Chem 1B Objective 3:
Identify the chemical forces in ionic and molecular solutions.

Key Ideas:
Most substances are mixtures. Important mixtures are solutions. Chemical forces are important in separating and transporting substances.
See chemical forces between solute and solvent, solute-solute, solvent-solvent.
The relative strength of these chemical forces determines solubility.
E.g., if solute-solvent forces are stronger than solute-solute or solvent-solvent, the solute dissolves in solvent.

Soaps and Detergents use Solubility to Clean

Automatic Dishwashing: Technology At Heart Of New Product (CEN, January 30, 2006, p. 16)

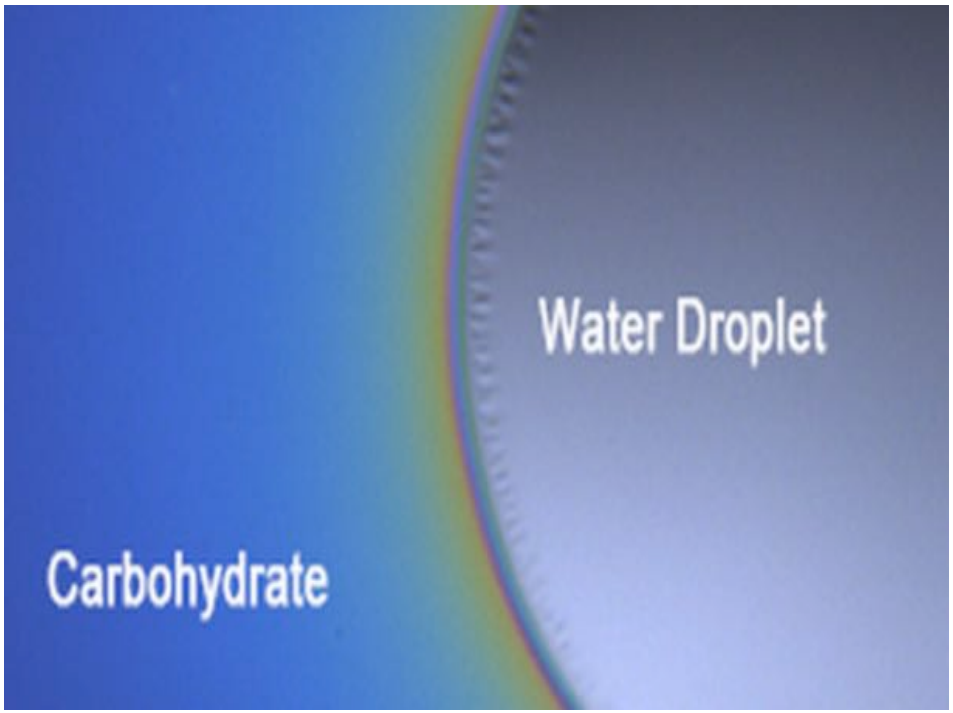
Finish Quantum, which contains a softening salt, a rinse aid, and a glass protector in one single-dose product that combines three physical forms: powder, gel, and the firm's Powerball cleaning sphere.

According to Reckitt, these forms can coexist because they are hived apart in a three-chambered capsule made of water-soluble polyvinyl alcohol. The chambers isolate otherwise incompatible cleaning agents and release them at the right stage of the dishwashing cycle, the company says.

One of the ingredients being kept separate is a self-activating bleaching agent called 6-(phthalimido)peroxyhexanoic acid, or PAP for short. Magg says PAP bleaches away stains more effectively than does the traditional ADW combination of sodium percarbonate with the activator tetraacetylethylenediamine.

http://www.foodnavigator.com/Science-Nutrition/Nestle-claims-credit-for-major-advance-in-beverage-powder-solubility?

6/5/14, Nestlé claims credit for ‘major advance’ in beverage powder solubility

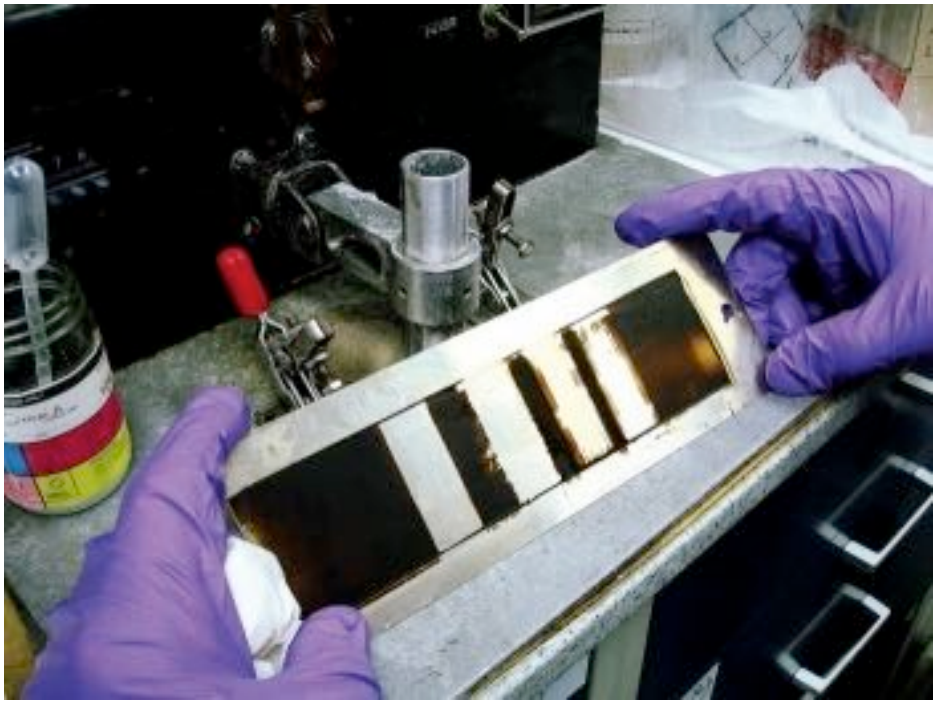


Complete dissolution of solid powders = smooth, appealing drink and adequate nutrient delivery and uptake

The SOFTNESS of the substrate in the immediate VICINITY of the water droplet determines the amount of water absorbed.

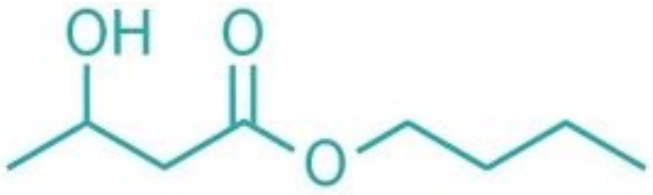
Dissolution depends on the physical and chemical nature of the substrate (sugar) and solvent (water).

C&EN, 6/2/14, p. 24 (http://cen.acs.org/articles/92/i23/Cleaning-Conundrum.html)
Eastman Chemical Invents a ***New Cleaning Solvent*** for household and industrial cleaning products that meets the EPA standards for toxicity and VOC content.



