: **PV = nRT**

$P \propto T$

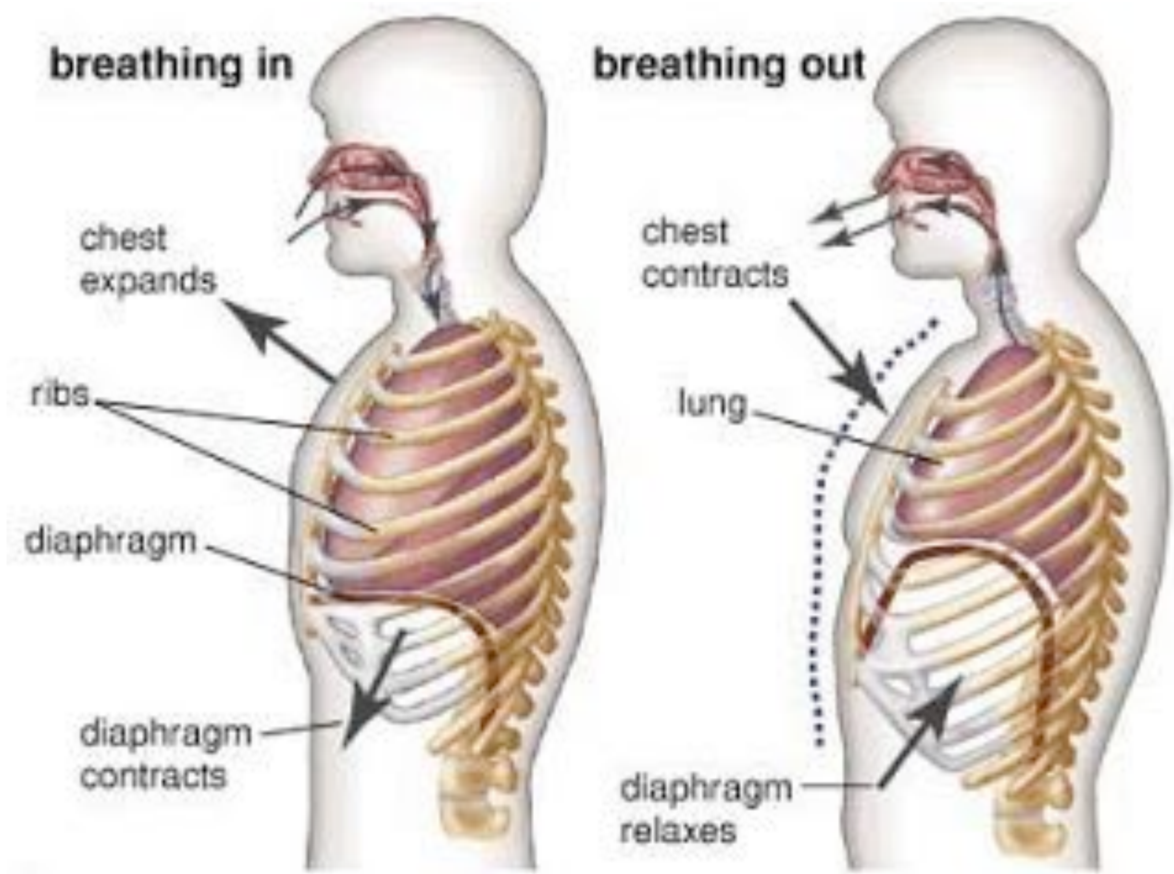
$P \propto 1/V$

$V \propto T$

$$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$$

$$\text{gas density} = \frac{(\text{molar mass})\,P}{RT}$$

Using your knowledge of gas laws, explain the breathing process (inhalation and exhalation).

