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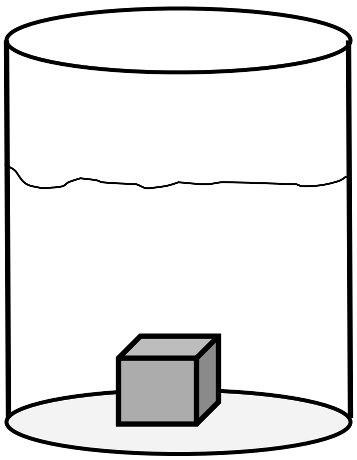
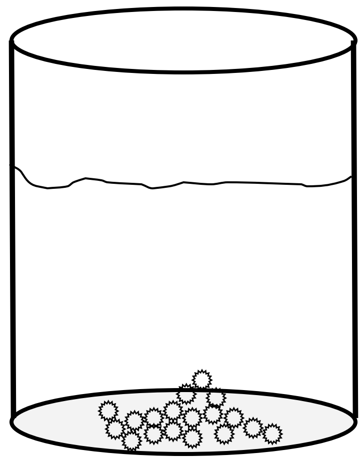
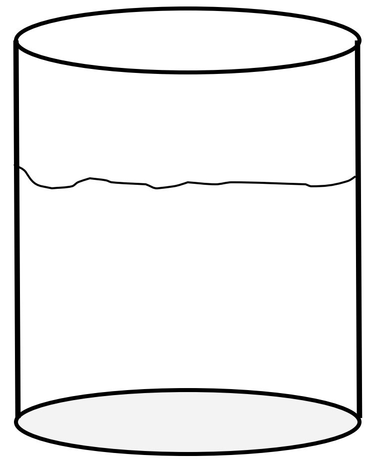
Solutions Pack — Arbuiso Chem

		
Sugar Cube in Water A sugar cube goes into water, and begins to break apart into smaller sugar chunks, all at the bottom of the beaker.	Sugar Cube begins to break down in water The sugar breaks down into smaller and smaller specks as the water crashes into it and helps pull it apart.	Sugar is totally dissolved in water At some point all of the sugar dissolves into loose mobile molecules of sugar (not into loose ions, this is not ionic). $C_{12}H_{22}O_{11(S)} \xrightarrow{H_2O} C_{12}H_{22}O_{11(AQ)}$ This is a phase change, not a chemical reaction.

Solutions are mixtures. They can be homogeneous (like salty water) or they can be heterogeneous (like chocolate milk that has settled). They usually are aqueous, but they can be dissolved in other liquids. They can also be gases or solids.

Solutions are concentrated or dilute, measured by Molarity (moles per liter). They can be made from scratch with the molarity formula as a guide, or you can mix up a new solution from a solution that you have on hand by diluting it. In high school we will only mix solutions that are more dilute than the solution you start with.

You can measure the concentration of solution in molarity, or in parts per million, or even in parts per billion if you like to do a lot of math.

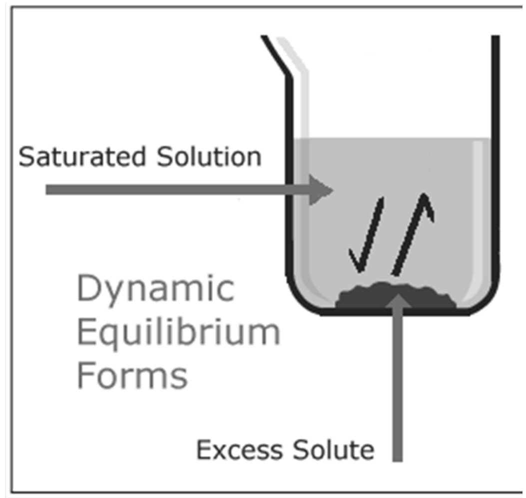
Normal solutions are measured in molarity, but when solutions are really, really dilute PPM works better. Either formula would work but the point is to get numbers we can grasp. If a solution is 11.4 PPM, the molarity is a crazy small decimal. Small numbers are easier on the brain than decimals.

Solutions BASICS

In this section of chemistry we'll be examining solutions, how they form, how to measure their strength, their properties, and how to dilute them exactly to get new solutions of lesser concentration and volume. We'll study about the 3 Colligative Properties of water, all affected by how much solute is dissolved into the water. Finally, we will do some math, the concept of parts per million for very un-concentrated solutions.

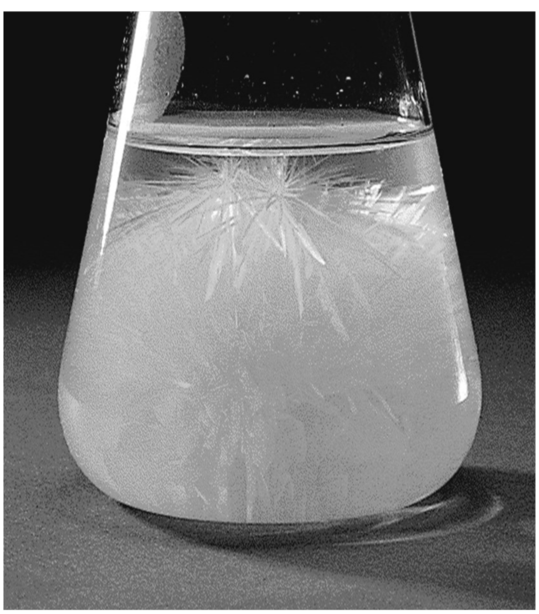
Solutions are homogeneous mixtures containing a solute in a solvent. We most often think of them as wet, with water as the solvent. Other liquids can be solutes as well. Gases can mix homogeneously which makes a gas solution, and we could even melt metals or other solids and stir them together. When they cool, they are solid solutions (like steel). For now we'll stick to the "wet" solutions.

Solutions can be saturated, holding as much solute in a given volume of solvent as possible. At some point there is just no more room in the solvent and added solute cannot be held, so it falls to the bottom of the container.



Although a saturated solution is "maxed out", excess solute continues to dissolve into solution while solute falls out of solution – **a <u>dynamic equilibrium</u>** is formed. The rate of dissolving is equal to the rate of precipitation. It's a "full" solution, but it's not stuck, rather it's constantly changing while the amount of dissolved solute remains constant.

An **<u>unsaturated solution</u>** has room to hold more solute. It's not full up yet, it could hold more solute.



A **<u>supersaturated solution</u>** is one that is more highly concentrated than is normally possible under given conditions of temperature of the solution. They way to do it is to start hot. Usually a hotter solution holds more solute than a cooler one. Some solutes can get "tricked" into staying in solution as you cool the hot saturated solution down. The cooler solutions now have more solute in them then can fit normally.

