# *Chemistry 12*
# *Tutorial 7*
# *Ionic and Molecular Solutions*

In this Tutorial you will be shown:

1. How to tell whether a substance will dissolve to form an ***ionic*** solution or a ***molecular*** solution.

2. Why ***ionic*** solutions conduct an electrical current while ***molecular*** solutions do not.

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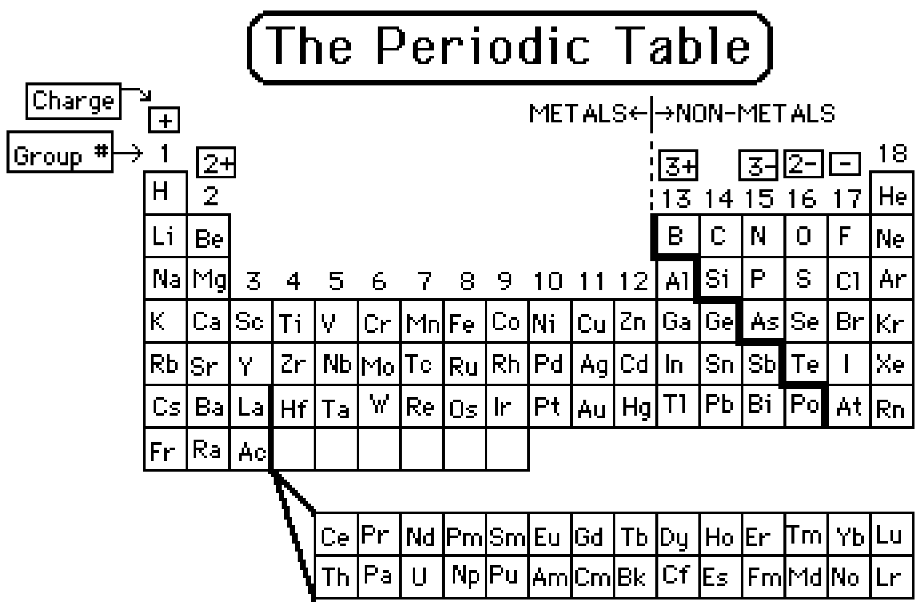
You might have noticed that this unit is called "Solubility of Ionic Substances". While this unit doesn't deal with molecular (or covalent) substances, you still have to know which are which by looking at formulas for the substances.

You must have your Periodic Table and Table of Common Ions. If you don't have it, get one out! Now!

First, a little Chemistry 11:




Remember the "staircase" which separates metals from non-metals?

The following rules will help you decide whether a compound forms an Ionic or Molecular Solution in water:

## ***Rules for Ionic and Molecular Solutions:***

1. Compounds made up of a ***metal*** (left side of staircase) and a ***non-metal*** (right side of staircase) form ***Ionic*** Solutions.

   Here are a couple of examples:

   ***NaCl*** forms an ***ionic*** solution. We show this by writing a **dissociation** equation:

   $$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

   ***$AlCl_3$*** forms an ***ionic*** solution:

   $$AlCl_{3(s)} \rightarrow Al^{3+}_{(aq)} + 3Cl^{-}_{(aq)}$$

   Both of these substances are made up of a metal and a non-metal. When they are dissolved in water, they break up into ***free ions***.

2. Compounds containing ***polyatomic ions*** form ***Ionic*** solutions.

   Remember you can find polyatomic ions on the "Table of Common Ions". Some examples are: $CO_3^{2-}$ (carbonate), and $NO_3^{-}$ (nitrate).

   Here's another example of a compound which forms an ***ionic*** solution:

   ***$KMnO_4$*** (is made up of $K^+$ ions and $MnO_4^-$ ions). When it is added to water, it *dissociates* as follows:

   $$KMnO_{4(s)} \rightarrow K^{+}_{(aq)} + MnO_{4}^{-}{}_{(aq)}$$

   $MnO_4^-$ is a polyatomic ion called "permanganate" and is found on the Ion Table.

3. ***Covalent*** Compounds (made up of a Non-metal and a Non-metal) generally form ***Molecular*** solutions.

   These include compounds in which ***both*** elements are found on the ***right*** side of the staircase.

   An example is: ***$SCl_2$***. (both S and Cl are on the right side of the staircase)
   Another example is the element ***iodine*** (formula is $I_2$). When iodine dissolves in water it does ***NOT*** break up into ions. It simply stays as ***neutral molecules*** and disperses itself in the water. The equation for it dissolving in water would be:

   $$I_{2(s)} \rightarrow I_{2(aq)}$$

Notice, there are **no ions** in the product, just $I_2$ ***molecules***.