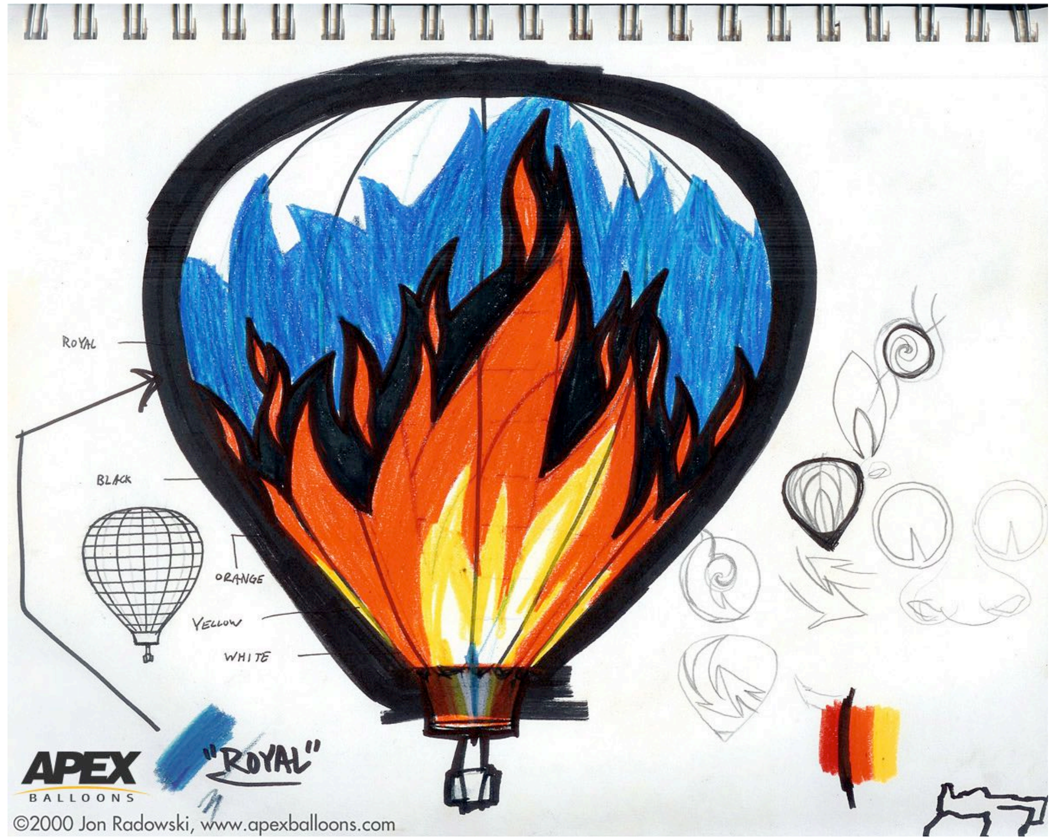


http://joygardnerteaches.blogspot.com/p/singing-anatomy-breath-vocal-folds.html

a. Hot air rises. Give reasons.

b. Calculate the density of air at 1 atm and 300 K.

c. Calculate the density of air at 1 atm and 500 K.



http://www.apexballoons.com/balloons/

d. In the Periodic Table World of Chemistry video, balloons are filled with Noble gases. Why does a balloon filled with He float whereas one filled with Ar sinks?

a. You half fill a 2 liter flexible plastic soda bottle with hot water and cap it tightly. Use gas laws to explain what happens as the water inside the bottle cools.

http://findingmyaloha.blogspot.com/2010/07/my-black-thumb-just-got-greener.html

b. Will the same thing happen to the bottle if you half fill a bottle with room temperature water in Lake Tahoe and drive to Salinas? Give reasons.

Air is a Mixture of Gases

Composition of Dry Air http://scifun.chem.wisc.edu/CHEMWEEK/PDF/airgas.pdf

Substance	% by Volume
N_2	78.1
O_2	20.9
Ar	0.9
CO_2	0.03
Ne, He, CH_4, Kr, N_2O, H_2, Xe, O_3	rest

Air is a commercial source of many gases. How is O_2 removed from air?

He supply shortage

Total Pressure of a gas mixture = the sum of the partial pressures of each gas

$P_{total} = p_1 + p_2 + p_3 + \ldots$

where p_1 = (mole fraction of component 1)(P_{total})

mole fraction of component 1 = n_1/n_{total}

p_2 = (mole fraction of component 2)(P_{total})

mole fraction of component 2 = n_2/n_{total}

Dalton's Law of Partial Pressures

<u>Example</u>: What is the partial pressure of N_2 and O_2 in air in Salinas?

$$P_{air} = \quad p_{N2} \quad + p_{O2} \quad + p_{rest}$$

mole fraction of N_2 = 0.78

p_{N2} = (mole fraction of N_2)(P_{total}) = (0.78)(1 atm) = 0.78 atm

P_{total} = 1 atm = 0.78 atm + 0.21 atm + 0.01 atm

Calculate the partial pressures of O_2 and N_2 in Lake Tahoe.

Elevation: 6,225 ft
P_{atm} = 0.85 atm

http://sierracyclesmith.com/rides/Nevada%20Rides/Lake%20Tahoe.html

<u>Note</u>: Our bodies work best when the partial pressure of O_2 is about 0.2 atm and partial pressure of N_2 is less than 1 atm.

What is the partial pressure of N_2 and O_2 in air on top of Mt. Everest?

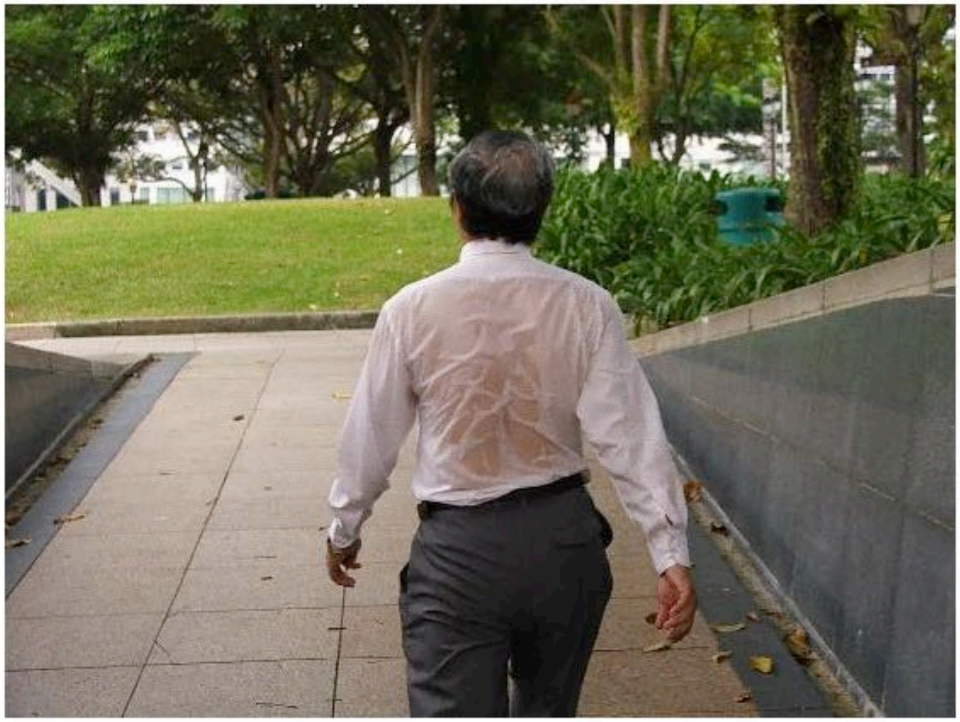
http://www.mount-everest.net/summit.html

Elevation: 29,029 ft

P_{atm} = 0.33 atm

Note: Our bodies work best when the partial pressure of O_2 is about 0.2 atm and partial pressure of N_2 is less than 1 atm.