Eastman's Scrubinator

Trade Name:
Omnia

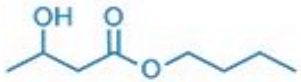
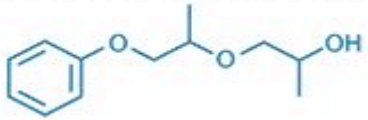
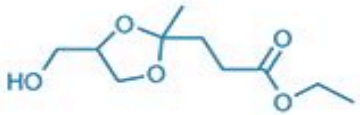


Butyl 3-hydroxybutyrate

Replaces: ethylene glycol monobutyl ether (CA hazardous substance)
dipropylene glycol monomethyl ether (VOC)

New Cleaning Solvents (http://cen.acs.org/articles/93/i3/Cleaning-Product-Makers-Bask-New.html)

PROBLEM SOLVERS New solvents that meet strict VOC standards are proliferating.

Solvent (and structure)	Trade name	Supplier	Select applications
 Butyl 3-hydroxybutyrate	Omnia	Eastman	Industrial cleaners and degreasers
 *N,N*-Dimethyl-9-decenamide[a]	Steposol MET-10U	Stepan	Household cleaners, adhesive removal, paint strippers
 Dipropylene glycol phenyl ether	Dowanol DiPPh	Dow	Household cleaners
 Ethyl levulinate glycerol ketal	None	Segetis	Detergents, hard-surface cleaners, graffiti removal
 Methyl-9-dodecenoate	Clean 1200	Elevance	Heavy manufacturing, food processing
 1,3-Propanediol	Zemea	DuPont	Laundry detergents, hard-surface cleaners, glass cleaners

a A surfactant targeted to replace solvents.

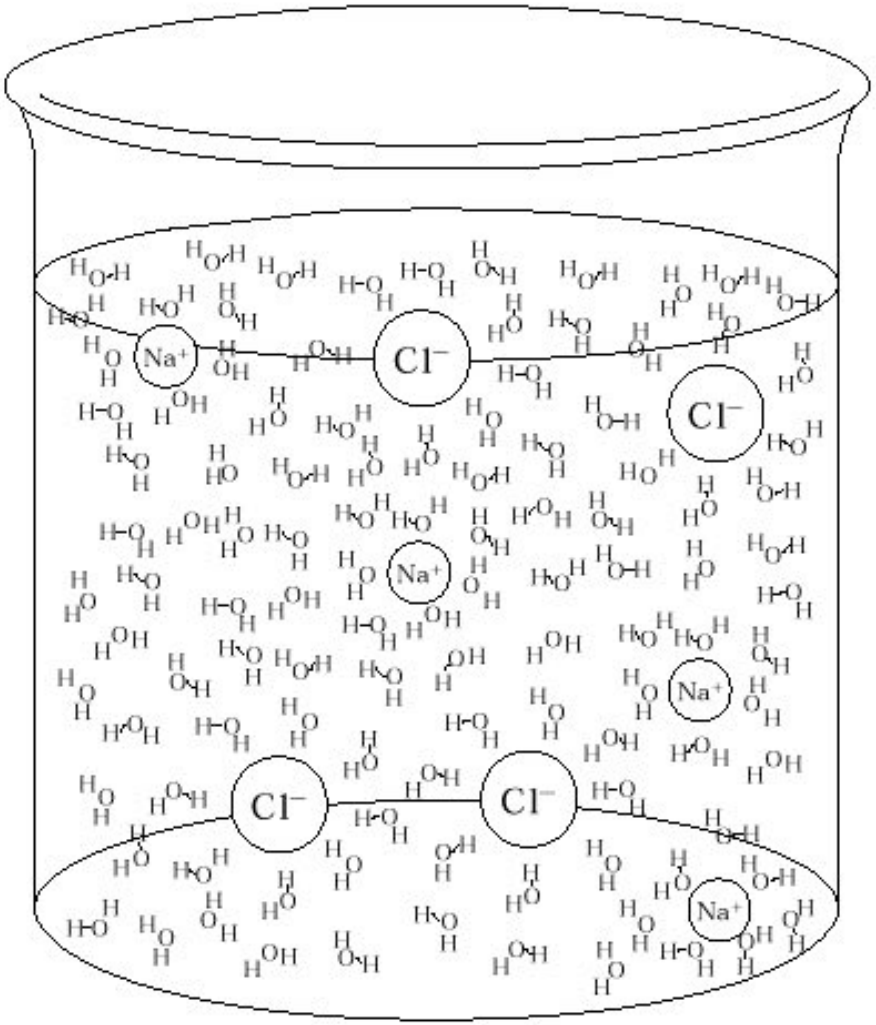
Most Substances are Mixtures: Solutions

A solution consists of

a) Solid and liquid
b) Solute and solvent
c) Solvent and substance

"If you're not part of the solution, you're part of the _____."

-- Steven Wright



http://wikis.lawrence.edu/display/CHEM/Practical+Solutions-Schroeder

Objective: Quantify the Amount of Solute in a Solution by Concentration

Molarity (M) = moles of solute/liter of solution

% by mass = g of solute/100 g of solution
% by volume = ml of solute/100 ml of solution
% (mass/volume) = g of solute/100 ml of solution

molality (m) = moles of solute/kg of solvent

20 g of NaCl is dissolved in enough water to make 1 cup of solution. Calculate the concentration.

Objective: Quantify the Amount of Solute in a Solution by Concentration

Molarity (M) = moles of solute/liter of solution
% (mass/volume) = g of solute/100 ml of solution
molality (m) = moles of solute/kg of solvent
20 g of NaCl is dissolved in enough water to make 1 cup (240 ml) of solution. Calculate the concentration.

$$\text{Molarity} = \frac{20 \text{ g NaCl}}{58.5 \text{ g/mole} \mid 0.240 \text{ l}} = 1.4 \text{ M}$$

$$\%\ \text{mass/volume} = \frac{20 \text{ g NaCl}}{240 \text{ ml}} \times 100 = 8.3\%\ \text{NaCl (m/V)}$$

$$\text{molality} = \frac{20 \text{ g NaCl} \mid [\,240 \text{ ml solution} \mid 1.06 \text{ g} \mid 20 \text{ g NaCl}\,] \mid 1000 \text{ g}}{58.5 \text{ g/mole} \mid \text{kg}} = 1.5 \text{ m}$$

Density of 8.3% NaCl (aq)

kg of solvent

Objective: Quantify the Amount of Solute in a Solution by Concentration

25 g of sugar (sucrose, $C_{12}H_{22}O_{11}$) is dissolved in enough water to make 250 ml of solution.

