Solutions

Forming Solutions

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- 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.
  - The atmosphere that surrounds us is a gaseous solution containing $O_2(g)$, $N_2(g)$, and other gases randomly dispersed.
    - A solution can be a gas, a liquid, or a solid.

Forming Solutions

Table 15.1

Various Types of Solutions

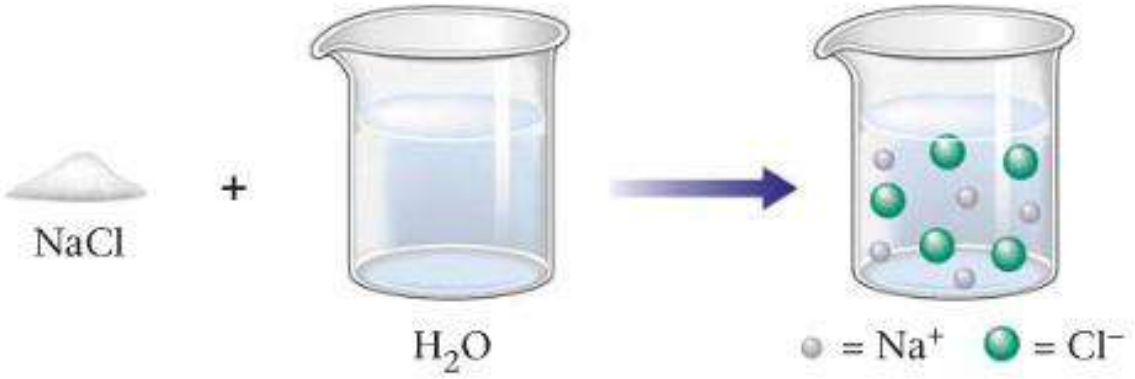
Example	State of Solution	Original State of Solute	State of Solvent
air, natural gas	gas	gas	gas
antifreeze in water	liquid	liquid	liquid
brass	solid	solid	solid
carbonated water (soda)	liquid	gas	liquid
seawater, sugar solution	liquid	solid	liquid

- The substance present in the largest amount is called the **solvent**, and the other substance or substances are called **solutes**.
- **Aqueous solutions** are solutions with water as the solvent.

Solubility

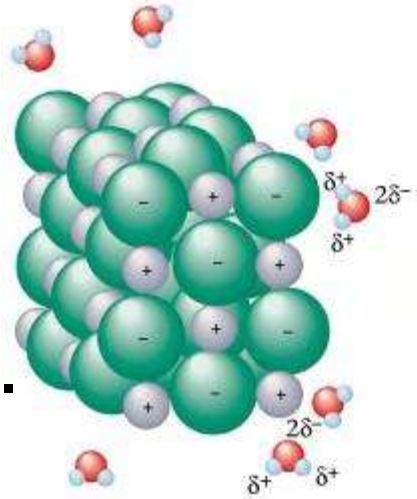
Solubility of Ionic Substances

- When sodium chloride dissolves in water, the resulting solution conducts an electric current.
- The solution contains *ions* that can move (this is how the electric current is conducted).