The amount of water in air varies from 0.1% (deserts and at low temperatures) to 6% (in warm, humid areas).



Humidity **Measures the Amount of Water in Air.**

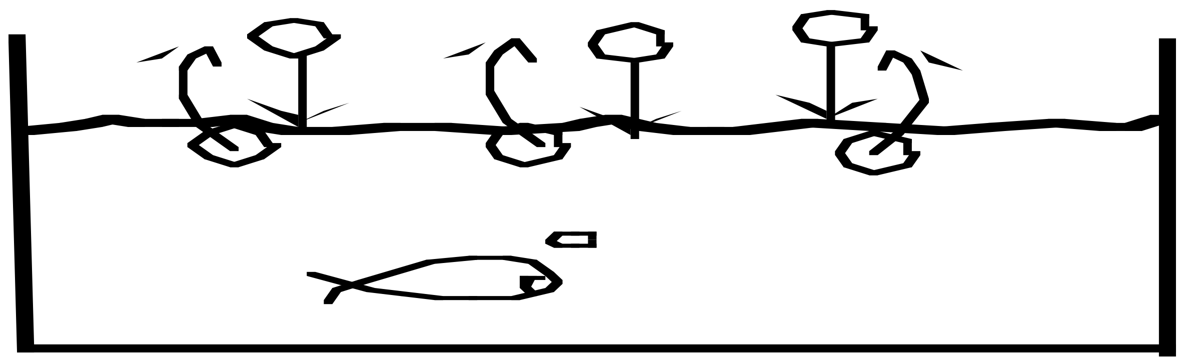
http://www.virtualtourist.com/travel/Asia/Singapore/Singapore-1495679/Local_Customs-Singapore-Weather-BR-1.html

$$\text{Relative Humidity} = \text{RH} = \frac{\text{partial pressure of water in air}}{\text{vapor pressure of water at T}}$$

Humidity **Measures the Amount of Water in Air.**

$$\text{Relative Humidity} = \text{RH} = \frac{\text{partial pressure of water in air}}{\text{vapor pressure of water at T}}$$

Vapor pressure is the pressure a gas, which is in equilibrium with its liquid, exerts on the surface of a liquid.



Vapor pressure varies with temperature:
As T increases, vapor pressure

(i) decreases (ii) stays the same (iii) increases

Table of Vapor Pressures of Water at Different T (Table 5.)

As Temperature Increases, Vapor Pressure Increases

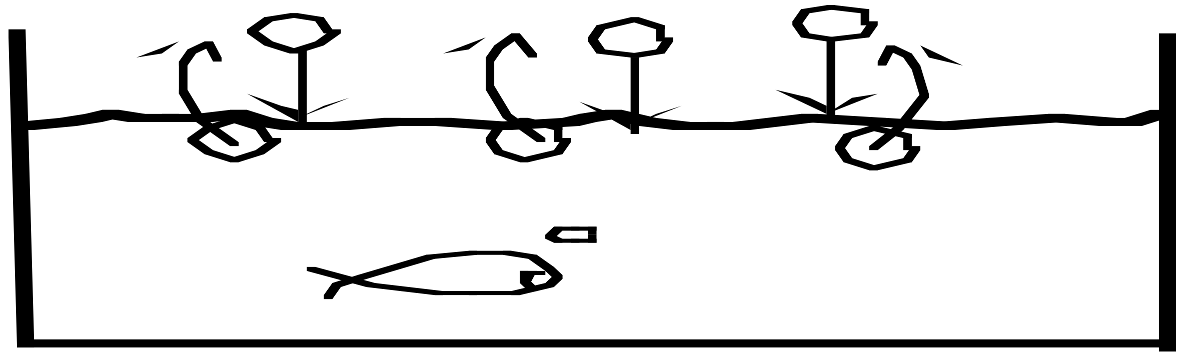


Table 1. Vapor Pressure of Water at Various Temperatures

T, ^oC	0	5	10	15	20	25	30	100
P, torr	4.58	6.54	9.21	12.8	17.54	23.76	31.82	760

What is the vapor pressure of a solid compared to a liquid?