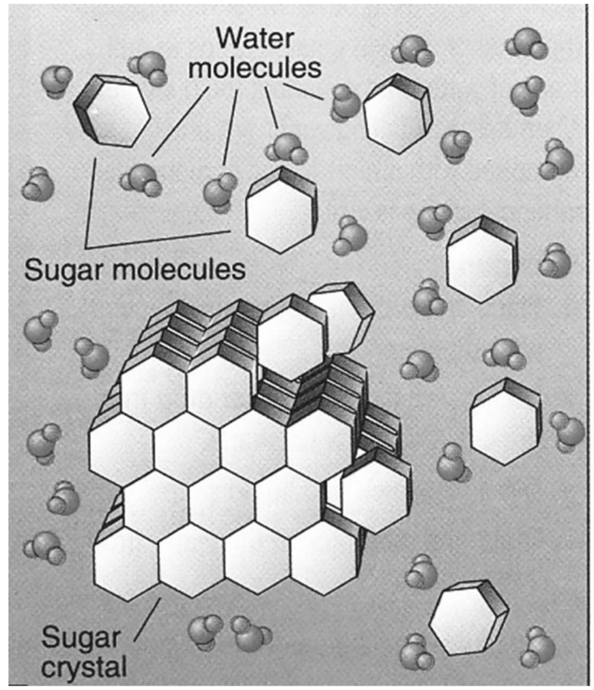
If you started with the same amount of solvent, COLD, you could not dissolve the same amount of solute into it, you could dissolve less. If you start with a cooler solvent, you can't put that much solute into solution, but if you start hot, some solutes get fooled and stay aqueous, until they ALL AT ONCE, collapse into solids, like this beaker at left.

If you add a "seed" crystal of solute to a super saturated solution, ions will begin to lock onto the "seed" crystal, and then all the excess ions solidify at once. This photo shows the crystallization of excess solute after the seeding.

When these bonds form, energy is released.

Formation of Solutions…

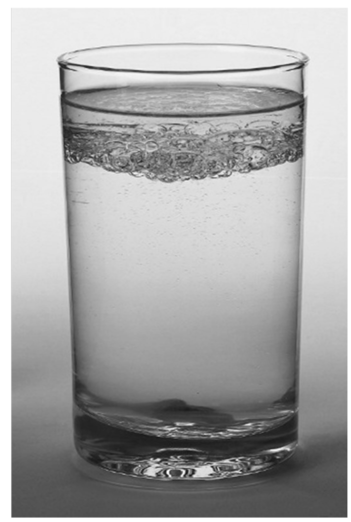
When a crystal of sugar (or other polar compound) is put into the polar solvent water, the crystal is "attacked" by the water molecules. The water molecules surround the sugar molecules, carrying them off molecules of the crystal into solution.



Of course, molecules are too small to see, so the visible crystal is soon invisible to the eye as it's broken into billions of molecules too small to see. At some point the solvent cannot hold a single molecule more, so as more sugar dissolves, some other sugar molecules will precipitate out of solution at the same rate.

<u>Like dissolves like</u> is the solution mantra; polar solvents such as water can only dissolve polar molecular compounds, or most ionic compounds.

Non-polar compounds can not mix with polar solvents.

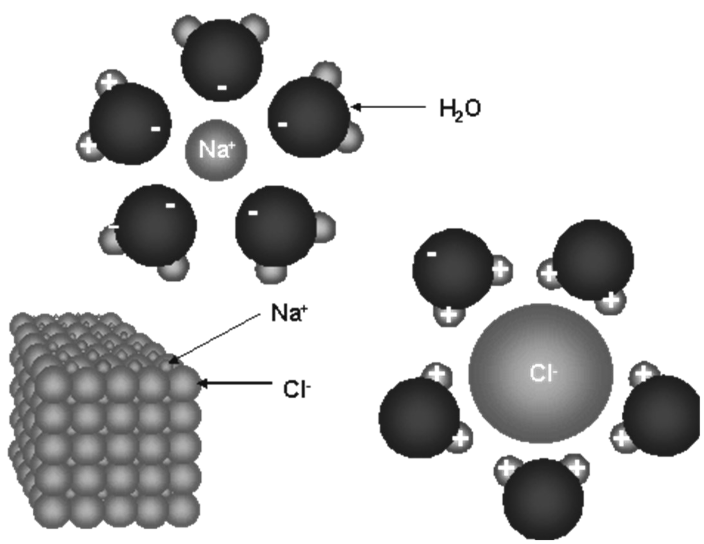


At right is oil sitting atop water. The polar water cannot mix with the nonpolar oil. The oil floats because it's less dense. It doesn't mix because:
<u>Like Dissolves Like</u> is always true. Nonpolar oil can't dissolve into polar water.

When ionic compounds are put into a polar solvent like water, they (usually) are dissociated or ionized into ions. The water molecules surround them as shown below. Solubility exceptions exist on table F!

In the picture below, note how the positive hydrogen side of the water molecules surround the negative chloride anions. The oxygen, with their negative charge, surround the positive sodium cations.

The solvent will dissolve solute until saturated, then the dynamic equilibrium will form.



Remember what an electrolyte is?
It's a solution that can conduct electricity.

Solutions with ions dissolved can conduct electricity, but solutions with dissolved molecules like sugar cannot conduct. The more ions, the better the conduction.

The less ions, the weaker the conduction.

Acids are special chemical compounds in aqueous solutions that appear to be molecular compounds like sugar (no metals), which they are, but they do form ions (we'll learn about acids and bases soon enough).

The CONCENTRATION of solutions.

One of the coolest concepts in chemistry is MOLARITY, the measure of how concentrated a solution is. Molarity can best be described as the molar concentration of a solution, expressed as the number of moles of solute/ liter of solution. The formula is:

$$\text{Molarity} = \frac{\text{number of moles of solute}}{\text{Liters of solution}}$$

The formula is set up as moles divided by LITERS of solution but any volume of a solution can be made, and its CONCENTRATION will be measured by this formula.

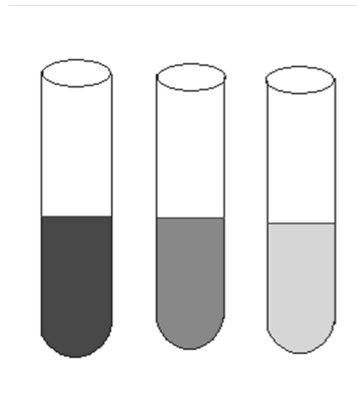
For example…

A 1.0 Molar aqueous solution of HCl could be made by putting 1.0 moles HCl into 1.0 Liters of H_2O.

Or, the same strength or concentration solution could be made with 0.25 moles HCl and 250 mL water.

In fact, an infinite number of combinations of moles to volume exist to make the same concentration.

These three tubes represent 3 different solutions of the SAME compound, but at different concentrations. The darkest one, on the left, would have the HIGHEST MOLARITY or greatest concentration.
The one on the far right the LOWEST MOLARITY or least concentration.