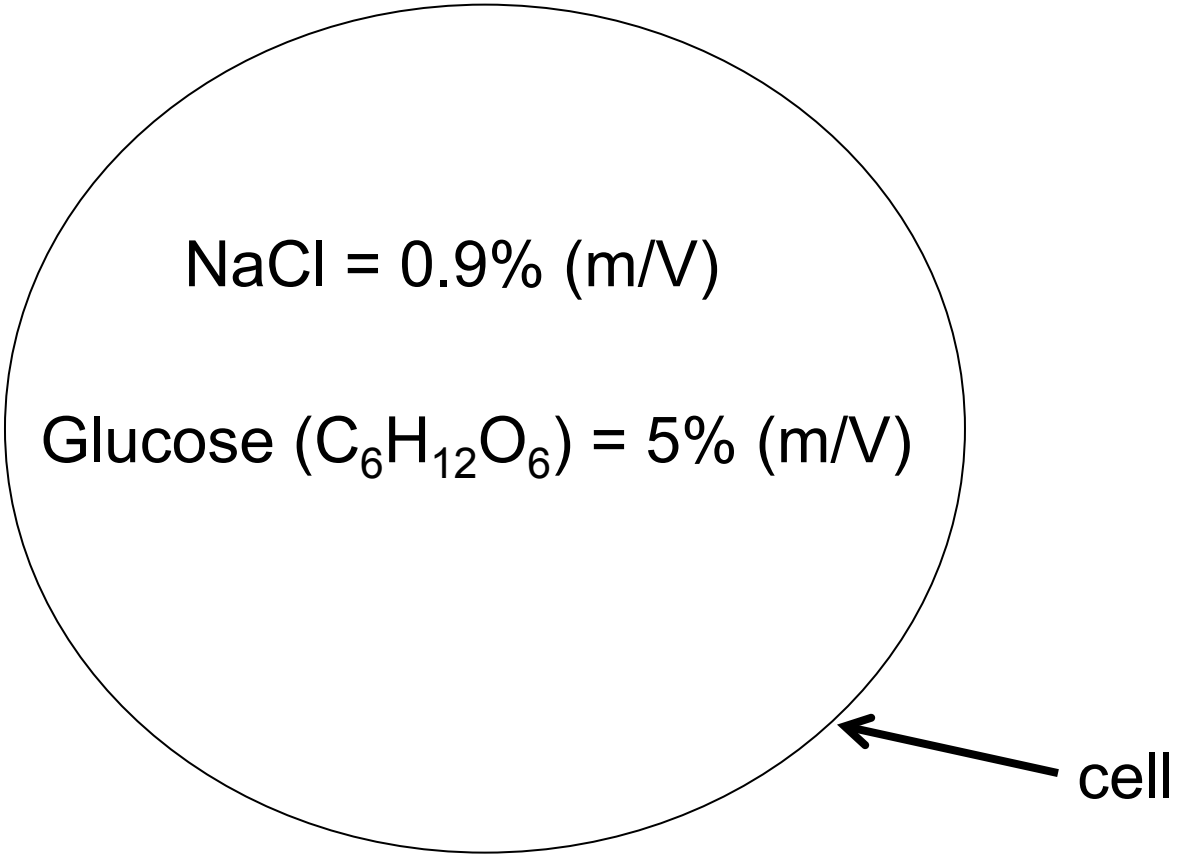
Calculate the concentration in:

(i) Molarity
(ii) molality
(iii) % (mass/volume)

Useful information: density of this sugar-water solution is 1.04 g/ml (http://homepages.gac.edu/~cellab/chpts/chpt3/table3-2.html)

In Us Humans

(physiological concentrations)



0.9% NaCl has a _____ ***Molarity*** than 5% glucose.

(higher/lower/same)

Give reasons.

Chem 1A: Solubility of one substance in another depends on polarity ("like dissolves like"). You can predict whether one substance is soluble in another.

1. Is salt (NaCl) soluble in water? Give reasons.
2. Is oil soluble in water? Give reasons.
3. Is gasoline soluble in oil? Give reasons.

http://jerpchem11.blogspot.com/2010/03/solution-chemistry-mar30.html

But According to the **Solubility Rules Table** ===> ***Not*** all ionic compounds are soluble in water.

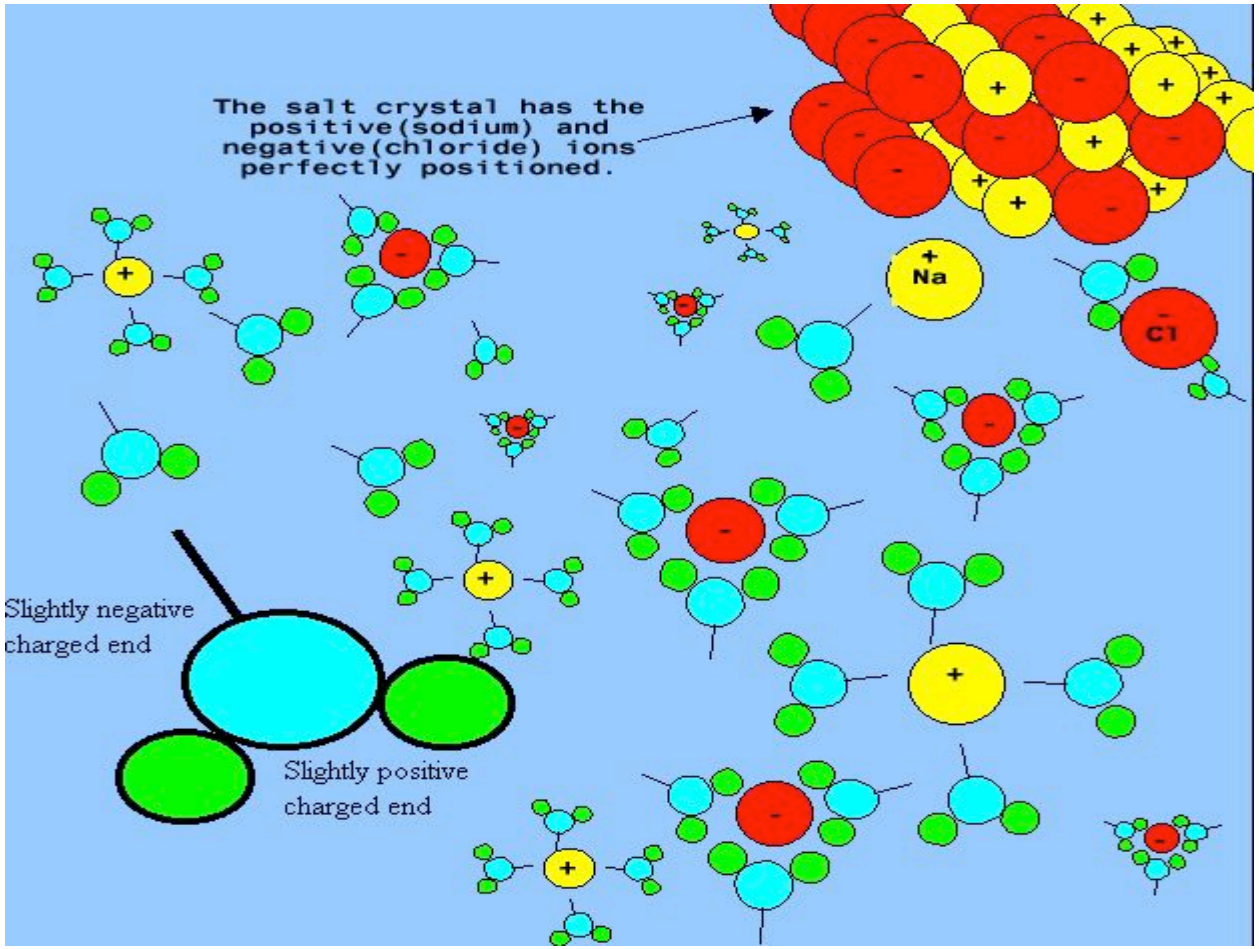
E.g., AgCl is not soluble in water. Why not?
$CaCO_3$ is not soluble in water. Why not?

