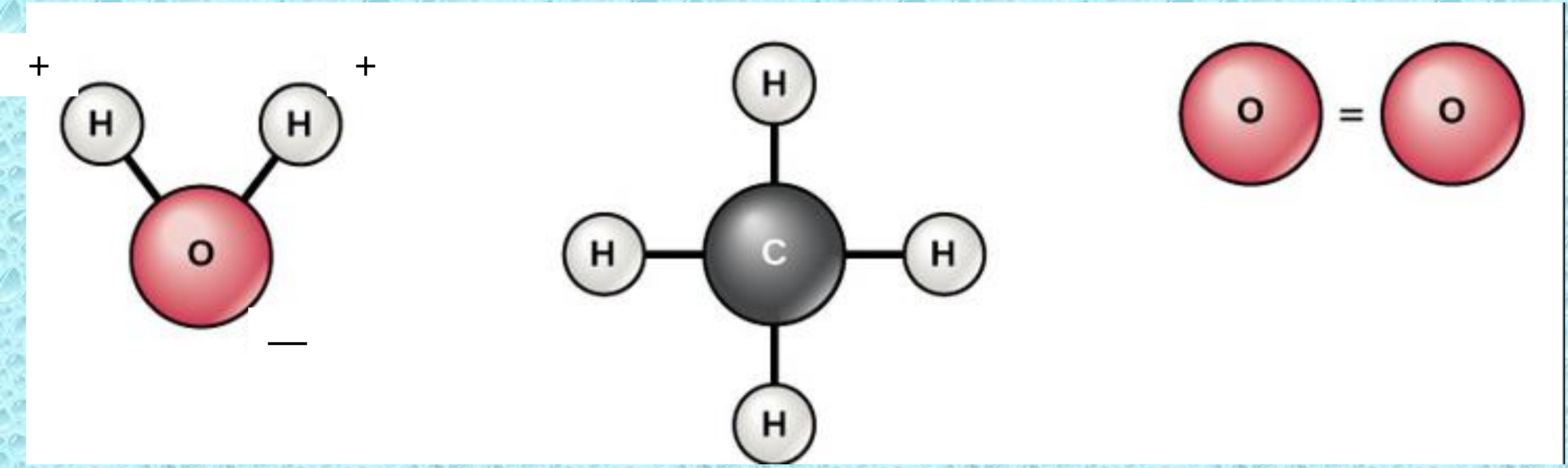
Chapter 8
Solutions

Formation of Solutions

Solubility and Concentration

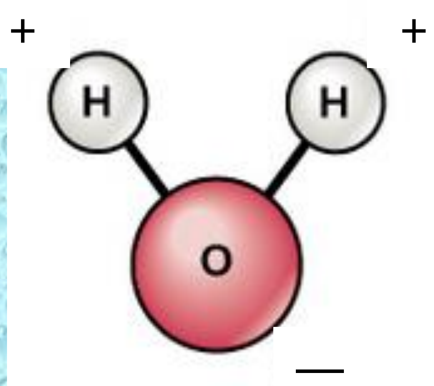
WARM-UP

Label the bonds (covalent/ionic) and types of molecules (polar/nonpolar) below.

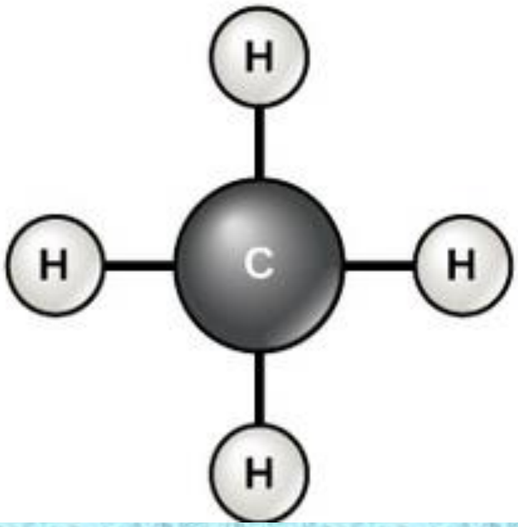


Label the bonds (covalent/ionic) and types of molecules (polar/nonpolar) below.

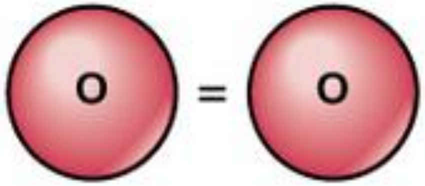
Polar molecule



nonpolar molecule



nonpolar molecule



All the molecules have Covalent bonds

Water is a polar molecule and produces particular bonds. Therefore, it exhibits special properties.

Solutions

WARM-UP

For each pair of coffee samples below, select the sample that contains more grams of sugar per gram of coffee.

O 5 grams of sugar added to 50 grams of coffee

O 5 grams of sugar added to 100 grams of coffee

O 2 grams of sugar added to 50 grams of coffee

O 5 grams of sugar added to 50 grams of coffee

Rank the following coffee samples in terms of likely sweetness based on the amount of sugar added. Use 1 for the sweetest coffee and 4 for the least-sweet coffee.

5 grams of sugar added to 50 grams of coffee

5 grams of sugar added to 100 grams of coffee

2 grams of sugar added to 100 grams of coffee

2 grams of sugar added to 50 grams of coffee

Solutions

For each pair of coffee samples below, select the sample that contains more grams of sugar per gram of coffee.

5 grams of sugar added to 50 grams of coffee

5 grams of sugar added to 100 grams of coffee

2 grams of sugar added to 50 grams of coffee

5 grams of sugar added to 50 grams of coffee

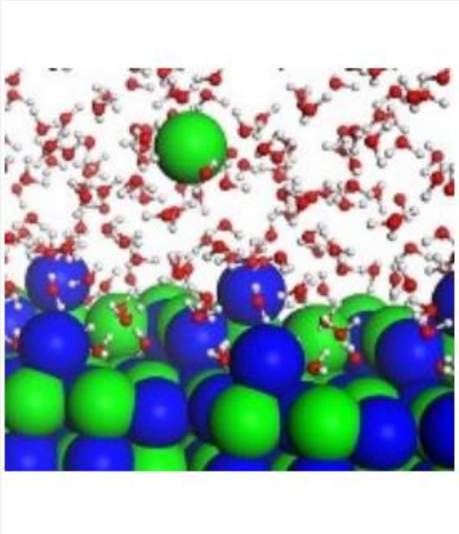
Rank the following coffee samples in terms of likely sweetness based on the amount of sugar added. Use 1 for the sweetest coffee and 4 for the least-sweet coffee.

1 5 grams of sugar added to 50 grams of coffee

2 5 grams of sugar added to 100 grams of coffee

4 2 grams of sugar added to 100 grams of coffee

3 2 grams of sugar added to 50 grams of coffee

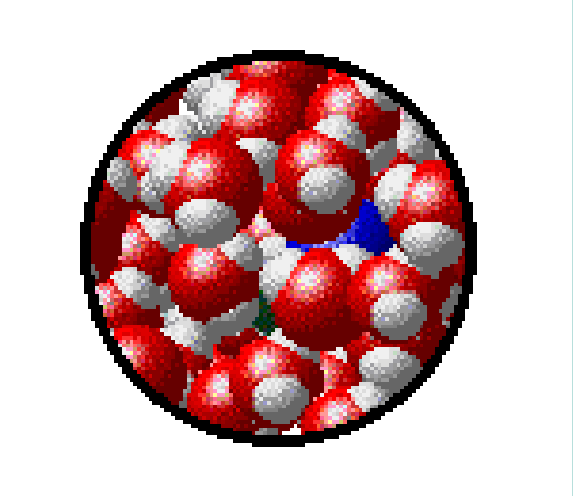


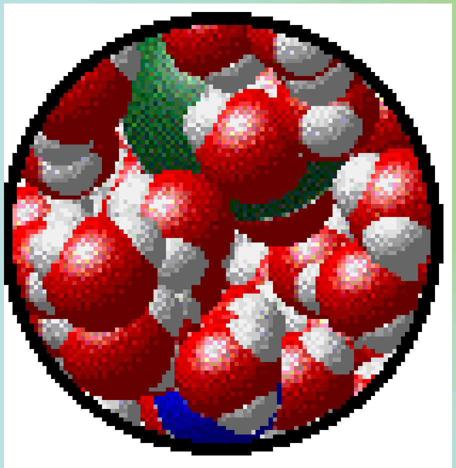

Solutions
Focus Points

- Define solute, solvent, and distinguish dissociation (ionic compounds), dispersion, and ionization of solutions (covalent molecules).
- Recognize properties of solutions (conductivity, freezing and boiling points) that differ from the solute and solvent.
- Identify factors affecting how substances dissolve and the rate at which substances dissolve (surface area, stirring, pressure, and temperature).
- Distinguish concentrations of solutions (unsaturated, saturated and supersaturated).
- Explain factors that affect solubility (temperature, pressure).
- Define concentration in terms of percent by volume, percent by mass, and molarity, and calculate these expressions.

Solutions

Solutions are **homogeneous mixtures** of two or more pure substances (elements and/or compounds).





A solution is made of a **solute** (*the substance being dissolved*) and a **solvent** (*the substance doing the dissolving*).

QUICK CHECK

Solute Versus Solvent

In the following solutions, identify the solute (what is being dissolved) and the solvent (what does the dissolving).

Sea water, a solution composed of a variety of salts.

Soda water, a solution composed of carbon dioxide gas.

Air, a solution composed of 78% nitrogen and 21% oxygen.

Choose the factors that help you to identify the solute and the solvent in a solution.

[ ] In a solution, the solvent is present in a greater amount.

[ ] In a solution, the solute dissolves in a solvent.

[ ] In a solution, the solute is the dissolving agent.

QUICK CHECK

Solute Versus Solvent

In the following solutions, identify the solute (what is being dissolved) and the solvent (what does the dissolving).

Sea water, a solution composed of a variety of salts.

Solute: salts solvent: water

Soda water, a solution composed of carbon dioxide gas.

Solute: CO_2 solvent: water

Air, a solution composed of 78% nitrogen and 21% oxygen.

Solute: O_2 solvent: N_2

Choose the factors that help you to identify the solute and the solvent in a solution.

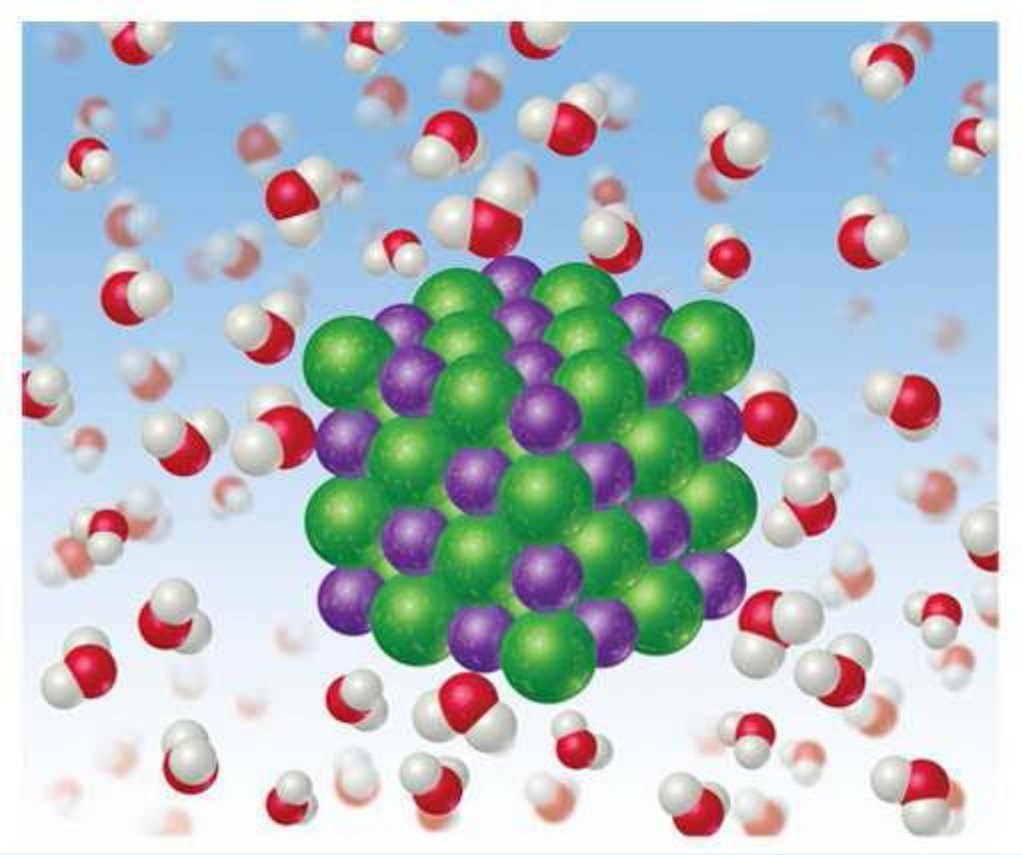
[X] In a solution, the solvent is present in a **greater** amount.

[X] In a solution, the solute dissolves in a solvent.

[ ] In a solution, the solute is the dissolving agent.

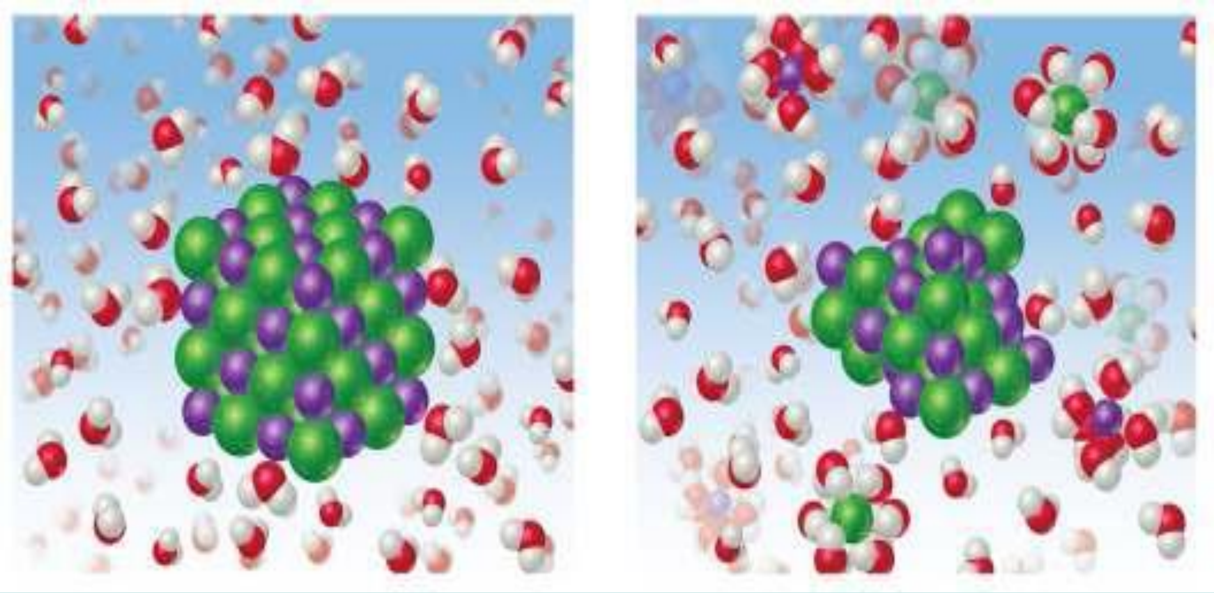
How Does a Solution Form?

The intermolecular attraction between SOLUTE and SOLVENT particles become stronger than the attraction between solute particles themselves or between solvent particles themselves.



How Does a Solution Form?

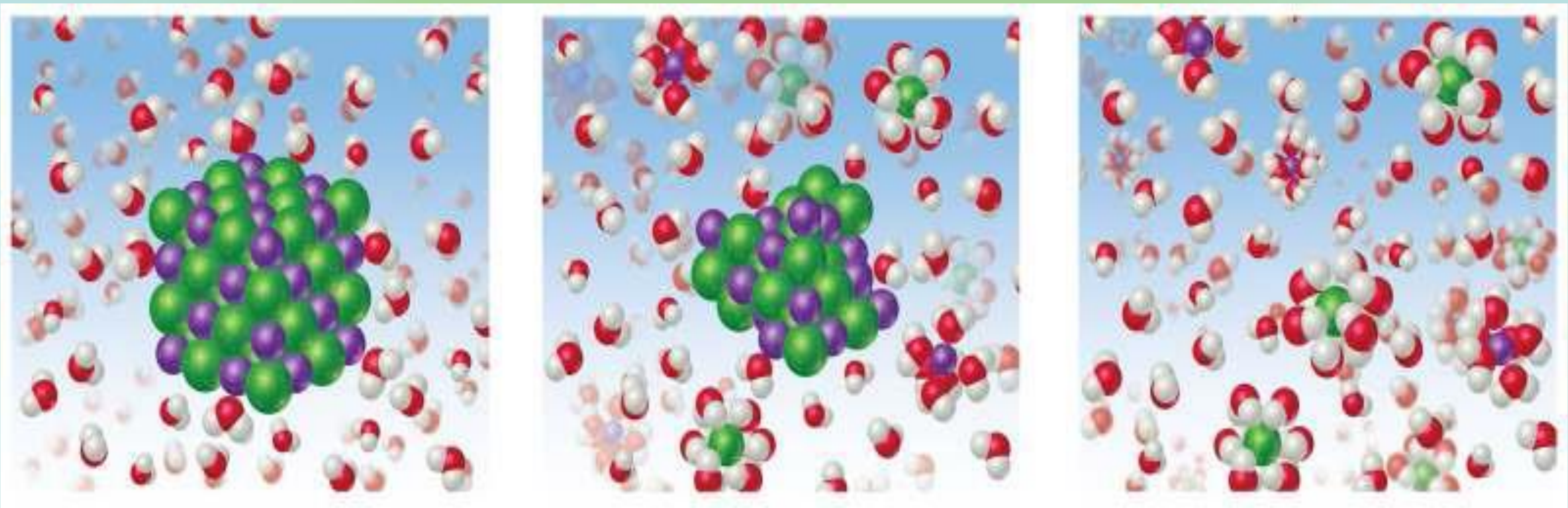
As a solution forms, the solvent pulls solute particles apart at the surface of the solute. This dissolving process is generally called **dispersion**.



