Solubility

Whether or not a solute will dissolve in a solvent and how much of it will dissolve depends on the **solubility** of the solute. The solubility is the maximum amount of a solute that will dissolve in a specific solvent under given conditions.

When a solution contains the maximum amount of solute that it can possibly dissolve under the existing conditions of temperature and pressure, it is said to be **saturated**. When more solute is added to a saturated solution, it will not dissolve.

A solution that has less than the maximum amount of solute that can be dissolved is called an **unsaturated** solution. A solution that contains a greater amount of solute than that needed to form a saturated solution is said to be **supersaturated**. Supersaturated solutions are very unstable, meaning they will not remain supersaturated for very long. Instead, the excess solute particles will escape from the solution and reform the pure solute.

Supersaturation

We know that hot water dissolves more sugar than cold water. This property can be used to create a supersaturated solution.

To make a supersaturated solution, a saturated solution is formed at a high temperature and then cooled slowly. The slow cooling allows the excess solute to remain dissolved in solution at the lower temperature.

If a tiny amount of solute, called a seed crystal, is added to a supersaturated solution, the excess solute will precipitate (move out of solution) quickly. This can also occur if the inside of the container is scratched or if the supersaturated solution undergoes a physical shock (stirring or tapping).

Solubility

Several factors affect the extent to which a solute will dissolve in a solvent. These factors include:

- the nature of the solute and solvent
- temperature
- pressure (for gases)

Nature of Solute and Solvent

A liquid made up of polar molecules is called a polar solvent. Water is the most common polar solvent. A liquid made up of nonpolar molecules is called a nonpolar solvent.

When two substances are similar, they can dissolve in each other. Thus,

- ionic and polar solutes will dissolve in polar solvents
- nonpolar solutes will dissolve in nonpolar solvents

This principle is usually expressed as "like dissolves like." According to this rule, two liquids dissolve in each other because their molecules are alike in polarity. The table below lists some common polar and nonpolar substances.

Polar	**Nonpolar**
water (H_2O)	hexane (C_6H_{14})
alcohols	heptane (C_7H_{16})
methyl alcohol (CH_3OH)	octane (C_8H_{18})
ethyl alcohol (C_2H_5OH)	carbon tetrachloride (CCl_4)
isopropyl alcohol (C_3H_7OH)	in general, greases, petroleum oils, vegetable oils, waxes, tars, gasoline
acetone (C_3H_6O)	
acetic acid ($HC_2H_3O_2$)	
formic acid ($HCHO_2$)	

Temperature

Solutions of gases in liquids are greatly affected by temperature. As the temperature increases, the kinetic energy of the solute (gas) particles becomes greater, so they are more likely to escape from the solvent. Thus, **the solubility of a gas in a liquid decreases as the temperature increases**.

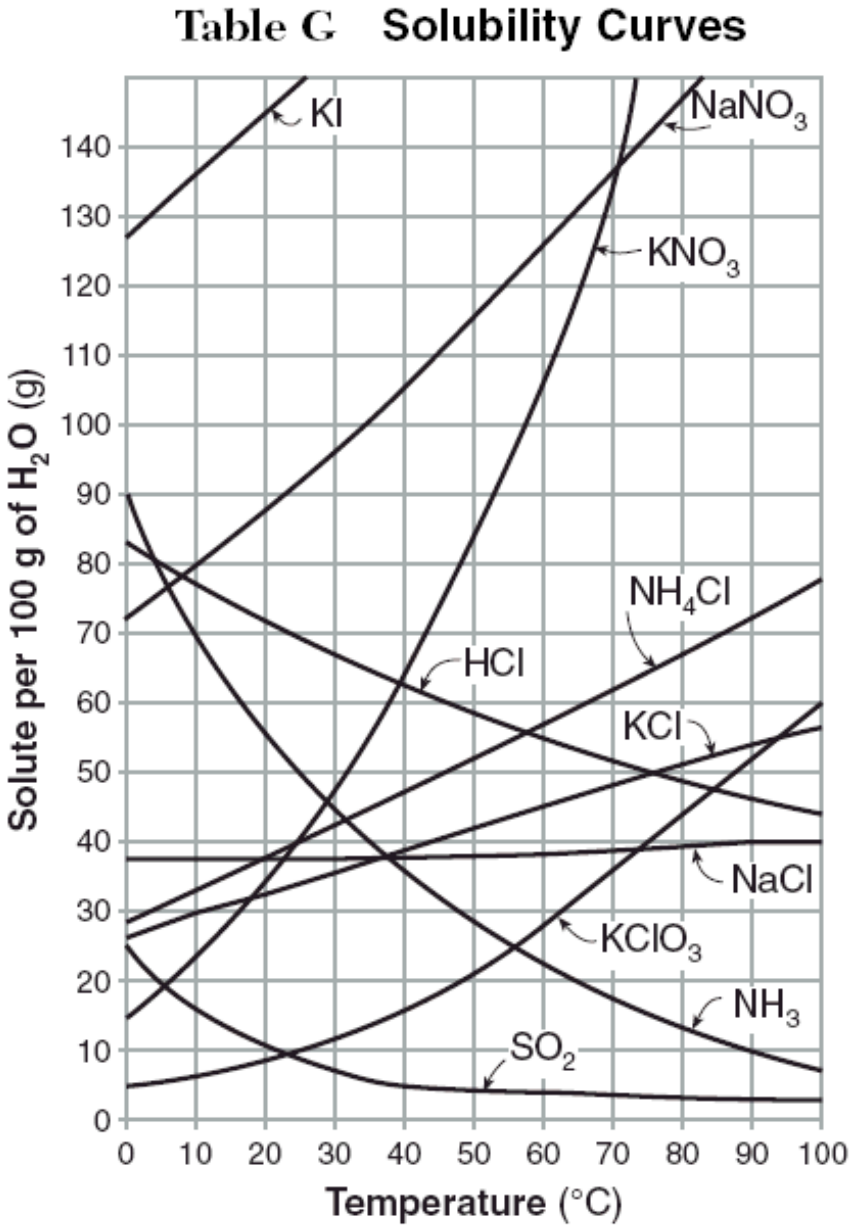
The effect of temperature changes on the solubility of solids in liquids is very different from that of gases. Although there are a few exceptions, in general **the solubility of a solid solute increases as the temperature increases**.

The relationship between solubility and temperature depends on the energy change during solution formation.

- If the temperature drops (endothermic) when the solute and solvent are mixed, raising the temperature will increase solubility.
- If the temperature stays the same when they are mixed, the solubility will not be affected significantly by changing the temperature in either direction.
- If the temperature rises (exothermic) when the solute and solvent are mixed, raising the temperature will decrease the solubility.

Solubility Curves

A solubility curve can be used to determine how much of a solute can be dissolved in a solvent at a given temperature. The solubility curve shown below illustrates the solubility of several substances in water.



Example 1
What is the solubility of potassium nitrate (KNO_3) at $45°C$?

Example 2

$25\ g$ of potassium nitrate is dissolved in $50\ g$ of water at $30°C$. Determine whether this solution is saturated or not. Explain your answer.

Example 3

A solution contains $5.2\ g$ of potassium nitrate dissolved in $10\ g$ of water at $40°C$. What amount of KNO_3 would be required to saturate this solution?

Example 4

A solution contains $33\ g$ of KNO_3 in $30\ g$ of water at $72°C$. How much must this solution be cooled in order to saturate the solution?

Solubility Worksheet

1. Using a solubility curve, determine the amount of each solute that can dissolve in 100 g of water at the given temperature

   a) KNO_3 at $70°C$

   b) NH_4Cl at $90°C$

   c) $NaNO_3$ at $35°C$

   d) NH_3 at $20°C$

   e) $NaCl$ at $100°C$

   f) $KClO_3$ at $65°C$

   g) NH_4Cl at $65°C$

   h) $NaNO_3$ at $70°C$

   i) KNO_3 at $10°C$

2. Solubility data for four different salts in water at $60°C$ are shown in the table below.

Salt	Solubility in Water at $60°C$
A	$10\ g/50\ g\ H_2O$
B	$20\ g/60\ g\ H_2O$
C	$30\ g/120\ g\ H_2O$
D	$40\ g/80\ g\ H_2O$

   Which salt is most soluble at $60°C$?

3. When soda pop is manufactured, carbon dioxide (CO_2) gas is dissolved in it.

   a) A capped bottle of cola contains carbon dioxide gas under high pressure. When the cap is removed, how does pressure affect the solubility of the dissolved carbon dioxide?

   b) A glass of cold cola is left to stand for 5 minutes at room temperature. How does temperature affect the solubility of the dissolved carbon dioxide?

4. A student uses 200 g of water at a temperature of $60°C$ to prepare a saturated solution of potassium chloride, KCl .

   a) Identify the solute in this solution.

   b) How many grams of KCl must be used to create this saturated solution?

   c) This solution is cooled to $10°C$ and the excess KCl precipitates (settles out). The resulting solution is saturated at $10°C$. How many grams of KCl precipitated out of the original solution?

5. The following data table shows the solubility of a solid solute.

Temperature ($°C$)	g of solute per 100 g H_2O
0	18
20	20
40	24
60	29
80	39
100	49

a) Graph the data from the data table. Connect the points.

b) Based on the data table, if 15 g of solute is dissolved in 100 g of water at $40°C$, how many more grams of solute can be dissolved in this solution to make it saturated at $40°C$?

c) How many grams of $KClO_3$ must be dissolved in 100 g of H_2O at $10°C$ to produce a saturated solution?

6. A saturated solution of $NaNO_3$ is prepared at $60°C$ using 100 g of water. As this solution is cooled to $10°C$, $NaNO_3$ precipitates (settles) out of the solution. The resulting solution is saturated. Approximately how many grams of $NaNO_3$ settled out of the original solution?

7. An unsaturated aqueous solution of NH_3 is at $90°C$ in 100 g of water. How many grams of NH_3 could this unsaturated solution contain?