Objective: explain solubility of a substance in a solvent

Chem 1B: Solubility of one substance in another depends on solution type:

Ionic solution - look at *lattice energy* *vs.* *hydration energy*

NaCl is soluble in water because hydration energy > lattice energy



But AgCl is **not** soluble in water because

_____.

Draw a picture.

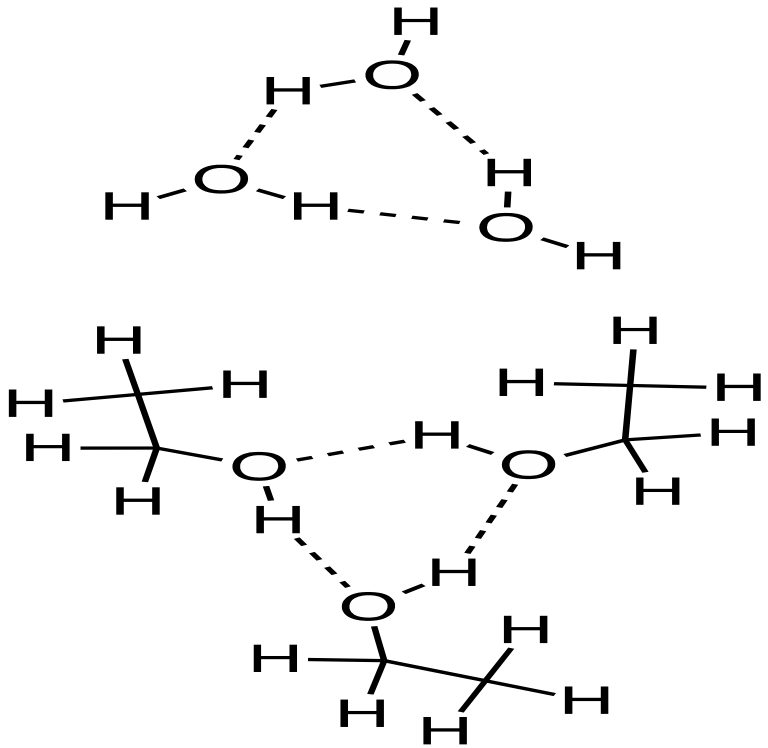
http://www.dynamicscience.com.au/tester/solutions/chemistry/solutionconcentration.htm

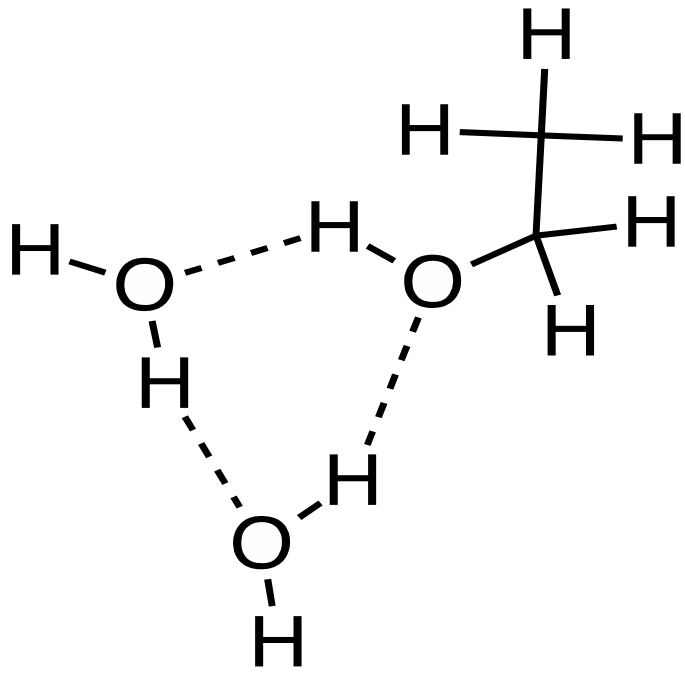
Objective: explain solubility of a substance in a solvent

Chem 1B: Solubility of one substance in another depends on solution type:

Molecular solution - look at *similar intermolecular forces*

E.g., ethanol is soluble in water. Each substance has H bonds. So ethanol can H bond to water (and break H bonds between water molecules).



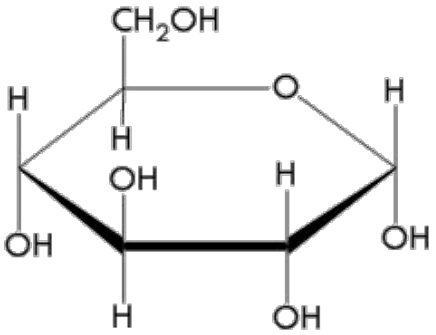


Objective: explain solubility of a substance in a solvent

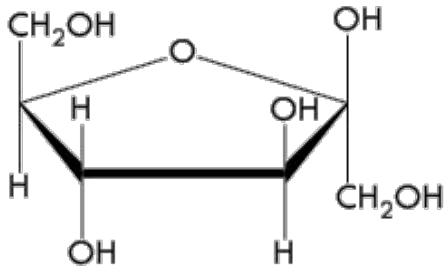
Chem 1B: Solubility of one substance in another depends on solution type:

Molecular solution - look at *similar intermolecular forces*

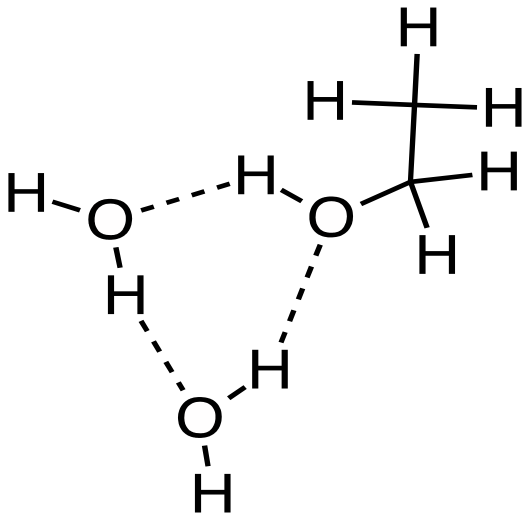
E.g., sugar is soluble in water because _____. See Lab 2.