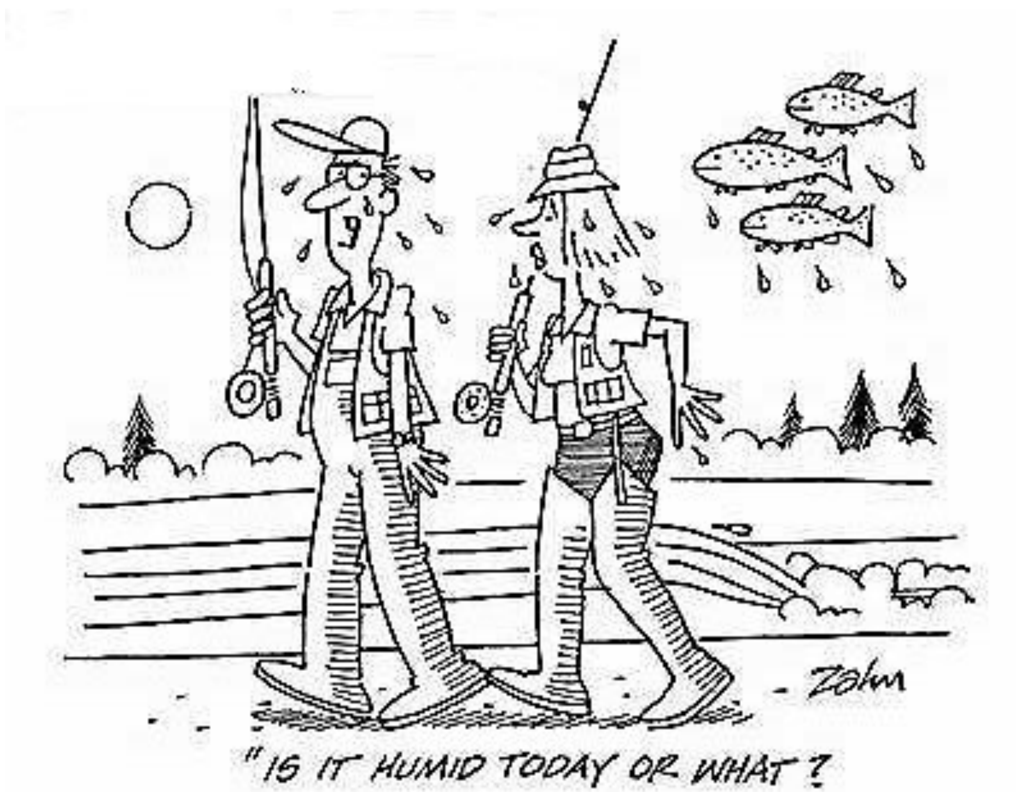
Compare acetone to water. Which substance is more volatile? Why?

Summers in the Midwest are hot and humid. Weather reports often report humidity and dew point.

a. What does humidity measure? What is the dew point?

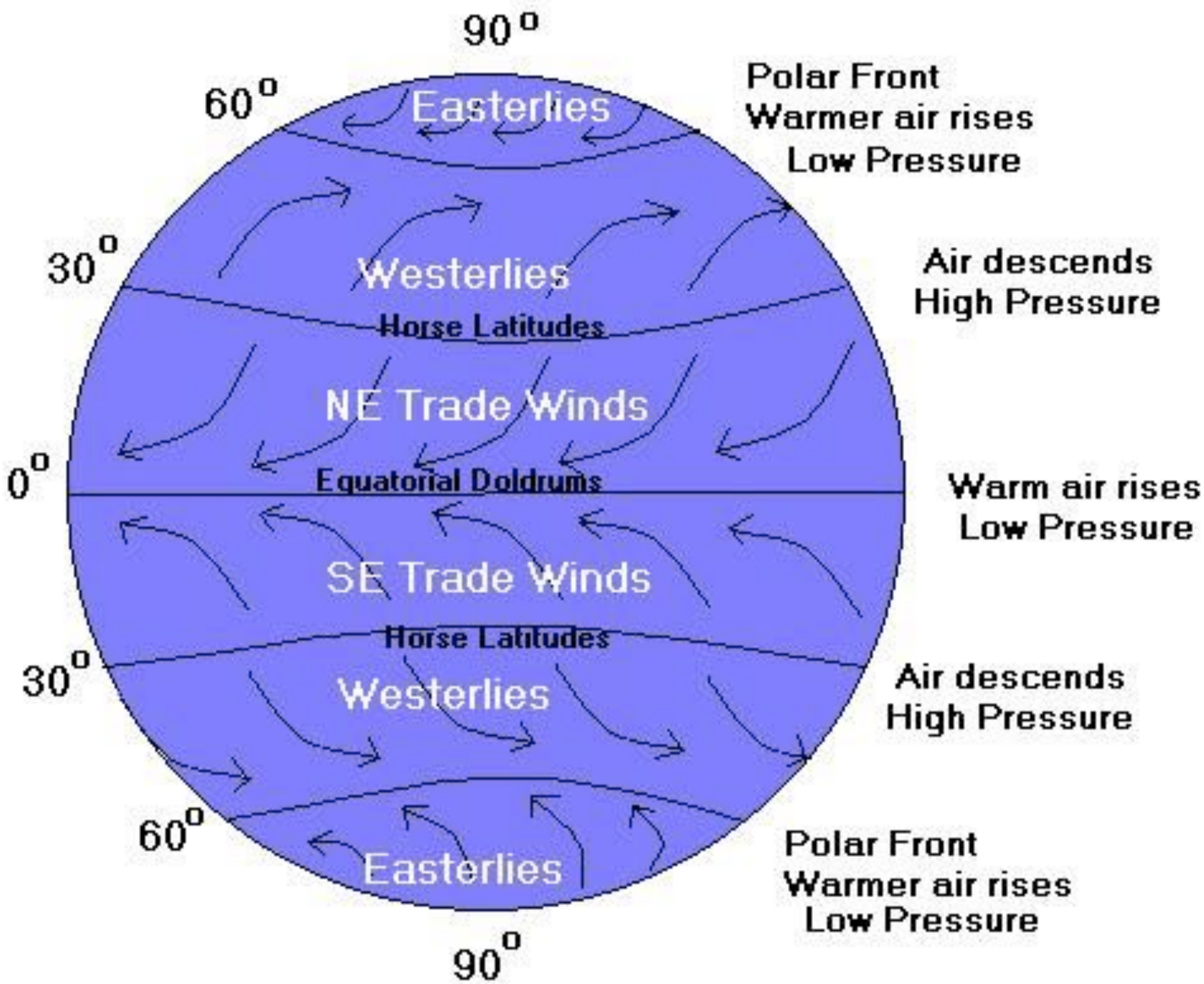
b. What is the RH when it rains?