THINKING PROBLEM:

What is the concentration of an aqueous solution of KCl containing 370 grams KCl dissolved into 2.5 liters water?

Using the formula above for molarity, we figure this way…

$\text{Molarity} = \frac{\text{\#moles KCl}}{\text{liters of solution}}$	$370 \text{ g KCl} \times \frac{1 \text{ mole KCl}}{74 \text{ grams KCl}} = 5.0 \text{ moles KCl}$	$M = \frac{5.0 \text{ moles KCl}}{2.5 \text{ Liters}}$ M = 2.0 molar solution

Making a solution from Scratch.

How do you prepare a 1.00 M of $NaCl_{(AQ)}$ solution of 3.00 Liters in volume?

Start with the molarity formula, putting in the data you have, solving for moles of solute (here that's the NaCl).

$$\text{Molarity} = \frac{\#\text{moles solute}}{\text{liters of solution}}$$

$$\frac{1.00\ M}{1} = \frac{\#\ \text{moles NaCl}}{3.00\ \text{Liters}} = 3.00\ \text{moles NaCl}$$

$$\frac{3.00\ \text{moles NaCl}}{1} \times \frac{58\ \text{grams NaCl}}{1\ \text{moles NaCl}} = 174\ \text{g NaCl}$$

So to make this solution, put 174 grams of NaCl into a large beaker, then fill it up to 3.00 Liters of total volume with water.

NOTE: do not think for one moment that you can put 174 grams of salt into 3.00 Liters of water! That salt has a small but real volume, and this solution is NOT CORRECT.
Do not ever make such a silly mistake! Finish your work with the water filling up to the line! Always solute in, THEN water up to the total volume.

How do you make a 1.75 M $CuCl_{2(AQ)}$ of 245 mL? (start with molarity formula)

$$\frac{1.75\ M}{1} = \frac{\#\ \text{moles } CuCl_2}{0.245\ \text{Liters}} = 0.429\ \text{moles } CuCl_2$$

$$\frac{0.429\ \text{moles } CuCl_2}{1} \times \frac{134\ \text{grams } CuCl_2}{1\ \text{moles } CuCl_2} = 57.5\ \text{grams } CuCl_2$$

So, to make this solution, put 57.5 grams of copper (II) chloride into a beaker, then fill with water up to the 245 mL mark. DO NOT PUT 57.5 g $CuCl_2$ into 245 ml Water!

The Molar Dilution Formula

Another formula that we can use is called the dilution formula. We can start out with a concentrated stock solution of known volume and molarity, and use it to make a new solution with a new volume and concentration.

The Molar Dilution formula is: $M_1V_1 = M_2V_2$

How much of the strong solution is needed to create a new solution as stated?

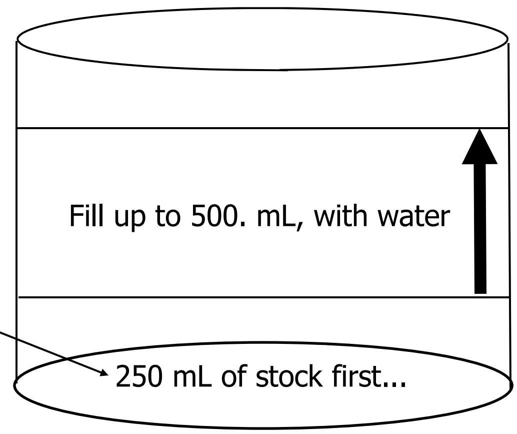
To do a problem like this we substitute in what we know, and calculate our answer. So…

For example, assume you have a lot of a concentrated $CuSO_{4(AQ)}$, of 2.0 Molar strength. How would you dilute this to create a 500. mL $CuSO_4$ solution of only 1.0 Molarity? How much of the strong solution is needed? We'll write at the formula, then we'll do the math.

$$M_1V_1 = M_2V_2$$

$$(2.0\ M)\ (V_1) = (1.0\ M)(500.\ mL)$$

$$V_1 = 250\ mL\ \text{stock solution}$$



This means you will need to add 250 mL of the stronger, original stock solution into a flask, and add enough water to dilute it and fill up the beaker to 500. mL solution.

Another example:

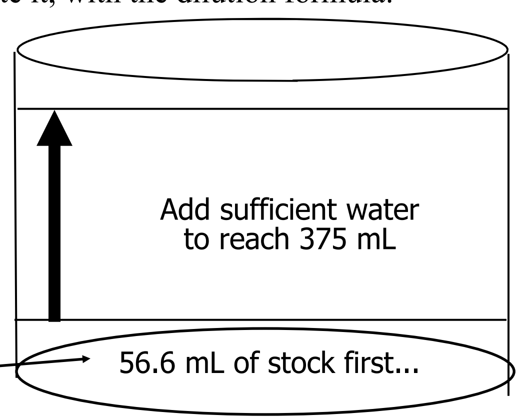
You have a 5.00 M stock NaCl solution. You want to prepare a 375. mL salt water solution of 0.755 M concentration. When you start with a stock solution, you need to dilute it, with the dilution formula:

$$M_1V_1 = M_2V_2$$

$$(5.00\ M)\ (V_1) = (0.755\ M)(375\ mL)$$

$$V_1 = \frac{(0.755\ M)(375\ mL)}{5.00\ M}$$

$$V_1 = 56.6\ mL\ \text{of stock solution}$$



That means, you need 56.6 mL of the concentrated stock salt water solution and you need to dilute it then with enough water to reach the 375 mL mark. In HS Chem we don't know exactly how much water, but enough to fill the beaker to 375 mL exactly).

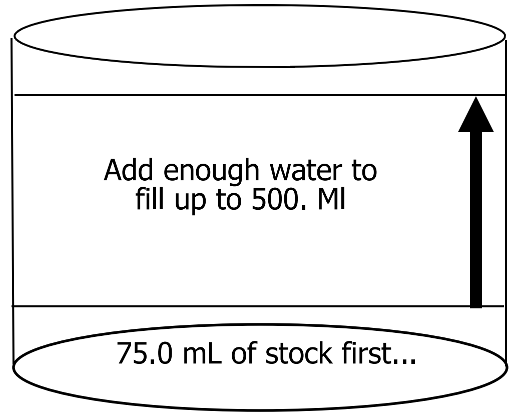
Example 2: Now we'll do a second dilution: How do you prepare a solution of 0.30 M and 500. mL total volume from the original 2.0 M stock solution?