4. Most ***organic substances*** (those with C's, H's and O's in the same formula) form ***molecular*** solutions *with the exception of organic acids.*

   Common table sugar, for example is $C_{12}H_{22}O_{11}$ . It forms a ***molecular solution*** when dissolved in water.

$$C_{12}H_{22}O_{11(s)} \rightarrow C_{12}H_{22}O_{11(aq)}$$

5. Organic Acids (compounds with C's, and H's and a group called COOH) consist of neutral molecules as a pure substance. When they dissolve in water, they dissociate partially to form some ions, thus they become ***Ionic*** Solutions.

Here are a couple of examples: $CH_3COOH$ (acetic acid) is molecular as a pure liquid (and doesn't conduct) BUT, when it is dissolved in water, some of the molecules break apart and form ions. This is called "***ionization***". Only a small fraction of the molecules will do that, so you get a limited number of free ions. This is what makes the solution a "Weak" conductor or ***Weak Electrolyte***.

$$CH_3COOH_{(l)} \rightleftharpoons H^+_{(aq)} + CH_3COO^-_{(aq)}$$

The subscript (l) stands for a liquid. Notice that the arrow is double but the longer one pointing left tells us that the ***reactants are favoured***. In other words, not many $H^+$ and $CH_3COO^-$ ions are formed, but it is still called an ***ionic*** solution.

Another example is $HCOOH_{(l)}$. This partially ionizes. (the H comes off of the "COOH")

$$HCOOH_{(l)} \rightleftharpoons H^+_{(aq)} + HCOO^-_{(aq)}$$

***An important note here***: Only compounds ending in the *entire group*, "***COOH***" are organic acids!

Compounds with C's, H's and ending in "OH" are still regular organic compounds and you can think of them as ***molecular***.

eg.) $CH_3CH_2COOH$ when dissolved in water forms an ***ionic*** solution. (It ends in "COOH", so it is an ***organic acid***.)

eg.) $CH_3CH_2OH$ forms a molecular solution in water. Compounds with C's and H's and ending in "OH" are called *alcohols*. These are all ***molecular***.

One more little note: Although "OH" is a polyatomic ion in ionic compounds, when you see it with *organic compounds* (containing C's, & H's mostly), it does NOT act as an ion.

$CH_3OH$ is ***molecular***. The letters "OH" at the end of a compound with C's and H's indicate an alcohol, which is ***molecular.***

We can show the equation for this substance ***dissolving*** in water as follows:

$$CH_3OH_{(l)} \rightarrow CH_3OH_{(aq)}$$

Notice that the substance does NOT produce ions. It stays together as $CH_3OH$ molecules. During dissolving, these molecules fit into spaces between water molecules.

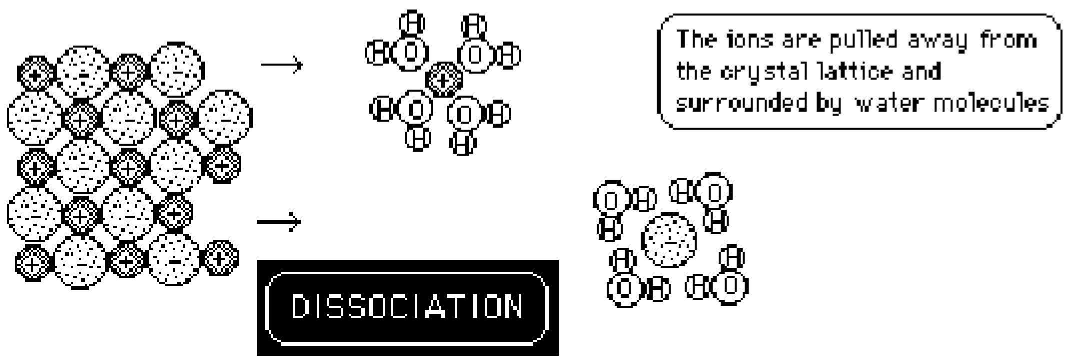
As you can see, the way we show this is by changing the (l) subscript (meaning pure liquid) to an (aq) subscript. (meaning a mixture of water and whatever substance has the subscript.)

## What Causes Conductivity?

If a liquid conducts an electrical current, it means the liquid must have ***IONS*** in it. (The only exception to this is liquid mercury, which is a metal.)

Even though a *solid* ionic compound is made up of ions, they are all "stuck together" or "immobile" in the solid form. Therefore ionic compounds *do not conduct in the solid form*.

When they are dissolved in water, the ions are removed from the solid and move *independently* anywhere in the solution.




The "+" and "-" ions are now free to move around. The "+" ions would be attracted to a negative electrode and the "-" ions would be attracted to a positive electrode. In this way, the ***ionic solution*** conducts a current.

