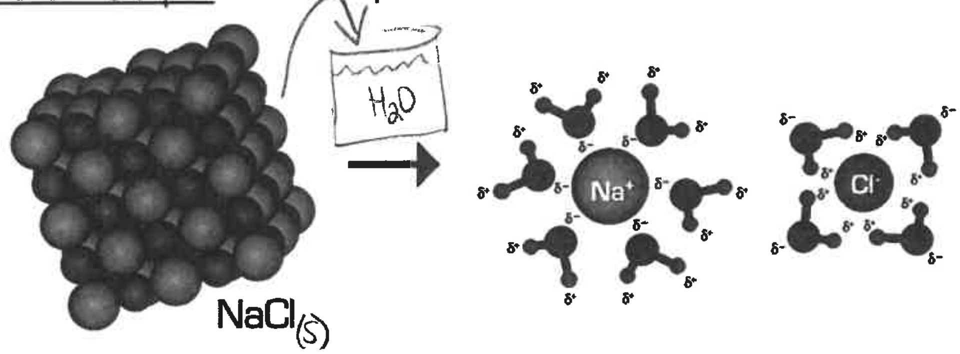
Solubility Equilibria

An equilibrium can exist between a Solute and solvent.

How?

When dissolved in water, ionic solids dissociate into the ions they contain. This process is called dissociation. For example:



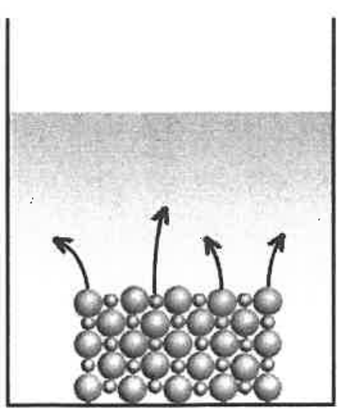
$$NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

Once the ions are free in solution, they can collide with one another, causing them to reform the solid compound they once were. When this happens, a precipitate (or solid) will form. This process is called precipitation.

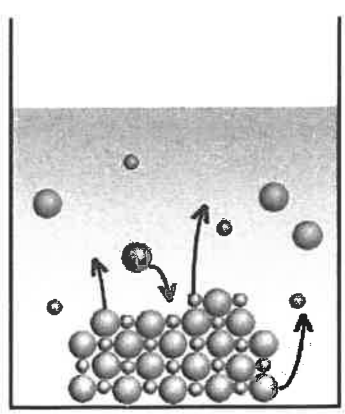
$$Na^+_{(aq)} + Cl^-_{(aq)} \rightarrow NaCl_{(s)}$$

Notice how two opposite processes are occurring here: the dissociation reaction and the precipitation reaction.

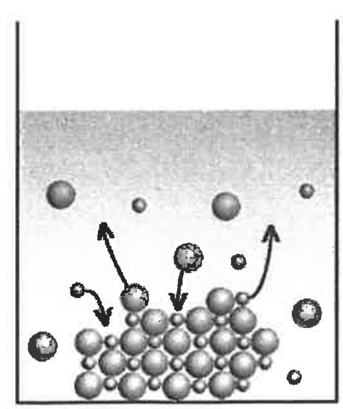
Eventually, the rate at which ions dissolve will be equal to the rate at which ions precipitate. When this happens, the solution is at equilibrium.



Salt is initially put into the water and begins dissolving.



Salt continues to dissolve; however, dissolved ions will also precipitate. Because the salt dissolves faster than its ions precipitate, the net movement is towards dissolution.



Eventually, the rate of dissolution will equal the rate of precipitation. The solution will be in equilibrium, but the ions wil continue to dissolve and precipitate.

At equilibrium, the solution is saturated - meaning it contains the maximum amount of solute that can dissolve under certain conditions.

In saturated solutions, the concentrations of ions remain constant.

This is an example of **solubility equilibrium**, the equilibrium between a solute and a solvent that occurs in a saturated solution. It is represented as a balanced equation as follows:

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

<u>Example</u>: (a) calcium fluoride (used to make steel and glass)

$$CaF_{2(s)} \rightleftharpoons Ca^{+2}_{(aq)} + 2F^{-}_{(aq)}$$

(b) barium sulphate (used in medical imaging of the gastrointestinal tract)

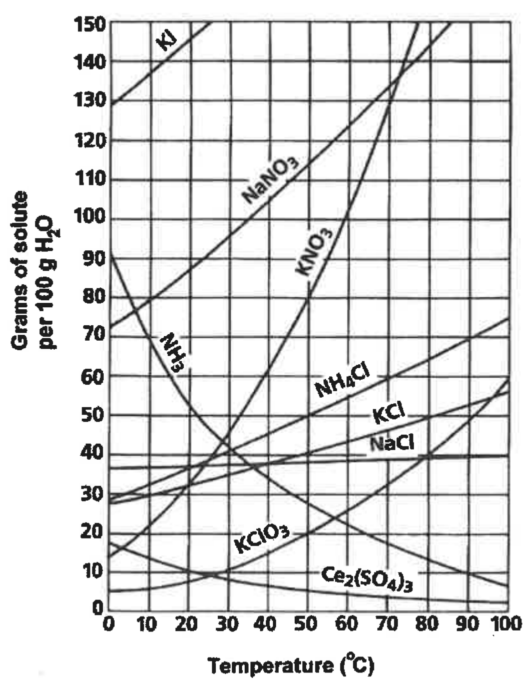
$$BaSO_{4(s)} \rightleftharpoons Ba^{+2}_{(aq)} + SO_4^{-2}{}_{(aq)}$$

covalently bonded

Note: Solubility equilibrium is based on solids dissolving in water to give the basic particles from which they are formed. As such, molecular compounds, such as sugar, do not dissociate but rather dissolve to give individual aqueous molecules. This is shown as:

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

* Beware of acetate ($CH3COO^{-}$) and other organic ions. They will dissociate into ions! *



Solubility Curves

- Each line represents the maximum amount of solute that can be dissolved in 100 g of H_2O at a particular temperature. In other words, this is the amount of solute in a saturated solution.
- Below the line, the solution is unsaturated – more solute can dissolve.
- Above the line, the solution is supersaturated - more than the usual amount of solute is dissolved – a precipitate is formed.

For most substances, as temperature increases, solubility increases.

Exceptions to this include: NH_3, $Ce_2(SO_4)_3$

Example: Label the following solutions as saturated, unsaturated, or supersaturated. If unsaturated, determine how much more solute can be dissolved in solution.

(a) 50g of dissolved NH_4Cl per 100 g H_2O at 50°C?

on the line ∴ a saturated solution

(b) 70g of dissolved $NaNO_3$ per 100 g H_2O at 30°C?

below the line ∴ unsaturated

how much? 96g − 70g ≙ 26g more $NaNO_3$