$$M_1V_1 = M_2V_2$$

$$(2.0\ M)\ (V_1) = (0.30\ M)(500.\ mL)$$

$$V_1 = \frac{(0.30\ M)(500.\ mL)}{2.0\ M}$$

$$V_1 = 75.0\ mL$$



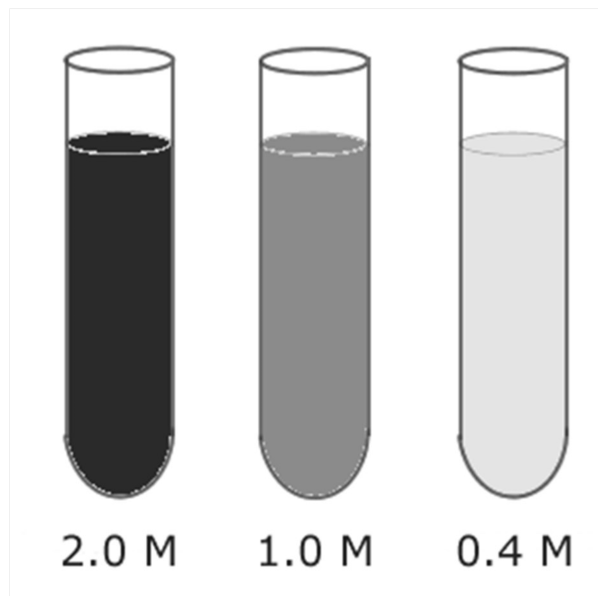
75.0 mL of 2.0M $CuSO_{4(AQ)}$ + ENOUGH water to fill up to 500. mL to make the 500. mL 0.30M $CuSO_{4(AQ)}$

These three tubes represent the $CuSO_4$ solutions we just made.

First is the 2.0 M stock solution.
Second is the 1.0 M diluted solution.
Third is the final weakest 0.4 M $CuSO_{4(AQ)}$.

All made of the same $CuSO_4$, but of different concentrations or strengths.

Aqueous solutions of $CuSO_4$ would be shades of blue, the darkness of solution would depend upon the concentration or molarity of the solutions.



To make a solution from scratch you use the molarity formula.
To make a solution from an existing stock solution, use the dilution formula.

No matter, always draw a picture of an empty beaker, and "show making the solution" so you can see clearly what you are doing.

Colligative Properties of Solutions

These are physical properties that can change depending upon how much solute is dissolved into a liter of the solution. They include boiling point, freezing point, & vapor pressure. These three different properties get adjusted by the solute mixed into the water. If you dissolve particles (ions or polar molecules) into water, you change all of these properties. The more particles in solution, the greater the properties change.

First we need to examine what happens when substances dissolve into water. Molecular compounds, like sugar, dissolve into water, they do not form ions. They are not ionic. When soluble ionic compounds dissolve, the compound ionizes, or it dissociates into ions this way:

$C_6H_{12}O_6$	$C_6H_{12}O_{6(S)} \xrightarrow{\text{water}} C_6H_{12}O_{6(AQ)}$	1 mole $C_6H_{12}O_6 \rightarrow$ 1 mole of molecules
NaCl	$NaCl_{(S)} \rightarrow Na^{+1}_{(AQ)} + Cl^{-1}_{(AQ)}$	1 mole NaCl → 2 moles of ions
$CaCl_2$	$CaCl_2 \rightarrow Ca^{+2}_{(AQ)} + Cl^{-1}_{(AQ)} + Cl^{-1}_{(AQ)}$	1 mole $CaCl_2$ → 3 moles of ions
$AlCl_3$	$AlCl_3 \rightarrow Al^{+3}_{(AQ)} + Cl^{-1}_{(AQ)} + Cl^{-1}_{(AQ)} + Cl^{-1}_{(AQ)}$	1 mole $AlCl_3$ → 4 moles of ions
AgCl	AgCl → no moles of ions, it's insoluble!	1 mole AgCl = zero particles.

So when things dissolve into water, depending upon what the substance is, the change of colligative properties is not always the same. 1 mole of substance does not always equal one mole of particles.

BOILING POINT ELEVATION

The water boils when it can overcome both the air pressure pressing down on the surface, and the internal hydrogen bonding holding the molecules together. At normal pressure the boiling point of pure water is 373 Kelvin. When polar molecules or ions are dissolved into the water, the water molecules are ALSO attracted to the particles. This creates MORE INTERNAL ATTRACTION, which means it will take more energy to make the water boil (blow apart from itself into the gas phase).

The actual boiling point elevation for water is 0.50 K per mole of particles per liter of solution.
For every mole of particles, the boiling point goes up by 0.50 Kelvin.

FREEZING POINT DEPRESSION

The freezing point is also very affected by dissolved particles. The difference is that the freezing point requires colder temperatures to freeze around the annoying, cluttered ions or molecules that are "in the way" of the hydrogen bonding. Water only freezes when the hydrogen bonding is stronger than the kinetic energy that the particles have (the temperature more or less is the KE).

The freezing point depression for water is that each mole of particles depresses the freezing point by 1.86 Kelvin (that's a lot!).

Problems follow, read the math slowly and follow along….

Example 1. What is the boiling point of a 1.0 Molar NaCl solution of one liter?		
Start boiling point	Boiling point elevation	New boiling point
373 K	+ (2 x 0.50 K) =	373 + 1 = 374 K
Here we had to INCREASE THE boiling point, so we ADD the BP elevation to the normal BP of 373 Kelvin.		

Example 2. What is the boiling point of a 1.0 Molar $CaCl_2$ solution of one liter?		
Start boiling point	Boiling point elevation	New boiling point
373 K	+ (3 x 0.50 K) =	373 + 1.5 = 374.5 K
In this example, the salt has 3 ions per FU, so when it does ionize in water, one mole provides 3 moles of ions, and therefore a bigger affect on the BP.		

Example 3. What is the boiling point of a 2.0 Molar $CaCl_2$ solution of one liter?		
Start boiling point	Boiling point elevation	New boiling point
373 K	+ (6 x 0.50 K) =	373 + 3 = 376 K
Did you see that one? Each mole of calcium chloride forms 3 moles of ions. Here the solution contains 2 moles of $CaCl_2$, each forms 3 moles of ions, so 2 X 3 = 6 moles of ions		

Example 4. What is the boiling point of a 4.0 Molar $AlCl_3$ solution of one liter?		
Start boiling point	Boiling point elevation	New boiling point
373 K	+ (16 x 0.50 K) =	373 + 8 = 381 K
Did you see that one? Each mole of aluminum chloride forms 4 moles of ions. Here the solution contains 4 moles of $CaCl_2$, each forms 4 moles of ions, so 4 X 4 = 16 moles of ions		

Example 5. What is the boiling point of a 2.5 Molar $CaBr_2$ solution of one liter?		
Start boiling point	Boiling point elevation	New boiling point
373 K	+ (7.5 x 0.50 K) =	373 + 3.75 = 386.75 K
Did you see that one? Each mole of calcium bromide forms 3 moles of ions. Here the solution contains 2.5 moles of calcium chloride, each forms 3 moles of ions, so 2.5 X 3 = 7.5 moles of ions		

FREEZING POINT DEPRESSION

The water molecules wish to freeze normally at 273 Kelvin. The water forms six-molecule rings, locking into place when their hydrogen bonding is stronger than the kinetic energy provided by the temperature. At 273 K the hydrogen bonding is strong enough to lock the water into the grid like lattice we call ice.