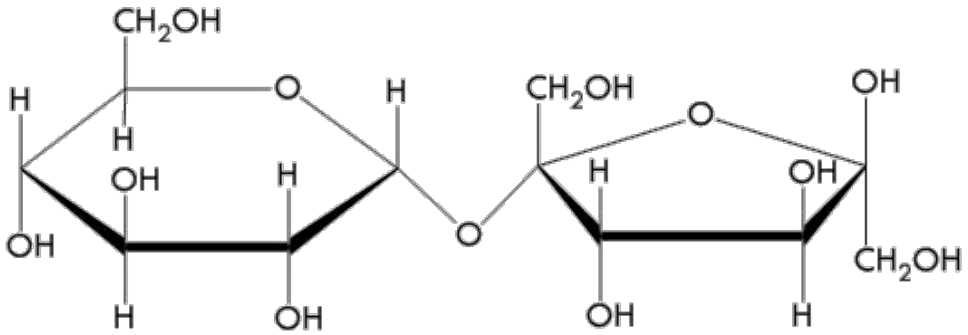


Glucose



Fructose





Sucrose

https://racheltestenc.blogspot.com/2013/09/high-fructose-corn-syrup.html

Objective: explain solubility of a substance in a solvent

Oil is not soluble in water because _____. Draw a picture.

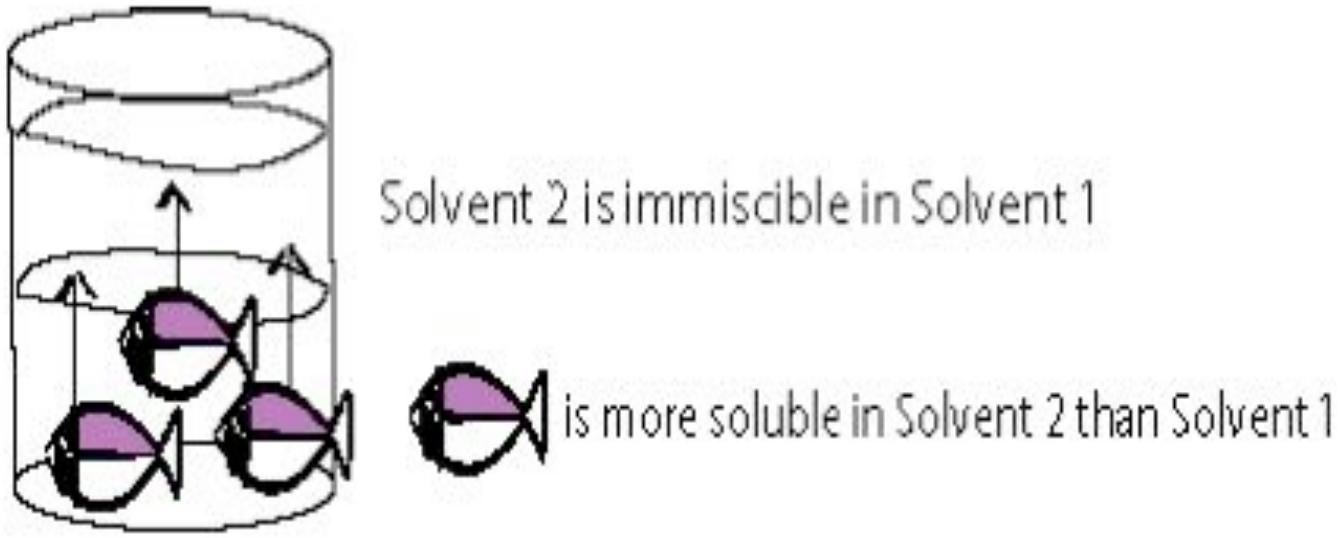
Oil = $C_{20}H_{42}$
Hint: Is oil polar or non-polar?
What IM forces exist between oil molecules?
What IM forces exist between water molecules?
Can oil break the IM forces between water?

Understanding the Solution Process and Properties Allows You to Control Nature

Solution music video:
http://jerpchem11.blogspot.com/2010/03/solution-chemistry-mar30.html

You can use the Solution Process to ***Separate*** a Mixture

Liquid-liquid extraction:



E.g., Cl_2 in water. Add hexane. Cl_2 is more soluble in hexane than water so Cl_2 moves (extracted/leached) from water to hexane.

Lab 1. Part C
You synthesized iso-amyl acetate (banana ester).
You have a mixture of banana ester, iso-amyl alcohol, and acetic acid.
Add this mixture to water.
You see two layers form.

The _____ and _____ are more soluble in _____ than in the _____ so the alcohol and acid are extracted into the water.

a) Ester, alcohol, acid, water

b) Alcohol, acid, ester, water

c) Alcohol, acid, water, ester

Solid-liquid extraction:

Coffee beans contain many compounds, including caffeine.

a) What substance is used to remove/extract caffeine and other substances from coffee beans to make a cup of coffee?

b) What factors determine how much "stuff" is extracted from coffee beans?

c) What substance can be used to remove/extract caffeine only from coffee beans to make decaf?

d) What factors are considered?

How to make a strong cup of coffee? Solid-Liquid Extraction

Find a solvent in which the caffeine and other substances are soluble. Solubility depends on _____.

http://cen.acs.org/articles/92/i39/Coffee-Brew-Coffee-Beans.html

Blossom Coffee:

$5,000 coffee maker!

Temperature control within 0.5 °F across a two- to four-minute brew cycle brews a $5,000 cup of coffee.

Coffee beans:

hundreds of flavor components

soluble at *different* rates and temperatures

Adjustable brewing temperature brings out many different desirable flavors.

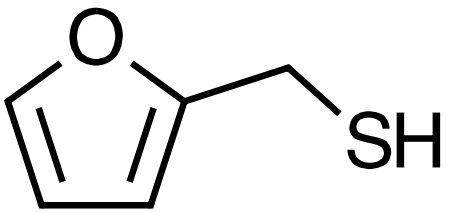
Coffee has over 1500 substances (850 volatile, 700 soluble)

http://www2.illy.com/wps/wcm/connect/us/illy/the-world-of-coffee/the-science-of-coffee/

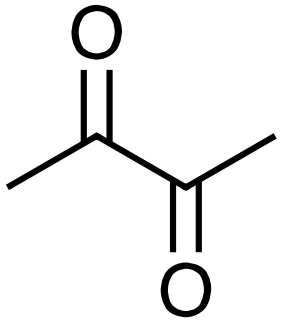
http://www.coffeeresearch.org/science/aromamain.htm

"Coffee: Physiology", 1988, By R. J. Clarke, R. Macrae

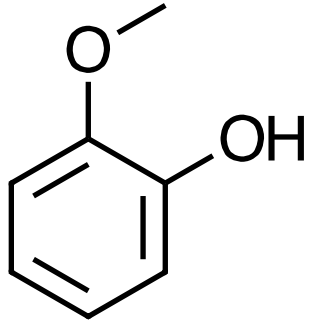
(http://books.google.com/books?id=oI6LtxfEKkwC&pg=PA2&source=gbs_toc_r&cad=4#v=onepage&q&f=false)