Solutions

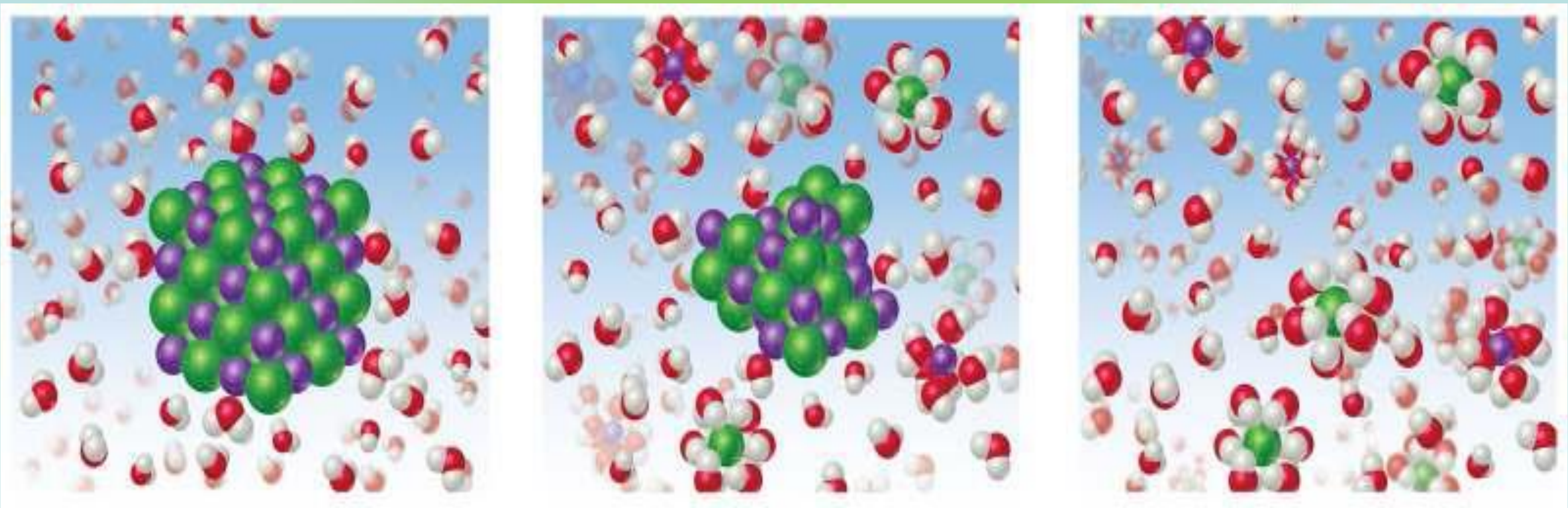
How Does a Solution Form?

After dispersion, water surrounds the "broken apart" particles. This process is called hydration (enrichment).



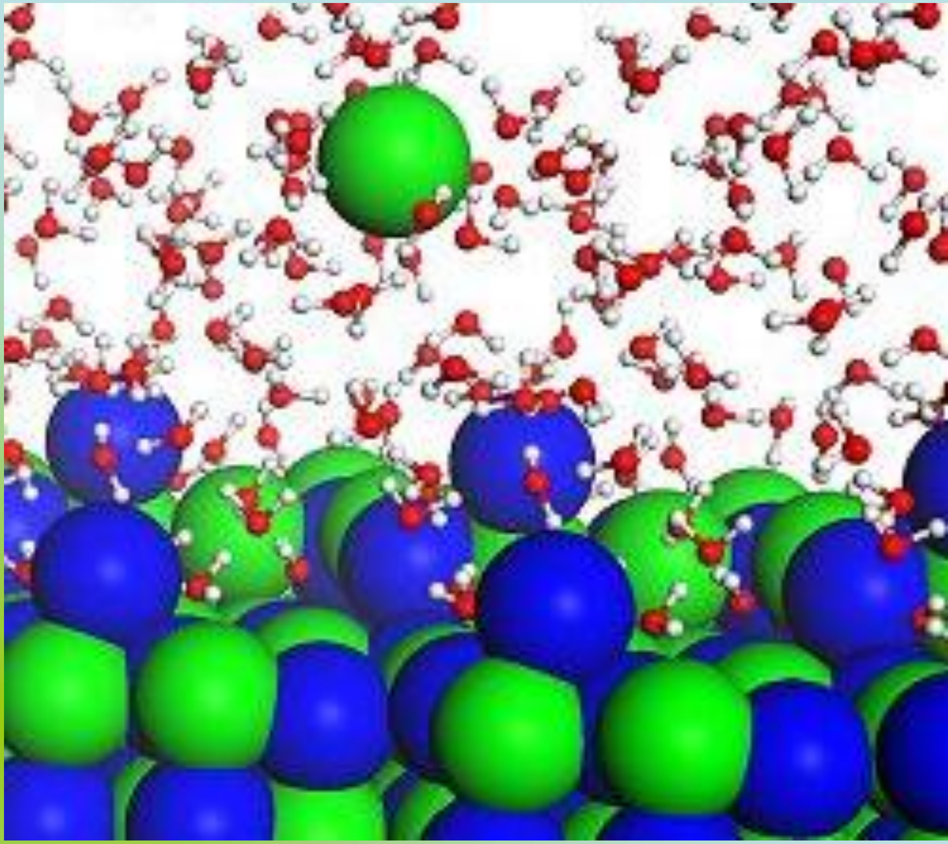
How Does a Solution Form?

Solute/Solvent | Dispersion | Hydration



Salt / Water | Breaking Apart | Water Surrounds particles

Dissolving (dispersion) involves a Physical Change



You can get back the original solute by evaporating the solvent. In other words, NO new substance is produced.

Solute particles are "pulled apart" by the solvent. NON ionic molecules break apart from each other remaining whole molecules.

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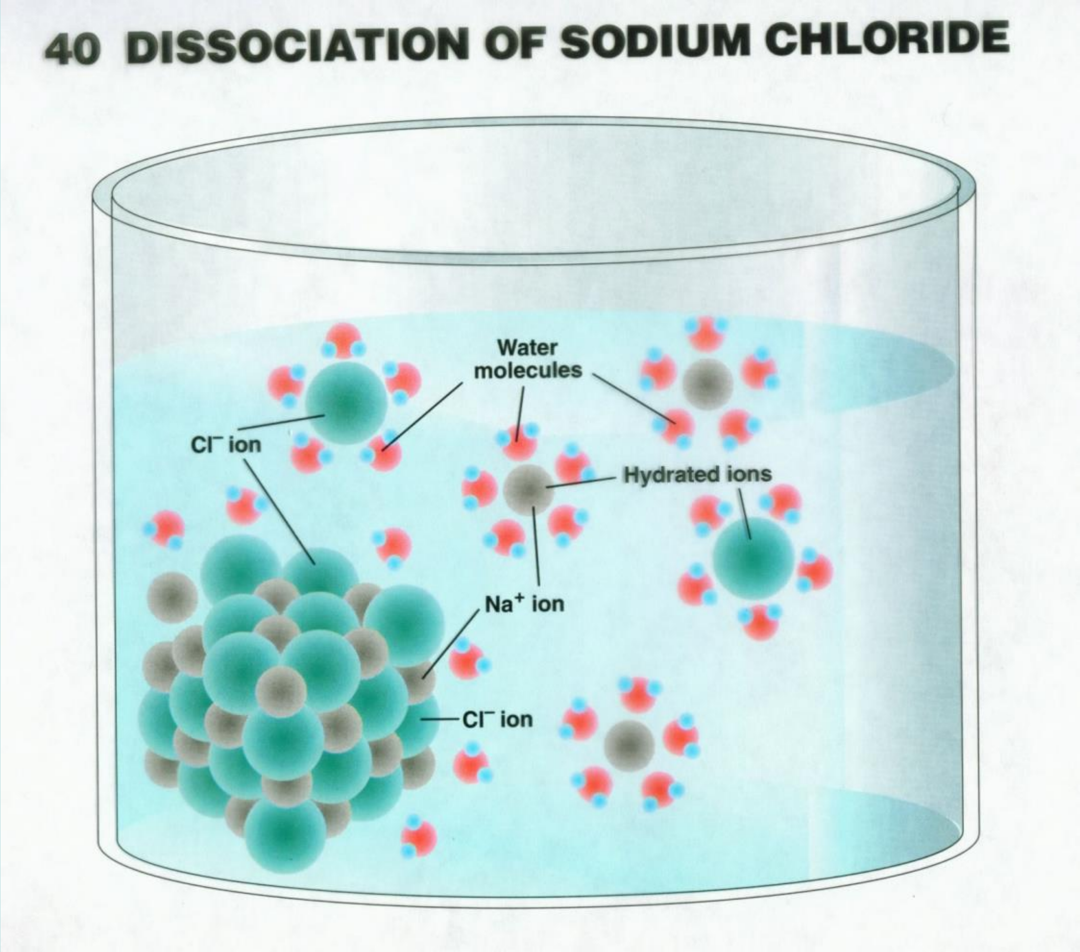
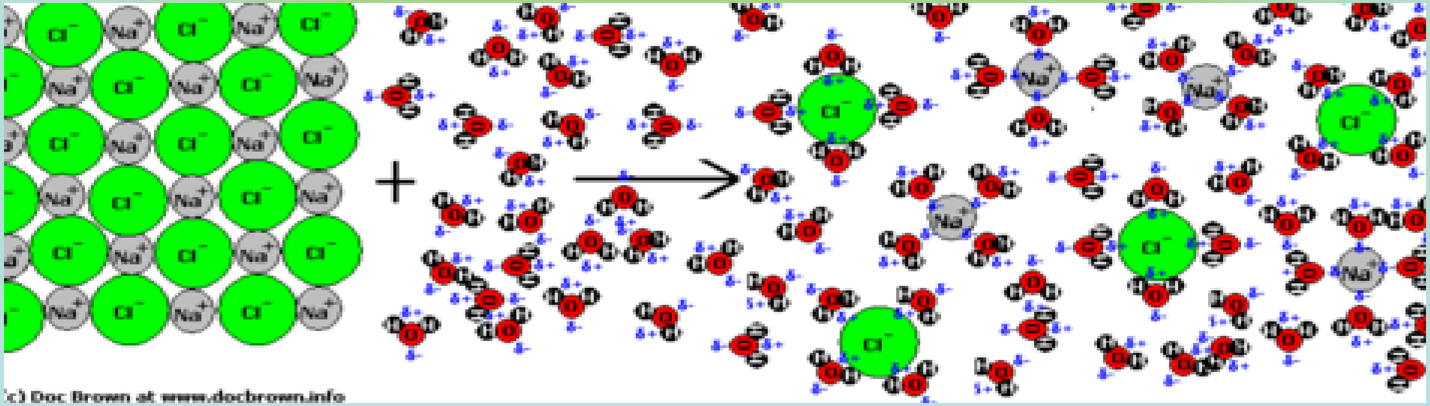
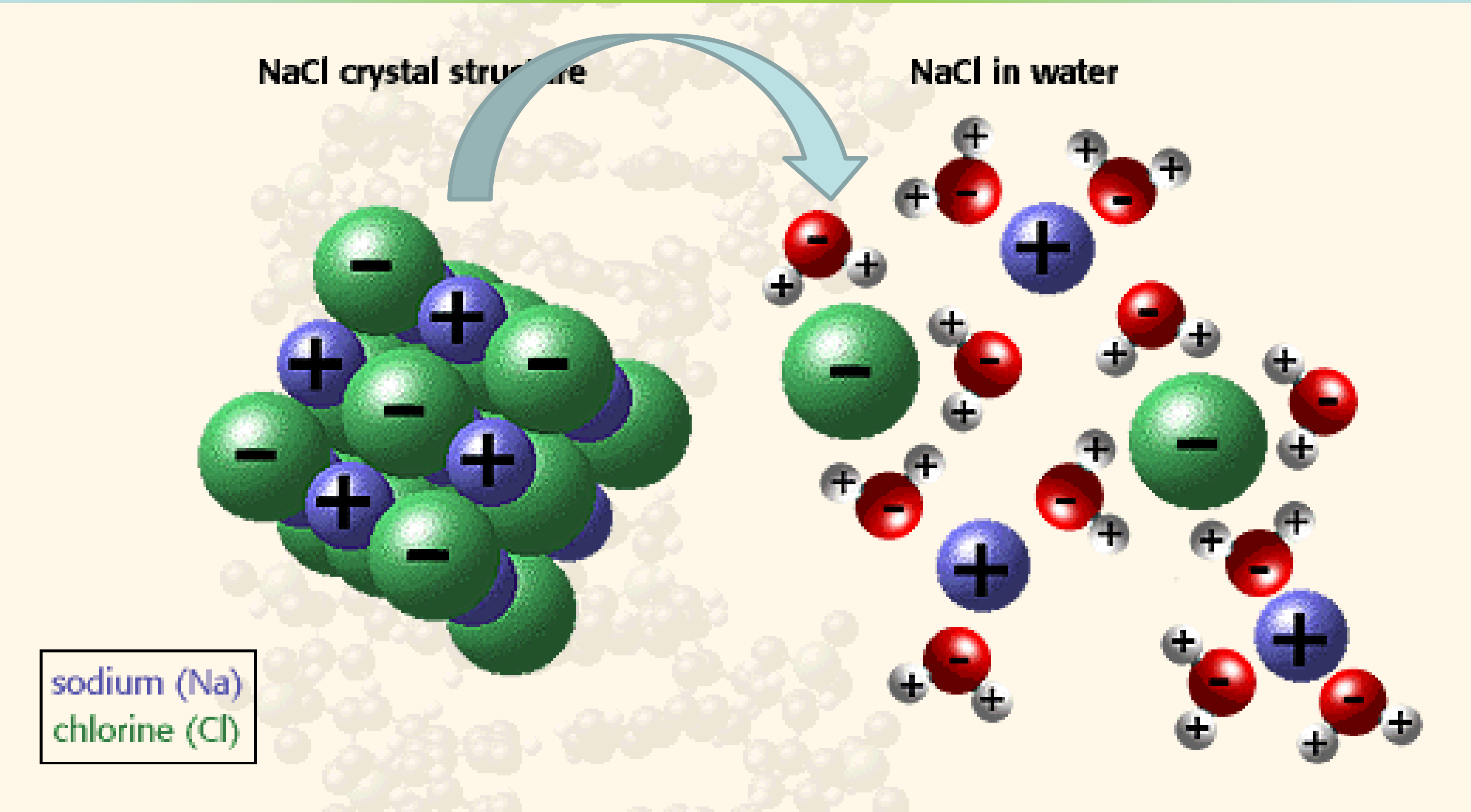


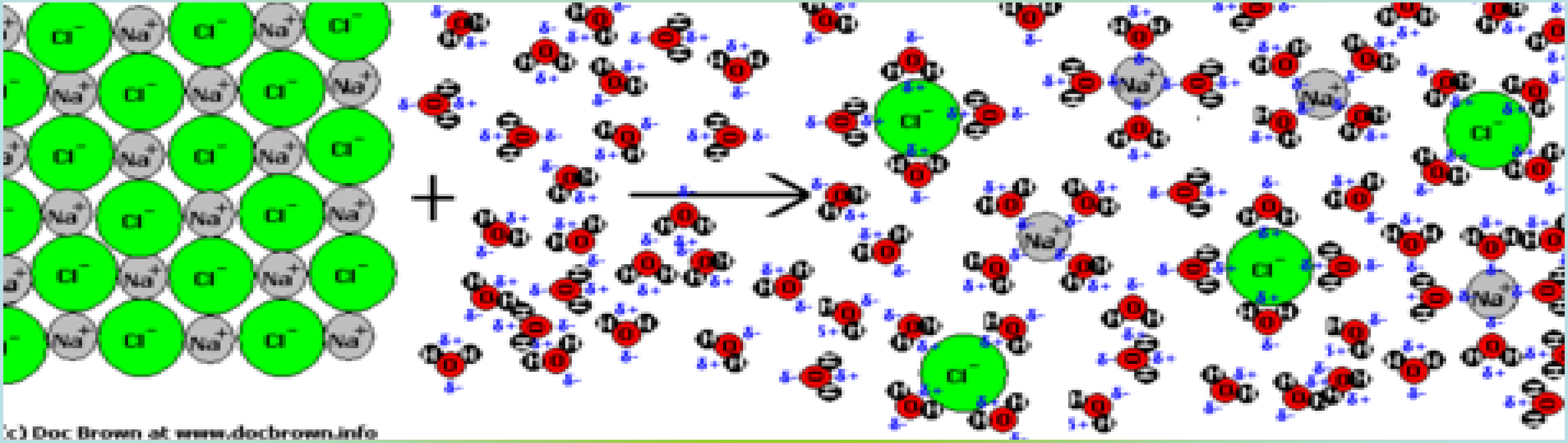
Dissociation is a form of dissolving in which **ionic compounds** break apart into its ions.



Salt Dissociation & Hydration



Solution Dissociation Hydration



Solute/Solvent

Breaking Apart

Water Surrounds particles

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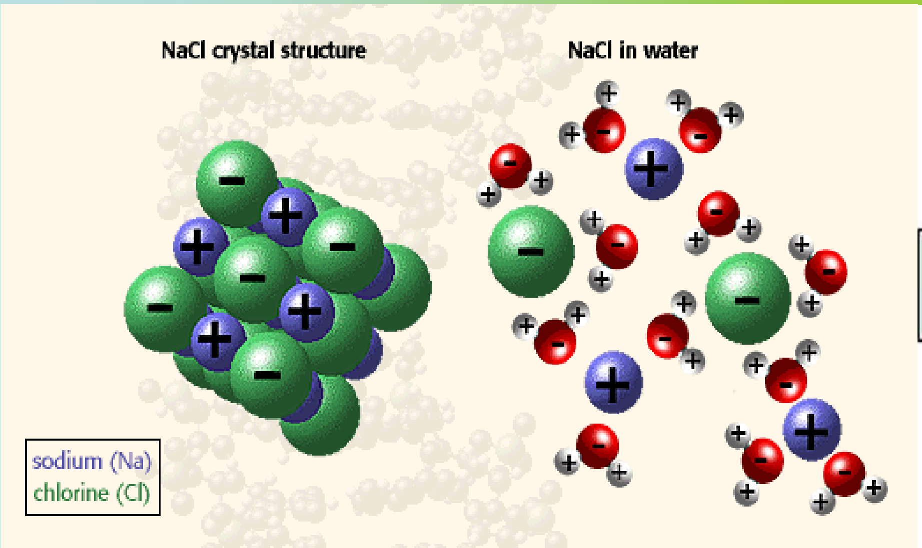
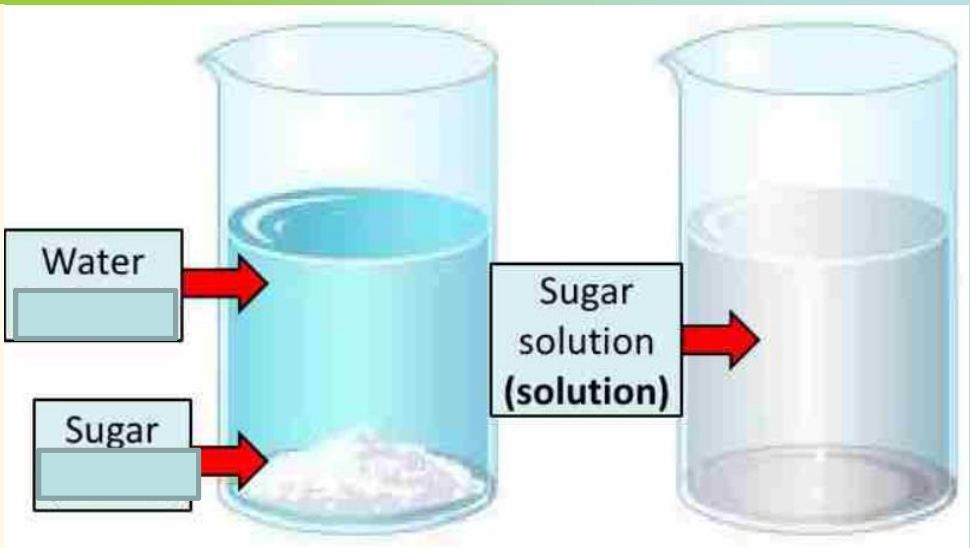
Which is which? What do they mean?