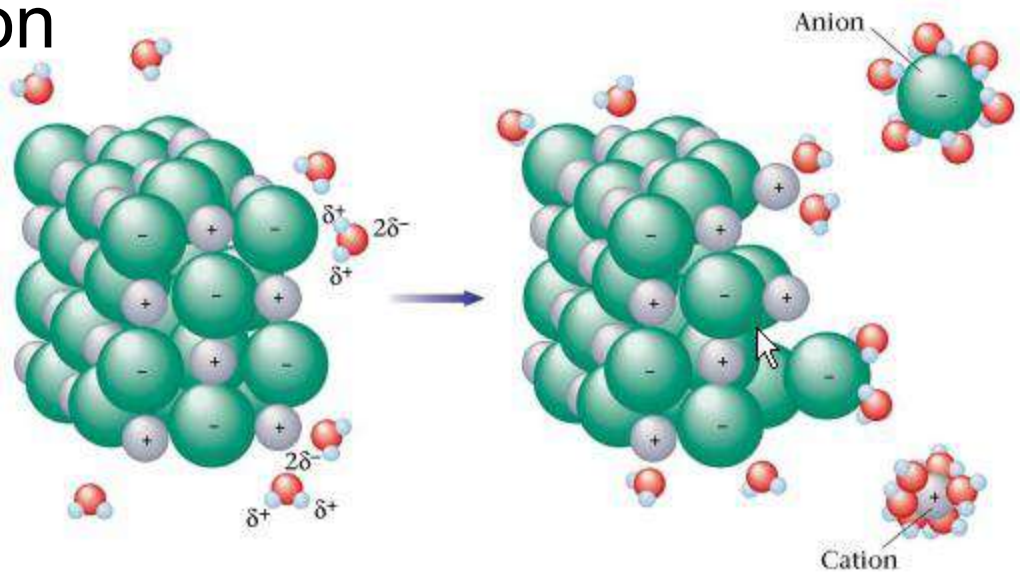
Solubility

- In the solid state the ions are packed closely together.
- When the solid dissolved, the ions are separated and dispersed throughout the solution.
- The strong ionic forces that hold the NaCl crystal together are overcome by the strong attractions between the ions and the polar H_2O molecules.



Solubility

- Each polar water molecule orients itself in a way to maximize its attraction with a Cl^- or Na^+ ion.
  - The negative end of a water molecule is attracted to a Na^+ ion, while the positive end is attracted to a Cl^- ion.
  - The strong forces holding the positive and negative ions in the solid are replaced by strong water-ion interactions and the solid dissolves (the ions disperse).



Solubility

- It is important to remember that when an ionic substance dissolves in water, it breaks up into individual cations and anions, which are dispersed in the water.
  - For instance, when ammonium nitrate, NH_4NO_3, dissolves in water, the resulting solution contains NH_4^+ and NO_3^- ions, which move around independently.
  - This process can be represented as

$$NH_4NO_3\,(s) \xrightarrow{H_2O} NH_4^+\,(aq) + NO_3^-\,(aq)$$

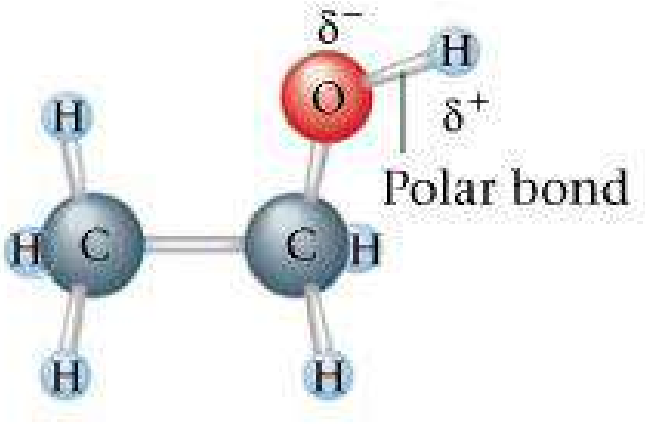
Solubility

Solubility of Polar Substances

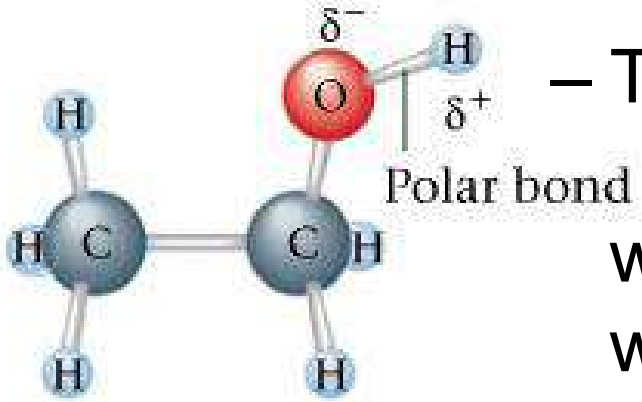
- Water also dissolves many nonionic substances.
- Sugar is one example.
- Another example is ethanol, C_2H_5OH.

Why is ethanol so soluble in water?

– The answer lies in the structure of the ethanol molecule.