When the water has ions dissolved into it, or polar molecules dissolved into it, the water molecules can't lock together until they get colder than usual. They need to be able to "freeze out the particles, and that requires lower kinetic energy - lower temperature to happen.

The salt water also has a lower freezing point, as the ions disrupt the formation of the (neat) six sided rings of solid ice. It takes COLDER temperatures, or a lower kinetic energy to solidify into ice. One mole of particles in one liter of solution drops the freezing point by 1.86 Kelvin or 1.86°C.

Example 6. What is the freezing point of a 1.0 Molar NaCl solution of one liter?		
Start freezing point	Freezing point depression	New boiling point
273 K	– (2 x 1.86 K) =	273 – 3.72 = 269.28 K
Here the one mole of NaCl provides 2 moles of ions, so the FP is depressed by 2 X the 1.86 Kelvin.		

Example 7. What is the freezing point of a 2.0 Molar $CaCl_2$ solution of one liter?		
Start freezing point	Freezing point depression	New boiling point
273 K	– (6 x 1.86 K) =	273 – 11.16 = 261.84 K
Did you see that? Each mole of calcium chloride forms 3 moles of ions. Here there are 2 moles, so, 2 x 3 = 6 moles of ions in solution.		

Example 8. What is the freezing point of a 4.0 Molar $AlCl_3$ solution of one liter?		
Start freezing point	Freezing point depression	New boiling point
273 K	– (16 x 1.86 K) =	273 – 29.76 = 243.24 K
Did you see that? Each mole of aluminum chloride forms 4 moles of ions. Here there are 4 moles, so, 4 x 4 = 16 moles of ions in solution.		

THINK #1:
Why would people do better with calcium chloride than sodium chloride on their sidewalks in winter?
NaCl ionizes into TWO IONS, while the $CaCl_2$ ionoizes into THREE IONS.
More moles of ions in calcium chloride means that the sidewalk water would not freeze until a LOWER temperature, making them ice free, and safer, to a lower temperature.

THINK #2:
Why would adding one mole of sugar vs. one mole of table salt cause different boiling points?
Moles of particles also RAISES the BOILING POINT, each mole of particles raises the boiling point by 0.50 Kelvin or 0.50°C.

One mole of sugar molecules (1 mole of particles) raises the boiling point of one liter of water to 373.5 K.

One mole of NaCl ionizes into 2 moles of ions, raising the boiling point to 374 K.

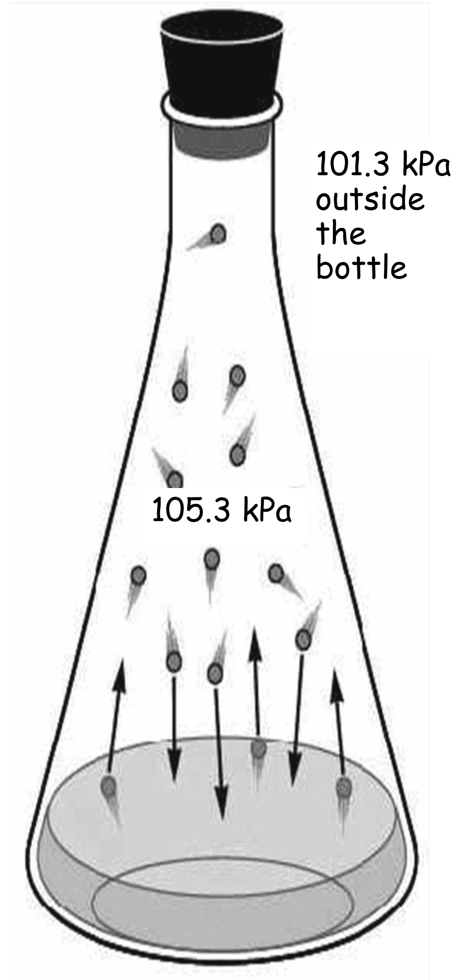
One mole of $CaCl_2$ ionizes into 3 moles of ions, raising the boiling point of one liter of water to 374.5 K.

THINK #3:
Why would there be different Vapor Pressure with different numbers of particles dissolved into solutions?
This occurs for the same reason as the change in boiling point — the water sticks together well due to the many hydrogen bonds. With the addition of extra charged (or polar) particles, there are MORE attractions that have to be over come to evaporate those water molecules into the gas phase. Vapor pressure is also affected by particles in solution, but we won't do any math with this.

In a sealed system, molecules of the liquid will evaporate into the space above the surface of the liquid. ***How much*** evaporation is determined by the attractiveness of the particles to each other which keeps them liquid, also by the temperature (the more Kinetic Energy means more evaporating), and also how many particles are dissolved into the liquid. The more particles that are dissolved, the more attractive the liquid is to itself; the less evaporation means lower vapor pressure.

Let's imagine an NaCl salt water solution. The salt ions are now present, and although the water molecules have plenty of hydrogen bonds to each other, they also have attraction to these ions. This makes evaporation more difficult or slower.

VAPOR PRESSURE ADJUSTMENT



The vapor pressure is shown in table H on the reference tables.
The vapor pressure is THE EXTRA PRESSURE ADDED TO A CLOSED SYSTEM BY THE EVAPORATION OF A LIQUID.

Room temperature water (25°C) has a vapor pressure of about 4 kPa. That means inside that bottle at right, if the starting air pressure inside the bottle was 101.3 kPa (normal), the water evaporating will add to it by about +4 kPa. That makes the pressure in the bottle about 105.3 kPa.

Water doesn't evaporate well because of all the hydrogen bonding it has. That means water has a low vapor pressure. Adding any solute to water only increases the internal attraction, making it harder to evaporate.

In our class we will only know that any solute in water decreases the vapor pressure (makes it evaporate less well).

More concentrated aqueous solutions have lower vapor pressure compared to dilute aqueous solutions.

We'll do NO MATH for the vapor pressure in this part of chem.

We will make relative decisions as to which solutions have the highest vapor pressure.

Which of the following aqueous solutions will have the highest and lowest vapor pressures?

A. 3.00 molar $Al(NO_3)_{3(AQ)}$
B. 5.00 molar $NaCl_{(AQ)}$
C. 8.00 molar $C_6H_{12}O_{6(AQ)}$
D. 15.0 molar $SrSO_{4(AQ)}$

$Al(NO_3)_3$ will ionize into 4 moles of particles,
so a 3.00 M solution will form 3.00 X 4 = 12 moles of ions in solution

NaCl will ionize into 2 moles of particles,
so a 5.00 M solution will form 5.00 X 2 = 10 moles of ions in solution

$C_6H_{12}O_6$ will NOT ionize, but will dissolve into one mole of particles,
so an 8.00 M solution will form 8.00 X 1 = 8 moles of molecules in solution

$SrSO_4$ will NOT ionize, it's ionic, but according to table F, this stuff is insoluble in water.
So, the strontium sulfate will form NO particles in water to measure.