c. Calculate the % water in air at 90% RH and 30^{o}C. What happens when the temperature drops to 25^{o}C?



http://www.springairinc.com/2011/05/humidity/

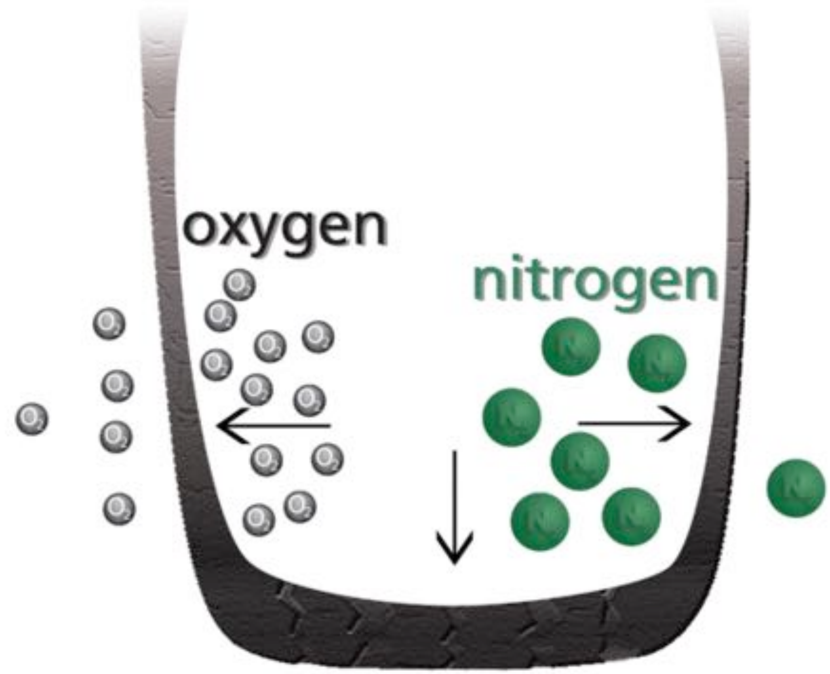
How does it get windy?



http://facstaff.gpc.edu/~pgore/Earth&Space/GPS/wind.html

Car Tires: Air or Nitrogen?

http://www.tiresalesandserviceinc.com/



http://www.wired.com/autopia/2007/10/pump-your-tires/

Costco will fill tires with N_2 at \$3 to \$10 per wheel

C&EN, 6/9/14, p. 11 WADA bans Xe and Ar

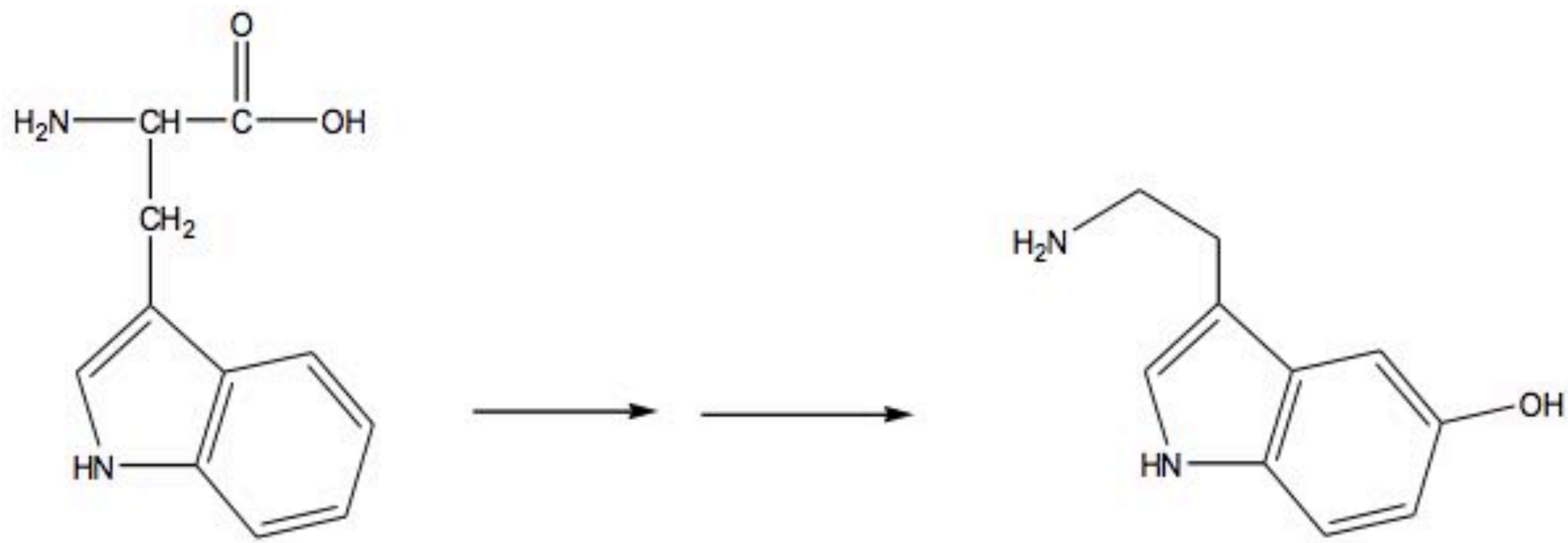
http://cen.acs.org/articles/92/i23/Doping-Agency-Bans-Xenon-Argon.html

http://www.chemicool.com/elements/xenon.html

http://www.chemicool.com/elements/argon.html

Xenon is surprisingly bioactive and can enhance the oxygen-carrying capacity of blood. Argon is thought to work the same way.