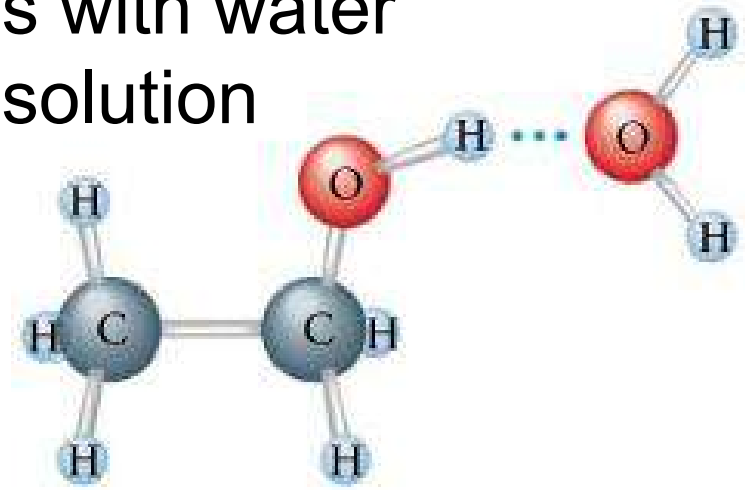


Solubility



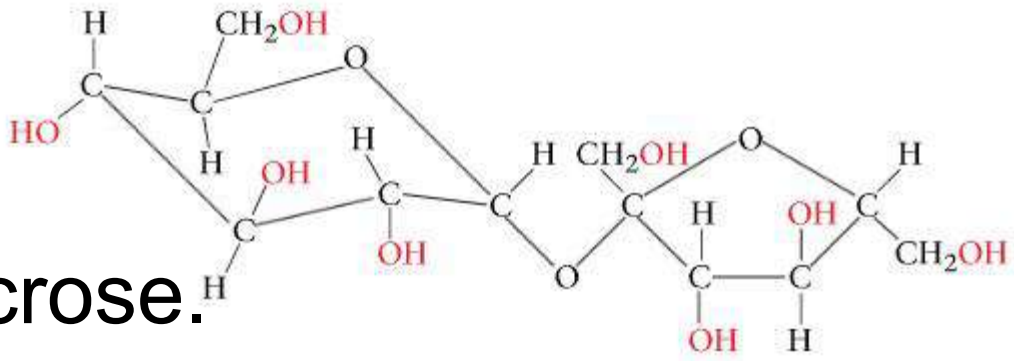
– The molecule contains a polar O—H bond like those in water, which makes it very compatible with water.

– Just as hydrogen bonds form among water molecules in pure water, ethanol molecules can form hydrogen bonds with water molecules in a solution of the two.



Solubility

- Common table sugar has the chemical name sucrose.

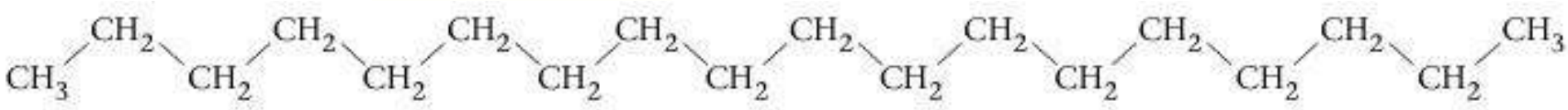


  - This molecule has many polar —OH groups, each of which can hydrogen-bond to a water molecule.
    - Solid sucrose is quite soluble in water.

Solubility continued

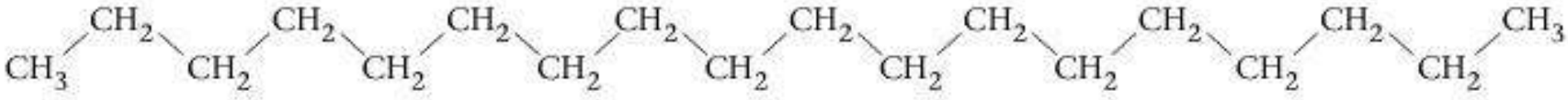
Substances Insoluble in Water

- Many substances do not dissolve in water.
- For example, when petroleum leaks from a damaged tanker, it does not disperse uniformly in the water (does not dissolve) but rather floats on the surface because its density is less than that of water.
  - Petroleum is a mixture of molecules like this one.



Solubility

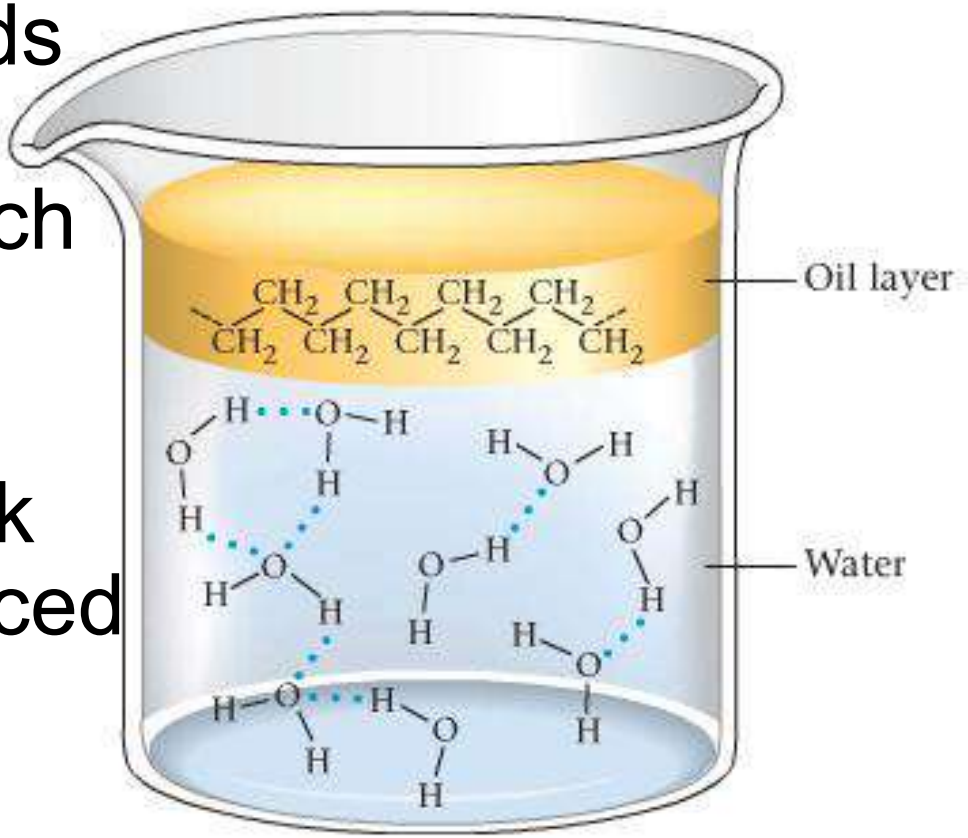
– Since carbon and hydrogen have very similar electronegativities, the bonding electrons are shared almost equally and the bonds are essentially nonpolar.



– The resulting molecule with its nonpolar bonds is not compatible with the polar water molecules, which prevents it from being soluble in water.

Solubility

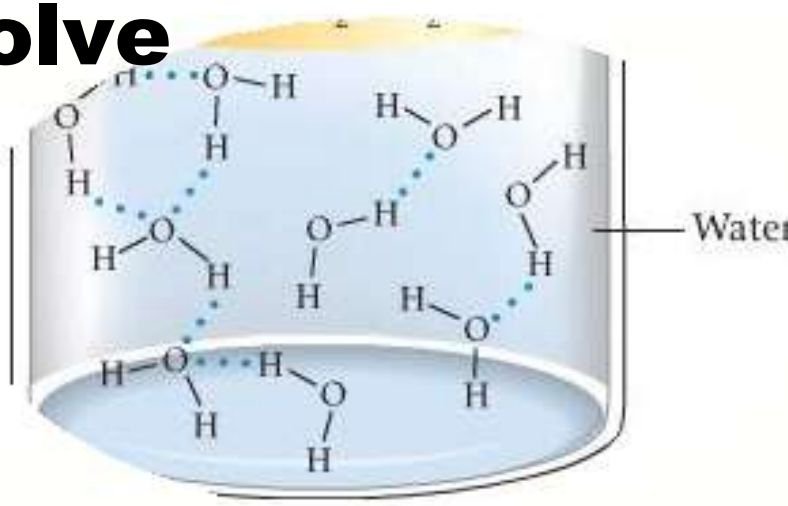
- For a substance to dissolve, the water-water hydrogen bonds must be broken to make a "hole" for each solute particle.
- The water-water interactions will break only if they are replaced by similar strong interactions with the solute.



Solubility

How Substances Dissolve

- In liquid water, the water molecules are associated with each other by hydrogen-bonding interactions.



- For a solute to dissolve in water, lost water-water interactions are replaced by similar water-solute interactions.

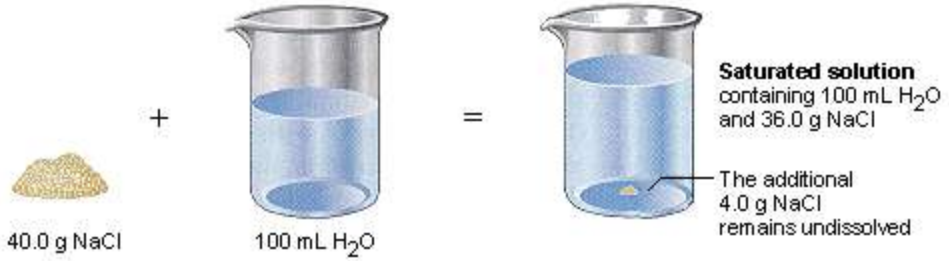
Solubility

”Like dissolves like."

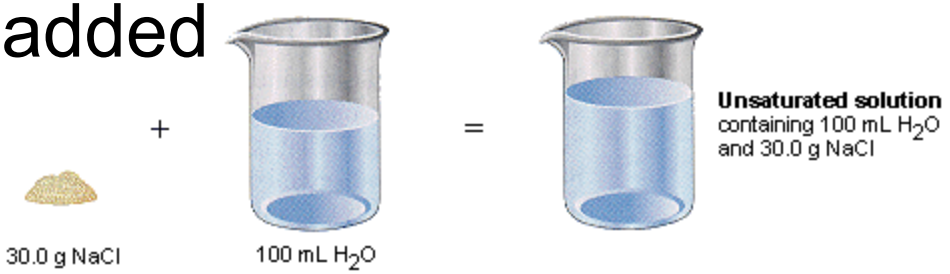
- A given solvent usually dissolves solutes that have polarities similar to its own.
  - Water dissolves most polar solutes, because the solute-solvent interactions formed in the solution are similar to the water-water interactions present in the pure solvent.
  - Likewise, nonpolar solvents dissolve nonpolar solutes.

Solution Composition: An Introduction

- When a solution contains as much solute as will dissolve at that temperature, we say it is **saturated**.
  - If a solid solute is added to a solution already saturated with that solute, the added solid does not dissolve.



- A solution that has not reached the limit of solute that will dissolve in it is said to be **unsaturated**.
  - When more solute is added to an unsaturated solution, it dissolves.



Solution Composition: An Introduction

- Sometimes when a solid is dissolved to the saturation limit at an elevated temperature and then allowed to cool, all of the solid may remain dissolved.
- This type of solution is called **supersaturated** solution -- it contains more dissolved solid than a saturated solution will hold at that temperature.
  - A supersaturated solution is very unstable.
  - Adding a crystal of the solid will cause immediate precipitation of solid until the solution reaches the saturation point.

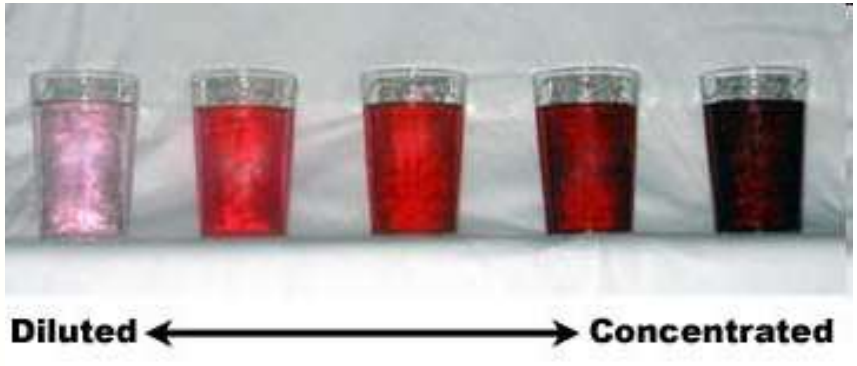
Solution Composition: An Introduction

- Although a chemical compound always has the same composition, a solution is a mixture and the amounts of the substances present can vary in different solutions.
  - For example: Strong coffee has more coffee dissolved in a given amount of water than weak coffee.