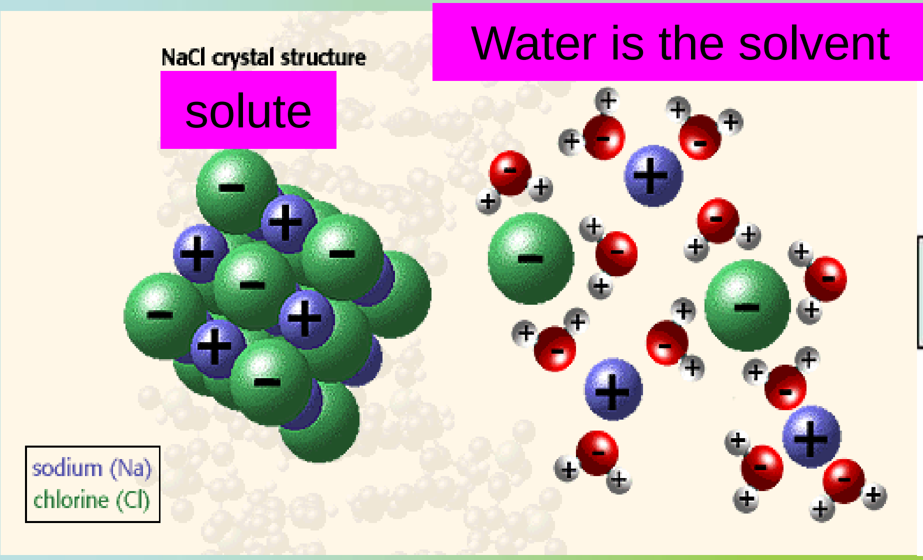


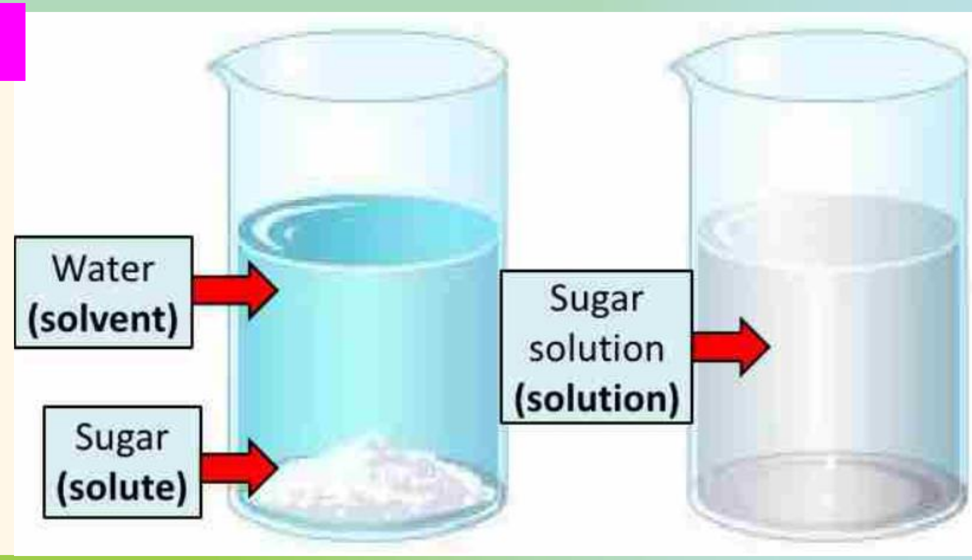


Use the terms: dissociation, dispersion, solute and solvent to distinguish the images.

QUICK CHECK

Which is which? What do they mean?





dissociation

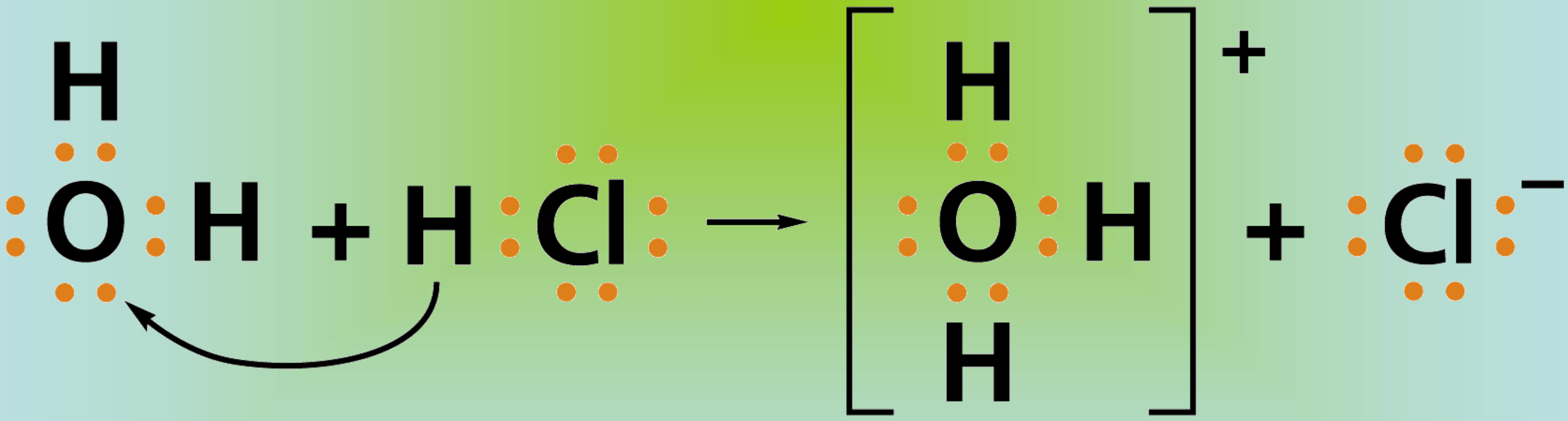
ionic compounds

dispersion

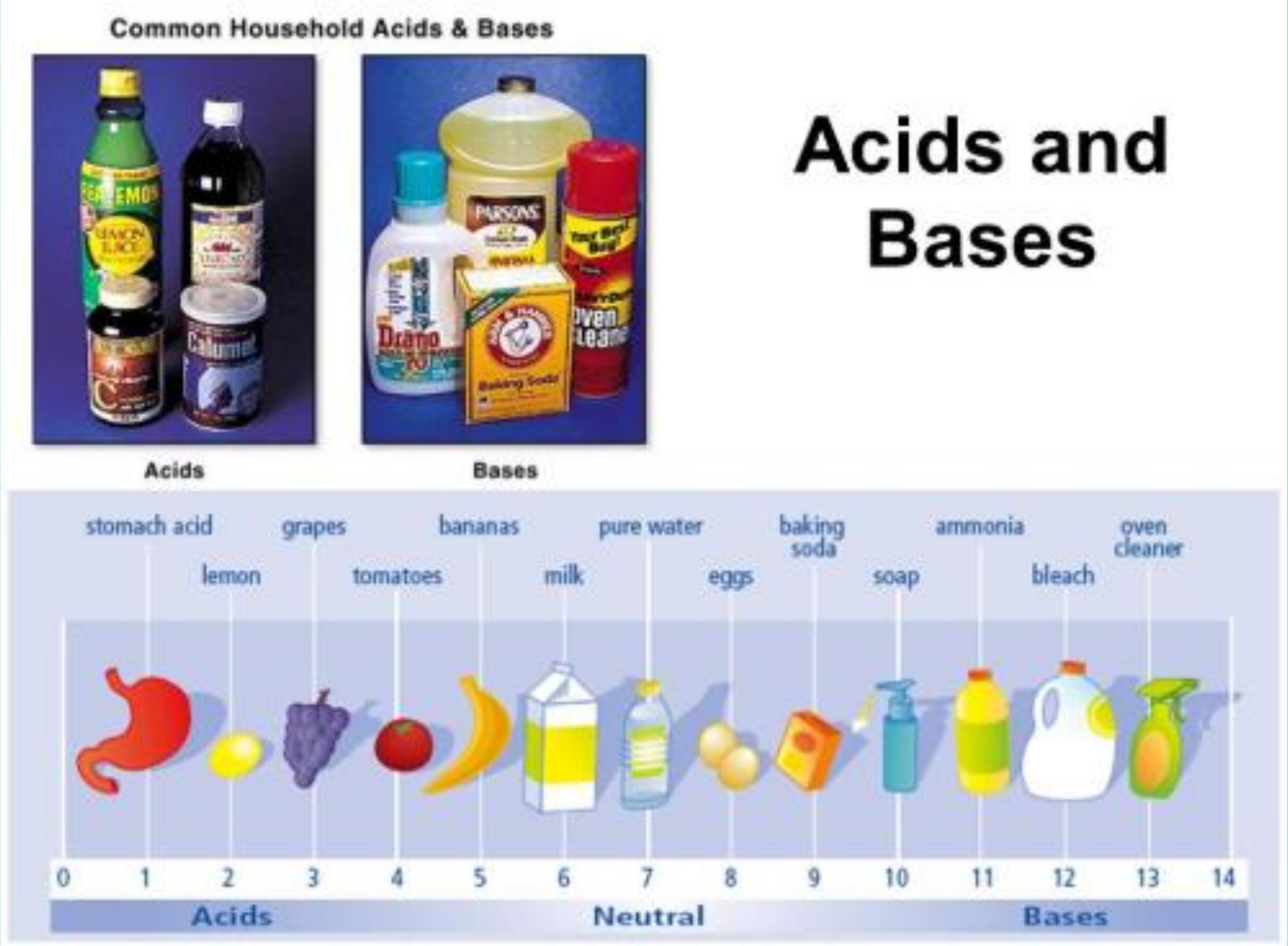
covalent molecules

Both dissociation and dispersion mean that the solvent breaks the solute apart to dissolve it.

Ionization is a process in which neutral molecules gain or lose electrons and is a chemical change because the solution that results contains new substances.

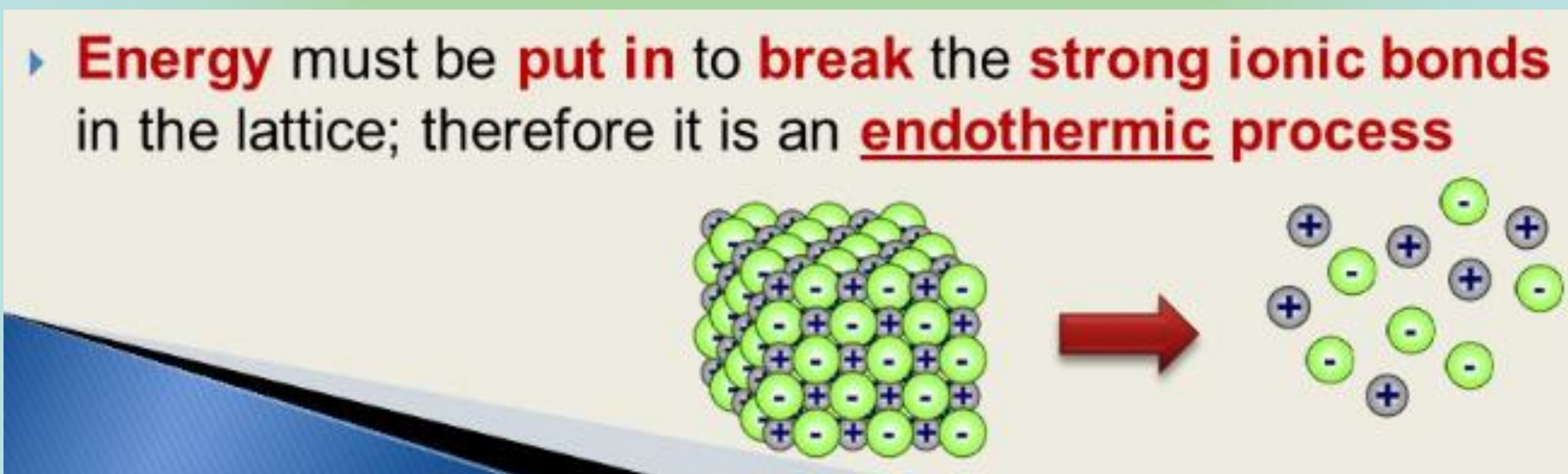


Ionization is the foundation of acid-base chemistry.



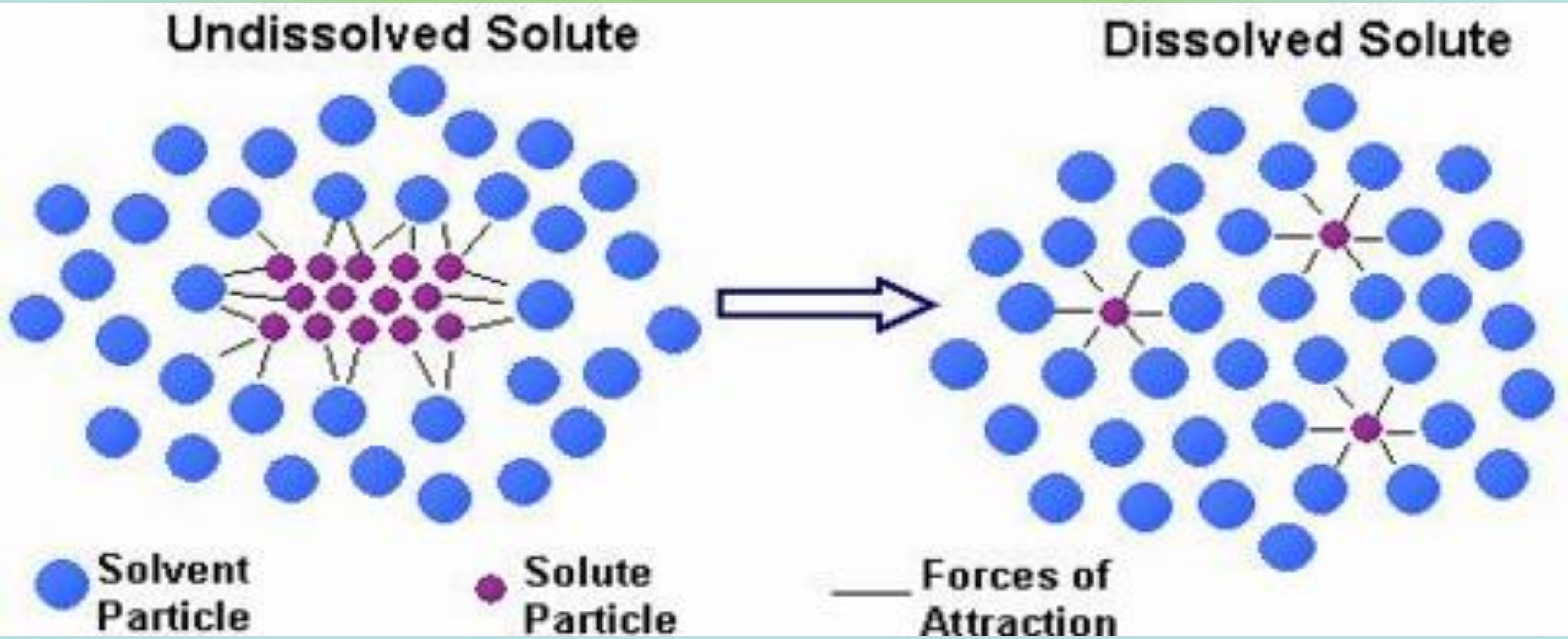
Heat of Solutions

Solvent particles engage undissolved solute particles at their surface and **SEPARATE** them. This is always **endothermic** … *requires some heat/energy to be added*).



Heat of Solutions

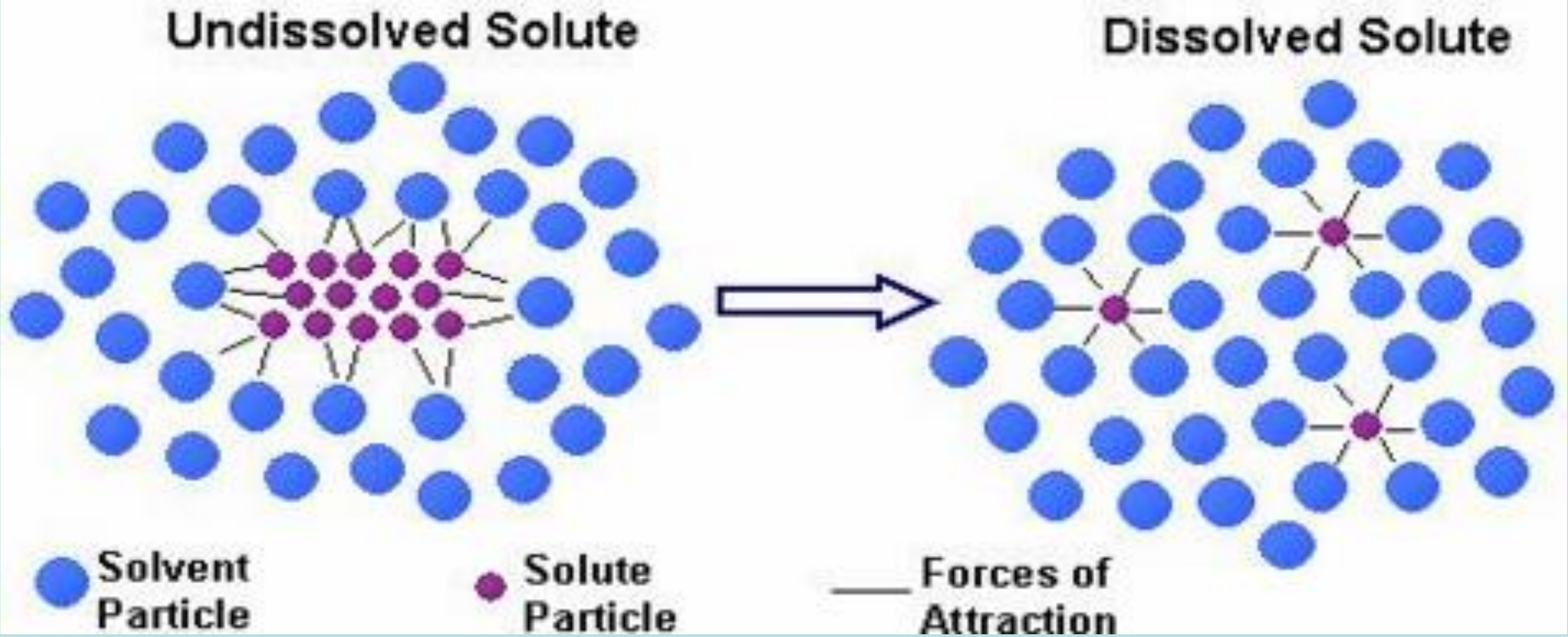
The solvent particles surround the solute particles (hydration), forming solute / solvent interactions & is always **exothermic** … *releases heat/energy into the solution).*



Solutions & Energy Changes

Endothermic | **Exothermic**

Dispersion | ***Hydration***



Properties of Solutions other than solute, solvent.

Ionic compounds conduct an electric current when dissolved in water or in the molten state.

All ionic compounds are “electrolytes” because they dissociate into ions when dissolved or molten.

