Chemistry 12
Tutorial 8
Solubility and Solubility Equilibrium

In Tutorial 8 you will be shown:

1. What is meant by the term "solubility".
2. What conditions are necessary to form a saturated solution.
3. What is happening at equilibrium in a saturated aqueous solution.
4. How to write the net ionic equation which represents a saturated solution.

Have a nice time!

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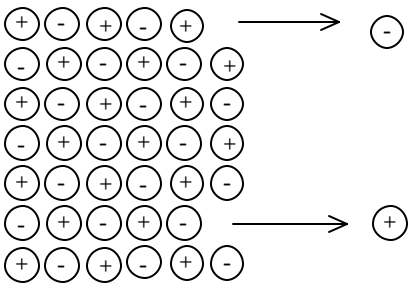
Try to imagine what happens to the ions of an soluble solid ionic substance as soon as you put it in water.

The following diagram might help you:



When the solid is first put into the water, the rate of dissolving is high. There is lots of room in the solution for ions.

Since, at first, there are no ions in solution, no free ions will go back onto the crystal.. Thus the rate of precipitation is zero to begin with..

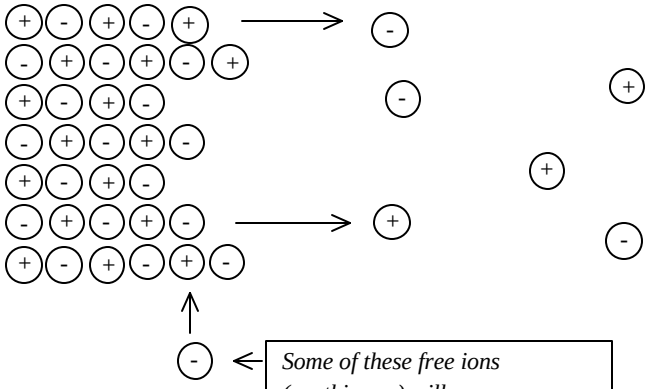
NOTE: The water molecules have been left out for simplicity.

At first, only the *forward reaction* is taking place:

$$\text{Ionic Solid} \rightarrow \text{Aqueous Solution}$$

As you may imagine, however, this situation does not continue very long. As dissolving continues, more and more free ions are found in solution. The chances that a free ion will collide with the crystal and stick onto it (precipitation or crystallization) get greater and greater.

What happens now is that the reverse reaction rate (which was initially zero), gradually increases:



Now there are more free ions in solution. because the crystal has dissolved for awhile.

Some of these free ions (eg. this one) will wander close to the crystal and stick onto it.. This process is called <u>*precipitation*</u> .

As you have probably guessed by now, as more free ions are found in the solution, the rate of precipitation will continue to <u>increase</u>.

Also, because the solution is getting "full" of ions (saturated with them), the rate of dissolving will decrease.

Sooner or later, the rate of the precipitation become equal to the rate of dissolving.

This is the situation we call ***<u>Solubility Equilibrium</u>***

Solubility Equilibrium exists when

The rate of dissolving = The rate of precipitation

The solution that forms when *some solid is still present* and *solubility equilibrium* exists is called a ***saturated solution***:

A <u>saturated solution</u> is a solution in which there exists a dissolved substance in equilibrium with the undissolved substance.

The equilibrium could be described by an equation with a double arrow:

Ionic Solid $\rightleftharpoons$ Aqueous Solution

A real example might be:

$$CaCO_{3(s)} \rightleftharpoons Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

Now, there's a term which describes ***how much*** of the solid dissolves at a given temperature. See if you can guess the term before you read the next line!

Well, the term that describes *how much* solid dissolves at a certain temperature is called the ***Solubility***. (like the "ability" to dissolve.)

Another way of saying this is that the solubility is the *amount that has dissolved* at a given temperature.

Remember that once *equilibrium* is established, ***dissolving*** will continue, but so will ***precipitation*** (at the same rate). So *the concentration of the solution will stay constant* as long as equilibrium is maintained. This concentration is called the ***equilibrium concentration***.

A definition of solubility is:

> ***Solubility*** is the ***equilibrium concentration*** of a substance in a solution at a given temperature.

Net Ionic Equations for Solubility Equilibrium

As was mentioned earlier, when a dissolving substance is at equilibrium:

The rate of dissolving = The rate of precipitation

We show this is at equilibrium by writing a double arrow. Chemists have chosen to show the **solid on the left** and the **dissolved ions on the right**. (Even though we know both the forward and reverse reaction are happening.)

The Net-Ionic Equation which represents the equilibrium reached when $MgSO_{4(s)}$ is dissolving is as follows:

$$MgSO_{4(s)} \rightleftharpoons Mg^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$$

This? of course means that the $MgSO_{4(s)}$ is dissolving and the $Mg^{2+}_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$ are precipitating to form $MgSO_{4(s)}$ at the same rate.

Since a *saturated solution* exists at equilibrium, this can also be referred to as the equation which represents what is going on in a ***saturated solution*** of $MgSO_4$ or an equation describing the ***equilibrium present*** in saturated $MgSO_4$.
Notice that the "4" subscript in the $SO_4^{2-}{}_{(aq)}$ ion does ***NOT*** change. *You cannot change the subscripts in a polyatomic ion!*

Here's another example: Write the Net-Ionic Equation for a saturated solution of $AlCl_3$.

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

Notice that the "3" subscript after the "Cl" in $AlCl_3$ comes up *in front of* the Cl^- ion in the products. This is because there is no such ion as Cl_3. Check the ion sheet for this. There is only Cl^-.

Ions in your Net-Ionic Equation must have the same formulas and charges as the ones shown on the Table of Common Ions!

Self-Test on Tutorial 8

Check answers on page 1 of Tutorial 8 - Solutions

1. Define the ***solubility*** of a substance (use the word *equilibrium* in your definition.)

   _____

   _____

   _____

2. What two conditions are necessary to have a ***saturated solution*** of a substance?

   1. _____

   2. _____

3. When a substance is first mixed with water, the *rate of dissolving* is (*fast/slow*)_____

   and the *rate of precipitation* (or crystallization) is (*fast/slow/zero*)_____

   As time goes on, the rate of *precipitation* gets _____ and the rate of *dissolving*

   gets _____. When the *rate of dissolving = the rate of precipitation*,

   _____ has been reached.

4. Give the ***Net-Ionic Equation*** which represents a ***saturated solution*** of each of the following ionic substances in water:(*Hint: These are just like dissociation equations but they have a double arrow, indicating equilibrium.*)

   a) $Ag_2SO_{4(s)}$ _____

   b) $FeS_{(s)}$ _____

c) $Mg(OH)_{2(s)}$ _____

d) $Ca_3(PO_4)_{2(s)}$ _____

e) $BaSO_{3(s)}$ _____

f) $(NH_4)_2CrO_{4(s)}$ _____

g) $Fe(OH)_{3(s)}$ _____

h) $Al_2(SO_4)_{3(s)}$ _____

The End of Tutorial 8