Thanksgiving Turkey: Tryptophan and Serotonin

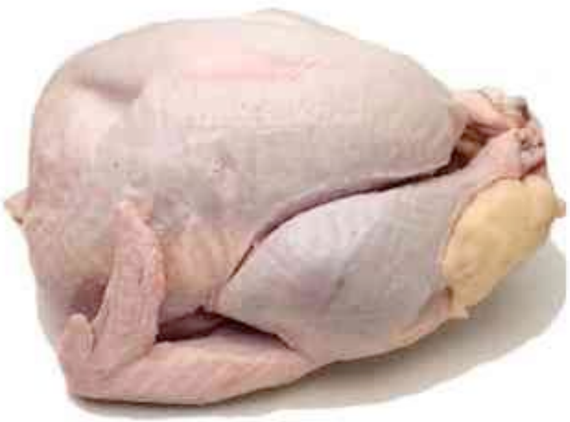


Tryptophan
amino acid

Serotonin
neurotransmitter
"happiness" hormone
regulates mood, sleep, apetite

What other foods are sources of tryptophan?
Do these other foods also make you feel sleepy?

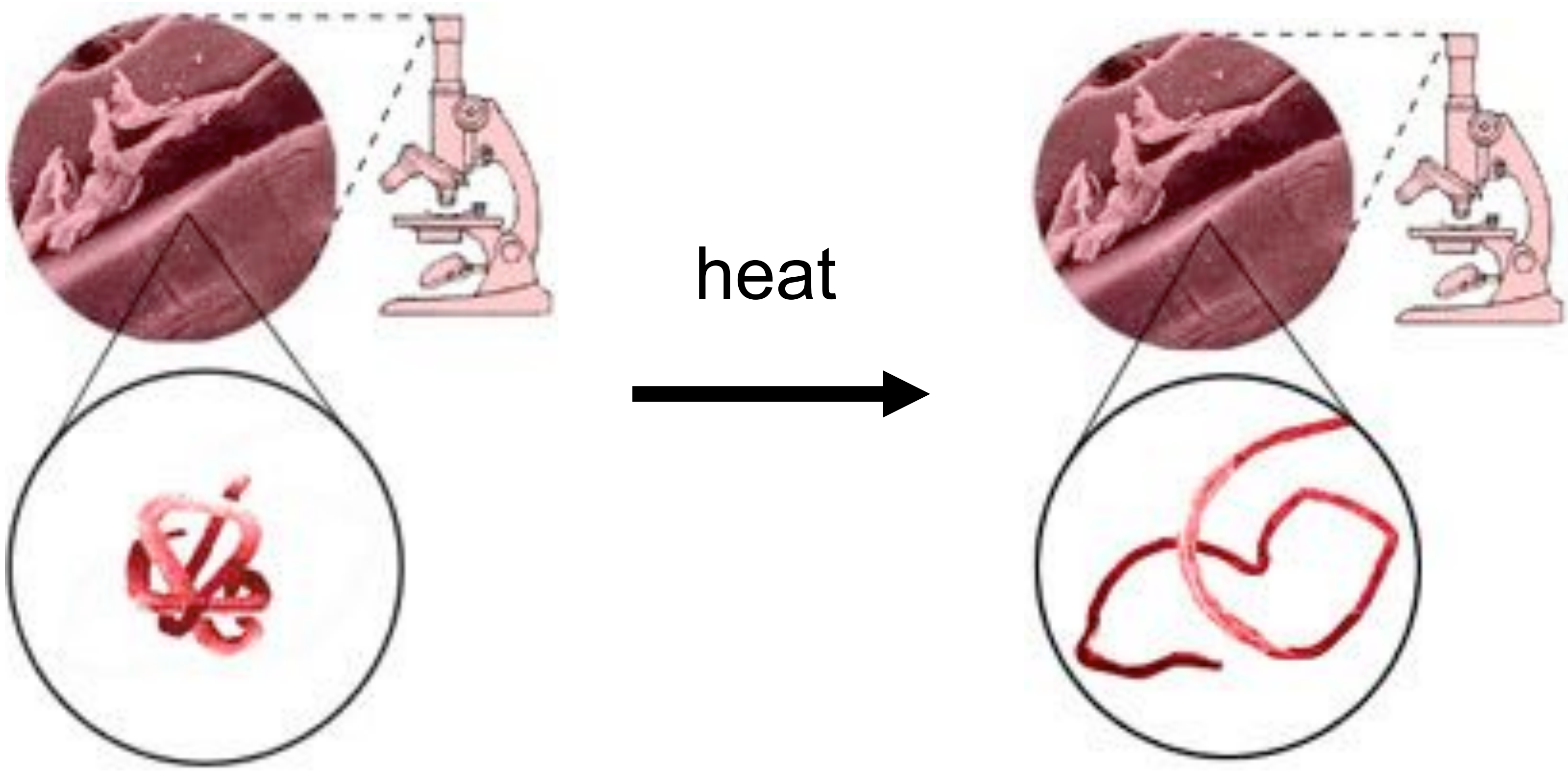
What happens to a Turkey when it Cooks?



http://kimbensen.com/node/1309

http://japho.com/turkey-cooking-instructions/

Heat Denatures Protein in Meat



http://www.exploratorium.edu/cooking/meat/INT-what-is-meat.html

Bonds break --> protein molecule unwinds
Muscle fibers shrink as water is squeezed out --> protein molecules coagulate