$SrSO_{4(}$ will have the highest vapor pressure (the same as water's) while the lowest VP will be with the solution with the MOST particles dissolved into solution, which is $Al(NO_3)_3$

PARTS PER MILLION

Some solutions are so very dilute that the molarity becomes a super small decimal that our brains can't make easy sense of. For example, when you add just 1.0 mole of NaCl into a swimming pool sized 43,000 Liter solution, the molarity works this way:

Molarity = $\frac{\text{moles of solute}}{\text{Liters of solution}}$	Molarity = $\frac{\text{0.250 moles NaCl}}{\text{43,000 Liters}}$	M = 0.00000581 M or it's 5.81×10^{-6} Molar NaCl solution which is silly small

This number is accurate, but 581 hundred millionths molar is just outside normal thinking zones.

Another way to do concentration is parts per million.

$$PPM = \frac{\text{Grams solute}}{\text{Grams solution}} \times 1{,}000{,}000$$

$$PPM = \frac{58 \text{ g NaCl}}{43{,}000{,}000 \text{ g } H_2O} \times 1{,}000{,}000 = 1.35 \text{ PPM salt}$$

1.35 PPM is a number you can more easily wrap your head around, although it is exactly equivalent to the silly small molarity of 0.00000581 M.

Example 9

If there is 0.125 grams of mercury dissolved into 101. liters of sea water, concentration is parts per million?

$$PPM = \frac{\text{Grams solute}}{\text{Grams solution}} \times 1{,}000{,}000$$

$$PPM = \frac{0.125 \text{ g Hg}}{101{,}000 \text{ g water} H_2O} \times 1{,}000{,}000 = 1.24 \text{ parts per million}$$

This means: 1.24 parts Hg per million parts water

Example 10 From an old regents exam was this problem…

What is the concentration of a solution in PPM, if 0.02 grams Na_3PO_4 is dissolved into 1000 grams water?

A. 20 PPM B. 2 PPM C. 0.2 PPM D. 0.02 PPM

ANSWER

$$PPM = \frac{\text{grams of solute}}{\text{grams of solution}} \times 1{,}000{,}000$$

$$PPM = \frac{0.02 \text{ g } Na_3PO_4}{1000 \text{ g water}} \times 1{,}000{,}000 = 20 \text{ parts per million (choice A)}$$

The regents will sometimes uses just one significant figure in a problem, they are trying to get across the concept, and not the math. You always pick the BEST possible choice. SF count, but the regents exam often breaks that rule.

Bits and Pieces

To make a proper solution, of perfect volume, there is only one way to proceed. First get a special flask with a line that shows exactly a particular volume (often 1.00 L).
Put the solute in first. Then fill with pure water up to the line.

This is the ONLY WAY to make a perfect solution. You can't just add solute into the solvent, it will affect the volume (in a small but measurable way).

When an ionic compound (NaCl, KCl, etc.) is dissolved into water it forms an ionic solution. It has free ions floating in the water. This is a homogeneous mixture. The more ions in solution, the better electrical conduction that occurs, which is a stronger electrolyte. With fewer ions means a lesser electrical conduction, or a weaker electrolyte.

If you melt an ionic compound like $NaCl_{(L)}$ or $CuBr_{(L)}$ it will be super-duper hot. It will also be able to conduct electricity because the ions are loose, almost like in an aqueous solution. This is weird, it would be way too hot to handle in most colleges and impossible in high school, but it would conduct. Ionic compounds that do not ionize in water are NOT electrolytes, but they can conduct electricity is their liquid or melted states.

Electrolytes are solutions with ions in them (soluble ionic compounds), and they can conduct electricity. Electrolytes are always able to conduct electricity. The more ions in solution, the better the electricity flows.

Ionic compounds in the solid form CANNOT conduct electricity because there are no loose ions, and no loose electrons (as with metals and metallic bonds). Solid ionic compounds are called electrolytes only if they are soluble in water. Electrolytes can be solutions that conduct, or (strangely enough) solids that *would form* soluble ionic solutions.

Insoluble ionic compounds like AgCl, or molecular compounds are never electrolytes, and cannot conduct electricity.

SOLUTIONS NOTES

Objective: Describing what solutions are, how they form, & how are they're strength is measured.

1	A solution is a
2	The dissolves into the
3	If you put sugar into coffee, the sugar is the while the coffee is the
4	When a solution holds the maximum amount of solute it is a ____________________________ solution.
5	If there is less than the maximum amount of solute in the solution it is
6	6. Compare a 10°C sugar solution to a 90°C sugar solution. At 10°C you can fit _______ g sugar into solution. At 90°C you can fit _______ g sugar into solution.
7	It's hard to see here, but the NaCl solubility increases just a tiny bit (_________________________) in a100 mL solution, a small increase.
8	Most solutions you think about will be aqueous which means dissolved in
9	Solutions can also be gases like ___________, or solid _______________________ like brass or cast iron
Demo one: Which dissolves faster, chunks of solute or powdered solute?	
Demo two: Which dissolves faster, Alka-Seltzer in cold water, or hot water?	
Demo three: Which dissolves faster, cube of sugar with stirring or without stirring?	
10	SMALLER PARTICLES = MORE SURFACE AREA
11	HOTTER TEMP = HIGHER KE = MORE MOTION
12	AGITATION = HIGHER KE = MORE MOTION

14	14. The rate of solvation increases with		
	More	Higher	and More

How much solute will dissolve into a solution? It depends first on	
15	
16	
17	

18	Draw structural diagrams of H_2O and CO_2	
19	What sort of molecules are these?	
20	The only way to make carbon dioxide dissolve into water, to make seltzer is…	

21. There are several ways to measure how strong a solution is in chemistry.

	Qualitatively we can say things like
	Or we could use "better" words like
	With numbers and units, in a quantitative measure, we will use

22	Molarity is the expression of concentration of a solution as measured by the number of moles of solute in a liter of solution. $M =$
23	What is the concentration of a $NaNO_3$ solution containing 4.50 moles of solute in 1220 mL volume?
24	SAY:
	WRITE:
	THINK:
25	What is the concentration of a 1650 mL salty water solution containing 125 g NaCl?
Convert grams of NaCl into moles first.	
Then convert mL into liters.	
Write the molarity formula, do the math	

26	If you add 43.5 g NaCl to water to form a 648 mL solution, what is its concentration?

Convert to moles first	
Convert to liters next	

SAY
WRITE
THINK

27	You put 111g KCl solid into a volumetric flask. You fill the flask to 250. mL, what is the molarity of this solution? (draw)