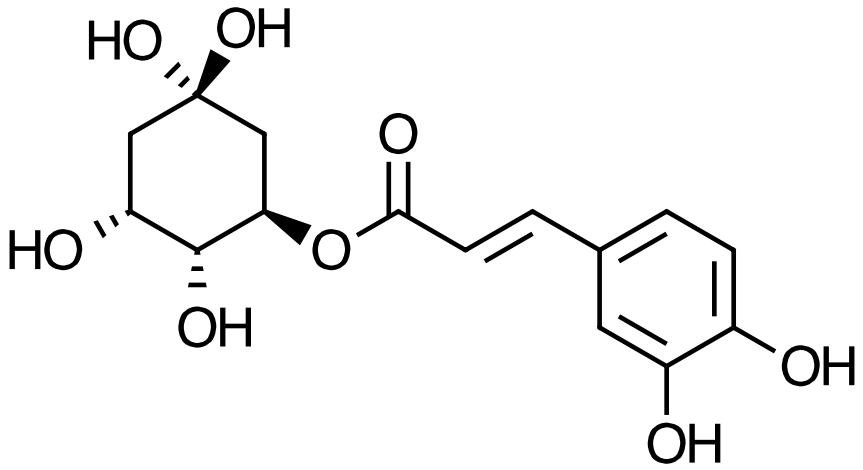
2-Furfurylthiol =
roasty (coffee) smell



2,3-Butanedione =
buttery



Guaiacol =
phenolic, spicy smell



Chlorogenic acid =
stimulates stomach secretion

How to make decaf? ***Extract caffeine only from coffee by:***

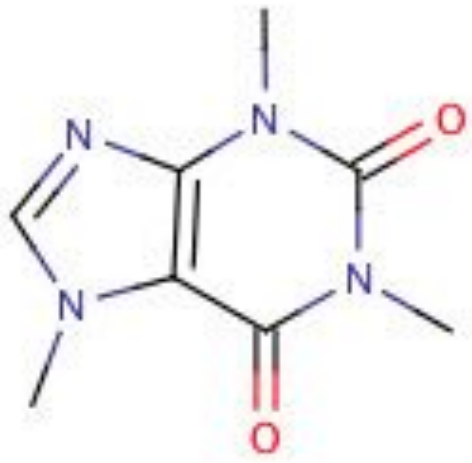
Using a solvent in which caffeine is soluble but the other substances are not. E.g., C_6H_6, $CHCl_3$, CH_2Cl_2, ethyl acetate

Measure amount of caffeine extracted by:

1. "Measurement of caffeine in coffee beans with UV/vis spectrometer", A. Belay, et al. (http://www.sciencedirect.com/science/article/pii/S0308814607010308) www.sepscience.com/.../449db804-202c-4e19-b793-4fb8ab12eb23

Absorption spectrum shows λ_{max} = 275 nm

2. HPLC analysis (www.csun.edu/~hcchm003/321l/321lmlc.pdf)



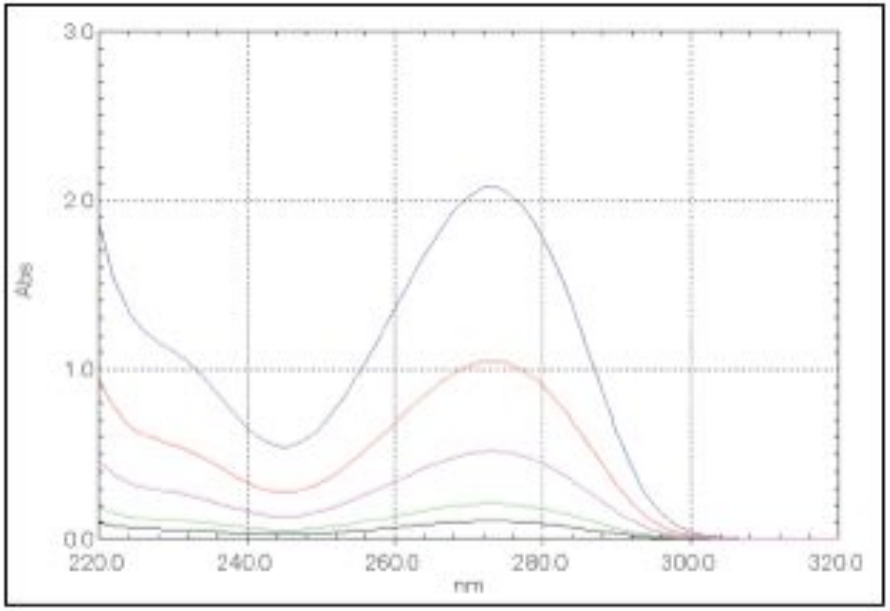
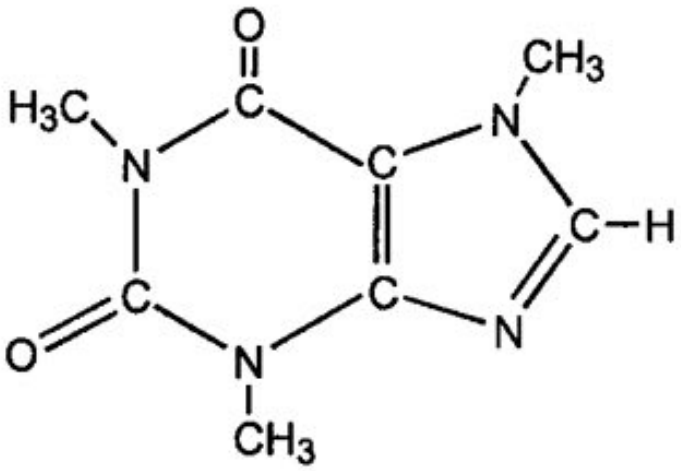
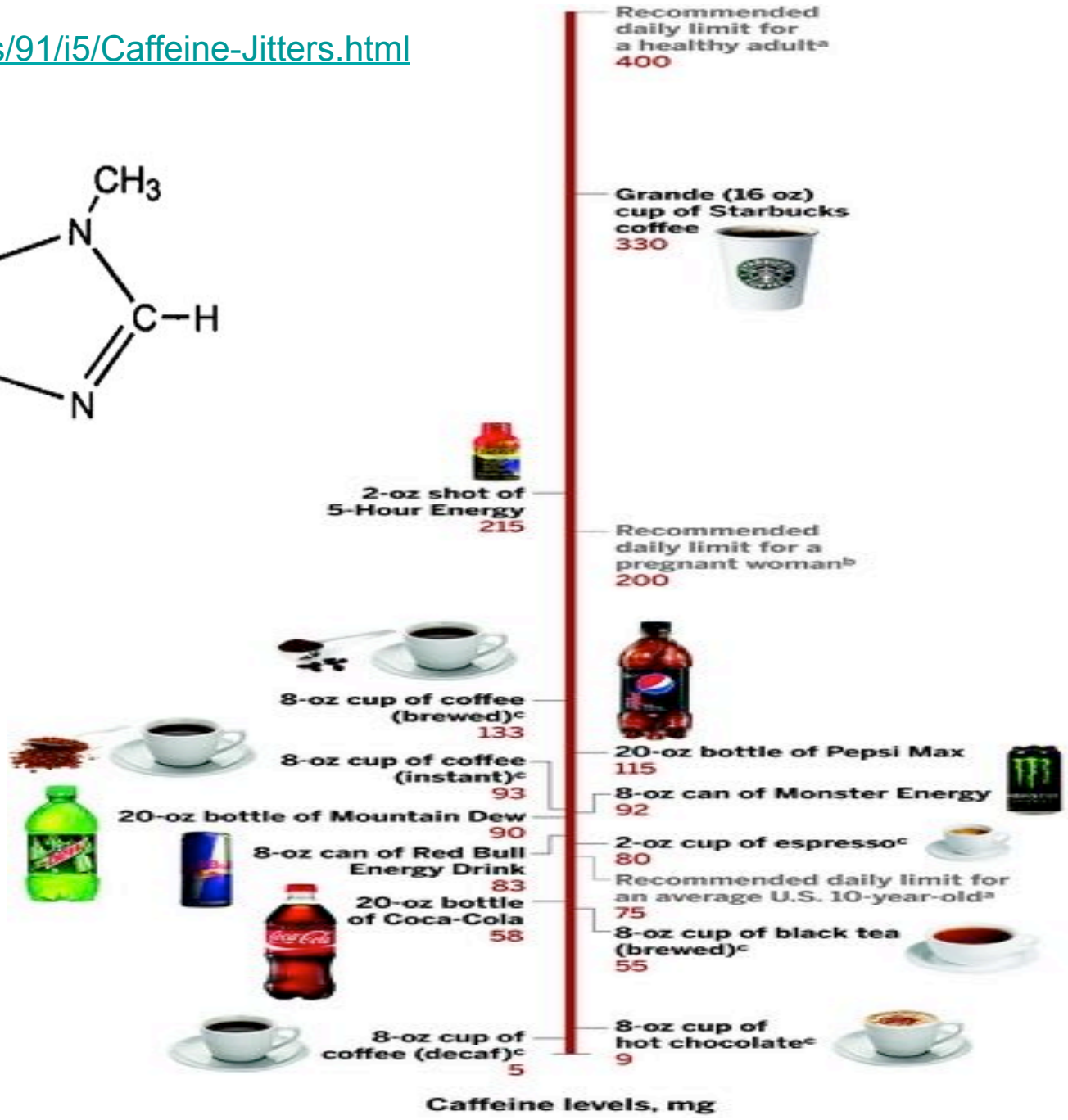