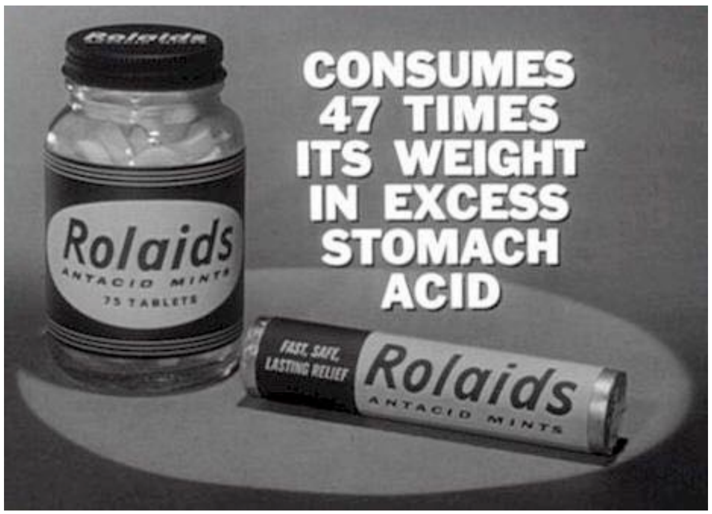
What are those <u>Bubbles</u> in your drink?

http://www.topnews.in/healthcare/content/22804sugar-packed-fizzy-drinks-hazardous-health-tobacco

http://blog.wineenthusiast.com/category/champagne/

And if you Eat too Much --> Acid Indigestion!

http://www.sugardoodle.net/Sabbath%20Day/Sabbath%20Day%20Observance.shtml



http://christinaciddio.com/2011/12/14/milk-of-magnesia-face-primer/

http://hungryholler.blogspot.com/2011/05/what-happened-to-rolaids.html

And if you Drink too Much --> Hangover!

$$C_2H_5OH \xrightarrow{\text{enzyme}} CH_3CHO \xrightarrow{\text{enzyme}} CH_3COOH$$

How Does Popcorn Pop?

"Popcorn, or popping corn, is corn (maize) which expands from the kernel and puffs up when heated. Corn is able to pop because, like sorghum, quinoa and millet, its kernels have a hard moisture-sealed hull and a dense starchy interior. This allows pressure to build inside the kernel until an explosive "pop" results. Some strains of corn are now cultivated specifically as popping corns." http://en.wikipedia.org/wiki/Popcorn

a. Briefly describe how a popcorn pops using gas laws.
http://recipes.howstuffworks.com/question255.htm
http://www.nasa.gov/audience/forkids/home/popcorn.html
b. Calculate the gas pressure inside a popcorn kernel.

http://pubs.acs.org/isubscribe/journals/cen/83/i19/html/8319newscripts.html

5/9/05, CEN, p. 48 Popcorn kernels must have a moisture level of about 15% in their starchy center in order to explode. "***Old Maids***" (unpopped popcorn kernels) are due to leaky pericarps, which prevent the moisture pressure buildup required and lack the structure needed for the kernel to explode

http://loyalkng.com/2009/07/27/popcorn-unpopped-kernels-separator-eat-pop-confusion/

Popcorn Minus Diacetyl (CEN, 9/10/07, p. 11)
Microwave popcorn makers are removing additive because of concern for workers' and consumers' health
David Hanson

Manufacturers of microwave popcorn in the U.S. are replacing diacetyl (2,3-butanedione) as the butter-flavor agent in their products because the compound can cause severe obstructive lung disease in workers.

Weaver Popcorn announced at the end of August that it had eliminated diacetyl from its products. Weaver makes about 20% of the microwave popcorn in the U.S. ConAgra Foods, the largest maker of microwave popcorn, including the brands Orville Redenbacher and Act II, tells C&EN that it will eliminate diacetyl from its products in the near future.

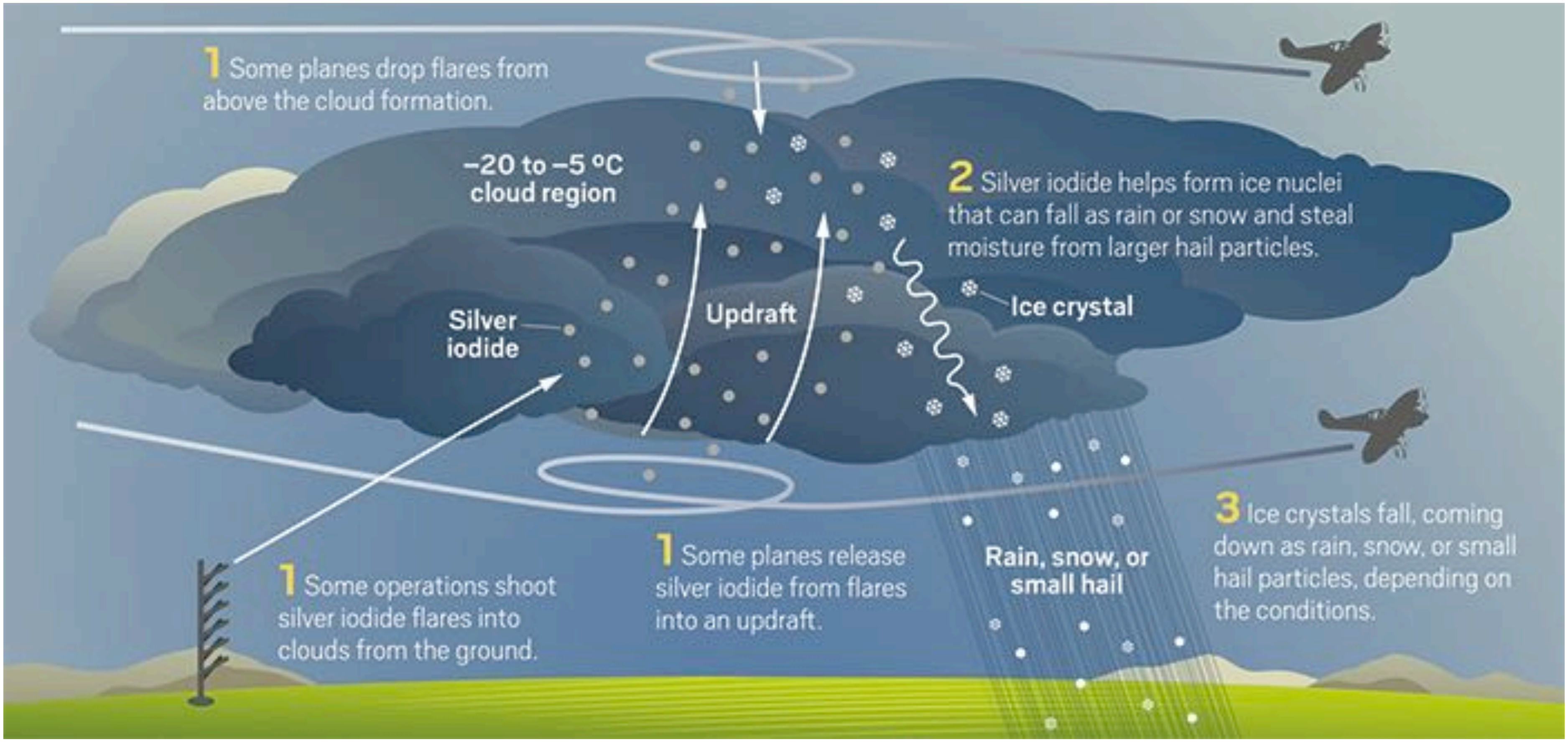
Diacetyl exposure has been a concern in microwave popcorn manufacturing facilities since at least 2000, when it was first recognized that some workers had developed lung problems. Investigations by the National Institute of Occupational Safety & Health pointed to diacetyl as the cause, and the agency proposed stricter limits on exposure.