28	You put 74.0 g KCl solid into a flask, fill to 1600. mL. What is the molarity of this solution?

M =

SAY
WRITE
THINK

29	Calculate the molarity of 750. mL $LiBr_{(AQ)}$ that has 215 g LiBr solute

30	How many grams of $NaNO_3$ are in a 100 mL aqueous solution that is saturated at 10°C?
31	How many grams of $NaNO_3$ fit into 325 mL of water at 10°C? (write temp, $NaNO_3$ over WATER)
32	What is the MOLARITY of this solution of 260. g $NaNO_3$ in 325 mL?
	M =

33. Solutions Vocabulary you have to memorize	
	the stuff dissolved into the solvent of a solution, the salt of salty water
	the part of the solution that the solute is dissolved into, the water of salty water.
	when a solution is holding the maximum solute at a particular temperature.
	when a solution is holding LESS THAN the maximum amount of solute at a particular temperature.
	the solubility guidelines for 10 compounds over all liquid water temps.
	the measured concentration of a solution in moles/Liter units.
	$M = \frac{\text{moles of solute}}{\text{Liters of solution}}$
	MOLES of solute per LITERS - not grams or mL!

34	Calculate the molarity of a solution containing 259 g $KBr_{(AQ)}$ with total volume of 750. mL (the molar mass KBr = 119 g/mole)
35	How many grams of sodium chloride are in a 100 mL aqueous solution that is saturated at 90°C?
36	How many grams of sodium chloride are in an 885 mL aqueous solution that is saturated at 90°C? Do this as shown, no variations allowed.
37	What's the molarity of this saturated solution of $NaCl_{(AQ)}$? *Convert 354 grams of NaCl into moles first.* M =
38	If you had two SATURATED $NaCl_{(AQ)}$ -one 25 mL, another of 1275 mL…   WOULD THEY… both taste the same? both conduct electricity? be "the same"?
39	How many grams of NaCl are required to form a 2.50 L of 0.900 M $NaCl_{(AQ)}$? *(use a formula)*

40	How many grams of KOH required to make a 1.20 M solution of $KOH_{(AQ)}$ of 3.20 Liters?

How can we prepare this 3.20 Liter solution of $KOH_{(AQ)}$ with 1.20 M concentration?

The wrong way is to get 3.20 Liters and add 215 g of KOH into it.

If you do that, the KOH SLIGHTLY increase the volume over 3.20 liters.

41	How can we prepare a 1.20 M solution of $KOH_{(AQ)}$ of 3.20 Liters? 
42	How would you mix up 2.65 liters of 2.50 M $KNO_{3(AQ)}$ from scratch? 

If you have some strong 2.50M $KNO_{3(AQ)}$ solution in the stock room, how would you use it make 1.64 Liters of 1.15 M $KNO_{3(AQ)}$?

Take out your reference table, back page, and add this dilution formula to the concentration box.

Concentration	For mixing solutions from scratch, or measuring solution concentration. **Molarity** = $\frac{\textbf{Moles of solute}}{\textbf{Liters of solution}}$	For mixing up a new solution from a stock solution you have on-hand $M_1V_1 = M_2V_2$

43	The DILUTION FORMULA is:

The symbols mean:

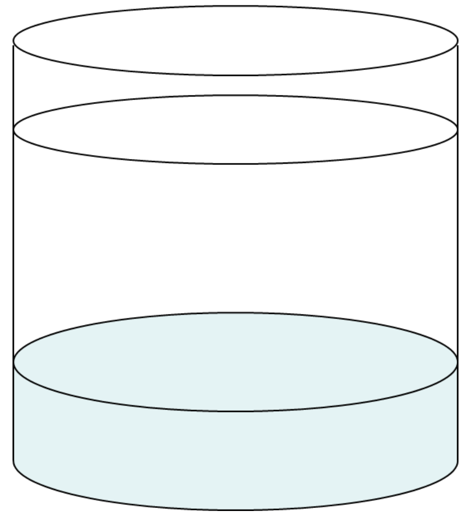
is Molarity of the original stock solution

is Volume of the original stock solution (unknown)

is Molarity of the new solution you want to make

is Volume of new solution that you want to make

44	Using a 2.50M $KNO_{3(AQ)}$ how would you make 1.64 Liters of 1.15 M $KNO_{3(AQ)}$?

45	How do you prepare a 135 mL $NaCl_{(AQ)}$ solution of 1.00 molarity from a stock solution of 5.50 M? 
46	Hydrochloric acid solution comes to the school very concentrated – at 12.0 M! Using this stock, how do you to make up 2.00 L of 2.25 M HCl solution? *start with a formula*
	Use words to tell how to make this solution, no diagram here.

No Writing, think about this, you put 1502 grams NaCl into a swimming pool of 312,000 liters of water. What is the molarity of this solution? (the answer is stupidly small to make a point)

$$\frac{1502 \text{ g NaCl}}{1} \times \frac{1 \text{ mole NaCl}}{58 \text{ g NaCl}} = 25.9 \text{ moles salt}$$

$$M = \frac{\text{moles solute}}{\text{liters solution}} \quad \frac{25.9 \text{ moles}}{312{,}000 \text{ Liters}}$$

M = 0.0000830 Molar $NaCl_{(AQ)}$

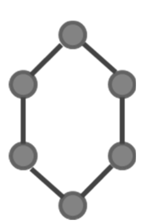
830 ten millionths Molar!! Sort of a stupid.

It's true, but the number is way too small to "make any sense" to us.

47	PPM = PPM stands for:
48	Write the formula, from back page of reference tables
49	You put 1502 grams NaCl into a swimming pool of 312,000 liters of water. ~~What is the molarity of this solution~~? What's the concentration of this in PPM? *use the formula*

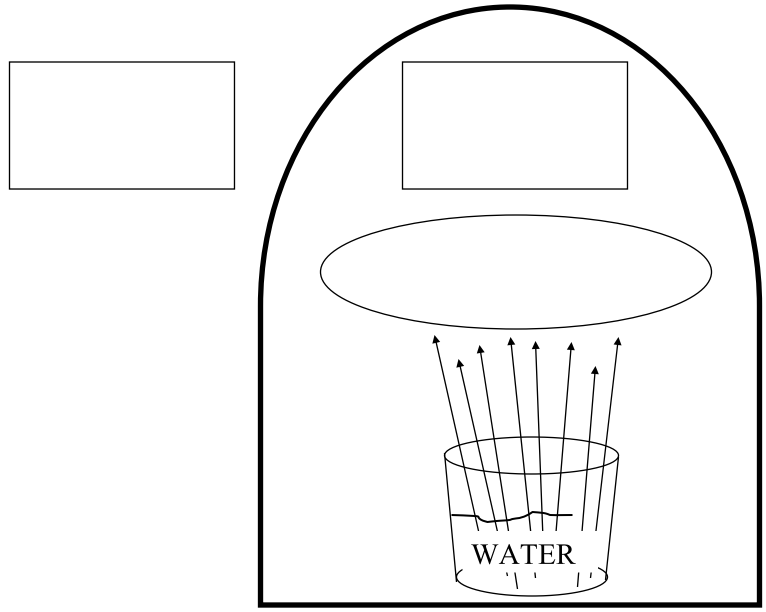
Sometimes low concentration environmental **poisons** are measured this way.

MOLARITY & PPM are mathematically interchangeable, just try to use "normal" numbers.

50	There are 3 properties of called the colligative properties.
51	The 3 colligative properties of water are:
52	The reason for these properties is
53	For water to boil, energy must break the ________________________________ bonds.
54	If solute like NaCl ions are dissolved into water, the hydrogen bonds still need to break, but now, the water must also overcome the polar attractions to the ____________________ too.
55	Water has a BP of __________________. Salty water will have a _____________________ BP.
56	For water to freeze, the molecules must make those neat little 6-molecule rings to solidify. The molecules are hydrogen bonded to each other. Draw an ion getting in the way of six molecules of water to form an ice ring. 

When solute is dissolved into the water, these particles literally get in the way of the hydrogen bonding. Water can't freeze at a normal 273 must it has to be colder for the ions to be pushed aside as ice forms.

The more solute (polar molecules like sugar, or ions) the colder the water must be to freeze.

	
57	Vapor pressure is (like a bell jar).
58	Water has a ___________________________________ vapor pressure.
59	What is the vapor pressure of water at 25 centigrade?
60	Why does water have LOW VAPOR PRESSURE?
61	What impact would polar molecules, or ions, (solute) have on vapor pressure?
62	At 25 C, what are vapor pressures for water and propanone? Why?

63	The boiling point ELEVATION for water is
64	The freezing point DEPRESSION for water is

65	Formula	When the ionic compounds go into water, this is what they turn into
ex	1.0 M $NaCl_{(S)}$	1 mole Na^{+1} and 1 mole Cl^{-1} = 2 moles ions
	2.0 M $NaCl_{(S)}$	__ moles Na^{+1} and __ moles Cl^{-1} = __ moles ions
	3.0 M $NaCl_{(S)}$	__ moles Na^{+1} and __ moles Cl^{-1} = __ moles ions
	2.0 M $CaCl_{2(S)}$	__ moles Ca^{+2} and __ moles Cl^{-1} = __ moles ions
	3.0 M $CaCl_{2(S)}$	__ moles Ca^{+2} and __ moles Cl^{-1} = __ moles ions

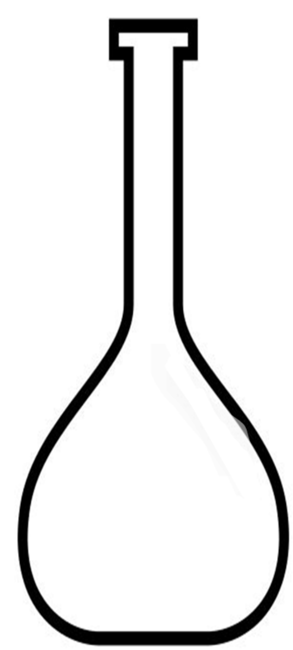
66. Formula	Numbers of moles of particles*
2.50 M $NaCl_{(AQ)}$	__ mole Na^{+1} & __ mole Cl^{-1} = ___ moles ions
1.25 M $NaCl_{(AQ)}$	___ moles Na^{+1} & ___ moles Cl^{-1} = ___ moles ions
1.75 M $NaCl_{(AQ)}$	___ moles Na^{+1} & ___ moles Cl^{-1} = ___ moles ions
2.25 M $CaCl_{2(AQ)}$	___ moles Ca^{+2} & ___ moles Cl^{-1} = ___ moles ions
3.0 M $Al(OH)_{3(AQ)}$	___ mole Al^{+3} & ___ moles OH^{-1} = ___ moles ions
1.0 M $NH_{3(AQ)}$	___ mole of MOLECULES
2.50 M $C_{12}H_{22}O_{11(AQ)}$	___ moles of MOLECULES
1.0 M AgCl	***

67	Calculate the temperature that a 1.00 liter, 2.00 M $NaCl_{(AQ)}$ solution will boil in Kelvin.
68	Calculate the Kelvin BP of a 1.00 Liter, 3.00 M $CaCl_{2(AQ)}$.
69	Calculate the temperature that a 1.00 liter, 2.00 M $NaCl_{(AQ)}$ solution will freeze in Kelvin.
70	Calculate the FP in Kelvin of a 1.00 Liter, 3.00 M $CaCl_{2(AQ)}$.
71	What is the parts per million concentration of a solution containing 98.0 grams of lithium chromate (Li_2CrO_4) that is dissolved into a swimming pool of 57,800 liters?

72. Aqueous solution	Moles of particles/liter	Vapor pressure rank
1.00 M NaCl		
1.00 M $CaCl_2$		
1.00 M NBr_3		
1.00 M $Al(NO_3)_3$		

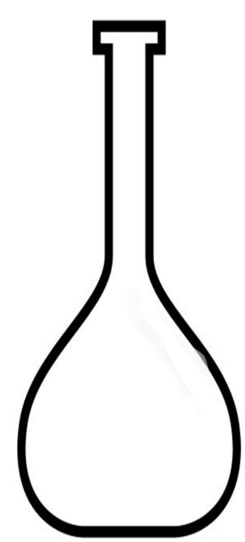
The dissociation of ionic compounds into water. Count the ions!		
73. Compound	Formula	When put into water, these ions form
Sodium carbonate		
Ammonium sulfide		
Aluminum nitrate		
Lead (IV) acetate		
Silver chloride		

74	What is the freezing point of a 1.00 liter solution of 1.00 M Tin (IV) nitrate?

75	In a solution labeled 2.46 M $KCl_{(AQ)}$ that is exactly 2.00 Liters in volume, how many grams of KCl are in this solution?
76	*According to an article in the New England Journal of Medicine, mercury toxicity begins at 0.100 PPM.* If someone dropped 125 grams of $Hg_{(L)}$ into the school pool, that is 102,900 liters, would the mercury level be low enough to be safe, or over the limit of safety?
77	What is the molarity of a solution if 278 g KCl is dissolved into a solution of 5000. mL total volume?
78	How do you prepare 100.0 mL 0.850 M $NaOH_{(AQ)}$ if you start with a stock solution of 6.40 M? 

79 You dissolve 2.25 moles of KBr into water forming a 1.00 liter solution.
What is this solution's BP and FP?

80 If you have a 2.40 M HCl stock solution, how do you make a 50.0 mL of 3.00 M HCl solution from it?
A diagram might help you think through this math.



81 Three ions are shown below. Draw in 3 water molecules oriented to <u>each of these ions</u>