UNIT 2: SOLUTIONS READING NOTES

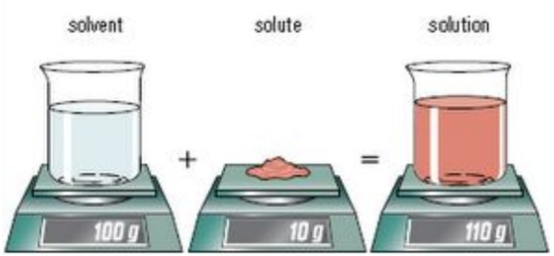
Dissolving Process

SECTION OBJECTIVES

1. To understand the composition of a solution: solvent and solute.
2. To know what an aqueous solution is.
3. To know that water is the universal solvent.
4. To describe the dissolving process.
5. To understand the factors that affect the rate of dissolution.
6. To know the properties of solutions.

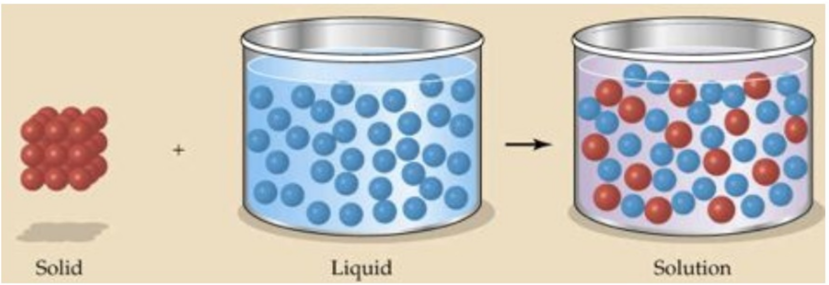
The study of solutions is an important topic in chemistry. Since most of the important chemical reactions take place in solution, it is important to understand the chemistry of solutions.

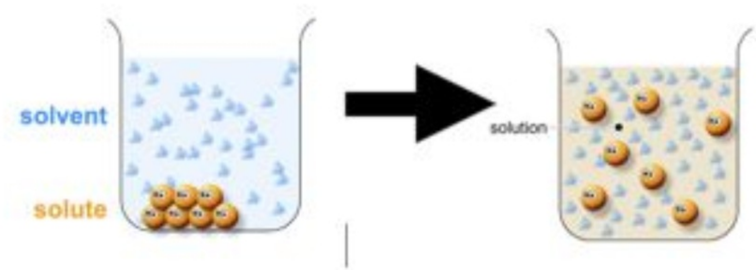
Solutions are homogeneous mixtures, which means that the components are uniformly dispersed throughout the solution. In other words, you cannot see the individual components of the solution. In addition, every sample of a solution is identical. For example, if you have a solution of sugar and water, every sip will taste the same.



A solution is made up of a **solute** and **solvent.** The solute is the substance being dissolved, found in least amount. The solvent is the substance doing the dissolving, found in greatest amount.

When the solute is completely dissolved, and is uniformly dispersed throughout the solvent, a solution is formed.





If sand is added to a cup of water, a solution would not form because the sand would just sit at the bottom and would not mix with the water. In a solution, the solute must dissolve in the solvent and form a homogeneous mixture.

When water is the solvent, the solution is referred to as an aqueous solution. Aqueous solutions are very common, and water is referred to as the universal solvent.

It's important to note that solutions can be composed of solids, liquids, and/or gases.

Solute	Solvent	Solution
Gas	Gas	Air
Gas	Liquid	Soda
Liquid	Liquid	Wine
Solid	Liquid	Kool Aid
Solid	Solid	Sterling Silver

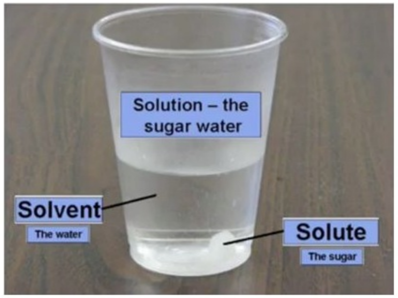
Air is a solution, composed of the gases nitrogen, oxygen, argon, carbon dioxide. Soda is a solution made up of liquid water and gaseous carbon dioxide. Mrs. Maffucci's "elixir of life" is a solution made up of two liquids - coffee and hot milk. Two liquids that are soluble in one another are referred to as being miscible.

My sterling silver bracelet is also a solution of two different metals, made up of 92.5 % Silver and the rest Copper.

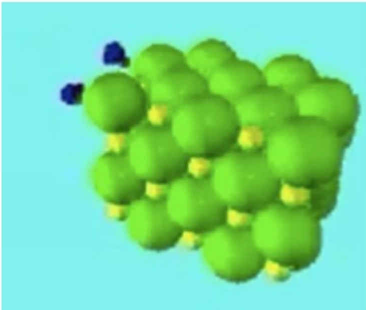
Dissolving is a physical change. The chemical properties of the substances in the solution do not change. So, what happens as sugar dissolves in water? In order to dissolve, the solvent particles must touch the solute. The sugar molecules on the surface of the sugar crystal leave the crystal and mix with the water. Eventually all the sugar molecules are evenly distributed throughout the water, creating a homogeneous mixture. Each sugar molecule is surrounded by water molecules.

1. Sugar Cube + Glass of Water

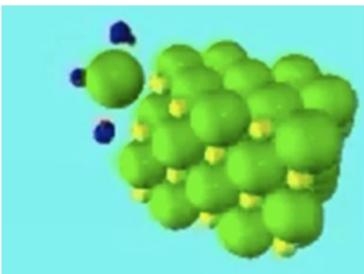
2. Sugar dissolves as the sugar molecules leave the surface of their crystals and begin to be surrounded by water molecules. Sugar cube decreases in size as the molecules continue to dissolve in the water to form a solution.



3. Eventually the sugar is evenly distributed throughout the solvent creating a homogeneous mixture, and all visible traces of the sugar are gone. The sugar will remain dissolved in the water as long as conditions remain constant.



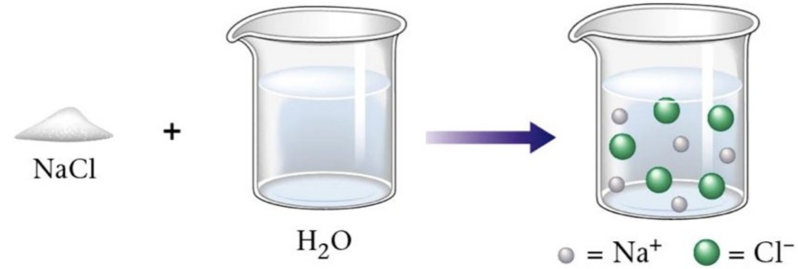
The green and yellow spheres represent sugar molecules, the solute. The dark blue spheres represent water molecules, the solvent.

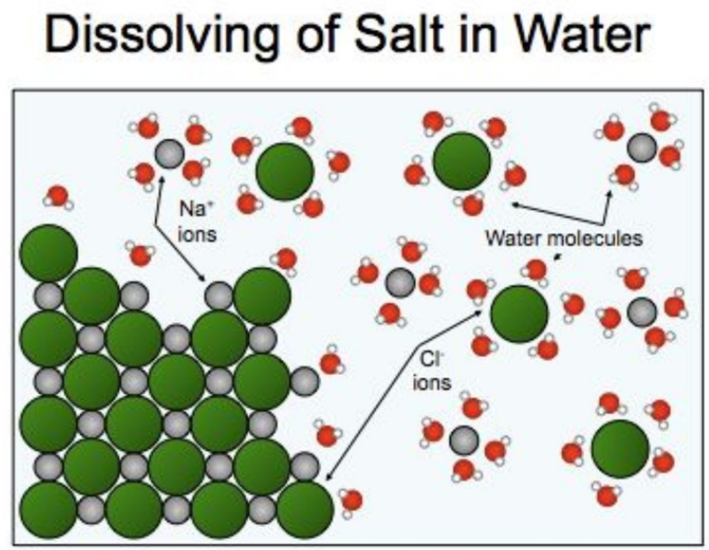


As the solvent comes into contact with the solute, a solution begins to form, the solvent pulls solute particles apart and surrounds them.

Sugar is a covalent molecule and does not form charged particles when it dissolves.

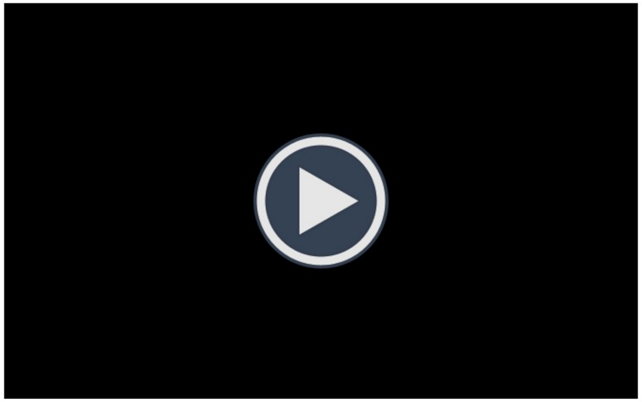
Salt (NaCl), on the other hand, is a substance made up of charged particles (positive and negative ions) held together by ionic bonds. When salt dissolves, the water molecules break the ionic bond, thus separating the positive sodium ions from the negative chloride ions.



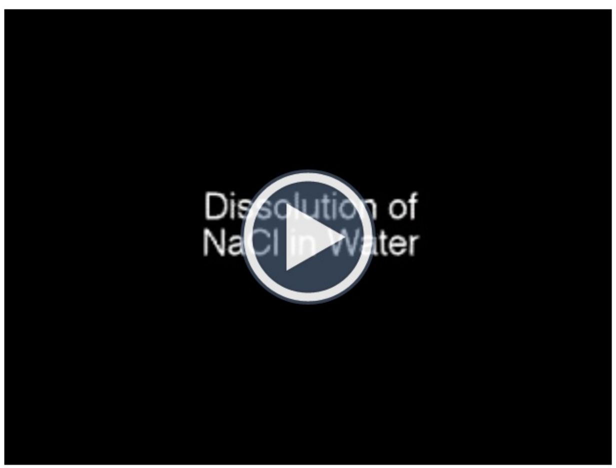


$NaCl(s) + H_2O \rightarrow Na^+(aq) + Cl^-(aq)$

Movie 1.2 How Water Dissolves Salt



Movie 1.1 Dissociation of Salt



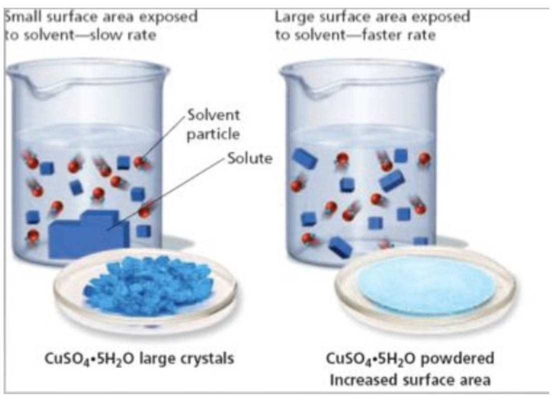
How quickly a substance dissolves in a solvent is affected by three main factors:

Temperature affects the speed at which particles move. As temperature increases, the kinetic energy of the particles increases. Dissolving depends on the collision between solvent particles and solute particles. When the particles are moving more rapidly, more collisions will occur, and the rate of dissolving will increase. Since the particles are moving at higher speeds, the collisions between solute and solvent will also be harder. In addition, once the solvent particles collide with the solute, they are able to "carry" the solute particles away from the crystal quicker. In general, most solutes dissolve faster at higher temperatures. This explains why it takes longer to dissolve sugar in iced tea that in hot tea.

2. particle size

As size ↓, rate ↑

Larger particles take longer to dissolve that smaller particles of the same substance. For example, sugar cubes dissolve more slowly than granulated sugar. Why? Since dissolving requires the collision between solvent particles and solute particles, granulated sugar has more surface area for the solvent particles to collide with. An increase in surface area results in more collisions, and the rate of dissolving speeds up.



Since dissolving occurs at the surface of the solute, an increase in the surface area will speed up the rate of dissolving by exposing the solute to solvent particles.

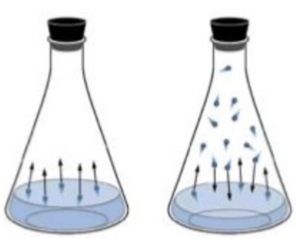
3. mixing

More mixing, rate ↑

Stirring a solution will increase the rate at which a solute dissolves. This is because the stirring increases the collisions between solute and solvent particles.

Colligative Properties

Colligative properties are the properties of solutions that depend on the number of dissolved particles in solution, but not on the identities of the solutes:



1. **Vapor Pressure Depression:** when a solute is dissolved in a solvent, the solute reduces the ability of the solvent particles at the surface to escape.

2. **Boiling Point Elevation:** when the dissolved solute lowers the vapor pressure, a higher temperature is needed for the solution to boil.

Adding a salt to water will increase the temperature at which it boils.

3. **Freezing Point Depression:** when a solute is dissolved in a solvent, the solute gets in the way and makes it difficult for the solvent to form the intermolecular bonds necessary for it to solidify. Salt is added to melt the ice on roads by lowering the freezing point of water.

Adding a salt to water will lower the temperature at which it freezes.

Solubility

SECTION OBJECTIVES: TO KNOW -

1. as temperature increases, solubility of a solid tends to increase, and gases are most soluble at low temperature and high pressure
2. how to determine if a substance is soluble in water by using a solubility chart
3. how to determine the solubility of a substance in water at a specific temperature by using the Solubility Curves
4. how to calculate the grams of solute that can dissolve in a given amount of solvent
5. how to calculate the grams of solvent required to dissolve a given amount of solute
6. miscible liquids are soluble in one another

Solubility is a physical property. The solubility of a substance depends on many factors: nature of the solute and solvent (type of chemical bonding), temperature, and pressure (only for gases). Solubility is defined as the amount of solute that can dissolve in a specific amount of solvent for a particular temperature.

$$\text{Solubility} = \frac{\text{grams solute}}{\text{grams solvent}}$$

Because it is a characteristic property of matter, solubility can be used to identify a substance. For example, suppose you had two beakers containing different white solids; one containing ammonium chloride, and the other sodium nitrate. At 65 °C, the solubility of ammonium chloride is about 60 g/100 g water, while the solubility of sodium nitrate is about 130 g/100 g water. This difference in solubility can be used to determine which white solid was in each beaker.

Since the majority of chemical reactions take place in water, we are mainly concerned with aqueous solutions, and the solubility of various salts in water.

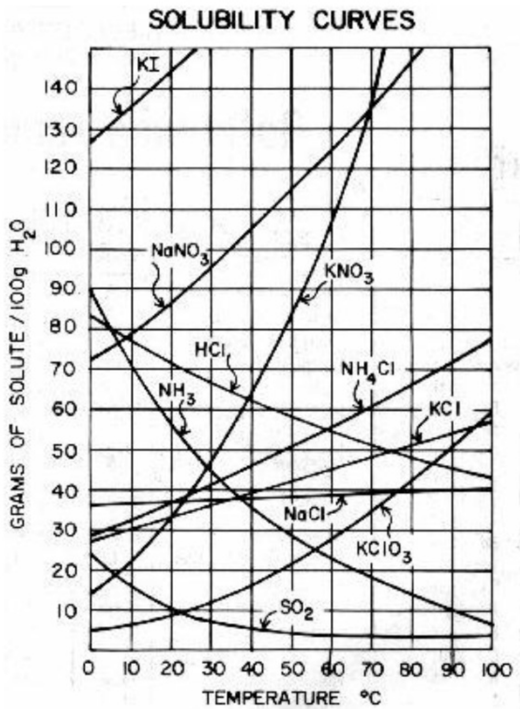
The chart on the following page is a solubility table of inorganic salts in water. Cations, or positive ions are found on the left side of the chart. Anions, or negative ions are found on the top row of the chart. If you look at aluminum acetate, you will find the symbol "s," meaning that aluminum acetate is soluble in water. However, if you look at aluminum hydroxide, you will find the symbol "i" meaning that aluminum hydroxide is insoluble in water.

Solubility Chart

	acetate	bromide	carbonate	chlorate	chloride	chromate	hydroxide	iodide	nitrate	oxide	phosphate	silicate	sulfate	sulfide
aluminum	S	S	-	S	S	-	A	S	S	a	A	I	S	d
ammonium	S	S	S	S	S	S	-	S	S	-	S	-	S	S
barium	S	S	P	S	S	A	S	S	S	S	A	S	a	d
calcium	S	S	P	S	S	S	P	S	S	P	P	P	P	P
copper(II)	S	S	-	S	S	-	A	-	S	A	A	A	S	A
hydrogen	S	S	-	S	S	-	-	S	S	-	S	I	S	S
iron(II)	S	S	P	S	S	-	A	S	S	A	A	-	S	A
iron(III)	S	S	-	S	S	A	A	S	S	A	P	-	P	d
lead(II)	S	S	A	S	S	A	P	P	S	P	A	A	P	A
magnesium	S	S	P	S	S	S	A	S	S	A	P	A	S	d
manganese(II)	S	S	P	S	S	-	A	S	S	A	P	I	S	A
mercury(I)	P	A	A	S	a	P	-	A	S	A	A	-	P	I
mercury(II)	S	S	-	S	S	P	A	P	S	P	A	-	d	I
potassium	S	S	S	S	S	S	S	S	S	S	S	S	S	S
silver	P	a	A	S	a	P	-	I	S	P	A	-	P	A
sodium	S	S	S	S	S	S	S	S	S	S	S	S	S	S
strontium	S	S	P	S	S	P	S	S	S	S	A	A	P	S
tin(II)	d	S	-	S	S	A	A	S	d	A	A	-	S	A
tin(IV)	S	S	-	-	S	S	P	d	-	A	-	-	S	A
zinc	S	S	P	S	S	P	A	S	S	P	A	A	S	A

S=soluble in water. P=partially soluble in water, soluble in dilute acids. A=soluble in acids, insoluble in water. a=slightly soluble in acids, insoluble in water. I=insoluble in dilute acids and in water. d=decomposes in water

In upper level chemistry classes you would be expected to know solubility generalizations, such as: all nitrates are soluble; all salts of sodium, potassium, and ammonium are soluble; all sulfates are soluble except for barium sulfate, calcium sulfate, and lead sulfate.



What trend do you notice based on these curves? As temperature increases, solubility increases. For example, the solubility of $NaNO_3$ increases from about 80 g/100 g water at 10 degrees Celsius to 140 g/100 g water at 75 °C.

The exceptions are HCl, NH_3, and SO_2. In these three examples, as temperature increases, solubility decreases. Why?

HCl, NH_3, and SO_2 are gases. For gases, as temperature increases, solubility decreases.

This graph shows the relationship between temperature and solubility. Notice that the solubility has the units g solute/100 g H_2O.

Maffucci's Tip:

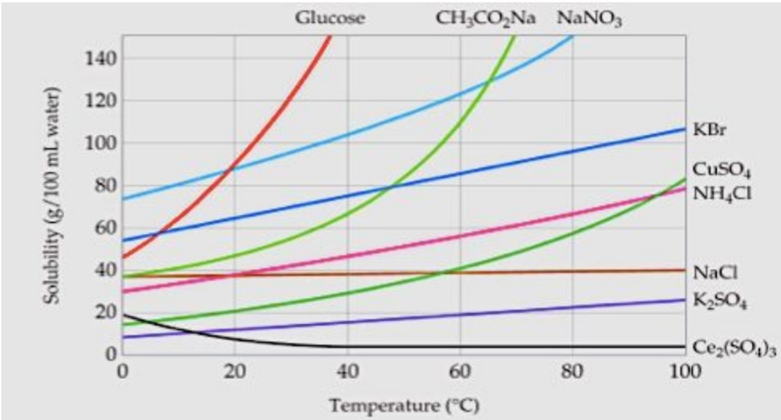
In general: For solids, as T increases, solubility increases. For gases, as T increases, solubility decreases,

Gases are most soluble at low temperature and high pressure. What is the practical application of this principle? Soda is a solution made up of sugar water and carbon dioxide gas. Carbon dioxide is responsible for the carbonation (fizziness) of soda, To keep the fizz in soda: 1) Keep the soda in a cold place, and 2) Keep the cap on the soda.

Why would a closed container of soda have a danger of exploding if left out in the hot sun? **As temperature increases, solubility of a gas decreases.** The carbon dioxide gas would escape from the solution and exert pressure on the soda can, possibly causing it to explode.

The solubility of oxygen gas in water is extremely important to the survival of fish. Since an increase in temperature causes the solubility of gases in water to decrease, water at a higher temperature will not contain as much dissolved oxygen gas. Therefore, many fish are only capable of existing in waters of a lower temperature where more oxygen exists.

It is interesting to note that large mouth bass can survive in warmer, more polluted water than the small mouth bass. That is why large mouth mass are found in the warmer lakes in Stockton, CA. They are better able to handle the lower concentration of oxygen than their small mouth bass cousins.



Considering the above solubility curves, answer the following questions:

1. What is the solubility of glucose at 20 °C? The solubility is about 90 g glucose/100 mL water at 20 °C.

2. What is the solubility of sodium acetate (CH_3CO_2Na) at 48 °C? The solubility is about 80 g sodium acetate/100 mL water at 48 °C.

3. Which of the salts above is the most soluble at 10 degrees Celsius? The least soluble? Sodium Nitrate ($NaNO_3$) is the most soluble, and Potassium Sulfate (K_2SO_4) is the least soluble.

4. Which of the salts above is least affected by temperature? Sodium Chloride (NaCl) is least affected by temperature?

Maffucci's Tip:

The solubility curves on the previous page are based on 100 mL water. Since the density of water is 1 g/mL, this means the solubilities are also based on 100 g water.

But what happens if you don't have 100 g water?

For example, if the solubility of sodium acetate (CH_3CO_2Na) is 80 g/100 g water at 48 °C, how many grams of sodium acetate can dissolve in 50 g water at 48 °C? Since you only have half the amount of solvent, you can only dissolve half the amount of solute. Therefore, only 1/2 of 80, or 40 g sodium acetate can dissolve in 50 g water at 48 °C.

Hey, we could do that in our heads. Give us something more difficult?

Problem # 1: How many grams of sodium acetate can dissolve in 39 g water at 48 °C?

Maffucci's Tip:

It's easy. Just use unit analysis. To solve any problem in chemistry, what's the first thing you write down?

Write down the given first, which is 39 g water, and then use a conversion factor to change from g water to g sodium acetate. Hint: 80 g sodium acetate/100 g water.

$$39\text{ g water} \times \frac{80\text{ g sodium acetate}}{100\text{ g water}} = 31.2\text{ g sodium acetate}$$

Problem # 2: How many grams of water are needed to dissolve 100 g sodium acetate at 48 °C?

$$100\text{ g sodium acetate} \times \frac{100\text{ g water}}{80\text{ g sodium acetate}} = 125\text{ g water}$$

Given: The solubility of glucose at 20 °C is 90 g glucose/100 mL water.

Problem # 3: How many grams of glucose can dissolve in 1500 g water at 20 °C?

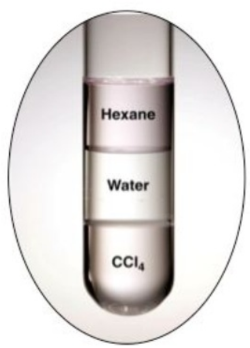
$$1500\text{ g water} \times \frac{90\text{ g glucose}}{100\text{ g water}} = 1350\text{ g glucose}$$

Problem # 4: How many grams of water are needed to dissolve 250 g glucose at 20 °C?

$$250\text{ g glucose} \times \frac{100\text{ g water}}{90\text{ g glucose}} = 277.78\text{ g water}$$

Movie 2.1 Solubility Calculations

Mrs, Maffucci teaching how to write the solubility of a substance, and how to calculate grams of solute that can dissolve in a particular amount of solvent and how to calculate grams of solvent necessary to dissolve a particular amount of solute.



What about the solubility of liquids in one another? The picture on the left shows the density differences between hexane, water, and CCl_4. Since hexane is on the top, hexane is the least dense, and since CCl_4 is on the bottom, it is the most dense. Since water does not dissolve in the hexane, they are said to be immiscible. Water and CCl_4 are also immiscible

You've heard the expression "Oil and Water do not mix," meaning oil and water are immiscible. The ability of one liquid to dissolve in another liquid depends on the chemical bonding and shape of the of the molecules making up each liquid. Oil and water (and hexane and water) do not mix because one is non-polar and the other is polar. Oil and hexane are both nonpolar molecules, meaning there is no apparent charge on the molecules. Water is a polar solvent, meaning that each end of the water has an apparent charge. The topic of polar and nonpolar bonding will be discussed in more detail in the book "Honors Chemistry: Bonding."

Maffucci's Tip:

Time to Review by Taking the Following Interactive Quiz