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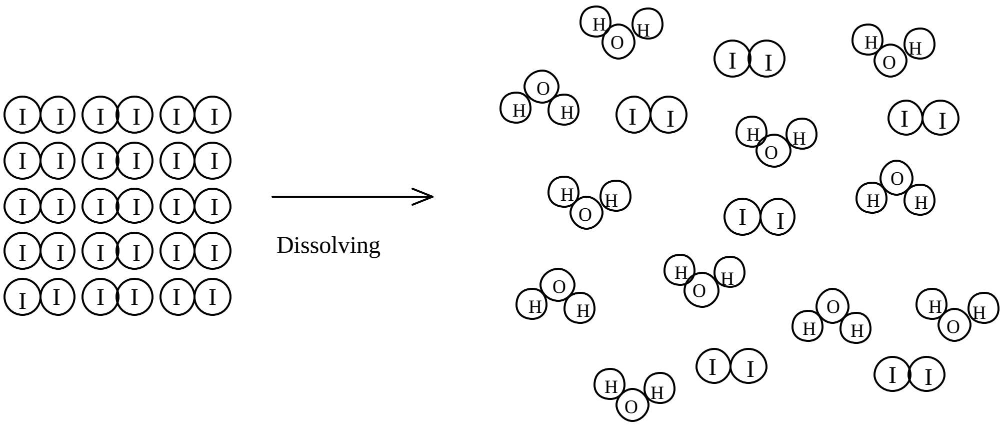
What happens with a molecular solid dissolving in water is shown on the diagram on the next page:

## ***A molecular solid ($I_2$) dissolving:***




$$I_{2\,(s)} \longrightarrow I_{2\,(aq)}$$

When iodine is dissolved in water, the molecules of $I_2$ do not break up into ions. They simply stay as molecules and fit between the water molecules. This is the way *molecular* solutions are formed.

So, in summary, you can tell whether a solid is going to form an ***ionic*** or ***molecular*** solution by what it is made up of:

1. Compounds made up of a ***metal*** and a ***non-metal*** will form ***ionic*** solutions.
2. Compounds containing ***polyatomic ions*** will form ***ionic*** solutions.
3. Compounds containing ***only non-metals*** (covalent compounds) will form ***molecular*** solutions.
4. ***Organic*** compounds (***other than*** those ending in the "COOH" group) will form ***molecular*** solutions.
5. ***Organic acids*** (organic compounds ending in the ***"COOH"*** group) will form ***partially ionic*** solutions. (These are ionic but because there are *fewer* ions formed, these solutions are *weak conductors* or *weak electrolytes*.)

Now you can do the Self-Test on the next page. Make sure you have your ion table with you!

# *Self-Test on Tutorial 7*

**Do this test right on this sheet. Check the answers on page 1 of** Tutorial 7 - Solutions.

1. Decide whether each of the following compounds will form an Ionic (I) solution or a Molecular (M) solution in water. Assume that all substances dissolve at least partially.
   a) $NiCl_2$ ............................................... ____________________________________
   b) $CH_3OH$ ............................................ ____________________________________
   c) $CH_3CH_2COOH$ ................................ ____________________________________
   d) $Fe(NO_3)_3$ .......................................... ____________________________________
   e) $K_2Cr_2O_7$ ........................................... ____________________________________
   f) $C_6H_{12}O_6$ ........................................... ____________________________________
   g) $PCl_3$ .................................................... ____________________________________
   h) CsBr ................................................. ____________________________________
   i) $HNO_3$ ............................................... ____________________________________
   j) HCOOH ........................................... ____________________________________

2. Write an equation showing what happens when each of the following are dissolved in water: (*"a" and "b" are done as an examples*)
   a) $Na_2SO_{4(s)}$ ; (*ionic*) $Na_2SO_{4(s)} \rightarrow 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$
   b) $CH_3OH_{(l)}$ ; (*molecular*) $CH_3OH_{(l)} \rightarrow CH_3OH_{(aq)}$
   c) $KCl_{(s)}$ ....................... ______________________________________________________
   d) $NH_4NO_{3(s)}$............. ______________________________________________________
   e) $Ca_3(PO_4)_{2(s)}$ ............ ______________________________________________________
   f) $CH_3CH_2CH_2OH_{(l)}$ .... ______________________________________________________
   g) $CH_3CH_2CH_2COOH_{(l)}$ ______________________________________________________

3. When ionic solutions are formed, the material dissolving breaks up into __________.

   These are free to move around and therefore will conduct a ______________________

4. When molecular solutions are formed, the material dissolving does what? _________

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