In 2006, several labor unions petitioned the Occupational Safety & Health Administration to set a temporary emergency standard for diacetyl to protect workers, but OSHA has not acted yet.

The possible health impact on consumers is an increasing concern. Cecile S. Rose, acting head of the Division of Environmental & Occupational Health Science of the National Jewish Medical & Research Center, in Denver, wrote a letter to FDA in July describing what may be the first consumer to contract obstructive lung disease from breathing fumes from microwave popcorn packages. FDA permits use of diacetyl as a flavoring and classifies it as "generally recognized as safe."

In 2003, EPA initiated a study of exposure to compounds from microwave popcorn packages. Those data have never been made public, but a spokeswoman for EPA says the results will be published soon.

CEN, 5/30/16 “Does Cloud Seeding Really Work?”
http://cen.acs.org/articles/94/i22/Does-cloud-seeding-really-work.html

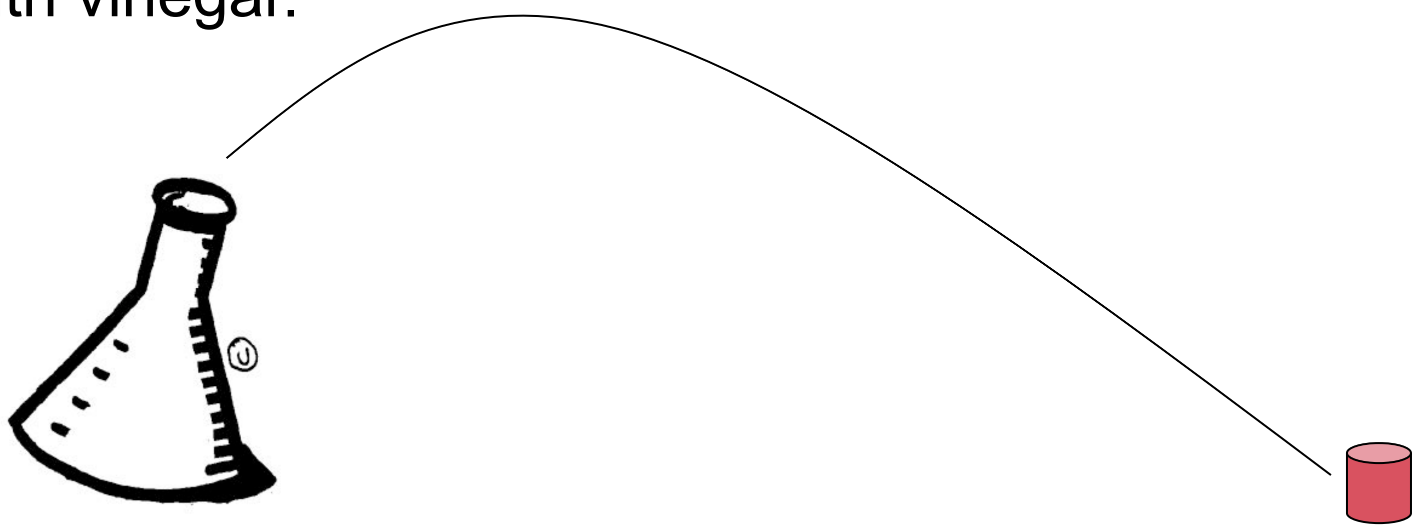


AgI (s) could transform supercooled H_2O (g) → H_2O (s) at T between -10ºC and -5ºC.

SLAC Lab

(record: 18 m)

Propel a stopper as far as you can by mixing 0.5 g of baking soda with vinegar.



http://school.discoveryeducation.com/clipart/clip/flask2.html

Experimental Variables: