

Solubility

The **solubility** of a solute is the maximum quantity of solute that can dissolve in a certain quantity of solvent or quantity of solution at a specified temperature.

The main factors that have an effect on solubility are:

- **the nature of the solute and solvent** -- While only 1 gram of lead (II) chloride can be dissolved in 100 grams of water at room temperature, 200 grams of zinc chloride can be dissolved. The great difference in the solubilities of these two substances is the result of differences in their natures.
- **temperature** -- Generally, an increase in the temperature of the solution increases the solubility of a solid solute. A few solid solutes, however, are less soluble in warmer solutions. For all gases, solubility decreases as the temperature of the solution rises.
- **pressure** -- For solids and liquid solutes, changes in pressure have practically no effect on solubility. For gaseous solutes, an increase in pressure increases solubility and a decrease in pressure decreases solubility. (When the cap on a bottle of soda pop is removed, pressure is released, and the gaseous solute bubbles out of solution. This escape of a gas from solution is called **effervescence**.)

The **rate of solution** is a measure of how fast a substance dissolves. Some of the factors determining the rate of solution are:

- **size of the particles** -- When a solute dissolves, the action takes place only at the surface of each particle. When the total surface area of the solute particles is increased, the solute dissolves more rapidly. Breaking a solute into smaller pieces increases its surface area and hence its rate of solution. (Sample problem: a cube with sides 1.0 cm long is cut in half, producing two pieces with dimensions of 1.0 cm x 1.0 cm x 0.50 cm. How much greater than the surface area of the original cube is the combined surface areas of the two pieces? 2.0 cm^2)
- **stirring** -- With liquid and solid solutes, stirring brings fresh portions of the solvent in contact with the solute, thereby increasing the rate of solution.
- **amount of solute already dissolved** -- When there is little solute already in solution, dissolving takes place relatively rapidly. As the solution approaches the point where no solute can be dissolved, dissolving takes place more slowly.
- **temperature** -- For liquids and solid solutes, increasing the temperature not only increases the amount of solute that will dissolve but also increases the rate at which the solute will dissolve. For gases, the reverse is true. An increase in temperature decreases both solubility and rate of solution.

Solubility and the nature of a solvent and a solute:

- In order for a solvent to dissolve a solute, the particles of the solvent must be able to separate the particles of the solute and occupy the intervening spaces. Polar solvent molecules can effectively separate the molecules of other polar substances. This happens when the positive end of a solvent molecule approaches the negative end of a solute molecule. A force of attraction then exists between the two molecules. The solute

molecule is pulled into solution when the force overcomes the attractive force between the solute molecule and its neighboring solute molecule. Ethyl alcohol and water are examples of polar substances that readily dissolve in each other.

Ammonia, water, and other polar substances do not dissolve in solvent whose molecules are nonpolar. The nonpolar molecules have no attraction for polar molecules and exert no force that can separate them. However, nonpolar substance such as fat will dissolve in nonpolar solvents.

Polar solvents can generally dissolve solutes that are ionic. The negative ion of the substance being dissolved is attracted to the positive end of a neighboring solvent molecules. The positive ion of the solute is attracted to the negative end of the solvent molecule. Dissolving takes place when the solvent is able to pull ions out of their crystal lattice or structure. The separation of ions by the action of a solvent is called **dissociation**. When you sprinkle table salt (NaCl) in water and stir, the grains of salt disappear. From what you have just read (on solubility), you have a model to explain what actually happens to the salt. Sodium chloride, an ionic compound, is made of sodium ions and chloride ions. The slightly charged ends of water molecules attract these ions. As a result the ions are *dissociated*, or separated by the water molecules and spread evenly throughout the solution.

Solubility Rules

1. All common salts of Group 1 elements and ammonium (NH_4^{1+}) are soluble.
2. All common **nitrates** (NO_3^{1-}) and acetates are soluble.
3. Most chlorides, bromides, and iodides are soluble except silver, lead (II), and mercury (I)
4. All sulfates are soluble except barium, strontium, lead (II), calcium, silver, and mercury (I)
5. Except for those in Rule 1, carbonates, hydroxides, oxides, and phosphates are **insoluble**.

The table that follows sums up solubility tests for over 100 ionic compounds. Positive ions are listed at the left. Negative ions are listed across the top. To read the table, start with a positive ion from the left column such as aluminum. As you read across the aluminum row, data is given for the following compounds: aluminum acetate (ss, slightly soluble), aluminum bromide (s, soluble), aluminum carbonate (not exist, not known to exist), and so on. The "decomp" indicates that the compound chemically reacts with water and decomposes.

	acetate	bromide	carbonate	chloride	chromate	hydroxide	iodide	nitrate	phosphate	sulfate	sulfide
aluminum	ss	soluble	not exist	soluble	not exist	nearly insol	soluble	soluble	nearly insol	soluble	decomp
ammonium	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble
barium	soluble	soluble	nearly insoluble	soluble	nearly insoluble	soluble	soluble	soluble	nearly insoluble	nearly insoluble	decomp
calcium	soluble	soluble	nearly insoluble	soluble	soluble	ss	soluble	soluble	nearly insoluble	ss	decomp
copper (II)	soluble	soluble	nearly insoluble	soluble	nearly insoluble	nearly insoluble	decomp	soluble	nearly insoluble	soluble	nearly insoluble
iron (II)	soluble	soluble	nearly insoluble	soluble	not exist	nearly insoluble	soluble	soluble	nearly insoluble	soluble	nearly insoluble
iron (III)	soluble	soluble	not exist	soluble	nearly insoluble	nearly insoluble	not exist	soluble	nearly insoluble	ss	decomp
lead (II)	souble	ss	nearly insoluble	ss	nearly insoluble	nearly insoluble	ss	soluble	nearly insoluble	nearly insoluble	nearly insoluble
magnesium	soluble	soluble	nearly insoluble	soluble	soluble	nearly insoluble	soluble	soluble	nearly insoluble	soluble	decomp
mercury (I)	ss	nearly insoluble	nearly insoluble	nearly insoluble	ss	not exist	nearly insoluble	soluble	nearly insoluble	ss	nearly insoluble
mercury(II)	soluble	ss	nearly insoluble	soluble	ss	nearly insoluble	nearly insoluble	soluble	nearly insoluble	decomp	nearly insoluble
potassium	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble
silver	ss	nearly insoluble	nearly insoluble	nearly insoluble	ss	not exist	nearly insoluble	soluble	nearly insoluble	ss	nearly insoluble
sodium	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble	soluble
zinc	soluble	soluble	nearly insoluble	soluble	soluble	nearly insoluble	soluble	soluble	nearly insoluble	soluble	nearly insoluble