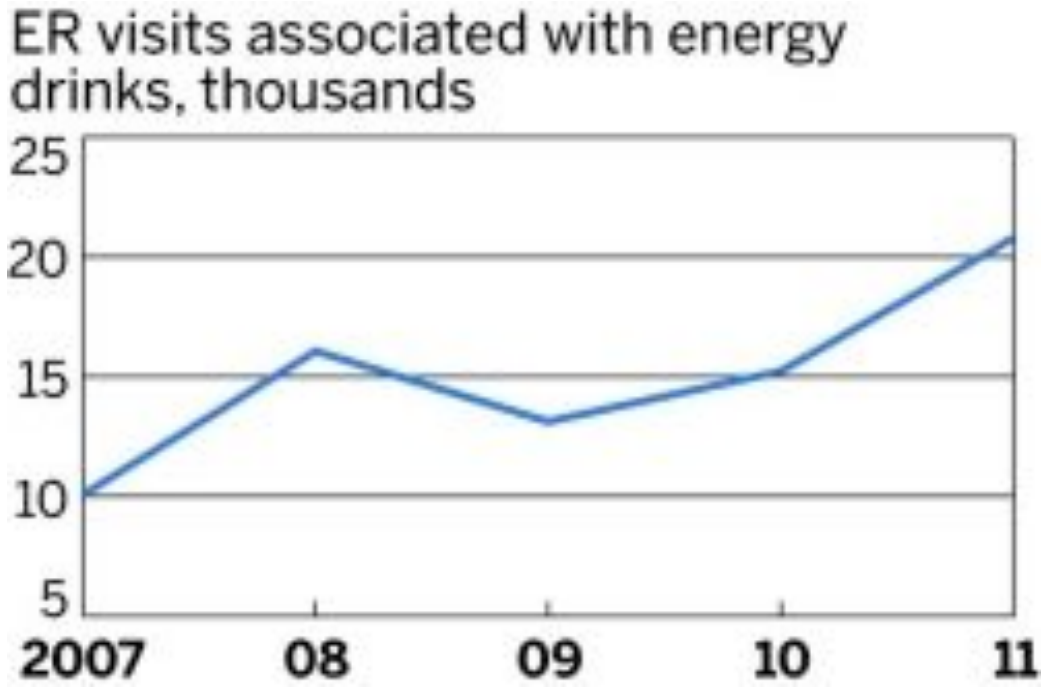
Fig. 4 Absorption Spectra of Caffeine Aqueous Solutions at Different Concentrations Black: 2 mg/L, Green: 4 mg/L, Pink: 10 mg/L, Red: 20 mg/L, Blue: 40 mg/L

http://cen.acs.org/articles/91/i5/Caffeine-Jitters.html



Caffeine





EMERGENCIES

Energy drinks are being increasingly linked with hospital visits in the U.S. Note: ER visits for 2012 not yet available. Source: Substance Abuse and Mental Health Services Admininstration

http://cen.acs.org/articles/91/i5/Caffeine-Jitters.html

C&EN, 8/12/13, p. 6
http://cen.acs.org/articles/91/i32/Caffeine-Disrupts-Brain-Growth-Mice.html

Caffeine disrupts brain growth in mice
(who were given the equivalent of 3-4 cups of coffee per day)

C&EN, 1/20/14, p. 34
http://cen.acs.org/articles/92/i3/Caffeine-Boosts-Memory-Humans.html

Caffeine boosts memory in humans (who drank 1.5 cups of coffee per day)

You're boiling water to cook pasta or beans

Why Add Salt to Water?

Adding salt to the water

a) Makes the water salty
b) Makes the water boil faster
c) Cooks the pasta or beans faster

You're not paying attention and keep adding salt to water. At some point,

a) The water is still salty
b) The salt will continue to dissolve in the water
c) The solution will become saturated and no more salt dissolves

What does "saturated solution" mean?

Objective: determine the solubility of a solid in water.