- We must specify the amounts of solvent and solute.
- We sometimes use the qualitative terms ***concentrated*** and ***dilute*** to describe a solution.

Solution Composition: An Introduction

- A relatively large amount of solute is dissolved in a **concentrated** solution (strong coffee is concentrated).
- A relatively small amount of solute is dissolved in a **dilute** solution (weak coffee is diluted).
    - The concentration of a solution is a measure of the amount of solute dissolved in a given volume of solution.



Solution Composition: An Introduction

- **Which solution is more concentrated?**

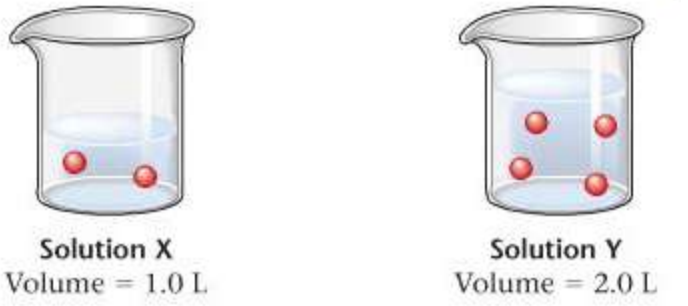
Solution A
Volume = 1.0 L

Solution B
Volume = 1.0 L

- The volume of each of the solutions is the same.
- The amount of solute in solution A is less than the amount of solute in solution B.
- Solution B is more concentrated than solution A.

Solution Composition: An Introduction

- When comparing the concentrations of two solutions you have to consider both the amount of solute and the volume of solution.
  - The following two solutions have the same concentration.



- Although the volume of solution Y is twice the volume of solution X the amount of solute in solution Y is also twice as much as that in Solution X.

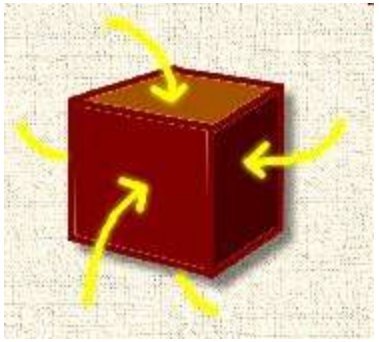
Factors Affecting the Rate of Dissolving

- When a solid is being dissolved in a liquid to form a solution, the dissolving process may occur rapidly or slowly.
- Three factors affect the speed of the dissolving process:

1.surface area

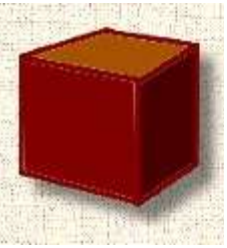
2.stirring

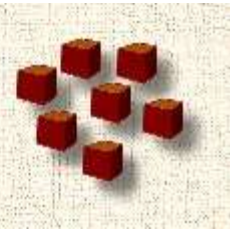
3.temperature



Factors Affecting the Rate of Dissolving

- The dissolving process occurs at the surface of the solid being dissolved, so the greater the amount of surface area exposed to the solvent, the faster the dissolving will occur.
  - **If we want to dissolve a cube of sugar in water, how can we speed up the process?**
    - The answer is to grind up the cube into tiny crystals.
    - Because the crystals from the ground-up cube expose much more surface area to the water than the original cube did, the sugar dissolves much more quickly.





Factors Affecting the Rate of Dissolving

- The dissolving process is also increased by stirring the solution.
  - Stirring removes newly dissolved particles from the solid surface and continuously exposes the surface to fresh solvent.
- Finally, dissolving occurs more rapidly at higher temperatures.
  - Sugar dissolves quicker in hot than iced tea.
  - Higher temperatures cause the solvent molecules to move more rapidly, thus increasing the rate of the dissolving process.

Factors Affecting the Rate of Dissolving

- In addition to dissolving faster at higher temperatures, most solids are more soluble at higher temperatures.
  - In most cases more solid will dissolve in water at 90 ℃ than in water at 25 ℃.
- The opposite is true for gases dissolved in water.
  - The solubility of a gas in water typically decreases as the temperature increases.

Factors Affecting the Rate of Dissolving

Let's Review

Factors Affecting Dissolving

- Surface area
- Stirring
- Temperature

Forming Solutions
The end