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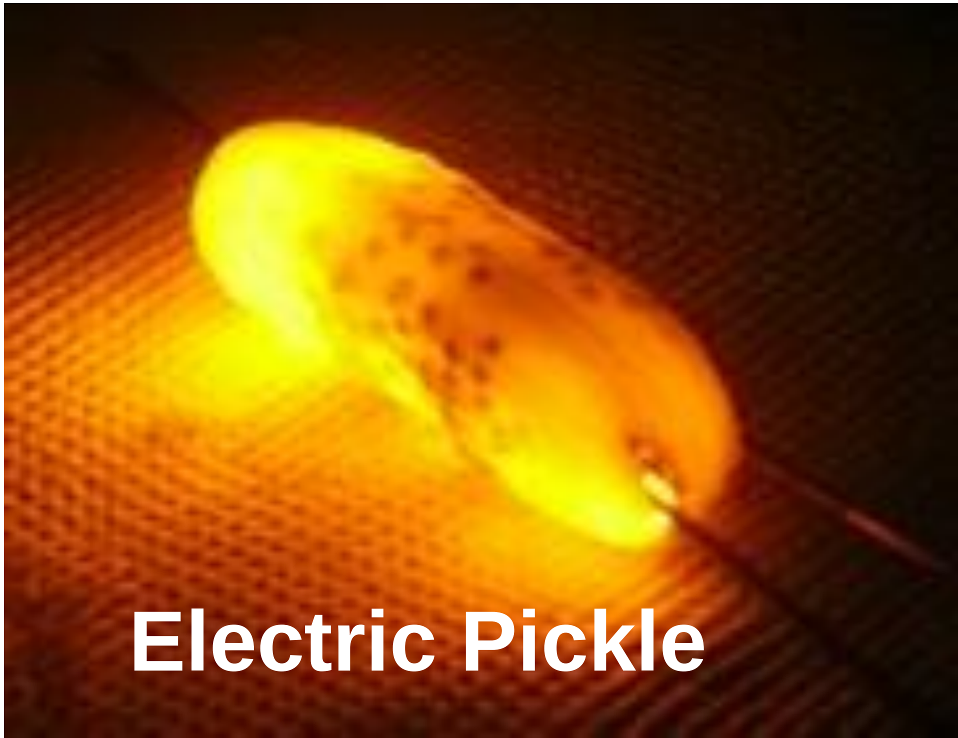
(2:07)



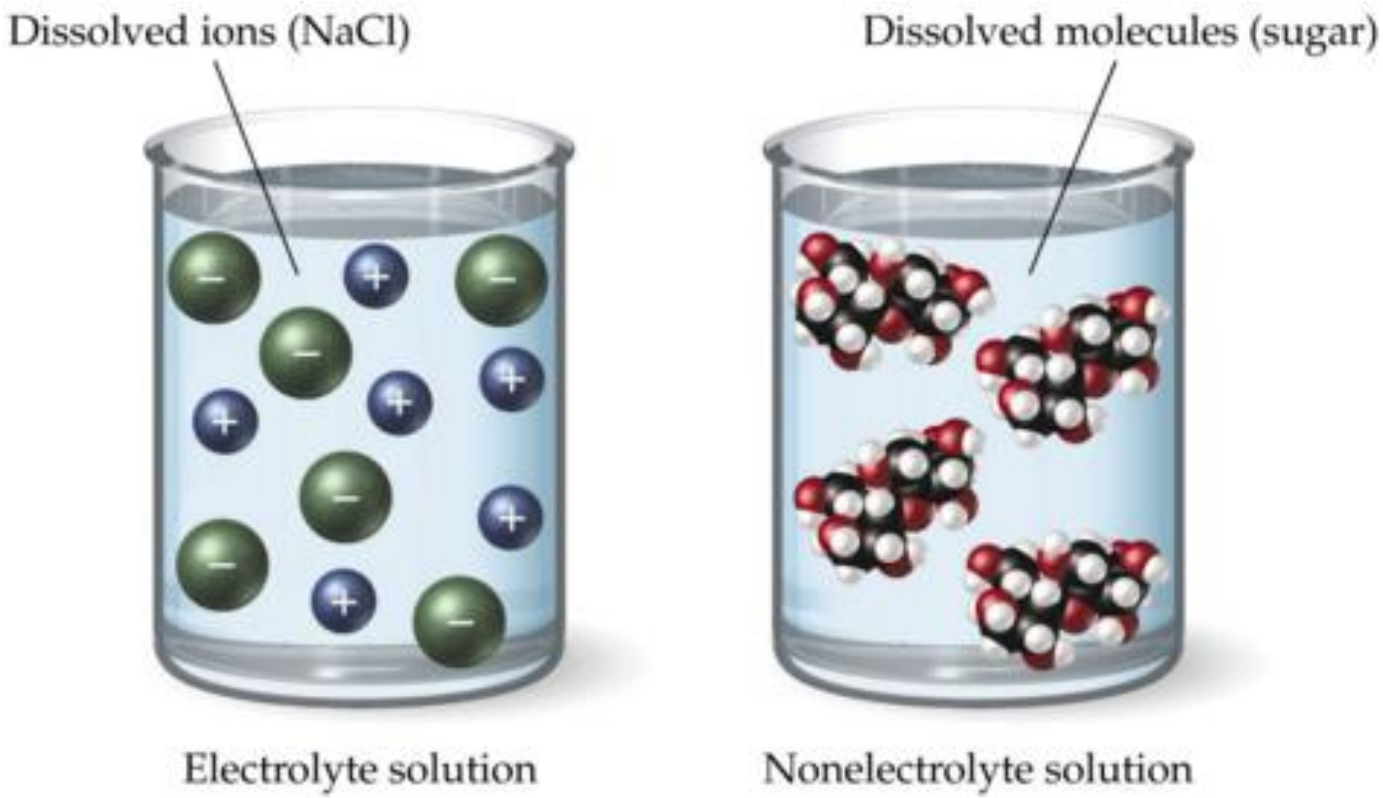
Properties of Solutions other than solute, solvent.

Covalent Molecules

Dissolving particles are not charged (Example: glucose)

Ionic Compounds

Dissolving particles are charged & free to move (e.g. Na^+Cl^-)

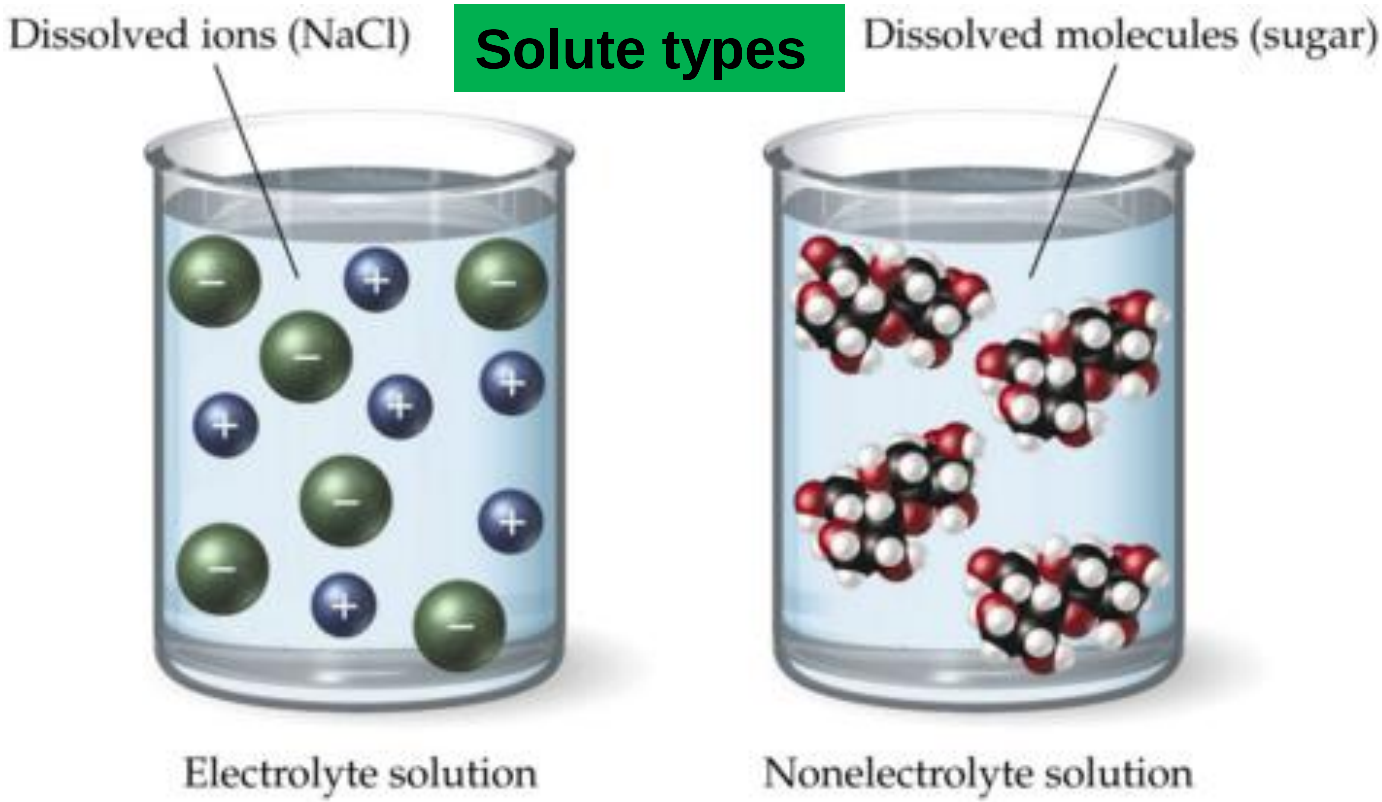


BOTH are "dissolving"

Ionic Compound | **Covalent Molecule**

Dissociation | **Dispersion**

Solute types



Properties of Solutions other than solute, solvent.

Some properties of solutions depend upon the concentration of solute molecules or ions, but not upon the identity of the solute.

Properties of Solutions other than solute, solvent.

- **Freezing Point Depression**
- **Boiling Point Elevation**

Boiling Point Elevation

A solution of water will boil at 100.512 C rather than 100.00 C if solute is added.

Solvent	Normal Boiling Point (°C)	K_b (°C/*m*)
Water, H_2O	100.0	0.51
Benzene, C_6H_6	80.1	2.53
Ethanol, C_2H_5OH	78.4	1.22
Carbon tetrachloride, CCl_4	76.8	5.02
Chloroform, $CHCl_3$	61.2	3.63

Boiling Point Elevation

The amount of solute influences the boiling point of pure water:

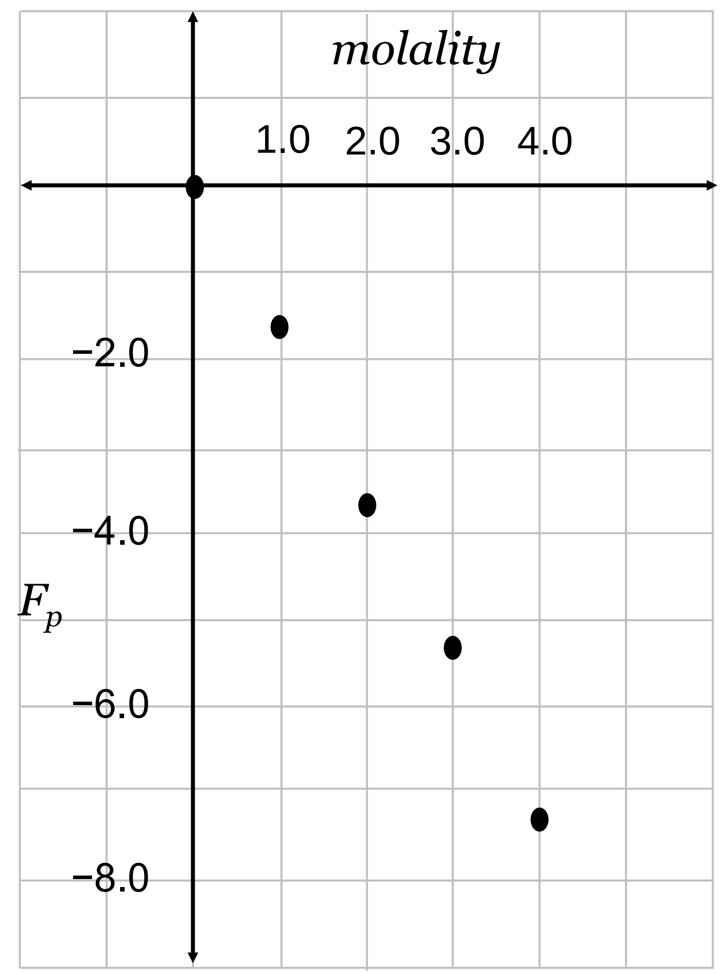
molality	moles of solute per 1000 g of H_20	BP	ΔT
0 m	pure water	100.00 C	0.00 C
1 m	1 mole / 1000 g	100.51 C	0.51 C
2 m	2 moles / 1000 g	101.02 C	1.02 C
3 m	3 moles / 1000 g	101.53 C	1.53 C
10 m	10 moles / 1000 g	105.10 C	5.10 C

Freezing Point Depression and Solution Concentration

Freezing point depression:

the decrease in freezing point of a solution as a function of the number of particles dissolved in solution

Molality	Freezing Point (°C)
0	0.00
1.0	−1.86
2.0	−3.72
3.0	−5.58
4.0	−7.44



Freezing Point Depression

A solution of water will freeze at -1.86 C rather than 0 C if solute is added.

Solvent	Normal Freezing Point (°C)	K_f (°C/*m*)
Water, H_2O	0.0	1.86
Benzene, C_6H_6	5.5	5.12
Ethanol, C_2H_5OH	–114.6	1.99
Carbon tetrachloride, CCl_4	–22.3	29.8
Chloroform, $CHCl_3$	–63.5	4.68

Freezing Point Depression

Making Ice Cream

uses this principle!

Making Ice Cream

Some simple ingredients to make ice cream:

½ Cup Whole Milk (half & half cream?)

4 Cups Crushed Ice

½ Teaspoon Vanilla Extract

1 Tablespoon Sucrose (table sugar)

How would you go about making ice cream?

Freezing Point Depression

Companies need to lower the freezing point to -15 C for ice cream's consistency.

Distinguishing Properties of Compounds.

The process of forming a solution of a molecular compound is endothermic if the solute

a. forms stronger attractions to the solvent than to other solute molecules.
b. forms weaker attractions to the solvent than to other solute molecules.
c. dissolves very rapidly in the solvent.
d. dissolves very slowly in the solvent.

Before boiling water on the stove, you add salt to form a solution. The solution's boiling point will be

a. the same as the boiling point of water.
b. the same as the boiling point of salt.
c. higher than the boiling point of water.
d. lower than the boiling point of water.

Distinguishing Properties of Compounds.

QUICK CHECK

The process of forming a solution of a molecular compound is endothermic if the solute

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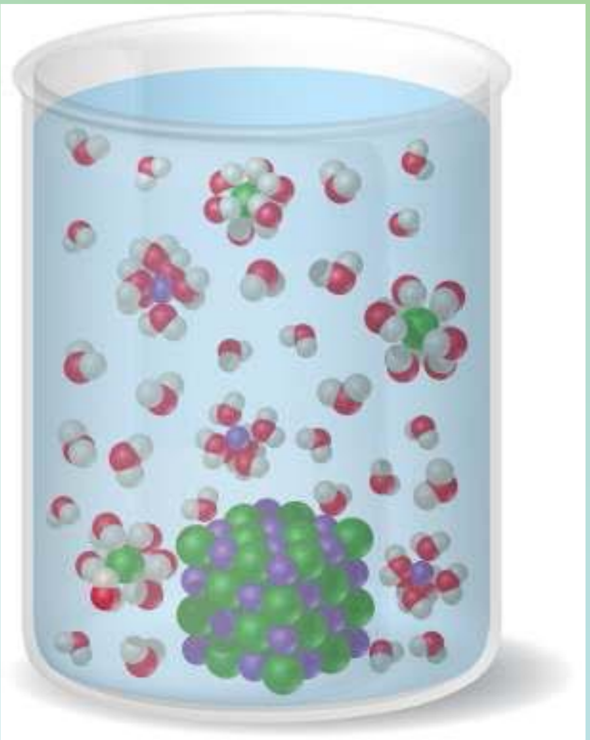
Before boiling water on the stove, you add salt to form a solution. The solution's boiling point will be

a. the same as the boiling point of water.
b. the same as the boiling point of salt.
c. higher than the boiling point of water.
d. lower than the boiling point of water.

The maximum amount of a solute that can be dissolved in a solvent is called that substance's **solubility**.

Solubility also describes the **concentration** of solutions by using three terms



Unsaturated, Saturated, & Supersaturated Solutions

- **Unsaturated solution**

  the concentration of solute is **less than** the maximum concentration the solvent can dissolve.

- **Saturated solution**

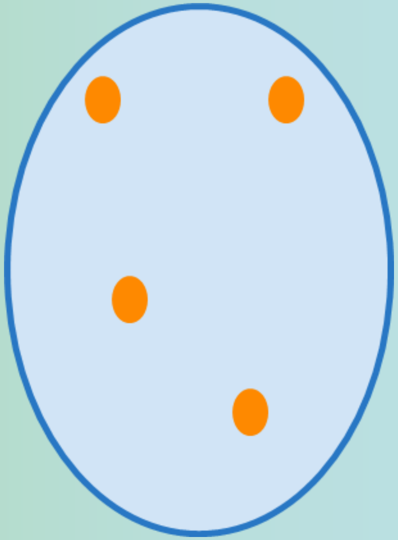
  the concentration of solute is **equal to** the maximum concentration the solvent can dissolve.

- **Supersaturated solution**

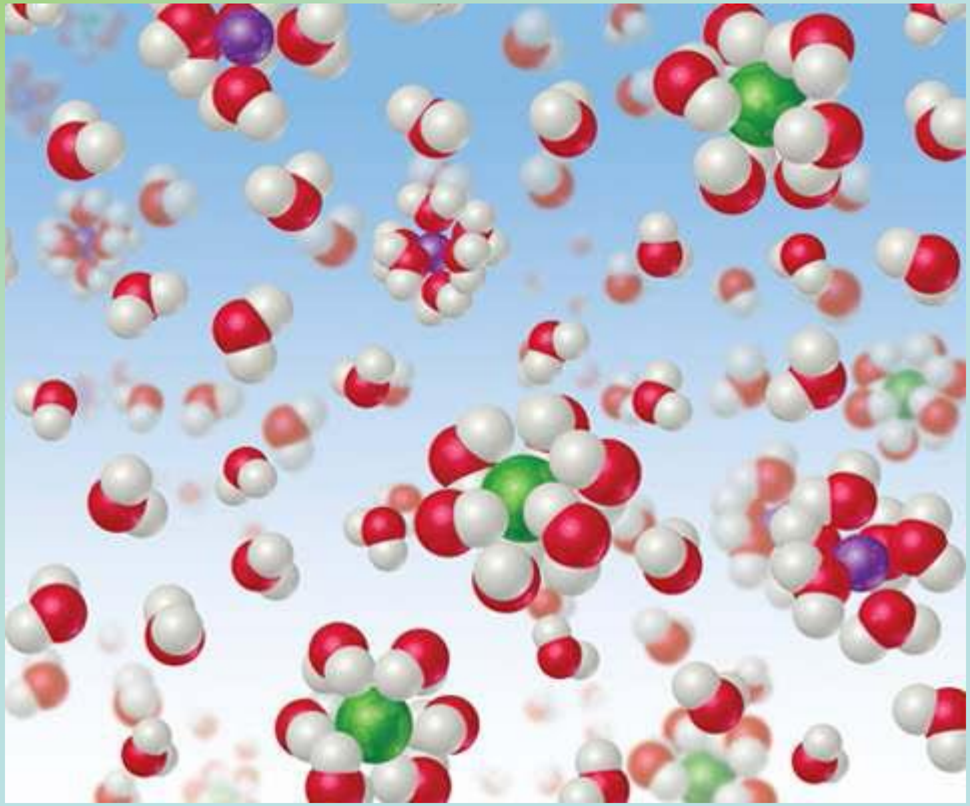
  the concentration of solute is **greater than** the maximum concentration the solvent was expected to dissolve.

Types of Solutions

Unsaturated

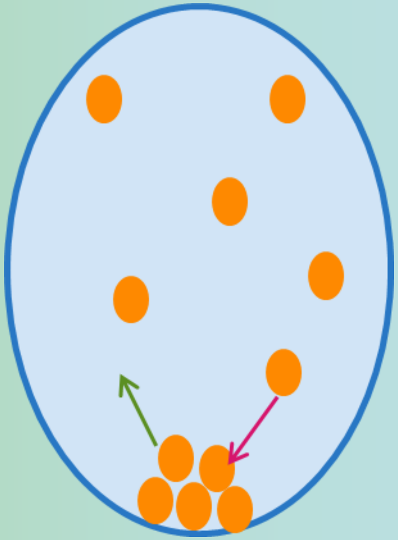


When LESS than the maximum amount of solute is dissolved in the solvent at a given temperature.



Types of Solutions

Saturated

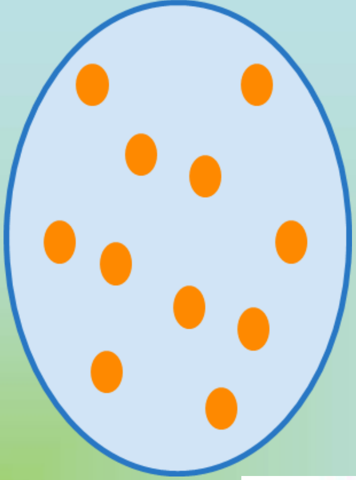


When the solvent holds as much solute as possible at a particular temperature.

Notice particles have settled out in solution.

Types of Solutions

Super Saturated

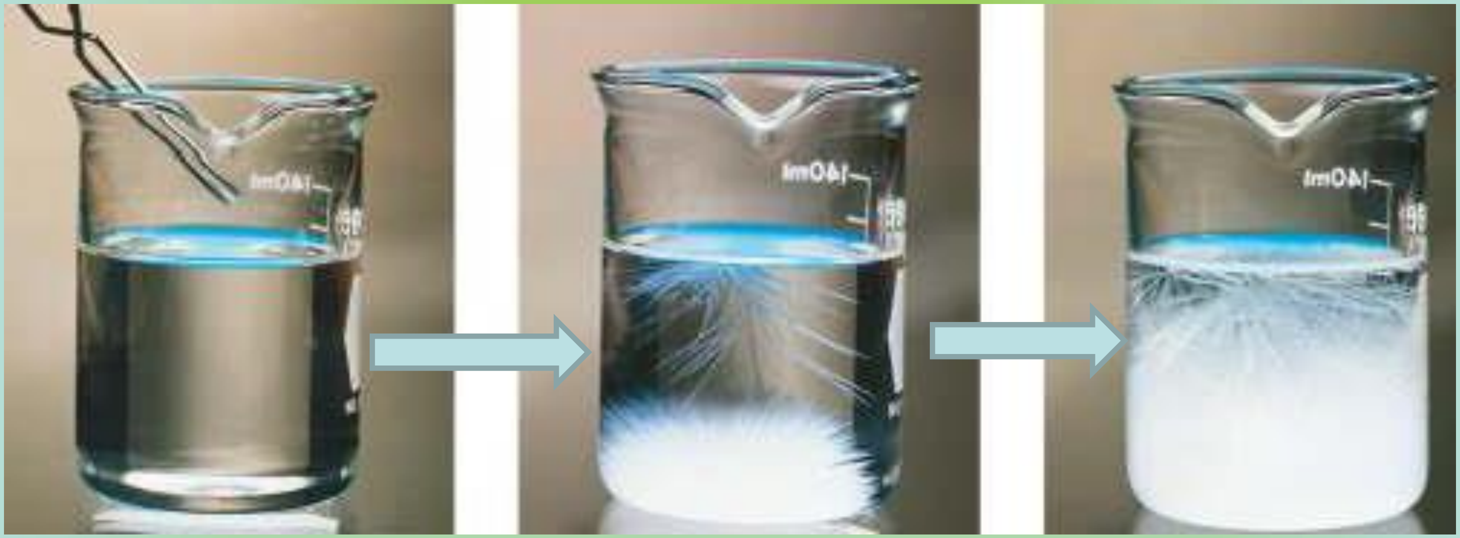


No particles have settled out.

When the solvent holds more solute than is normally possible at that temperature by *heating gently and stirring the excess solute into the solution until the solute dissolves. Allow the solution to cool slowly without disturbing it. [e.g. hand warmers]*

Seeding a Super Saturated Solution

These solutions are unstable; crystallization can usually be stimulated by adding a "seed crystal" or scratching the side of the flask or agitation.



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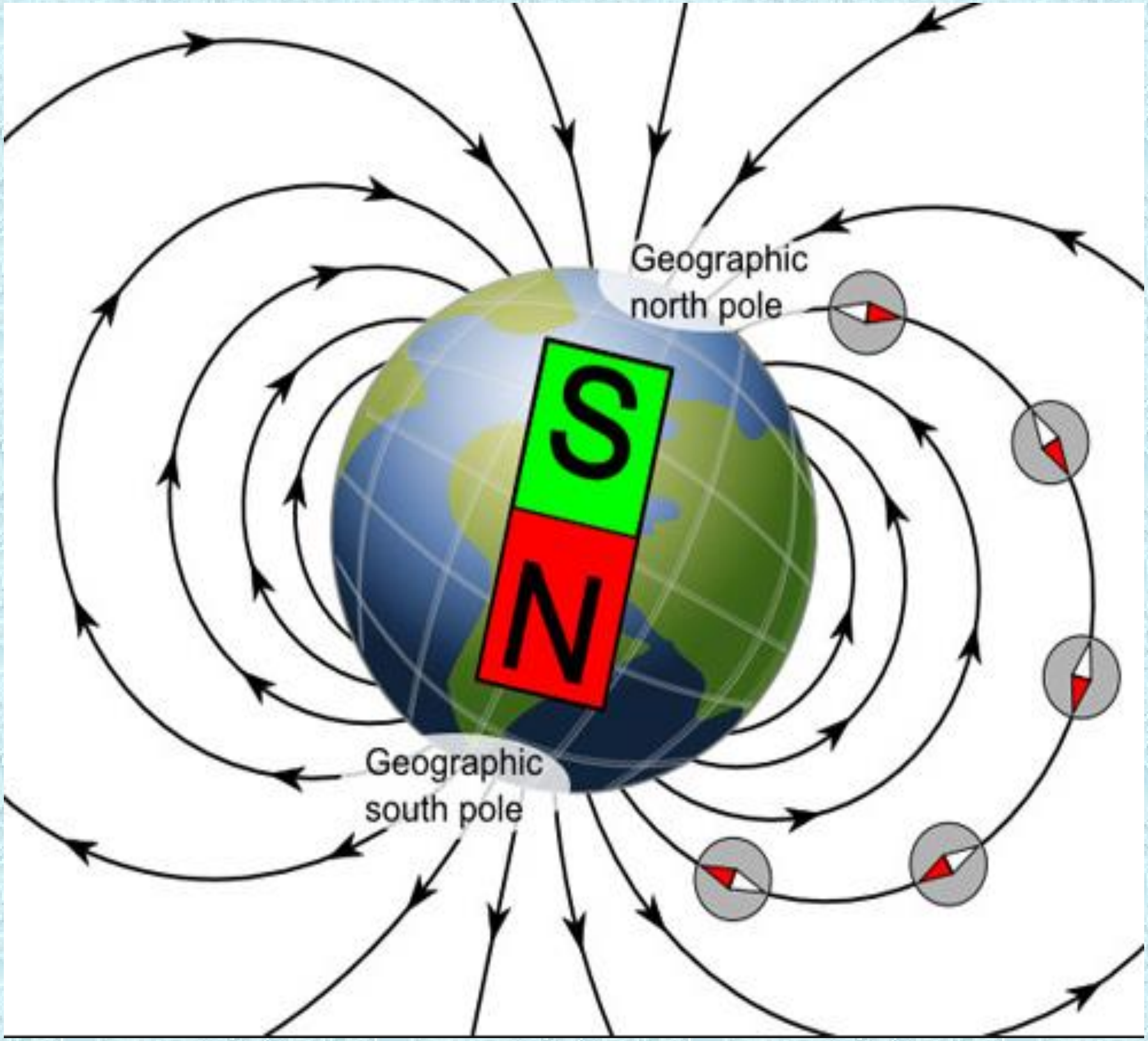
Solubility Depends on Polarity

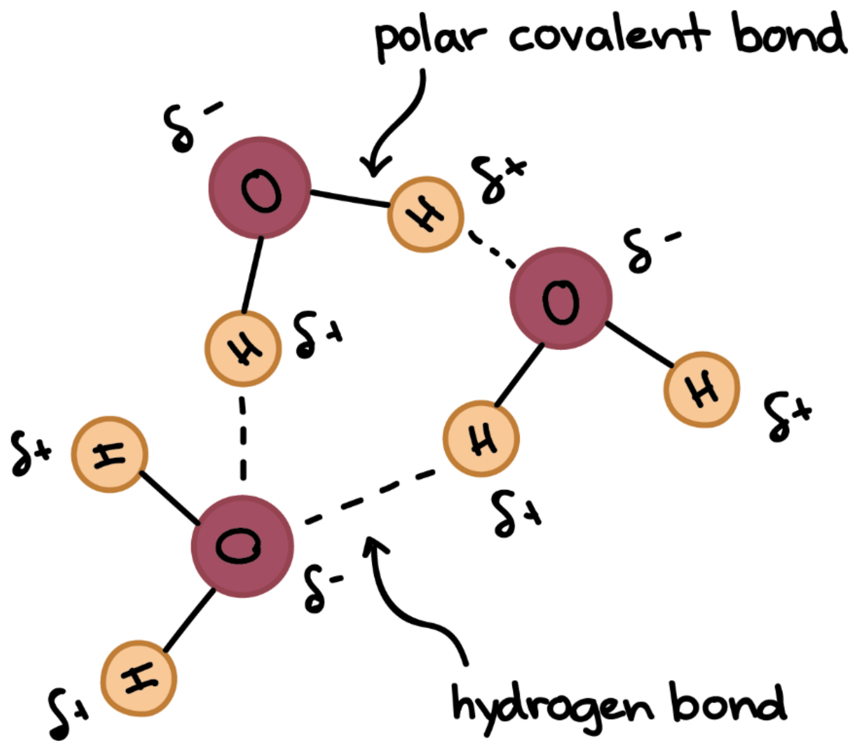


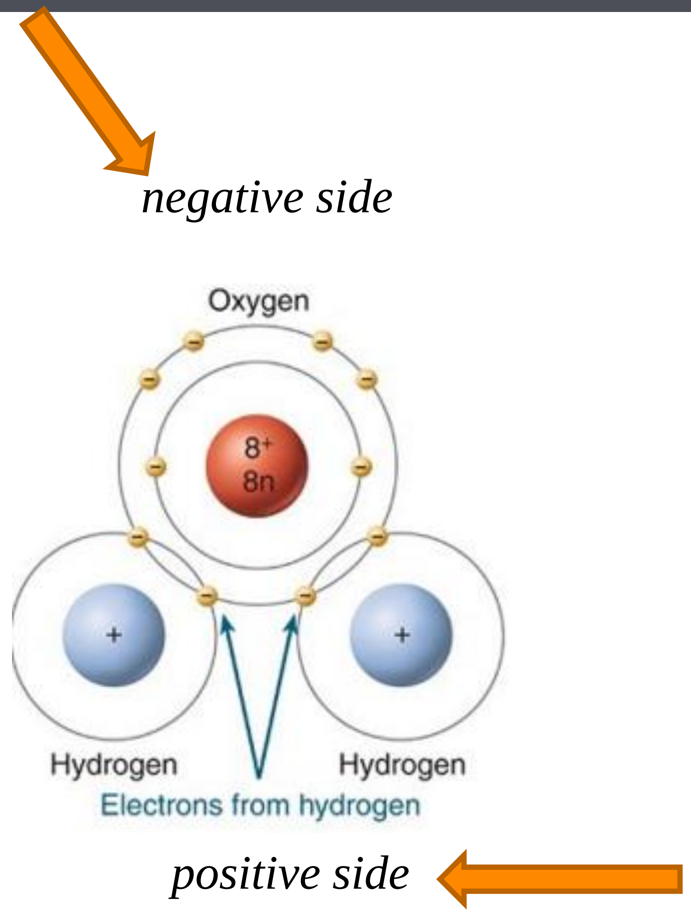
Notice the "poles" on the earth and magnet.

How would you define "polarity"?

Solubility Depends on Polarity

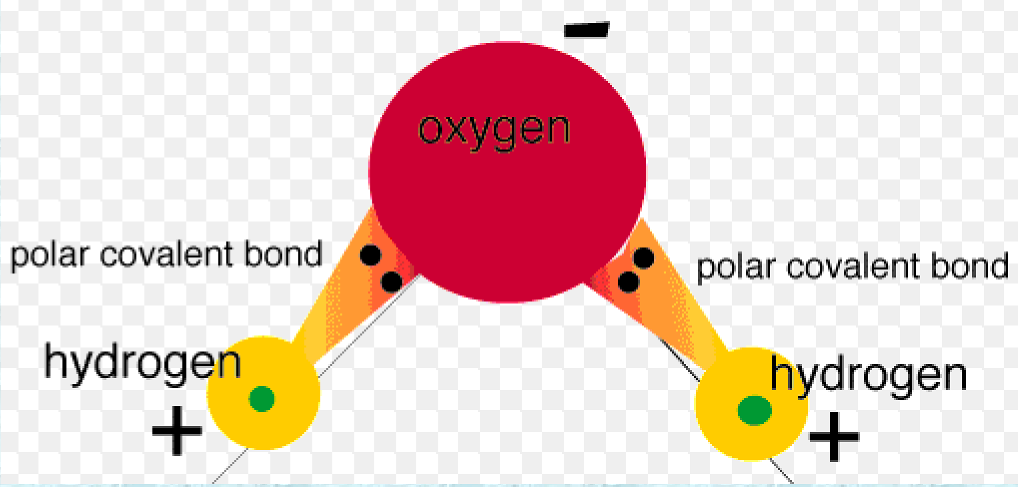
- Water is a Polar Molecule

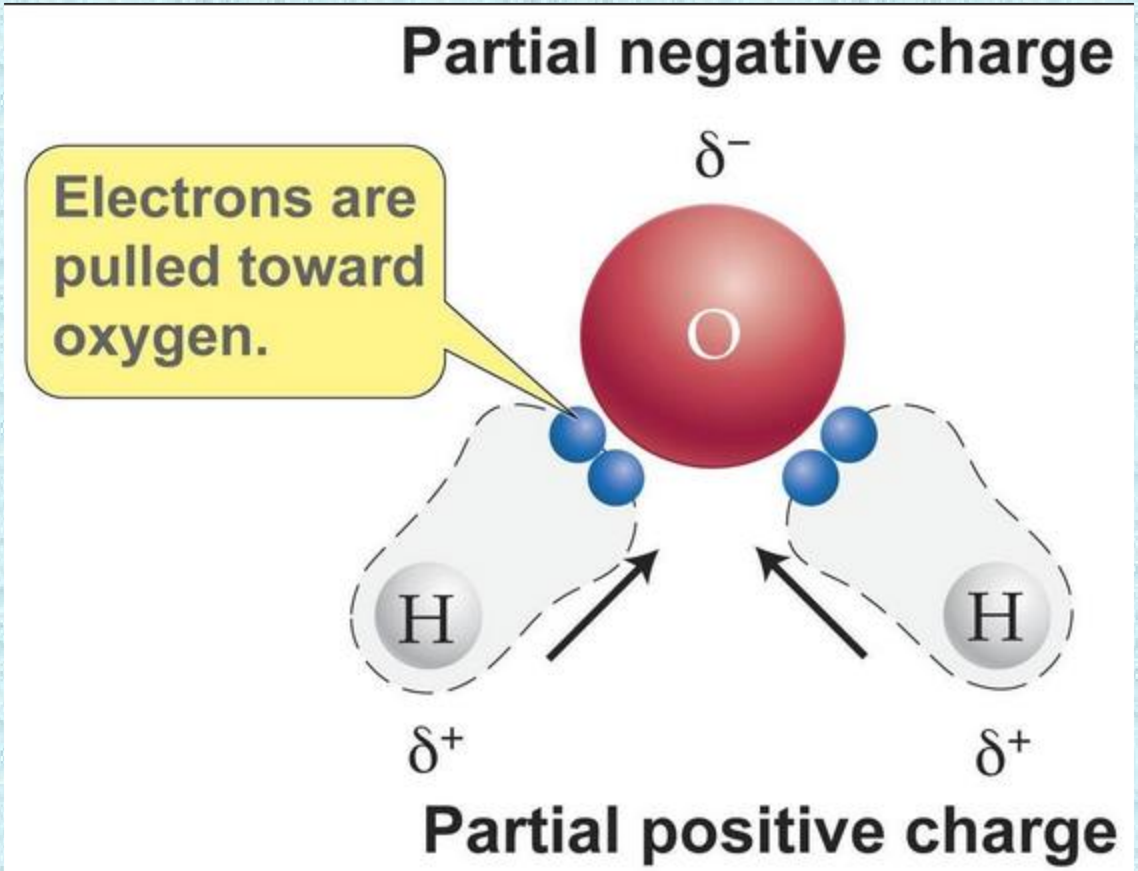




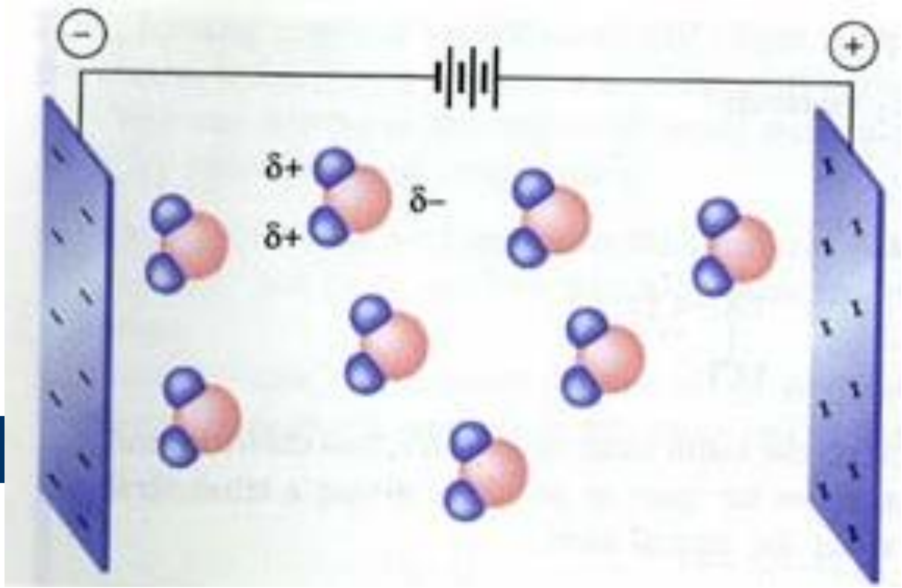
https://screencast-o-matic.com/watch/cFXiD9YP5e (1:09)

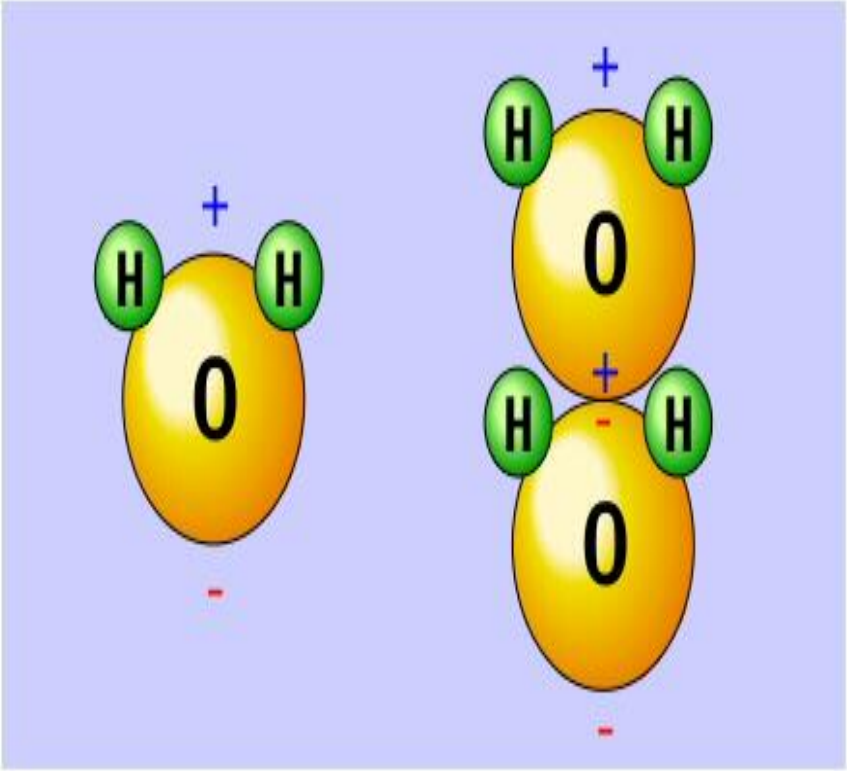
Water's Polarity





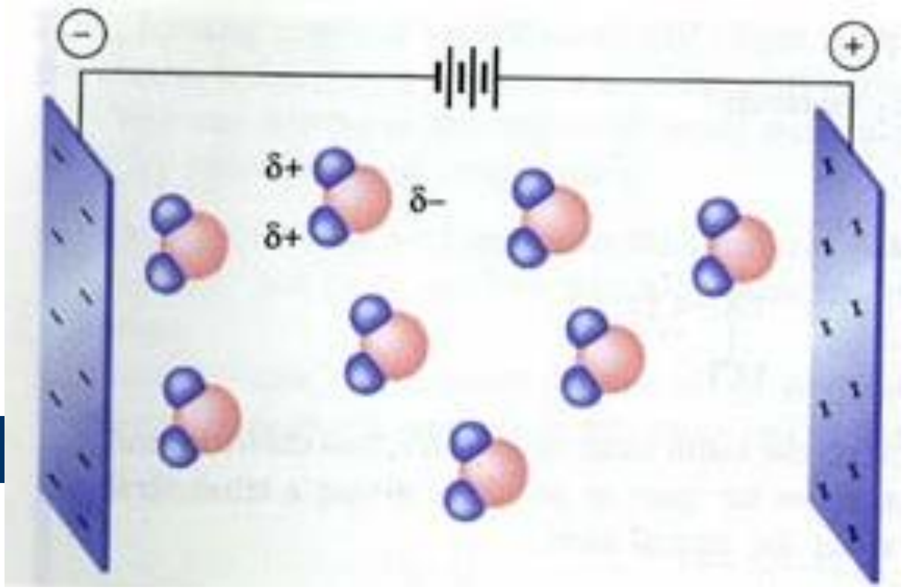
Polarity

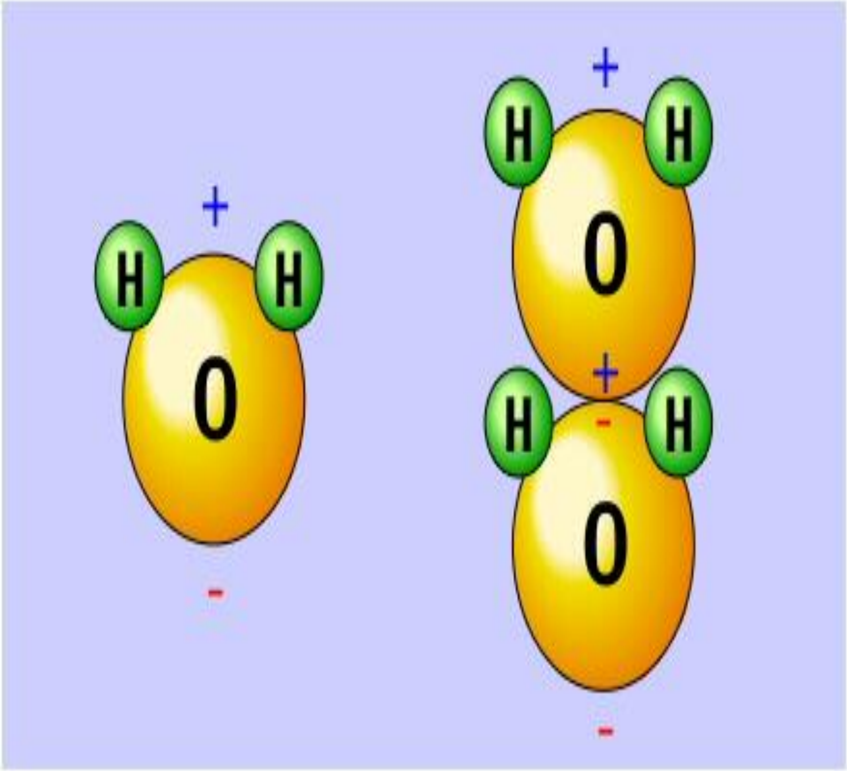




The negative end of water is facing which charge?

Polarity





- As a result of polarity, water molecules easily bond together.

https://screencast-o-matic.com/watch/cF6elPYlbr (2:59) Electrostatic Attractions show Polarity

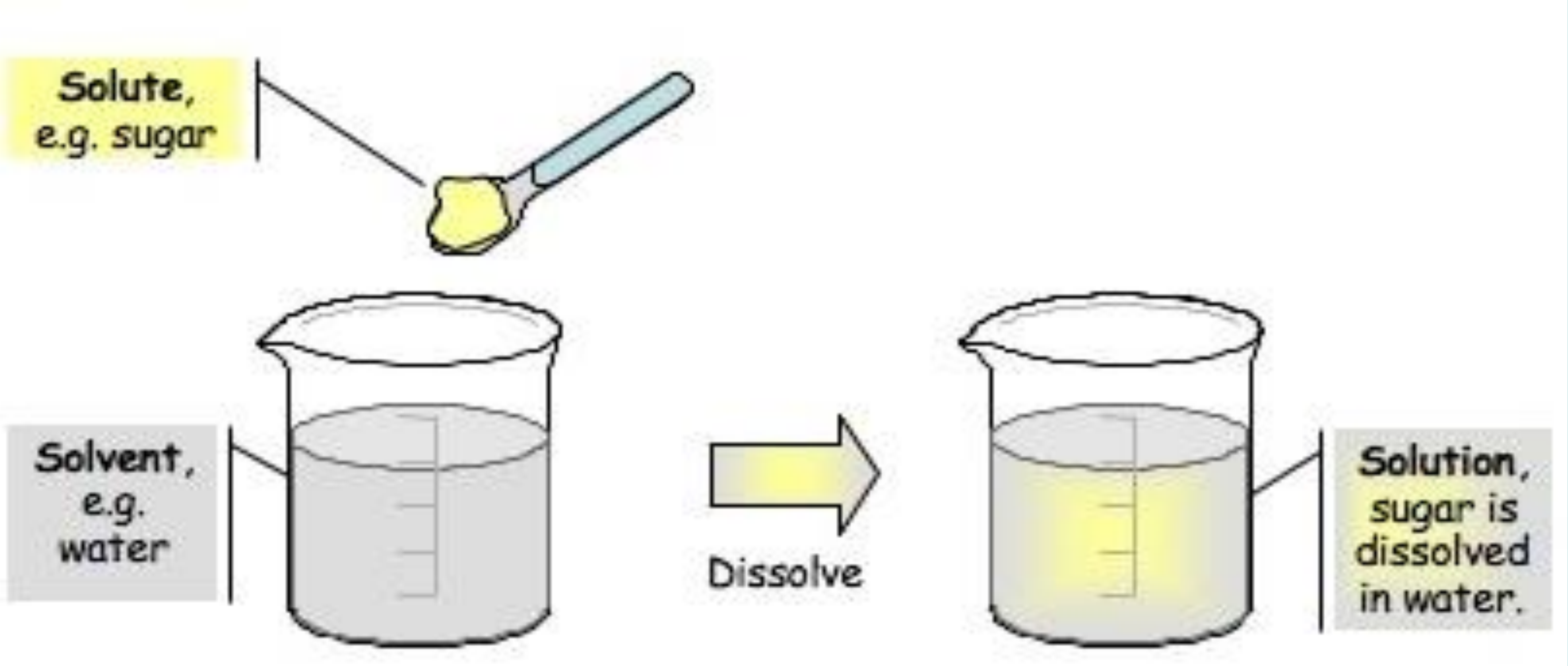
Like Dissolves Like

- Refers to "polar" and "nonpolar" solvents and solutes.
- Basic example: Water is polar. Oil is non polar. Water will not dissolve oil.
- Water is polar. Salt (NaCl) is ionic (which is considered extremely polar). Like dissolves like, that means polar dissolves polar, so water dissolves salt.
- https://screencast-o-matic.com/watch/cF6h2BYotW (2:24)

Water

is considered a **universal solvent** for inorganic (*no C-H bonds*) substances, meaning that it dissolves most non-organic matter ...

due to Polarity.



QUICK CHECK

1

F_2 gas is a molecule composed of two atoms chemically bonded together. Is this molecule polar or nonpolar? Explain.

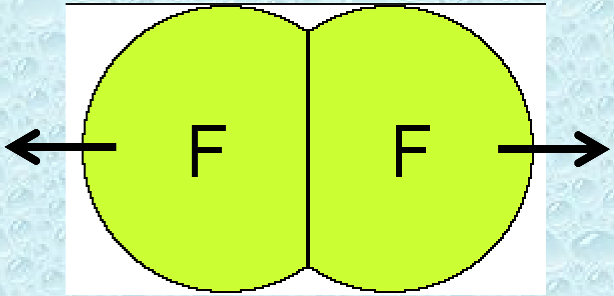
2

If the comb is brought near the water, will anything happen?

Water's Polarity:
https://screencast-o-matic.com/watch/cFQUlaYixQ (0:39)

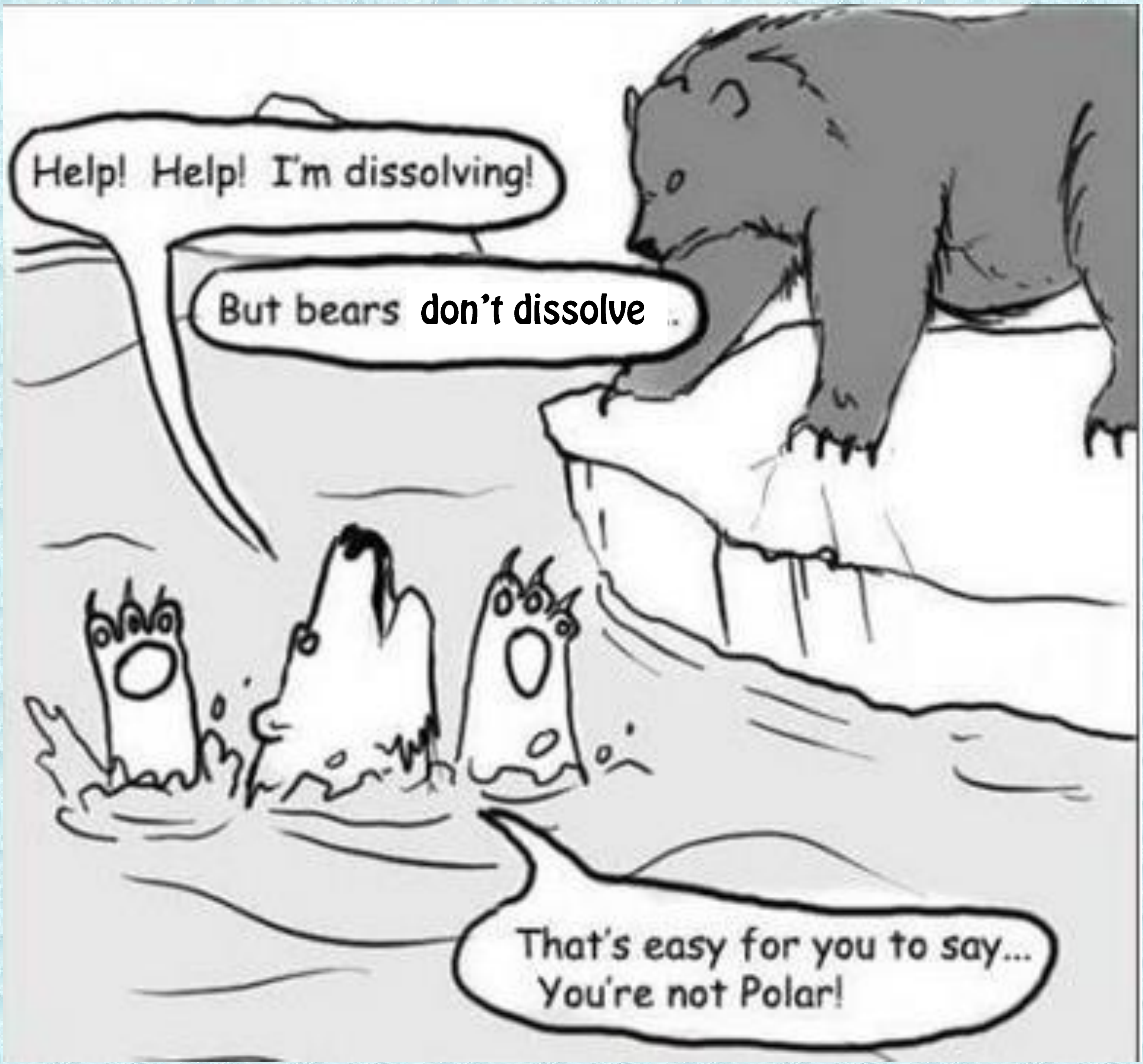
F_2 gas is a molecule composed of two atoms chemically bonded together. Is this molecule polar or nonpolar? Explain.

Fluorine gas is nonpolar because the two atoms are identical so electrons pull equally apart.



If the comb is brought near the water, will anything happen?

When you bring the charged comb near the faucet it is attracted to the polar end of the water. (*in this case – to +*).


Help! Help! I'm dissolving!
But bears don't dissolve .
That's easy for you to say...
You're not Polar!

Factors Affecting Solubility & Rate of Dissolving

http://somup.com/cFXQoVnioR (4:08)

Factors that Affect Solubility

- Pressure
- Nature of solute
- Nature of solvent

Both (overlap)

- temperature

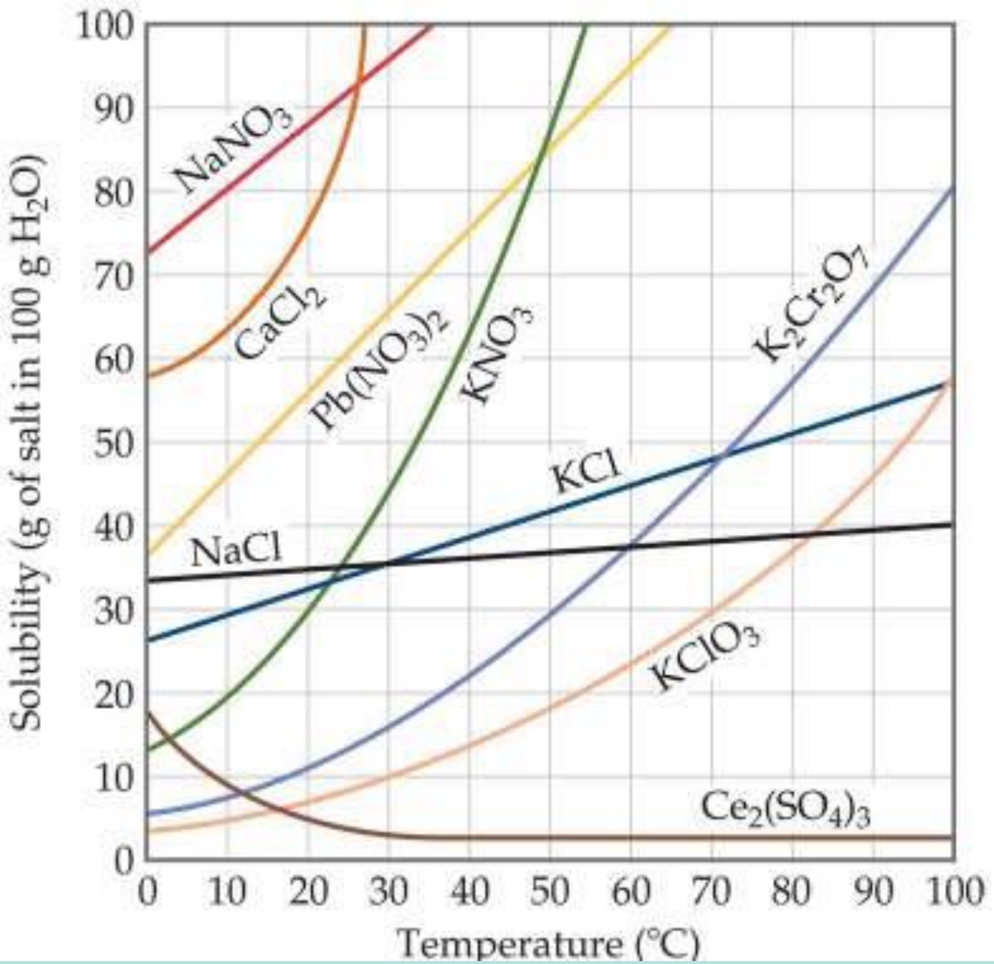
Factors that Affect Rate of Dissolution

- Stirring (**agitation**)
- **Particle size** (surface area)

Solubility of SOLIDS Graph

Notice that solubility of solids (y axis) is shown based on varying temperature (x axis).

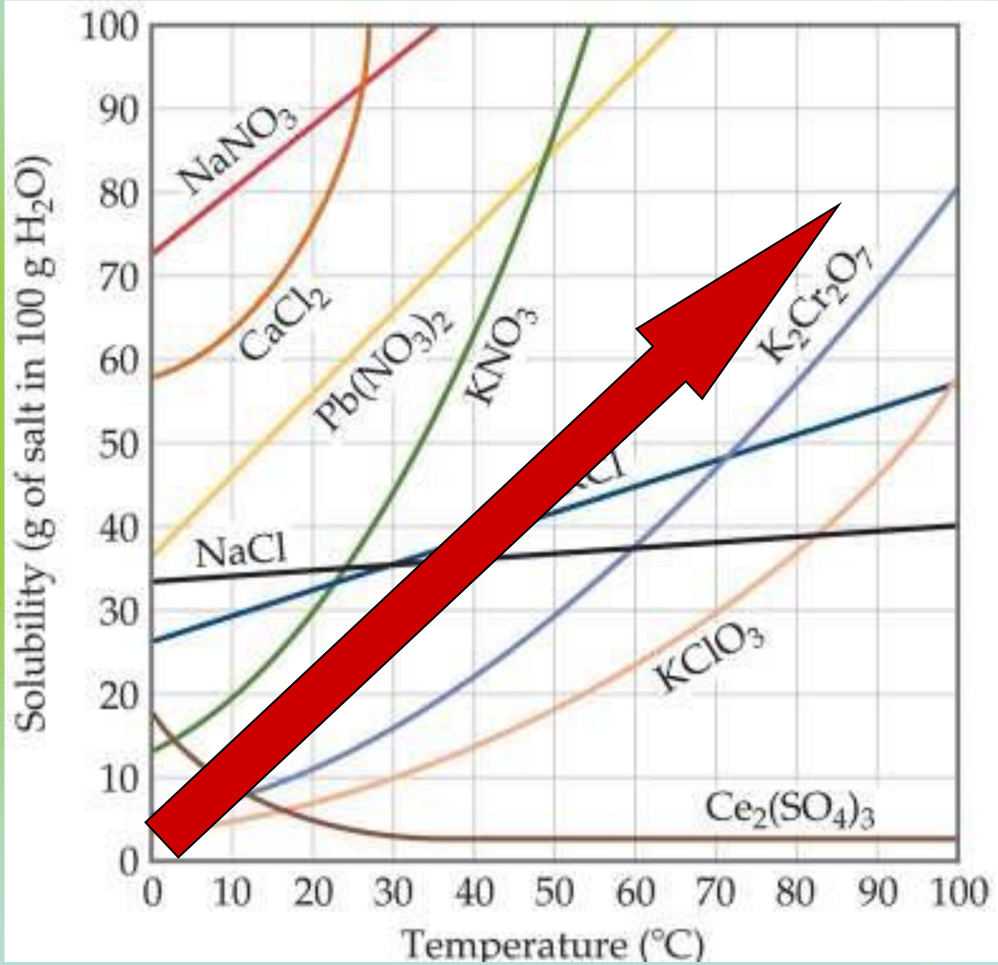
Except for Ce_2SO_4, what trend do you observe on the graph?



Solubility of SOLIDS Graph

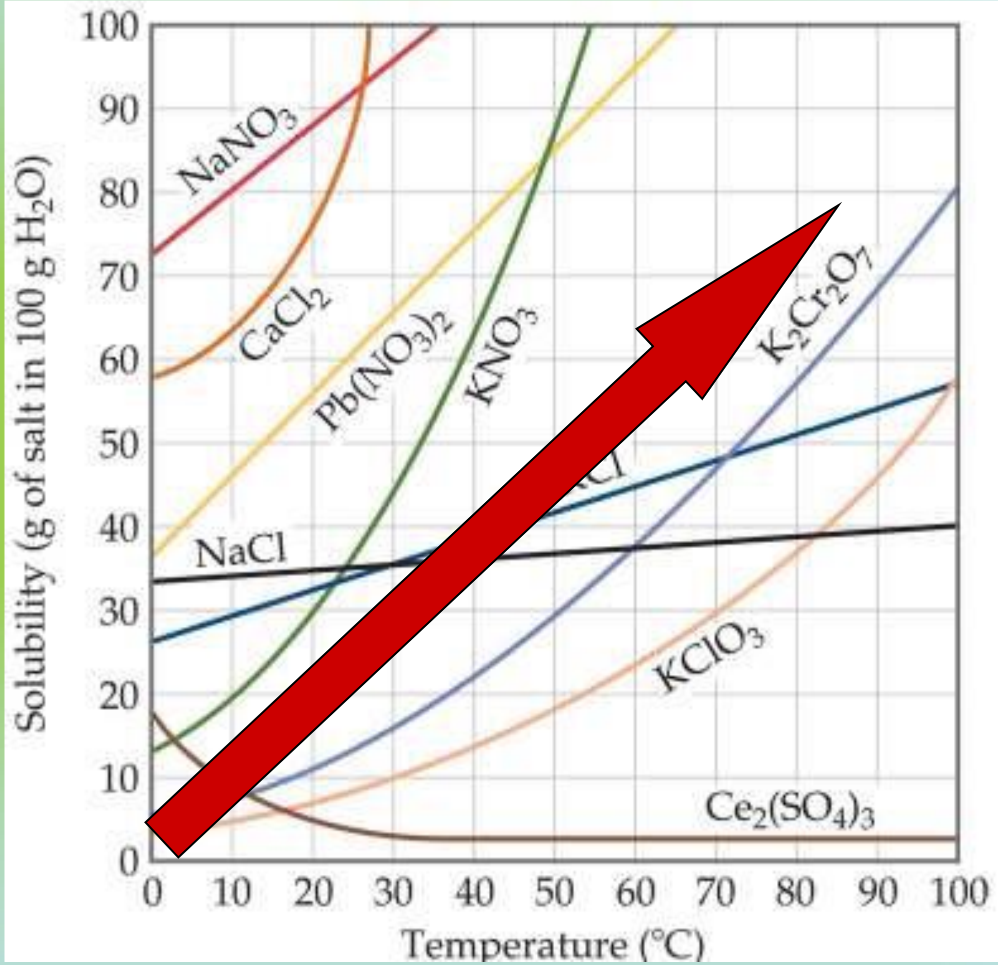
Generally, the solubility of solid solutes in liquid solvents increases with increasing temperature.

What kind of relationship is this?



Solubility of SOLIDS Graph

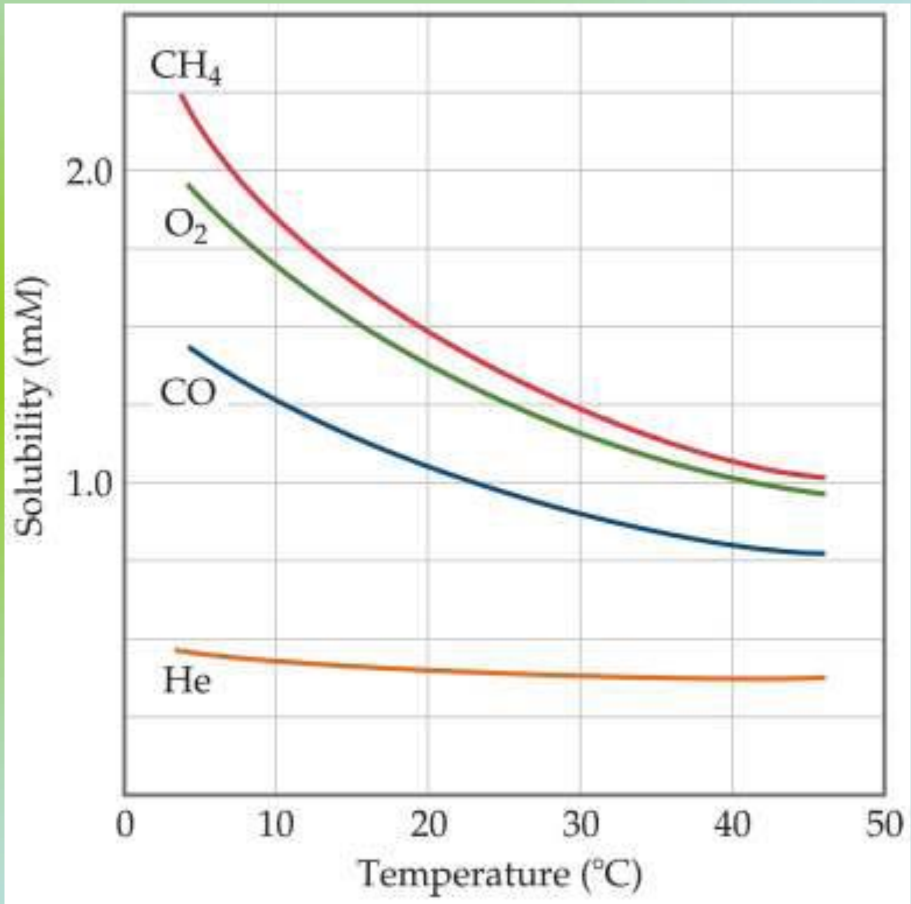
Solubility of solids exhibits a Direct relationship with temperature.



Solubility of GASES Graph

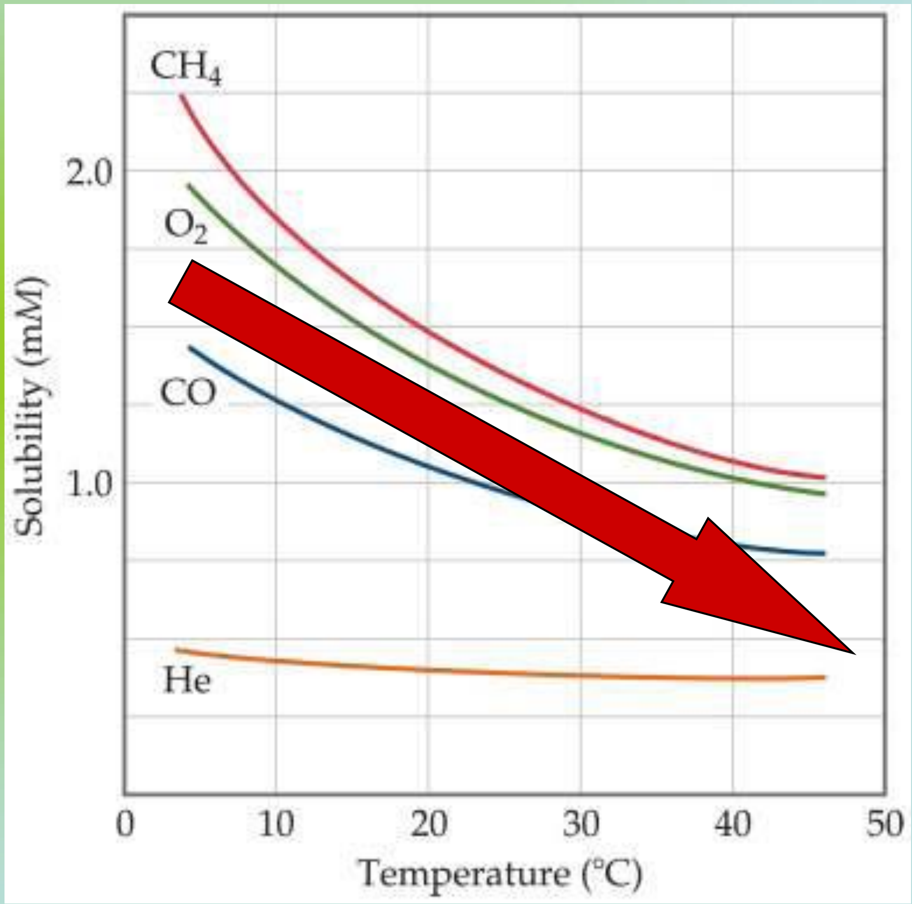
Notice that solubility of gases (y axis) is shown based on varying temperature (x axis).

What relationship is shown?



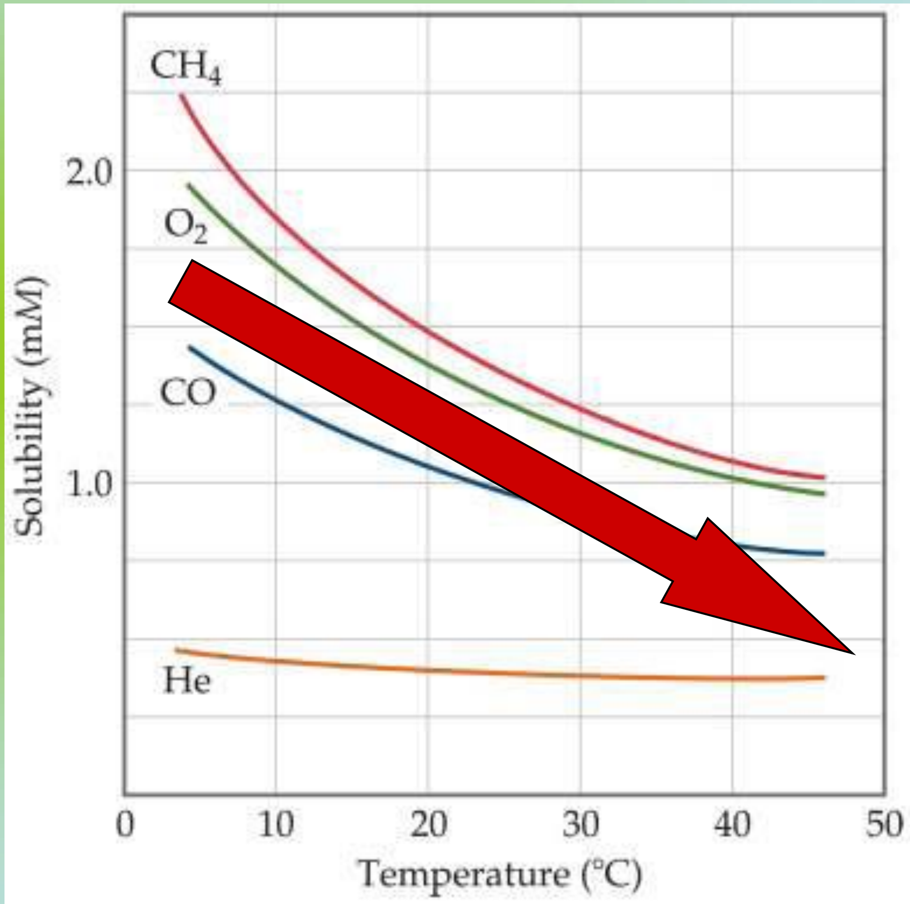
Solubility of GASES Graph

Generally, the solubility of gas solutes in liquid solvents decreases with increasing temperature.



Solubility of GASES Graph

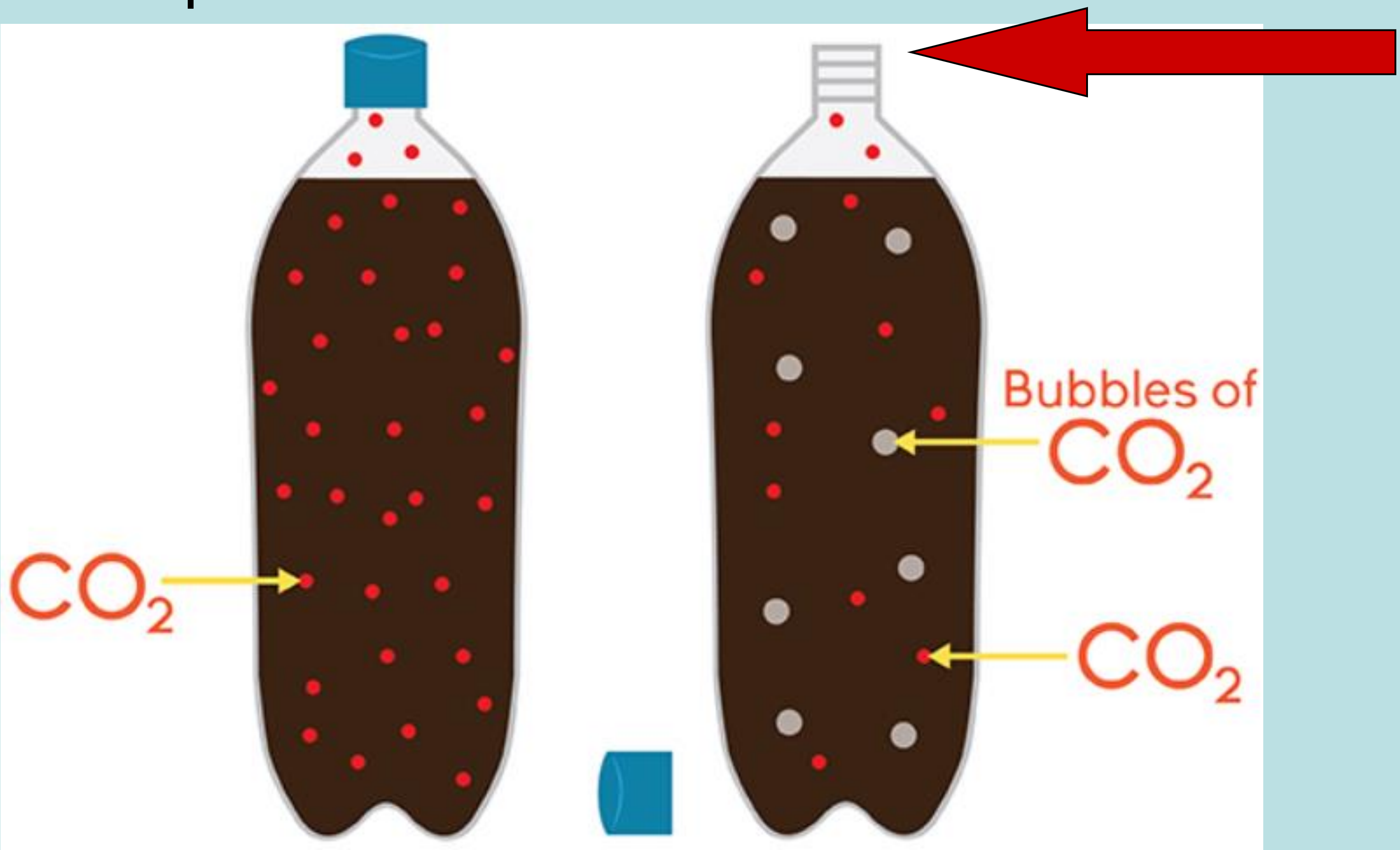
Solubility of gases displays an Inverse relationship with temperature.



Solubility & Pressure

What relationship is shown between solubility (*S*) of a gas in a liquid and the pressure (*P*) of the gas above the liquid at a given temperature?

THINK ABOUT IT

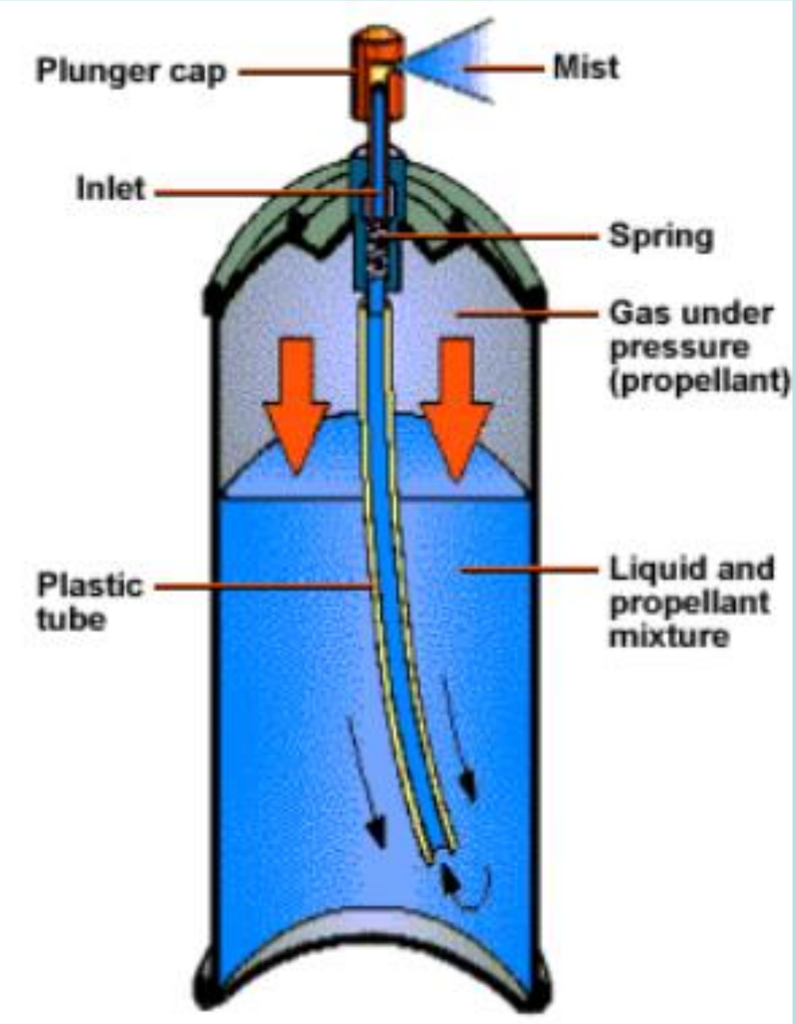


Solubility & Pressure

The solubility (S) of a gas in a liquid is directly proportional to the pressure (P) of the gas above the liquid at a given temperature.

As the pressure of the gas above the liquid increases, the solubility of the gas increases.

As the pressure of the gas decreases, the solubility of the gas decreases.



Solubility & Pressure

Carbonated beverages contain large amounts of carbon dioxide ($CO_{2\ (g)}$) dissolved in water.

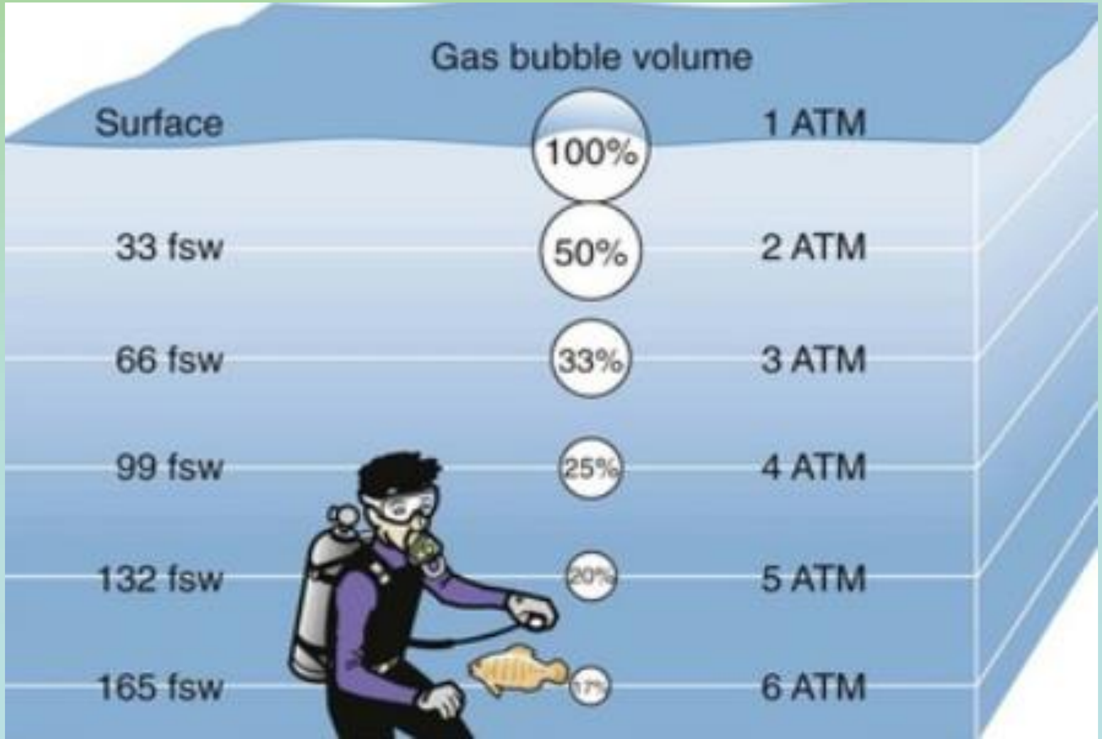
The drinks are bottled under a high pressure of CO_2 gas, which INCREASES solubility of the gas in solution.

When the container is opened, the pressure of CO_2 above the liquid decreases.

Immediately, bubbles of CO_2 form in the liquid & escape from the bottle [Solubility DECREASES].

Scuba Divers & the "Bends"

The air scuba divers breathe is ~78% nitrogen. As one dives deeper pressure increases, meaning the solubility of nitrogen increases. Surfacing causes pressure to decrease, making nitrogen less soluble (i.e. "boils out"). If the divers surface too quickly, nitrogen bubbles just as in carbonated soda pop (the Bends). Helium is added to oxygen tanks, reducing this affect.



Describe Solutions

QUICK CHECK

Check factors that affect solubility.

[ ] Increasing temperature decreases the solubility of gases.

[ ] Stirring increases the solubility of solids.

[ ] Increasing pressure increases the solubility of liquids.

[ ] Decreasing temperature decreases the solubility of solids.

[ ] Increasing pressure increases the solubility of gases.

[ ] Decreasing the amount of solvent decreases the solubility of solids, liquids, and gases.

A solution is made by adding 200 g table salt to 1 L water. The solubility of salt is 36 g/100 mL water.

Which of the following **best** describes this solution?

O dilute

O saturated

O supersaturated

O unsaturated

Describe Solutions

QUICK CHECK

Check factors that affect solubility.

[X] Increasing temperature decreases the solubility of gases.

[ ] Stirring increases the solubility of solids. **Just dissolves faster**.

[ ] Increasing pressure increases the solubility of liquids. **Only gases.**

[X] Decreasing temperature decreases the solubility of solids.

[X] Increasing pressure increases the solubility of gases.

[ ] Decreasing the amount of solvent decreases the solubility of solids, liquids, and gases. **The solubility is the same, but the amount of solute dissolved is less.**

A solution is made by adding 200 g table salt to 1 L water. The solubility of salt is 36 g/100 mL water.

Which of the following **best** describes this solution?

O dilute

O saturated

O supersaturated

!!! **unsaturated**

Identify Factors that Affect Dissolving Rate

QUICK CHECK

A spoon of salt is added to water. Which of the following will increase how fast the salt dissolves? Check all that apply.

[ ] adding another spoon of salt

[ ] stirring the salt and water

[ ] cooling the water

[ ] crushing the salt so the grains are smaller

[ ] removing some water

Order the steps in the dissolving process from first to fourth.

__ the solvent molecules surround the solute molecules or ions (hydration).

__ the solute molecules break apart into solution (dissociation).

__ the solute is mixed with the solvent.

__ the solvent molecules are attracted to the molecules at the surface of the solute particles.

Identify Factors that Affect Dissolving Rate

QUICK CHECK

A spoon of salt is added to water. Which of the following will increase how fast the salt dissolves? Check all that apply.

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[X] stirring the salt and water

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[X] crushing the salt so the grains are smaller

[ ] removing some water

Order the steps in the dissolving process.

_4_ the solvent molecules surround the solute molecules or ions (hydration).

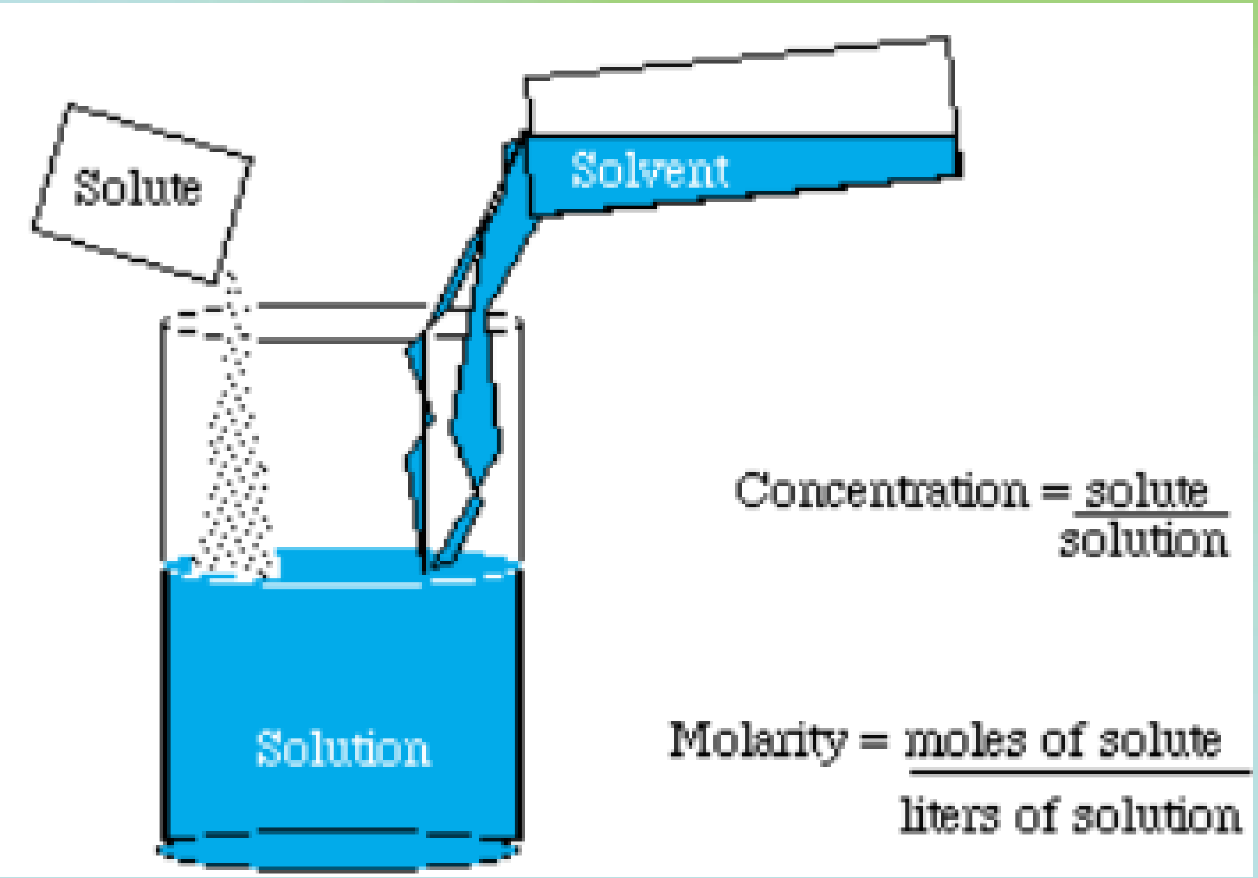
_3_ the solute molecules break apart into solution (dissociation).

_1_ the solute is mixed with the solvent.

_2_ the solvent molecules are attracted to the molecules at the surface of the solute particles.

Solute **Concentration**

- is helpful to know in order to describe solutions



- is an important "real life" variable

Concentration

Dilute ⟷ Concentrated

$$\text{vol}\ \% = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100$$

$$\text{mass}\ \% = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

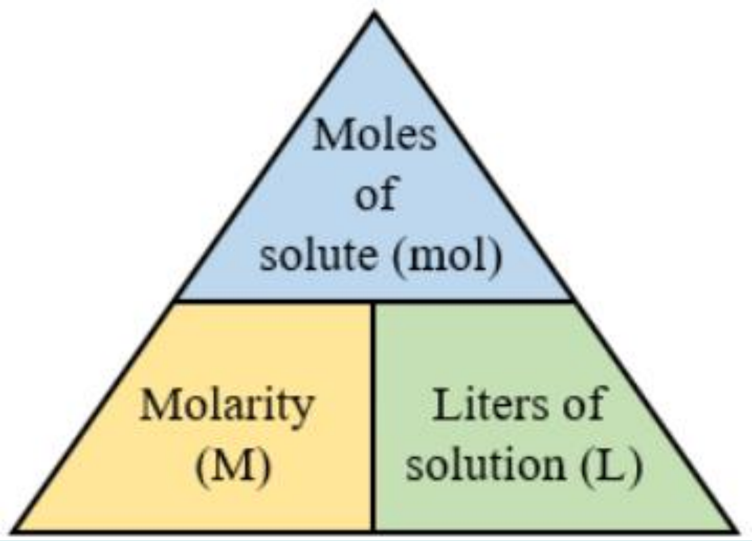
$$\text{M} = \text{molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

Molarity

The number of moles of solute in 1 liter of solution.

This term is the most used when describing concentration (symbolized by "[ ]") in a general chemistry lab.

$$\text{Molarity } (M) = \frac{\text{moles of solute}}{\text{liters of solution}}$$



Molarity

Volume of a liquid is more easily measured than mass, therefore, laboratory reagents are usually made up of a specific molarity to give us a standard.

How does the number of particles in a 1 M solution of LiOH (molar mass = 24) compare to the number of particles in a 1 M solution of NaCl (molar mass = 58.5)?

a. There are more particles of solute in the LiOH solution.
b. There are more particles of solute in the NaCl solution.
c. The number of particles of solute is the same in both solutions.
d. More information is necessary in order to compare the solutions.

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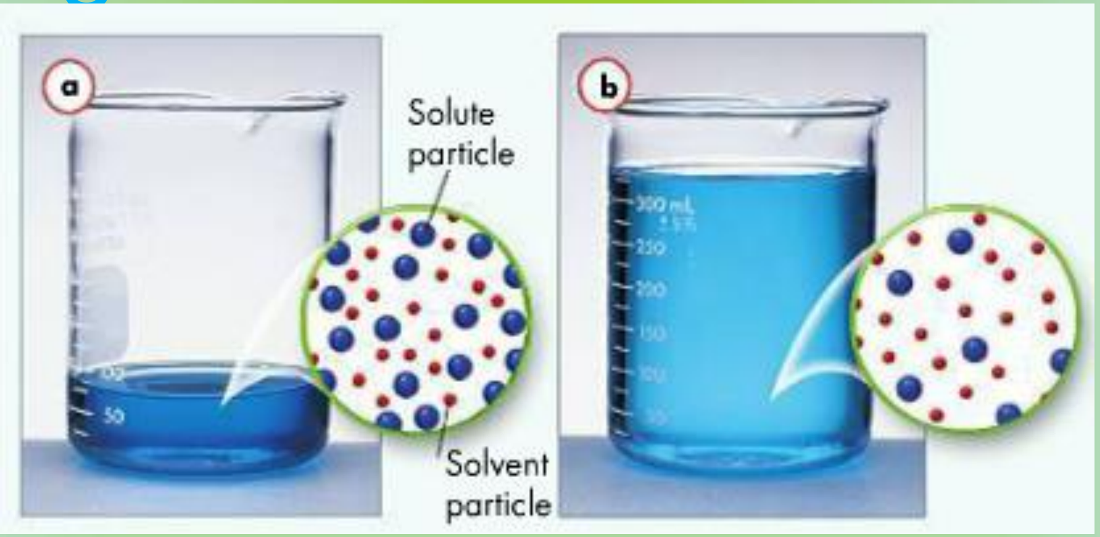
Using Concentrated Solutions



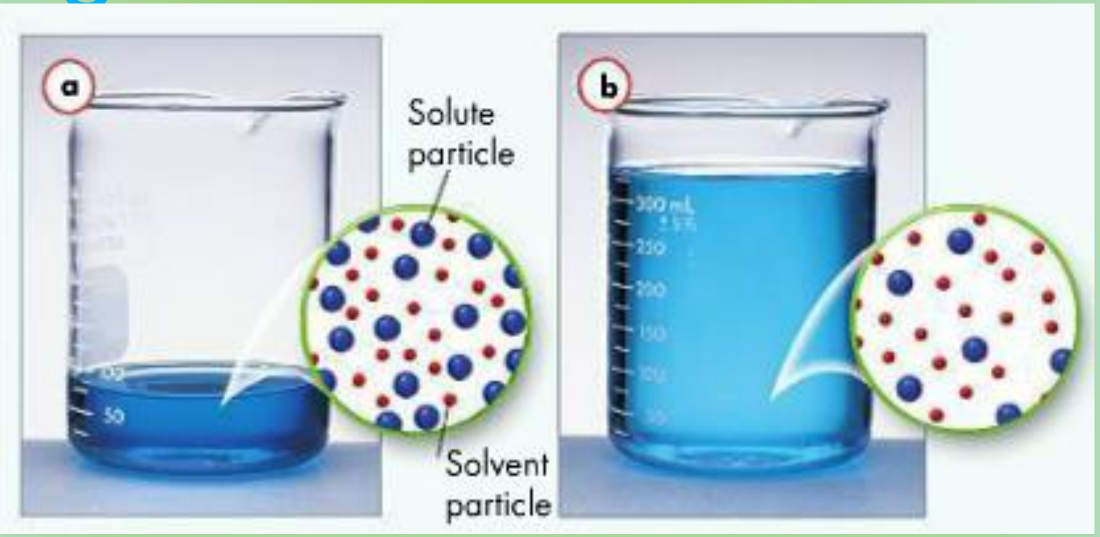
Both solutions above contain the same amount of solute. Which is more concentrated?

Which has a greater molarity?

Use the molarity equation to answer the following:

When dilution B was made, the ____ decreased, the ____ increased, and the ____ remains the same.

Using Concentrated Solutions



Both solutions above contain the same amount of solute. Which is more concentrated? A

Which has a greater molarity? A

Use the molarity equation to answer the following:

When dilution B was made, the <u>molarity</u> decreased, the <u>volume of solution</u> increased, and the <u>moles of solute</u> remains the same.

Distinguishing Properties of Compounds.

Compound X has a solubility of 20 g in 100 g of water at 20°C. What is the minimum amount of water needed to dissolve 50 g of compound X?

a. 250 g
b. 100 g
c. 500 g
d. 200 g

A saturated solution of carbon dioxide in water suddenly experiences an increase in pressure. What happens to the solution?

a. Bubbles form as the carbon dioxide comes out of the water.
b. It becomes supersaturated.
c. It remains saturated.
d. More carbon dioxide can now be dissolved in the water.

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Compound X has a solubility of 20 g in 100 g of solution at 20°C. What is the minimum amount of solution needed to dissolve 50 g of compound X?

a. **250 g**
b. 100 g
c. 500 g
d. 200 g

20 g / 100 g = 50 g / X = 20%

$$\text{mass }\% = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

A saturated solution of carbon dioxide in water suddenly experiences an increase in pressure. What happens to the solution?

a. Bubbles form as the carbon dioxide comes out of the water.
b. It becomes supersaturated.
c. It remains saturated.
d. **More carbon dioxide can now be dissolved in the water.**

TRY IT

Distinguish Components of Solutions

What is a compound?

O a combination of two or more substances that are not chemically combined

O a combination of two or more elements that are combined in a definite ratio

What is a solution?

O a mixture of two or more substances that are mixed evenly throughout

O a mixture of two or more substances that are chemically combined

What is a solute?

O the liquid in a solution

O the solid in a solution

O the substance that dissolves

What is a solvent?

O always water

O the liquid in the solution

O the substance that the solute dissolves in

Distinguish Components of Solutions

TRY IT

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O a combination of two or more substances that are not chemically combined

!!! a combination of two or more elements that are combined in a definite ratio

What is a solution?

!!! a mixture of two or more substances that are mixed evenly throughout

O a mixture of two or more substances that are chemically combined

What is a solute?

O the liquid in a solution

O the solid in a solution

!!! the substance that gets dissolved

What is a solvent?

O always water

O the liquid in the solution

!!! the substance that the solute dissolves in