You can get more NaCl to dissolve in water by

a) Heating up the water
b) Cooling down the water
c) Using less water

http://www.thehungrymouse.com/2009/02/12/creamy-mashed-parsnips-potatoes/

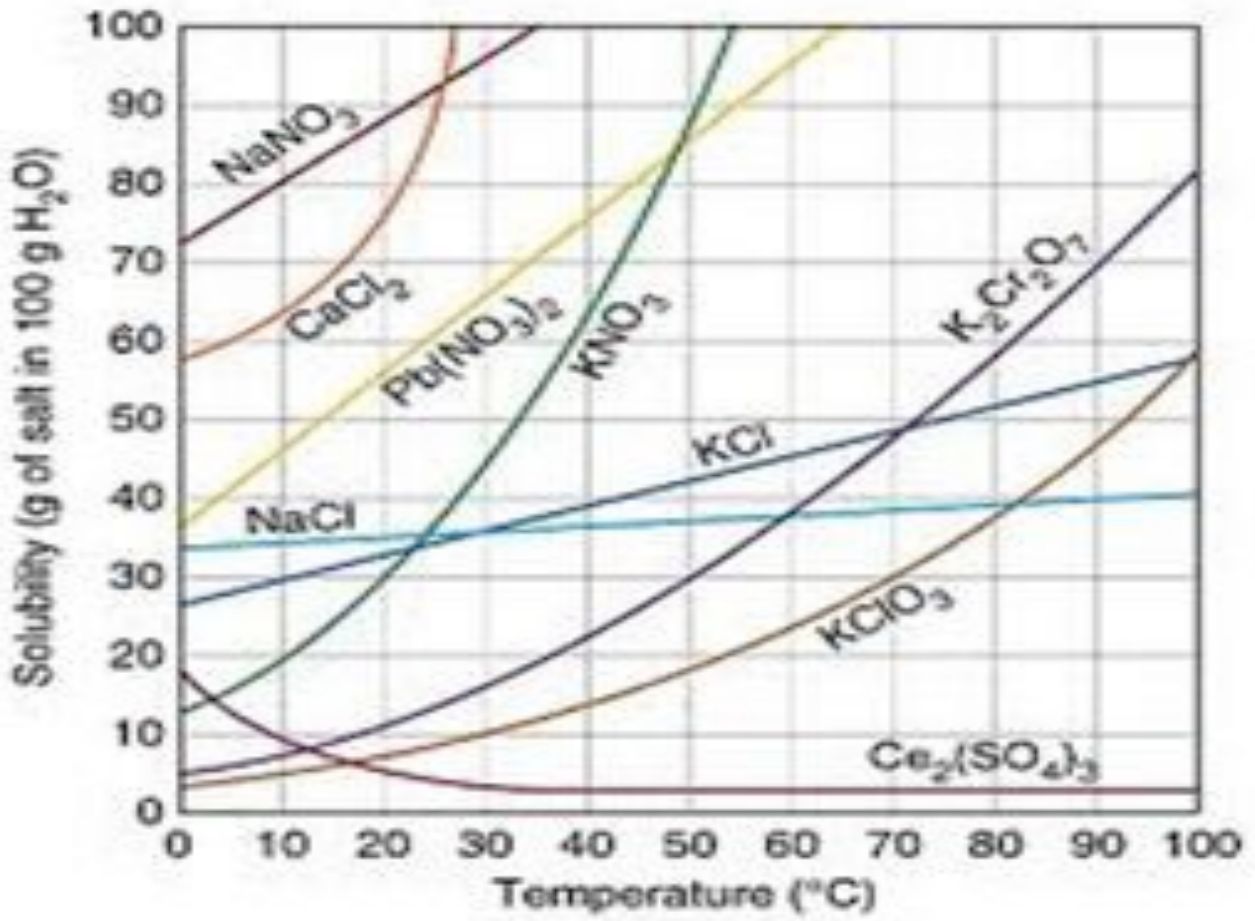
In general, **Solids are _____ Soluble in Hot Solvent**

See heat of dissolution and equilibrium principles

Temperature dependence on solubility of ionic salts

http://chempaths.chemeddl.org/services/chempaths/?q=book/General%20Chemistry%20Textbook/1174/introduction-ambit-chemistry&title=Saturated_and_Supersaturated_Solutions&title=Saturated_and_Supersaturated_Solutions_in_the_Environment

(See also Chang, 6th ed., Ch. 13, Fig. 13.2)



Temperature dependence on solubility of SUGAR in water

Determines SUGAR COMPOSITION (% sugar) and

Determines CANDY TEXTURE and TYPE.

Texture = crystal size

http://www.thekitchenwitchblog.com/wp-content/uploads/2013/12/Milk-Duds.jpg

https://macarenastore.com/wp-content/uploads/2019/03/BULTO-JOLLY-RANCHER.png

Lab 2. bring table sugar (sucrose), corn syrup, milk (for Part C), a cooking pot or pan, spoon, and cooking thermometer (measures to 350^{o}F/180^{o}C))

Objective: determine the solubility of gases in water

Soda Stream lets you make your own soda! You can get CO_2 to dissolve in water by

a) Heating up the water
b) Cooling down the water
c) Raising the pressure

http://www.amazon.com/Sodastream-Fountain-Soda-Maker-Starter/dp/B001KYT6CS

Gases are _____ Soluble in Hot Solvent
Gases are _____ Soluble at High Pressure

FizzKeepers - does it work to keep soda from going flat?

http://fizzkeeper.org/
http://www.stevespanglerscience.com/experiment/00000103
http://www.amazon.com/Jokari-5100-Fizz-Keeper-Pump-Pour/dp/B00004XSH6

http://www.jokari.com/products/g_05002.html

As Pepsi is heated, it loses mass. Explain this observation.

http://www.dairyqueen.com/en/Menu/Drinks/Pepsi/

http://www.rickly.com/sai/hotplate.htm

R. Chang, "General Chemistry: The Essential Concepts," 6th ed., Problem 13.107

"A student carried out the following procedure to measure the pressure of CO_2 in a soft drink bottle. First, she weighed the bottle (853.5 g). Next, she carefully removed the cap to let the CO_2 gas escape. She then reweighed the bottle with the cap (852.3 g). Finally, she measured the volume of the soft drink (452.4 ml). Given that Henry's law constant for CO_2 in water at 25^oC is 3.4×10^{-2} mol/L atm, calculate the pressure of CO_2 in the original bottle. Why is this pressure only an estimate of the true value?"

Henry's law: $k\,p = C$

where k = Henry's law constant, p = partial pressure of solute in gas above solution, C = concentration

Lab 2: ***How Can We Measure the Amount of CO_2 in Soda?***

Explain what happens when a can of soda is opened. Name two ways to get more CO_2 to dissolve in water.

1. Solubility of a gas is proportional to Pressure (Henry's law)

2. Measure the gas pressure in an unopened soda can.
Capture CO_2 gas after opening can.
Determine pressure by:

3. Quickly pour soda into a graduated cylinder.
Measure _____.
Determine pressure by: