

Solutions

What is a solution?

A solution is a homogeneous mixture,
a mixture in which the components are uniformly intermingled.

A sample from one part is the same as a sample from any other part.



Components of a Solution

Solvent:

The solution component (typically present in the largest amount)
in which one or more solutes are dissolved to form the solution.

Solute:

The solution component that is dissolved in a solvent.
A solution may have several solutes, which generally
are present in lesser amounts than the solvent.

Table 14.1 Types of Solutions

Solute	Solvent	Solution
<i>Gaseous Solutions</i>		
gas	gas	air (nitrogen, oxygen, argon gases)
liquid	gas	humid air (water vapor in air)
<i>Liquid Solutions</i>		
gas	liquid	carbonated drinks (CO ₂ in water)
liquid	liquid	vinegar (HC ₂ H ₃ O ₂ in water)
solid	liquid	salt water (NaCl in water)
<i>Solid Solutions</i>		
liquid	solid	dental amalgam (Hg in Ag)
solid	solid	sterling silver (Cu in Ag)

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Solubility:

Maximum amount of solute that will dissolve in specific amount of solvent at a given temperature.

Example:

Identify the solute and solvent in a sample of carbonated water ($H_2O + CO_2$)

Solute: _____

Solvent: _____

Gases in Solution

- Temperature Effects

As temperature increases, solubility decreases

As the temperature increases, the kinetic energy of the solute gas becomes greater, and the molecules acquire more of a tendency to find the surface and escape from the solvent.

- Pressure Effects

Henry's Law

The greater the partial pressure above a liquid, the greater the solubility.

The greater the number of gas molecules above the liquid, the more they hit the walls of the container and therefore the higher the vapor pressure. When this happens, where can the gas molecules go??

→ Back into solution. So the greater the solubility of the gas in solution.

Liquids in Solution

Polar and Nonpolar Solvents

Polar Solvents: consist of polar molecules (with net dipoles)

Nonpolar Solvents: consist of nonpolar molecules (without net dipoles)

Table 14.3 Selected Polar and Nonpolar Solvents

Polar Solvents	Nonpolar Solvents
water, H_2O	hexane, C_6H_{14}
methanol, CH_3OH	heptane, C_7H_{16}
ethanol, C_2H_5OH	toluene, C_7H_8
acetone, C_3H_6O	carbon tetrachloride, CCl_4
methyl ethyl ketone, C_4H_8O	chloroform, $CHCl_3$
formic acid, $HCHO_2$	methylene chloride, CH_2Cl_2
acetic acid, $HC_2H_3O_2$	ethyl ether, $C_4H_{10}O^*$

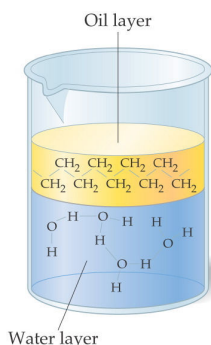
*The general rule that oxygen-containing solvents are polar has some exceptions. For example, ethyl ether contains oxygen and is a nonpolar solvent.

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"Like Dissolves Like"

Intermolecular Forces

- Polar solvents such as water (H_2O) and ethanol (C_2H_5OH) dissolve in one another.
- Nonpolar solvents such as hexane (C_6H_{14}) and carbon tetrachloride (CCl_4) dissolve in one another.



Miscible: Two solvents that dissolve completely in one another.

Immiscible: Two solvents that *do not* dissolve completely in one another.

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Solids in Solution

The solute-solvent interaction is strongest when the polarities of the solute and the solvent are similar.

Molecular Solids:

In general, if the molecular solid is polar, it will likely dissolve in a polar solvent.

If the molecular solid is nonpolar, it will likely dissolve in a nonpolar solvent.

Ionic Solids:

Since ionic compounds are composed of charged ions, they are similar to polar compounds and will likely dissolve in polar solvents.

Always check solubility rules!!

Example 1:

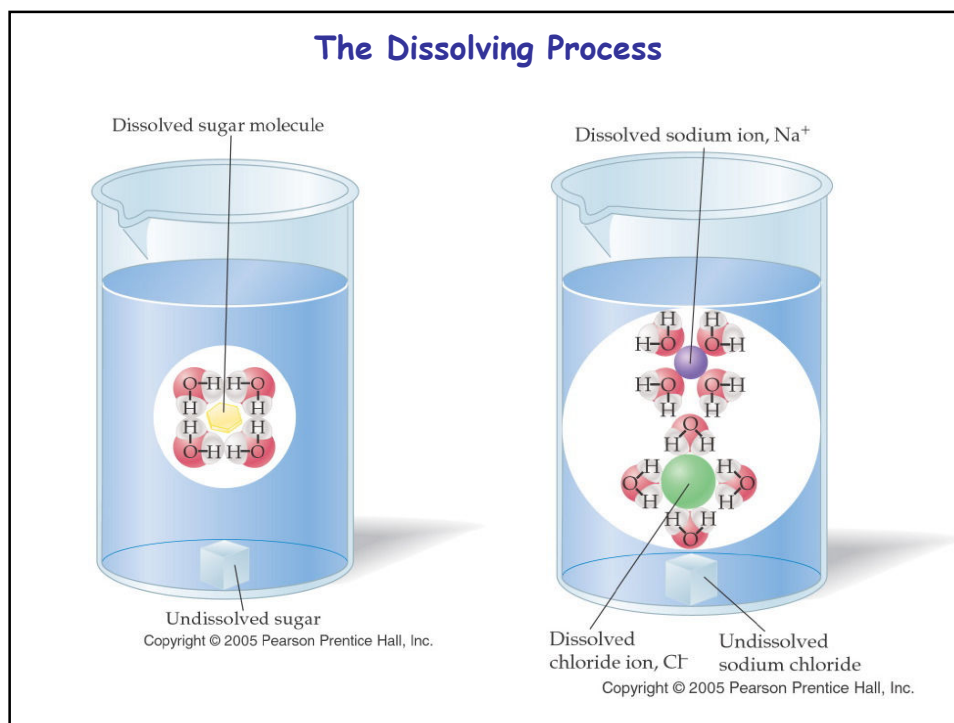
Please state whether the following are miscible, immiscible, soluble, or insoluble.

	Polar Liquid	Nonpolar Liquid
Polar Liquid		
Nonpolar Liquid		
Polar Solid		
Nonpolar Solid		
Ionic Solid		

Example 2:

Circle all that are miscible with ethanol (C_2H_5OH), a polar solvent.

water CCl_4 (l) NH_3 (l) H_2S (l)
 C_6H_{14} (l) CH_3F C_2H_5NH



Solvation

- The solubility of a given solvent depends on the relative attraction between particles in the pure substances and in the solution.
- In the solid state, the ions in an ionic compound (salt) are packed closely together.
- Strong ionic forces hold the salt together in the crystal form.
- However, when the solute (salt) dissolves in the solvent (water), the ions separate and disperse themselves throughout the solution.
- The strong ionic forces holding the cations and anions together must be overcome as well as the strong intermolecular forces holding the solvent molecules together.
- The solute and solvent molecules must be able to interact and be attracted to each other.
- This new attraction must be strong enough to overcome the existing forces.
- Only then can solvation occur.

The solvent molecules align themselves around the solute.

Rate of Dissolving

We can increase the rate of dissolving by any of the following:

1. Heating the solution

Solvent molecules move faster and attract the solute particles more often.

2. Stirring the solution

The solvent can then encounter the solute particles more often.

3. Grinding the solid solute

This increases the surface area of the solute giving more solute surface for solvent to attract.

More Solution Terminology

Unsaturated:

Contains less than the maximum amount of solute that a solvent can hold at a specific temperature

Saturated:

Contains the maximum amount of solute that a solvent can hold at a specific temperature

Supersaturated:

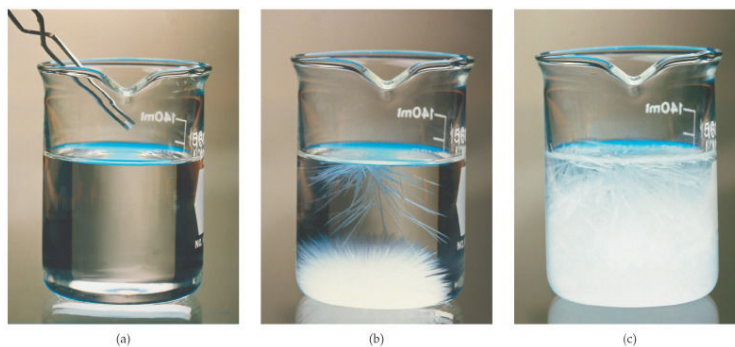
Contains more than the maximum amount of solute that a solvent can hold at a specific temperature

How ?

At higher temperatures, solvents can hold more solute than at lower temperatures. If a given amount of solute is dissolved in a solvent at a higher temperature, then allowed to cool without being disturbed, the solute will remain in solution.

The solution is unstable, though, and the solute will fall out of solution if the solution is disturbed.

- by adding a few more solute particles.



Mass Percent Concentration

$$\text{mass/mass percent (m/m \%)} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100 \%$$

a.k.a. The mass of solute dissolved in 100 g of solution

$$\text{Mass of solution} = \text{mass of solute} + \text{mass of solvent}$$

$$\frac{\text{g of solute}}{\text{g solute} + \text{g solvent}} \times 100 \% = \text{m/m \%}$$

Writing mass percent concentration unit factors:

A 5.00 % solution of NaF

5.00 g of NaF in 100 g of solution

$$\frac{5.00 \text{ g NaF}}{100 \text{ g solution}} \quad \text{and} \quad \frac{100 \text{ g solution}}{5.00 \text{ g NaF}}$$

If the solution = 100.0 g,

then 5.00 g is the solute NaF and 95.00 g is the solvent (water)

$$\frac{5.00 \text{ g NaF}}{95.00 \text{ g water}} \quad \text{and} \quad \frac{95.00 \text{ g water}}{5.00 \text{ g NaF}}$$

Example 1:

A solution is prepared by dissolving 30.00 g of NaCl in 120.00 g of water. Calculate the mass percent concentration.

Example 2:

Given 125.0 g of a 15.0% sucrose solution, what is the mass of sucrose solute?

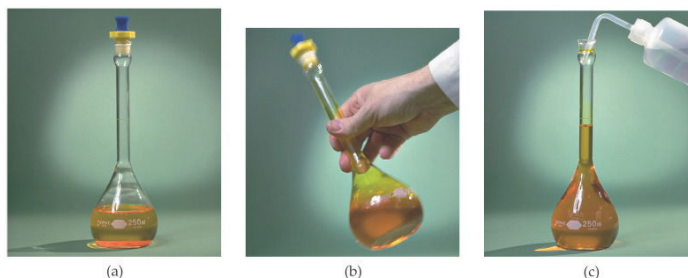
Example 3:

What is the mass of water required to dissolve 2.25 g of KI for a 15.00 % saline solution?

Molar Concentration

Molarity (M) is the moles of solute per liter of solution.

$$M = \frac{\text{mole solute}}{\text{L solution}} = \frac{\text{mol}}{\text{L}}$$



- (a) Add the solute and dissolve with a little bit of solvent first.
 (b) Shake to dissolve the solvent.
 (c) Then fill to the special line on a volumetric flask to give the total volume of solution.

We can also indicate molarity (concentration) with square brackets.

$$[\text{KCl}] = \text{"the molarity or molar concentration of KCl"} = \text{mol/L}$$

Examples

- Find the molarity of a solution prepared by dissolving 0.250 mol of KBr in 100.0 mL of solution.
- What is the molarity of a solution that is made by dissolving 2.50 g of HCl in enough water to the mark on a 250.0 mL volumetric flask?

Write 2 unit factor for each of the following:

A. 6.00 M HCl (aq)

B. 0.125 M KCl (aq)

1. Calculate the number of moles of NaOH present in 75.0 mL of a 6.00 M NaOH solution.
2. Calculate the mass of CuCl_2 in 25.0 mL of 0.500 M CuCl_2 .
3. What mass of AgNO_3 is needed to prepare 250.0 mL of 0.675 M AgNO_3 .
4. What is the mass of NaOH in 125.0 mL of a 6.00 M NaOH solution?
(40.00 g/mol)
5. How many milliliters of 12.0 M hydrochloric acid contain 7.30 g of HCl solute?
(36.46 g/mol)